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PILOTING A WATER RIGHTS INFORMATION SYSTEM FOR CALIFORNIA

JULY 2021

Policy Report

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**“The future is already here –
it’s just not evenly distributed.”**

— William Gibson

Records Room. State Water Resources Control Board, Sacramento, CA

JULY 2021 | POLICY REPORT

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EXECUTIVE SUMMARY

California's complex water management challenges are growing and intensifying. Systemic stressors like the more frequent and severe droughts and floods driven by climate change are only making it harder to respond. Accordingly, California needs to dramatically improve the ability of local, regional, and State entities to make agile and effective water management decisions. We believe doing so will require enhanced understanding of our water resources and how they align with the needs of a range of agencies and stakeholders. Water rights data provide a crucial opportunity for advancing this understanding. We find that modernizing water rights data is feasible, affordable, and can increase transparency and clarity for better decision making.

Water data are currently insufficient to meet the needs of California's existing water management challenges, let alone to enable the next generation of water innovations. California has recognized this challenge with a raft of recent legislation and policy actions geared towards improving the accessibility and useability of data to support water decision making. Water rights data are a particularly important ingredient for understanding our water system, but they are currently difficult or impossible to access for modern decision making.

California relies largely on paper records for foundational information on water rights and water use that are central to its legal system, including documents such as permits, licenses, and a range of other documents that support claims of right. Where available, water use records submitted by water rights holders are also often in paper form. Even if they were fully available and organized, paper records cannot support the kind of complex decisions California water managers must make on rapid timelines.

California's existing Electronic Water Rights Information System (eWRIMS) does not effectively support water management decision making in most use cases. eWRIMS is incompletely populated and lacks basic functionality and interoperability with other platforms. As a result of such information deficits, stakeholders and government entities have trouble understanding how much water is available to particular water users at particular times—information that is central to basic water allocation decisions, to planning for changes in future water availability, and to unlocking the system-scale efficiencies and innovations that underpin most forward-looking visions for California's water future.

This report describes an effort to evaluate the potential for California to move its water data systems into the 21st century. Through public workshops, focus groups, comparative research, use case exercises, and the development of a pilot water rights documents database system, we examined options, and evaluated opportunities and potential pitfalls. Our findings suggest that dramatic improvements in water rights and use data are not only possible, but are well within California's reach for California, if the State administration and key stakeholders are willing to take the necessary steps.

RESEARCH PROCESS AND PILOT PROJECT

We began with a simple set of questions: Does California need to modernize its water rights and use information system into an online record that is more complete, accessible, and useable to support water decision making? Is it feasible and affordable for California to develop such a system? If so, what should be the key elements of such a system? And how can it be actualized?

To answer these questions, we conducted a three-stage process of research and engagement. First, we developed conceptual and analytical background centered around a series of use cases which asked how water rights data plays into water management on a broader scale, combined with legal and institutional analysis and a process of stakeholder engagement. Next, we surveyed

other western states, observing how documents and records are digitized and maintained online. Finally, we designed and built the basic foundation of a water rights documents database. This last step involved scanning, digitizing, and assigning metadata to over 130,000 pages of water rights documents from the Mono Basin, resulting in a proof of concept for a searchable digital database of legal records.

TAKEAWAYS FOR A MODERN WATER RIGHTS INFORMATION SYSTEM (WRIS)

Our main research findings are simple but profoundly supportive of State action:

- Accessible and useable water rights data will benefit water rights holders, other stakeholders, and regulators.
- Modernizing California's water rights database in response to this demand is feasible from a technical standpoint, and its cost would be surprisingly reasonable.

A range of conclusions augment these two key messages. As California seeks to improve water-related decision making at all scales, the following considerations can guide its efforts to develop a more accessible and useful WRIS.

1. California should pursue a comprehensive, transparent, and accessible water rights information system. Such a system would help ensure equal access to vital information and help establish a shared baseline of understanding of the current state of water rights and use in the State.

2. California has huge problems to solve to assure reliable water supplies for all beneficial uses. Water management involves balancing a range of valid legal interests in how water is used and managed. As a matter of the law, water rights are property protected by due process. The current information system undercuts, complicates, and delays due process in resolving water rights disputes, as a result of inefficiencies in establishing basic facts. Simultaneously, the State has the fiduciary responsibility to manage its water effectively for the benefit of all of its citizens, including those who directly hold water rights, and also others who directly or indirectly depend on water. Providing sufficient information is crucial to achieving these aims with the greatest benefit to all parties.

3. The current electronic system for water rights data in California is incomplete and lacks key functionality. Experts in our focus groups and design workshops expressed that eWRIMS does not meet current needs for water data. Some types of water rights data, such as licenses, permits, and statements of use, are available in digitized form, but many relevant document types are not. The data types which are available are woefully incomplete, inaccessible, or incompatible with other systems. The inability for eWRIMS to link water rights data with other relevant datasets hinders the development

of helpful decision support tools. Because of this, it is impossible to develop a full picture of water entitlements and use in the State.

4. **Other western states have already built searchable water rights document databases from which California can learn. California should look to these examples for additional management functionalities to incorporate into a WRIS.** Our synthesis of other states' information systems concludes that while California is well positioned in terms of water data collection compared to other states, it is only in the middle of the pack in terms of creating a water data system that is functional and accessible. California can and should view the bar that has already been set by strong efforts in other states as an indication of possibilities, and a standard to exceed.

5. **Our pilot demonstrates that scanning and digitizing all of California's water rights documents can be done affordably and effectively.** Our team scanned and digitized 5,998 records, amounting to 132,422 pages. Scanning and indexing cost about 32 cents per page. All these records are now searchable by word or metadata (document type, author, title, and date). Based on our pilot (openly available at cawaterrights.org), we estimate the approximate cost of a statewide WRIS as:

    - $3.5M for scanning and indexing of an estimated 10 million pages of water rights records, plus the cost of State Water Board staff supervision of the process;
    - $10-$15M for basic information verification;
    - Complementary cost estimates for developing the new database infrastructure, which will depend on features and the approach to development;
    - Ongoing operation and maintenance costs.

    The actual costs will depend on choices made by the State, but are far outweighed by the savings that would result from an improved water rights information system and more data-driven management of California's water resources, particularly in light of the value of water to the State's trillion-dollar economy.

6. **A wide range of water management decisions would be enhanced by a database that includes available water rights data in searchable form.** Information and data from water rights documents is essential for a variety of water management decisions. Establishing water markets, facilitating water transfers, and determining environmental flows all require water rights data. Water rights data are crucial for establishing ownership of a water right for a water transfer, or clarifying water demand. Determining environmental flow requirements involves evaluating legal records to estimate future withdrawals and their potential effects on streamflow, alongside information about the amount and timing of historical and projected streamflow. Digital records for water rights will be fully and instantly searchable for key words or other search criteria.

7. A system for water rights data should be readily interoperable with other water-relevant data sources. Decisions about water rights rely on a wide range water-related data and information. State agencies, stakeholders, and courts rely heavily on legal records as well as hydrologic and ecological data for matters ranging from routine determination of whether to grant a new water right permit, to resolving knotty conflicts among water users. Effective information exchange with other water-relevant data sources will enable more effective and efficient water rights management.

8. With strong State leadership, California will become a leader in water rights data and governance. To its credit, the State already collects a significant amount of water supply and quality data. The State also possesses a trove of historic records of water use and of legal documents on water rights, albeit largely in paper form. If the State can backfill the gaps in its digitized records of water information, while ensuring that these data can be updated in real time, it will be well poised to design and build a comprehensive water management system that can modernize its water systems.

9. A new water rights database should be designed to protect privacy, preserve chain of custody, and ensure quality control. Although water rights documents are public records, a digitized database should take basic and necessary precautions to ensure that personally identifiable information is protected. Likewise, while the physical copies will remain the water rights documents of record, an effective chain of custody procedure between scanning the documents and uploading them to the public database system will help establish the quality of documents for legitimate uses, and enable trust among users of the system.

10. Accuracy reviews for water use records and data will be vital to a modern water rights information system. The quality of data, whether in paper or electronic form, must be made clear for those data to be legitimate for any uses. Procedures will be necessary for the modern system to authenticate that any electronic record is a true and correct copy of an original paper record, and to verify the accuracy of reported data. Our current system relies on self-reporting of use, and the State Water Board does not have or apply a standard procedure to check use data. This report advocates for a non-binding procedure that would be based on staff requests and user responses.

11. A water rights documents database is a crucial step towards building out a more reliable and comprehensive water management data support system. A database of documents, as illustrated by our limited pilot, would be the core of a more extensive system. A truly useful water management system would mesh water rights documents with an electronic filing system to streamline reporting and ensure that the database could be continually updated. The system would also be designed to enable interoperability with phys-

ical, environmental, and other databases. These are achievable goals – many other states, including those that lack California's storied history of tech innovation, have succeeded in producing working electronic water rights systems. There is no reason California cannot do as well, or better.

12. California can and should pursue a comprehensive, transparent, and accessible water rights information system. A WRIS will be a database, an information repository, and an aid to decision making, but it will also be a reflection of California's commitment to innovation, transparency, and the rule of law.

This report presents detailed findings that support the overarching conclusion that the State of California can and should develop a modern WRIS. It also lays out in broad brush stokes a pathway for the thoughtful evaluation, design, and development of a fully featured WRIS at scale.

More foundationally, given the challenges of managing our highly stressed water resources with an antiquated information system, California may face a starker choice. We have to make the information system we have work better, or risk its failure as a management tool. Data will be one critical element of systemic improvement. No investment in governance infrastructure could be more foundational to supporting the ability of our water system to function in the face of dramatically changing conditions. California should seize the opportunity provided by broader momentum on water data, and use it to actualize motion on water rights information.

ENGAGE WITH THE PILOT DATABASE AT CAWATERRIGHTS.ORG

One of the major elements of this research project was the development of a functional pilot water rights database for the Mono Basin. This pilot focused on one foundational aspect of water rights data, namely scanning and organizing water rights documents and making them searchable. The goal of the pilot was to clarify the potential process and cost for scanning, digitization, and metadata assignment. It also provides a proof of concept and functional software for direct engagement.

The pilot database is available online at cawaterrights.org, and we encourage interested parties to examine it for themselves. Additional description and analysis of the database can be found throughout the report, including in Appendix D: Document and Priority Search Function Details. In this report, discussion of the pilot is based on its version as of December 2020. The cawaterrights.org database and website may be updated and refined over time.

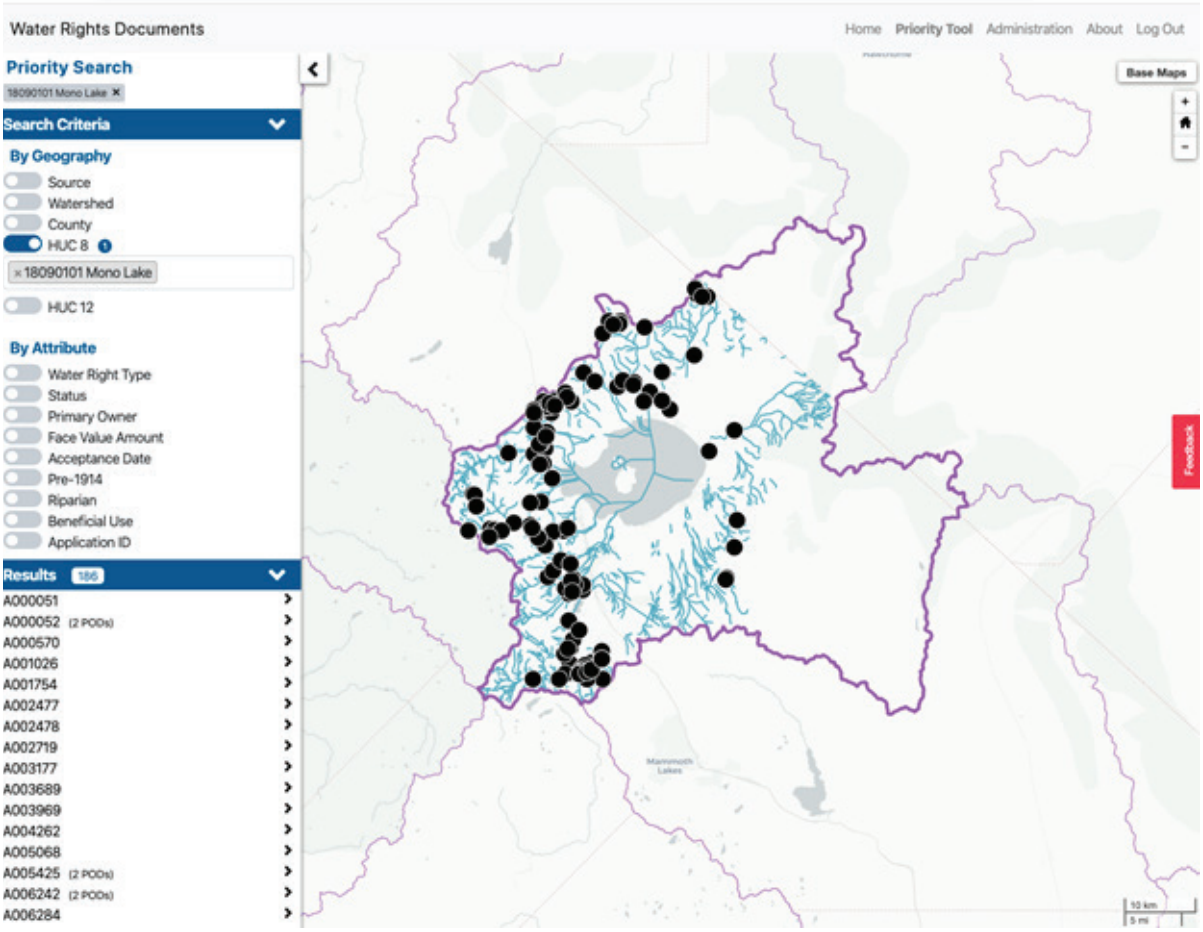

Figure 1. A Points of Diversion search with multiple filter options, including both boundaries and rights types from cawaterrights.org, illustrating one aspect of its functionality.

1. INTRODUCTION

California faces complex water management challenges even under the best of conditions. These challenges will intensify as the State confronts a range of growing systemic stressors including stronger and more frequent hydrologic extremes resulting from climate change. The only certainty for California water is that coming decades will not look like the past ones around which we have designed our water systems and practices. Accordingly, California needs to wring more efficiency and flexibility out of an already intensively managed water system.

Achieving these efficiencies will require water users, State agencies, and stakeholders to make informed, transparent decisions that balance human and environmental needs for water. Such choices require data and information for understanding the water system, including how water currently flows, where flexibility exists, and how potential changes to current operations might produce benefits.

For these and other reasons, improving water data is a hot topic in California.[1] Lack of data is increasingly recognized as a bottleneck to informed decision making, and improvements in data availability are seen as a crucial stepping-stone to greater effectiveness.[2] Recent legislation and policies, including the Open and Transparent Water Data Act, provide specific context and motivation (see **Recent Data-related Legislation and Policy Changes**, below).

Water rights data are a particularly important ingredient for understanding and improving our water system.[3] But they are currently difficult or impossible to use for many kinds of decision making, because California still relies largely on paper records. California's existing Electronic Water Rights Information System (eWRIMS) is incompletely populated and lacks the functionality and interoperability with other platforms. Because of this and other shortcomings, stakeholders and State agencies have trouble understanding how much water is available at particular places and times—information that is central to basic water allocation decisions and to planning for changes in future water availability.

Water management involves balancing a range of valid legal interests in how water is used and managed. Under California law, water is public property[4]

owned by the State. Water rights confer the right to use water under specific, defined circumstances, and to store and divert water only for reasonable and beneficial uses. These rights deliver water supply to 35 million Californians, sustain the most productive agricultural region in the nation, and underpin the economy and welfare of California. As a matter of the law, these rights are property protected by due process. The State has a fiduciary responsibility to manage its water effectively for the benefit of all of its citizens, including those who directly hold water rights, and also those who directly or indirectly depend on water.[5] This responsibility includes dual obligation for the State to protect the economic, public health, and myriad other benefits of water rights to individuals and communities, and to protect recreational and ecological public trust benefits of our streams and other water bodies against unnecessary harms.[6]

To achieve these dual obligations, water management must be a dynamic process that respects legal protections for water rights, and satisfies the State's obligation to protect all beneficial uses of water. The current state of water rights data reduces transparency and clarity. It limits the ability of all parties to manage water effectively, and hamstrings the State's ability to fulfill its fiduciary duty to the public interest and the public trust. It also poses an immense practical barrier to the large scale systemic innovation that California will need to weather the changes ahead.

Inadequate information limits our ability to avoid or resolve conflicts between users and uses. Effective, evidence-based decisions are often unnecessarily difficult, and sometimes impossible, without 1) efficient access to key information, 2) by relevant parties, and 3) in a time and manner that these parties can evaluate and act upon this information.

The current state of information on the more than 45,000 known water rights to surface water sources in California limits effective decision making. The current combination of millions of un-indexed paper records and a woefully incomplete electronic system housing a tiny fraction of water rights information simply does not enable an understanding of California water rights or how they relate to one another or to other potential uses.

RECENT DATA-RELATED LEGISLATION AND POLICY CHANGES

A WRIS builds upon recent legislative and policy actions related to the collection and distribution of water-related data. In 2015, the State adopted SB 88 in an effort to better track water diversions to inform real-time decision making and improve long-term planning. Accordingly, the State Water Board now requires all users to submit annual water usage reports to eWRIMS.[7] Large scale users must also install measurement devices and submit data on a weekly, daily, or even hourly basis, depending on the scale of their diversions.[8]

2016's Open and Transparent Water Data Act (AB 1755) called for State agencies to develop an integrated platform and procedures to share data to better inform water decision making.[9] Thousands of water and environmental datasets are being made accessible through the State's federated platforms, and efforts continue to refine and expand them.[10]

SB 19 (2019)[11] requires State agencies to develop a roadmap to modernize and expand the State's stream gage system, with the goal of improving management efforts and protecting native species. While still in the infancy of its implementation, it is an important recognition of the importance of foundational hydrologic information for water management.

In July of 2020, Governor Newsom's California Water Resilience Portfolio[12] was released in response to an executive order for agencies to assemble a comprehensive outline of the State's water needs and policy initiatives.[13] Among a broad suite of actions, the report highlights the importance of data in water management and decision making, setting the broad goal of further modernizing and integrating water data systems by building on AB 1755 and SB 19.[14] Crucially, the portfolio specifically calls for a new water rights database for California, setting forth "digital place of use, diversion and case history information...."[15]

The State is undertaking several pilots of potential improvements to eWRIMS, driven to produce useable water rights data. One pilot involves Holland Tract. Staff are reviewing use data from Statements of Use and other sources, identifying inconsistences among the data, and evaluating procedures that could be used going forward to improve the accuracy of the self-reported use data here, and elsewhere.

These policy advancements signal broad recognition of the importance and potential long-term impact of advancements in water related data. It is important to recognize that whether they are individually or collectively impactful will rest heavily on the degree to which these measures are prioritized and funded, and on the skill, vision, and will with which they are ultimately implemented.

The motivation for this report is not new. For generations, State leadership have called for modernization in California's water rights information system.[16] Indeed, the State Conservation Commission in 1913 found that water management was hampered by the dispersal of information among county courthouses, and it recommended the establishment of a State agency with authority and responsibility to administer water rights (and associated information) in a coordinated manner.[17]

This report presents research motivated by these ideas, and by the slow pace of progress towards an urgently needed modernization of data and decision making in the field. It describes in detail the information deficits in water rights that decision makers face in California, shows how other states have succeeded in addressing similar challenges, and details a pilot project that concretely demonstrates how California could build a useful and useable system to house and make accessible its water rights and water use information.

Ultimately, we conclude that remedying this information deficit is crucial to enabling effective, rational management of the State's water from year to year, and will remove a key barrier to sorely needed innovations. We demonstrate that it is entirely possible and achievable for California to build a modern system for its water rights and use data, and provide a detailed enumeration of how such a system could be designed and implemented.

In this report, we refer to different classes of data in specific ways. Please see also **Glossary of Terms** for other definitions.

KEY TERMINOLOGY: WHAT DO WE MEAN WHEN WE SAY "DATA"?

Water rights documents (or records) are the formal legal documents associated with water rights. They include permits, licenses, statements of use, change petitions, orders and judgments, and many other documents that directly define water rights, as well as supporting information such as maps, figures, environmental reports, and other exhibits that are formally attached to water rights records.

Water rights data refers to specific legal information that determines who gets to use what water and when. Water rights data can be gathered from water rights documents, and includes such information as owner, priority date, timing,[18] quantity of water permitted under the right, point of diversion, place of use, and purpose of use.[19]

Water use data tracks how water is stored, diverted, and used. Such data include diversions, consumptive use, and return flows, and can be based on direct measurements or estimates of various kinds.[20]

Water data and water-related data broadly encompass the above data types, which are the focus on this report, but also include other types of water and water-related information, including physical and ecological monitoring data, modeled estimates of water supply, and so forth.[21]

Information is data with meaning. For example, information includes data which, through the addition of context or analysis, has been processed or synthesized to answer questions.

A Water Rights and Use Information System (WRIS) refers to our vision for an internet-based database designed to modernize management and access to water rights and use documents, data, and information.

1.1 WHO SHOULD READ THIS REPORT

We provide information and analysis that may be useful to a range of audiences:

Water managers and agency staff with relevant responsibilities. As detailed in our report, water rights data are foundational for myriad decisions made by agency staff. This report can help these front-line decision makers understand the potential increase in effectiveness and efficiency that may accrue from a WRIS. Notably, the State Water Board and the Department of Water Resources (DWR) have important oversight and intervention responsibilities that relate directly to water rights. This report can help these agencies assess whether and how a WRIS might be integrated into their activities, and provide a structure to articulate their interests in the design of such a system.

Elected officials with an interest in water management. California's administration and legislature have an interest in water management, as do all Californians whose lives are affected by water. Ultimately, our State's elected officials have the responsibility for oversight of the structures by which water decisions are made, and will need to understand and articulate support for the potential benefits of a WRIS.

Water rights holders. California water rights holders have long operated in an environment where they must either invest substantial resources to understand the status of their own water rights relative to others, or operate without complete information about what is often a cornerstone of their livelihood. This report provides a vision for a way towards clarity for all water rights holders in California.

Stakeholders affected by water management. Stakeholders with diverse interests are affected in an ongoing way, directly or indirectly, by water management decisions. Such stakeholders include parties with groundwater or surface water rights; Native American tribes; disadvantaged communities; and third parties interested in maintaining or enhancing environmental flows. This report can help such stakeholders gauge how better access to water rights information might affect the things they care about and identify what questions and issues they want to see thoroughly explored during the planning, development, and implementation of a WRIS.

THE POTENTIAL FOR CULTURAL AND SYSTEMIC CHANGE

Many commentators have remarked that the water management status quo is not serving the State of California well. Changes in climate, population, land use, social values, and other crucial elements in the State will only exacerbate these issues, and will do so much more quickly and intensely than will be easy or comfortable to adapt to.

Many water rights attorneys believe it is impossible to resolve conflict except through years of litigation. To be sure, water law in California has historically evolved at a glacial pace. There are a range of reasons for this, including the challenges of establishing factual records in complex and dynamic systems, risk aversion by parties involved, a relative dearth of established case law relative to the importance of the resource, and an interest by some parties in delaying decisions. The Water Code involves equities, and due process around equities takes time and effort.

However, California has big water management problems to solve, and they are rapidly intensifying. Repeated observations about the unsustainability of California's current water management, and alarming projections about the pace and magnitude of stressors facing the status quo, suggest that California water is not the stable system it was once assumed to be. The traditionally measured pace of attempts to address those problems will not stave off the next crisis; it will only make it harder to resolve when it inevitably arrives. We believe developing efficient and effective development of new approaches and clear solutions is an urgent priority for all Californians who depend on water.

We argue that a crucial element of the necessary and inevitable cultural change will involve providing sufficient information. The current state of water rights data in California undercuts, complicates, and delays due process in resolving water rights disputes, as a result of easily correctible inefficiencies in establishing basic facts.

WHAT IS YOUR INTEREST IN THIS PROJECT?

The goal of this project is to examine the potential for more effective provision of information on water rights, for the benefit of anyone with an interest in California's water and the functions it enables.

Our analysis focuses on the provision of information that is accurate and usable for routine decision making. This report does not advocate for any particular legal or regulatory actions, such as adjudications.

Concerns

We recognize that the concept of more transparent water rights data raises concerns for some. Our research process has included conversations, workshops, and focus groups through which we have spoken with over 100 members of California's water and environmental mana`gement communities. Members of each group have expressed both support for, and reservations, about the ideas and recommendations proposed in this document.

From senior water rights holders, we have heard concerns that more accessible water rights data would facilitate more regulation and litigation. We heard objections that the Water Board is either not active enough, and therefore the effort to generate a WRIS would be wasted, or that it is too active and therefore not to be trusted with such information. Entities holding junior water rights, or contract entitlements to such water rights, tended to be more sympathetic to reforms in eWRIMS.

From environmental groups and other NGOs, we heard objections that our recommendations do not go far enough, because they stop well short of a legally binding understanding of the relative state of water rights in California. We also heard requests for greater detail on the functionality of a WRIS.

We heard objections from agencies about the potential for securing funding for database construction (see **This is a cheap proposal, page 56**), and additional staff for ongoing maintenance of the database.

These are all valid and understandable concerns.

A Simple Proposition

We emphasize that this pilot is driven by a simple principle: greater accessibility of water rights and use data will facilitate quicker, cheaper, and better management decisions by users, other stakeholders, and the State.

Clarity borne of better information will benefit all legitimate claims of right, and open new opportunities. Clarity will protect water right holders' interests during times of drought or other shortage. Clarity will protect senior rights holders if and when efforts are made to implement increased instream flow requirements, or from illegal expansion of riparian claims. Clarity will enable expanded opportunities for water transfers or sales.

Other western states with similar dynamics – persistent conflicts between users, uses, and regions – have transitioned to their own versions of a modern water rights information system. They have found that such systems facilitate better management decisions. California can achieve similar outcomes even though its legal and administrative systems are unique.

We believe that better and more accessible information would support progress and innovation, but that data by itself cannot and will not automatically result in change. Actions taken based on new information will be up to water users, other stakeholders, agencies, and the courts.

This project demonstrates that it is possible to provide data for improved clarity and transparency for decision making. To the extent that water governance processes in California have shortcomings, those should be the subject of other efforts.[22]

1.2 REPORT ORGANIZATION

The report is organized around three basic questions and a hierarchy of activities reflected in **Figure 2**. We begin by addressing "Why?" by providing foundational background information and context for the design of the pilot database. We first examine a series of water management use cases to demonstrate how an improved water rights information system can potentially support critical water management decisions (**Section 2.1**). We continue with describing functionalities needed for water rights decision making, as well as providing use cases on water rights data in practice (**Section 2.2**). Next, we compare California's existing systems to other water rights databases across the western states and Canada, highlighting both the shortcomings of California's current system, and examples of other systems which stand out for their usefulness, transparency, and completeness (**Section 2.3**).

Part 3 addresses "How?". We describe lessons learned from our development and testing of a pilot water rights database (**Section 3.1**). This section details the process of scanning water rights documents and building the database, and touches on the early stages of designing and creating a priority search tool. Next, we address technical considerations for a water rights database (**Section 3.2**), followed by funding estimates (**Section 3.3**).

Finally, we outline a vision for a WRIS, and describe the importance of understanding and integrating such work with other California water data to enable a coherent whole (**Section 4.1**). We discuss logistical and technical issues including privacy, chain of custody, quality assurance and control, data needs, and funding requirements. We then review other useful characteristics for WRIS, providing examples and guiding principles (**Section 4.2**). Lastly, we suggest next steps, recommendations, and topics for further research (**Section 4.3**).

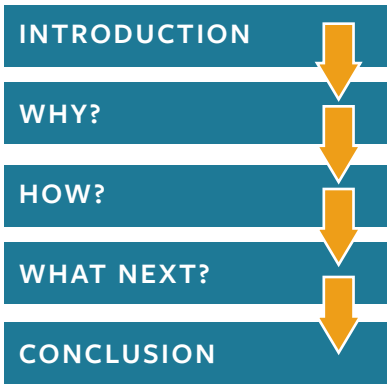

Figure 2. Roadmap to this report.

1.3 METHODS AND APPROACH

Given the range and complexity of the topic and questions motivating this research, we adopted an interdisciplinary, mixed-method approach.

The goal of Part 2 was to examine the rationale for a modern water rights and use information system. To do so, we blended legal and regulatory research, research on data systems, and analysis of publicly available records and published materials, with ongoing engagement with stakeholders and agency staff. This engagement incorporated expert interviews, focus groups, and formal facilitated workshops, conducted over a period of over four years. To develop a comparative picture of the state of practice, our empirical research combined document analysis and interviews to analyze water data systems in California, other western states and British Columbia.

The goal for Part 3 was to empirically develop a pilot to demonstrate two key elements of a complete water rights and use system. First, we scanned and digitized water rights documents. We developed methods and workflow to organize, steward, and prepare paper water rights records for scanning and Optical Character Recognition (OCR) assignment, while safeguarding their integrity. Second, we piloted metadata assignment for these records. For this process, we used legal research and engaged with agency staff to develop and implement a generalizable metadata template for California.

The goal for Part 4 was to develop a conceptual vision for a next generation WRIS. This effort built directly on the experience and lessons learned from Parts 2 and 3, augmented by additional qualitative research including interviews, focus groups, and workshops, plus traditional document analysis and a multi-disciplinary literature review.

Appendix A contains further details on specific aspects of our methods and approach.

2. WHY? CONCEPT AND RESEARCH

In order to understand how a new WRIS might be designed to optimize functionality and usability, we must first understand how such a system would be used. Accordingly, in this section we describe four use cases which illustrate how water rights data, and water data more generally, can be used to support management decisions at all levels of water governance. Next, we compare California's current eWRIMS system to other water databases in the western United States and British Columbia. These comparisons help identify ways in which a new system could improve on eWRIMS and help concretize recommendations for a path forward. The findings from this section informed our pilot activities discussed in Part 3.

2.1 CALIFORNIA'S CURRENT SYSTEM: EWRIMS AND RMS

Although there is no comprehensive and complete single repository of water rights documents, the largest centrally maintained collection is the Records Room at the State Water Board's headquarters in Sacramento. Examples of this system's shortcomings appear throughout this report, but the core challenge is searching voluminous, non-indexed paper files. Still, these documents would remain the State's official legal records even with the development of a modern information system.

The State Water Board also maintains a public information system for water rights known as eWRIMS. eWRIMS includes two components for public use: a Database System and the Report Management System (RMS). Nominally, eWRIMs has some features of a useful water data system, but its shortcomings make it insufficient as a modern water rights data tool.

OBSERVATIONS AND KEY TAKEAWAYS:

- Some California water rights data are available in digitized form, but the current system is limited by incompleteness of data and by outdated functionality.
- Interoperability between eWRIMs and other data sources is weak or nonexistent. Improving the ability for databases to interoperate could be a crucial part for faster and more efficient cross platform communication for decision support.

2.1.1 eWRIMS Database System

The eWRIMS Database System contains basic information on water rights in California, such as location, primary owner, and reported statements of use.[23] eWRIMS was not designed for the purpose of document storage and organization – rather, it has been adapted for the purpose by some, but not all, relevant State Water Board staff. While it contains many water documents, it is far from comprehensive, and has not been systematically populated.[24]

eWRIMS allows users to search for water rights records using multiple structured fields through its Water Rights Records Search. With a successful search, eWRIMS will generate a list of identification numbers associated with an application, license, or permit and limited additional information (*e.g.,* owner, geographic information, status of the water right, and face amount). The Water Rights Records Search also generates a list of statements of use and scanned copies of some water rights when that information is available. Alternatively, a system user can search for a water right by location using a Geographic Information System (GIS).[25]

2.1.2 Report Management System

RMS allows owners of water rights to file statements of use and other reports required by statute or by a specific water right.[31] The filed reports become public when they appear in the eWRIMS Database System, although not all filed reports are made publicly available.

CALIFORNIA WATER RIGHTS

There are several major classes of California water rights, each of which varies in the type and specificity of documentation, data and information associated with it. In California, surface water rights are classified into two broad categories: appropriative and riparian rights.[26]

A riparian water right is "a right to use the natural flow of water on riparian land."[27] Riparian land is land that is adjacent to a body of water, such as a lake, river, stream, or creek.[28]

An appropriative right grants the right to store and use water on non-riparian land.[29] For example, an irrigator diverting water from a river and transporting it miles away to farmland not bordering a water source would need an appropriative right. Appropriative rights in California fall under two categories: pre-1914 and post-1914. Whether a water right is considered a pre-1914 water right is based on whether a water right was initiated before the Water Commission Act of 1913, which established California's modern water permitting process starting in 1914.[30]

The pilot project described in this report focuses on post-1914 surface water rights to demonstrate proof of concept for scanning, digitizing, and making searchable relevant water right information. Other types of water rights would ideally be included in a full scale system, though each type of water rights has unique considerations.

2.1.3 Internal Functions of eWRIMS for the State Water Board

In addition to its public-facing information and reporting functions, eWRIMS provides internal functions for the State Water Board that are not available to the public. These internal functions include the calculation of annual fees for water rights and tracking compliance with reporting obligations.[32]

2.1.4 Limitations of Current eWRIMS System

eWRIMS was originally developed in 2007, and at the time represented a significant and visionary step forward in the State Board Board's information systems. The platform was originally developed as a billing and invoicing system.[33] Board staff and their contractors have made consistent efforts to maintain and incrementally update the software of eWRIMS itself, adding significant functionality over time. However, it is important to recognize the incongruity between the original design and the way it is currently pressed into service, as well as the simple fact that the 14-year-old product is ancient in software terms.

In addition to software improvements, eWRIMS has been populated with increasing amounts of data, and now contains a substantial number of water rights documents and data as described above. It is important to emphasize that populating eWRIMS with data population has happened in an *ad hoc* way. This is similar to the approach the State Water Board has taken to the software in general, which has been patched and extended far beyond its original intent and architecture. Board staff have used eWRIMS as a convenient place to store digital copies of water rights documents for cases they are working on, and over time have built a repository. However, this repository is far from comprehensive – it may contain 1% of the documents held by the Records Room.

The current search functionality in eWRIMS has limitations, including a complicated user interface that requires subject matter expertise to operate and understand. **Appendix B** walks through the steps of a search function in the current eWRIMS system and details some of the limitations in system functions and data. **Table 8** in **Appendix C** provides a detailed enumeration of some of the features and issues in eWRIMS.

For these and other reasons, eWRIMS has limited utility for agencies and stakeholders. Ultimately, it is not sufficient to meet California's varied water management challenges, let alone support the next generation of innovations.

2.2 FUNCTIONALITIES FOR DECISION MAKING

Water rights data are often the foundation of water management decisions. They are pivotal for common administrative actions like determining if a new water right should be granted, and for cutting edge proposed solutions such as establishing whether excess surface water is available for groundwater recharge. Many such decisions hinge on three types of water

information related to the supply of water, the demands for water, and the relative priority of relevant water rights.

A properly designed water rights information system will need to make these three types of information easily accessible. This section discusses elements of data system design for support of effective decision making.

OBSERVATIONS AND KEY TAKEAWAYS

- Use cases indicate that common water management decisions rely on data and information from water rights. California already possesses troves of valuable water rights information, but needs to make it available and more readily accessible.
- Currently available water rights data in eWRIMS do not support functional decision making across the observed use cases.

2.2.1 SUPPORTING CONCRETE AND VARIED DECISIONS

A first step is to identify *who* needs *what data* in *what form* to make *what decision*.[34] Water management decisions span a spectrum of issues, including choices about cropping patters; optimizing local diversion, conveyance and storage operations; investing in infrastructure at all scales; regulatory determinations; and many other concerns. Because these issues are so varied and diverse, starting with the end users' goals can arguably enable a more efficient and effective development of a data system.[35] We developed a set of use cases to help shape this design inquiry. Each use case below describes a water decision making process, and the data needs of that process.

Table 9 in **Appendix E** contains supporting details for these use cases, each of which is anchored by a specific water-related decision, and each of which would be supported by a modern WRIS. The use cases are derived from previously published research[36] in support of AB 1755, with input from our technical workshop, additional interviews, and other research.

A crucial, if basic, takeaway from the use case analysis is that expert practitioners consider water rights data to be vitally important for decision making not only about water rights issues but also on a wide range of topics. These data needs are briefly summarized in **Table 1**, and detailed in **Appendix E**. These data – plus data on physical aspects of the water system, ecological conditions, human health and other elements – complement one another and are all necessary for informed decisions.[37]

Table 1. Summary of water rights data required to support management decisions in our use cases.

	Beneficial Use (including purpose)	Type of right (e.g., pre-1914, post-1914, riparian)	Face Amount (Quantity)	Name of Permit or License Holder	Place of Use	Point of Diversion	Priority	Timing
Can the SWRCB approve a new water rights permit?	✓	✓	✓		✓	✓	✓	✓
Can a current water rights holder divert water?		✓	✓			✓	✓	✓
Can a water user sell or trade surface water this year?	✓	✓	✓	✓	✓	✓	✓	✓
What is the environmental water balance by stream segment and system?	✓		✓		✓	✓		

This table distills the explanations of data requirements for the use cases described in Section 2.2.2. More detailed descriptions can be found in in Appendix E.

2.2.2 Use Cases: Water Rights Data in Practice

Four use cases summarized below demonstrate how a WRIS could support specific water management decisions. The example use cases – granting new water rights permits, overseeing water rights, developing water markets, and protecting environmental flows – are illustrative, not exhaustive or definitive.[38] Each use case implicates the need for other water data, such as hydrologic, hydrogeologic, water quality, and biological metrics. **Table 10** in **Appendix E** details related decisions and actions, and ties them to examples of necessary supporting data. Please see Cantor et al. (2018) [39] for more details on water data needs in these and other use cases.

Granting New Appropriative Water Rights Permits

In order to obtain a new appropriative water right, a prospective diverter must apply for a permit from the State Water Board. To approve a permit, the Board must find, among other factors,[40] that there is sufficient unappropriated water available for diversion, and that granting the permit is in the public interest. Both of these determinations require information from existing water rights permits, because new water rights are junior to existing water rights. When evaluating whether the permit is in the public interest, the Board considers whether the applicant's proposed beneficial use, quantity, timing, place of use, or point of diversion may cause harm to existing water rights or the environment.

The process for new water right applicants would be more efficient and more equitable if it was faster, easier, and cheaper to determine whether unappropriated water is available for a new application, and whether the applicant could demonstrate that their permit would be in the public interest without harming existing users.[41] These questions are currently answerable, but deriving this information takes significant time and expertise, and often involves hiring lawyers and consultants. Applicants would benefit from information with which to conduct preliminary analyses, to ascertain whether a new right is worth pursuing. Senior water users and other stakeholders also desire clarity about whether and how new water rights permit applications might affect their interests.

Information including the face amount, timing, beneficial use, place of use, and point of diversion are all essential for this decision (see detail in **Table 10** in **Appendix E**). These data are typically found in particular fields on a water right permit, license, or application. These documents are stored as paper records and sometimes, but not always, duplicated as PDF files only accessible under certain conditions. Accessing any one of these specific documents for a single water right involves significant discovery effort, and generating useful information about the relationships between water rights often requires many such documents.

Oversight of Water Rights

Whether or not a water user with an existing permit can divert water at a particular time relies on, or should rely on, much more real-time data. Data from existing water rights are also an important part of the analysis. Water rights data help inform water rights holders' expectations about their likelihood of legal water diversion. Such clarity has value for planning, including whether to seek alternate water supplies. These same data are an important ingredient of the State Water Board's oversight of the water rights system with respect to timing, priority, and quantity limits of diversions. These data are also important for helping the agency decide when and where curtailment might be necessary in cases of water shortage.[42] **Table 11** in **Appendix E** enumerates necessary data, and how it can be used to support these decisions.

Establishing Water Markets and Facilitating Water Transfers

Water markets and individual water transfers are an increasingly important component of reconciling mismatch in supply and demand in California water.[43] But buying and selling water, or the right to use it, is often far from straightforward. Data and details matter. Most water transfers in California take place among Central Valley Project ("CVP") or State Water Project ("SWP") contractors. Better water rights information might enable greater access to trading for other water rights holders.

Rigorous water right accounting, with a credible, transparent, independent "ledger book" is a bedrock of any functioning market. A right holder cannot sell (and buyers should not buy) when ownership and other conditions are

not clear. Thus, all market participants need access to water data to verify ownership and determine whether a potential transfer or sale is economically, legally, and technically feasible. A range of stakeholders would benefit from availability of water rights data, including individual buyers or sellers, consultants or agencies seeking to design or develop new water markets, or academics working to develop new methods, metrics, and tools.

In many cases, State and federal regulators need water rights data to assess whether such sales or transfers should be approved.[44] For those transfers subject to its approval, the State Water Board must determine that 1) there is no injury to legal users of water; 2) there is no unreasonable effect on fish, wildlife, or other instream beneficial uses; and, for short term transfers, 3) the transfer does not exceed the amount of water that would have been consumptively used or stored by the original permit holder. To make these "no injury and no unreasonable effect" determinations and to verify the amount of water consumptively used, State Water Board needs priority, quantity, timing, beneficial use, point of diversion, and place of use information from the water right in question. **Table 12** in **Appendix E** outlines the selling and transfer data process.

Determining Environmental Flows

In order to protect ecosystem functions, environmental flows must be set, monitored, and protected, all while taking into account competing water uses.[45] Setting baseline environmental flows is data intensive, complicated, and requires intensive consultation among agencies, experts, and stakeholders.[46] Further, the measures necessary to maintain proper environmental flows can be highly variable year-to-year and largely depend on fluctuating natural conditions including water year type. Therefore, determining environmental flows and ecosystem needs requires current, updated data.[47]

Water rights information is necessary to set appropriate environmental flows, as indicated in Table 13 in Appendix E. Data on existing water rights help establish how natural conditions in a basin or stream may be altered by human activity. Data about ecological conditions and requirements, as well as data on existing uses, amount of use, and timing of use are essential for the State Water Board to fulfill its statutory obligation to balance human and ecological needs alongside.

2.2.3 Use Cases Demonstrate a Demand for Water Rights Data

These use cases concretely illustrate that water rights data are a crucial component of water management decision making. The activities described in the use cases are neither isolated nor rare. They are core agency functions, gating activities for water use, and crucial proceedings for ensuring environmental protection. These and other common water management activities rely on water rights data to generate the analysis and information that enables everything from day-to-day water operations to forward progress on future water innovation.

Many of the data described in this section already exist. California already possesses troves of valuable water rights information, but those data are generally difficult for stakeholders and even other regulators to access because they are housed in unindexed paper files held in Sacramento. But given the demand for rapid action in some use cases, and the sheer volume of data and decisions in others, the State needs to make its data more readily accessible.

2.3 CROSS-JURISDICTIONAL COMPARISON

In order to understand potential pathways to improving access to water rights data, California can look to other western states to see how analogous water rights database systems have been designed. While a new water rights database should be tailored to California's water management concerns, observing other existing data systems highlights areas where California could improve, and enables learning from others' experience. Our analysis mainly focuses on the availability of water rights documents and data, but also considers key elements such as metadata assignment, searchability, usability, and other design considerations. We also touch on decision support tools and other technical considerations.

Empirical results for this section were primarily generated through systematic examination of publicly available online databases in California, 11 other western states, and British Columbia (**Table 2**), augmented by literature review where applicable.[48] Jurisdictions in this analysis were chosen for overlapping characteristics with California such as geography, and some use of the prior appropriation doctrine. Note that in this section, we use "other states" as a shorthand for the collection of jurisdictions represented here.

We recognize that California is geographically, legally, and institutionally more complex than many other jurisdictions, and lacks some features that would support the kind of advances present in some of these other places. Still, California can learn much from successes in other jurisdictions.

OBSERVATIONS AND KEY TAKEAWAYS

- Perhaps surprisingly, California in many respects lags other western states in the accessibility, usefulness, and usability of its water data. Its current system has promise but does not live up to its potential – there is significant room for improvement.
- Our analysis revealed a range of specific functionalities that could help make a new WRIS effective and efficient for decision making. These functionalities are all achievable – they have been put in place by other states, and thus California could do so as well.
- Tools that house these data must do so in an accessible, interoperable, and usable way.
- Fully digitizing water rights records is a critical early step.
- The examples in other states illustrate the importance of other water data. For example, California would be able to more effectively answer existing management questions if it fills in gaps water supply data, such as through improvements in stream gage monitoring networks.
- Water data in California are plentiful, but mostly in forms that are inaccessible for efficient and effective practical use. Specific near-term steps could unlock the potential for innovation in the State and move California from data laggard to data leader.
- California could become a leader in water data and governance. The State already collects a large amount of data, including supply and water quality data. It also already possesses some limited historical records of water use and water rights. If the State can continue to fill in its water information gaps and ensure that data can be updated in real-time, it will be well poised to take the next step – designing and building a comprehensive water management system.
- Ultimately, a system comprised of three complementary components would be an ideal: paper records to maintain continuity with the current legally binding official documents of record; comprehensive, indexed, and searchable digital scans of these documents to enable rapid access; and extensive georeferenced metadata to allow for searchability, inter-comparison, and many other uses.

2.3.1 Water Rights Documents

California lags other western states in the electronic accessibility of its water rights documents and data. These data collectively enable the public and government entities to understand who is using how much water, for what purpose, when, and where. Water rights documents – such as permits, licenses, and statements of use – contain the foundational legal information on which water allocation and use is based. Permits and licenses give a water user the right to divert surface water. Statements of use record how much water was used under a claimed pre-1914 or riparian water right.[49]

States vary in how complete and accessible their records are (**Table 2**). While some states have incorporated information from original water rights documents in digital form in their databases (see **Availability and Completeness of Documents**, below) we emphasize the importance of keeping the original documents themselves available as a record of the originals and to preserve institutional memory.[50]

Ultimately, a system comprised of three complementary components would be an ideal: paper records to maintain continuity with the current legally binding official documents of record; comprehensive, indexed, and searchable digital scans of these documents to enable rapid access; and extensive georeferenced metadata to facilitate robust searchability, rapid inter-comparison, and broader analysis.

Table 2. Characteristics of water rights databases in western jurisdictions.

	AZ	BC	CA	CO	ID	MT	NE	NV	NM	OR	TX	WA	WY
Complete – all water rights documents (permits, licenses, and statements of use) can be found online for all surface water rights	✓	✓	x [51]	✓	✓	✓	x	✓	✓	✓	x	✓	✓
SOME water licenses and/or permits available	✓[52]	✓	✓	✓	✓	✓	x	✓	✓	✓	x	✓	✓
Online accessibility of documents – some original documents are publicly accessible online	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	x	✓	x [53]
Additional documents available – documents other than permits, licenses, and statements of use are available in the database system	✓	x	x	✓	✓	✓[54]	x	✓[55]	✓[56]	✓[57]	x	✓[58]	✓[59]
Downloading – Can available documents be downloaded?	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	x	✓	✓

✓	Data or function described is available.
x	No data or function publicly available. [60]

Note: Row 3 of this table asks whether states have ANY water rights documents available. A state that had a few documents available (even if those documents were sporadically entered, as is the case in California) received a green check. While a small number of water rights documents may be found in California's currently existing eWRIMS system, it is far from complete (Row 1).

Availability and Completeness of Documents

California lags other states in the online availability of basic water rights documents (**Table 2**). Most other states make water rights permits and other documents available online.[61] Among prior appropriation states, only Texas and Nebraska lack a water rights document database. For states with a document database, the breadth of available documents varies but can include pending water rights applications, administrative hearing orders, court orders, affidavits, change of ownership applications, transfer records, maps, agency inspection records, and records of correspondence. Ultimately, the State of California will need to decide how complete its database should be, weighing both the legal and administrative determinations of what constitutes water rights documents, and costs and benefits of increasing levels of completeness.

California's eWRIMS system only provides copies of some, but not all, water rights permits, licenses, and statements of use.[62] These documents are necessary baseline information to determine who gets to use what water, when, and where. However, these documents alone do not provide a complete or accurate picture of any particular water right, let alone its relationship to other rights or California's broader water management activities.

If California wants to provide the public with a clearer and more transparent view of water management activities and challenges, the State should pursue a system that makes available a broader and more complete range of documents. As one example among many areas for improvement, attaching change petitions related to a transfer of water to affected water rights records within a database would make it easier for the public to trace how water is redistributed across the State, whether by sale or lease. Currently, the scant available information on change petitions for water transfers is housed on a State Water Board webpage,[63] and the documents themselves are not made available to the public through an online document search.[64] Other states do this as a matter of routine practice.[65]

Searchability

The deeper value of digitization of records is unlocked once a user can find what they need using search functions. Effective searchability takes a number of forms, and its thoughtful design is a key component electronic records access. Searchability in water rights documents can take three main forms: metadata-based search on specific fields; within-text search; and map-based search. Each has different strengths, specific applications, and costs.

Table 3 summarizes the findings of our investigation of other states. California comes in the middle of the pack in terms of the available search types.

All surveyed states included metadata-based search for at least a limited number of fields such as permit identification number, owner name, source name, priority date, and watershed. See **The Role of Metadata in a Water Rights Database** page 43, for a discussion of the importance of metadata assignment for such systematic search capability. eWRIMs has the capability for a range of field-based searches, but without consistently and completely assigning metadata to individual water rights and records, this capability does not live up to its promise.[66]

In-text search capability involves the ability to search all of the words within each electronic document in a database. This can be enabled natively in electronically produced and filed documents such as search-enabled PDFs, or through Optical Character Recognition, a technology which converts handwritten or typed text in scanned documents into machine-encoded text which can be made searchable. Only Arizona has in-text search enabled in its water rights records. In-text search is not strictly necessary, particularly where thorough metadata assignment has been invested in, and where users are deeply familiar with the material and data system. For example, attorneys who already know exactly which water rights they are interested in, and what their permit numbers are, may be able to navigate easily without in-text searching. Without this level of familiarity manual searches by name or location can work, although perhaps less reliably. In-text search can make searches more thorough and comprehensive, and, as the example in **Section 3.1.3**. illustrates, can magnify the utility of a document trove in unexpected and powerful ways. eWRIMs does not have this capability.

Georeferencing tags records based on their geographical location, allowing map-based searches and investigations, typically through integration with a GIS-based user interface. For water rights data, GIS-based searches offer a powerful and important means of finding relevant information in many decision-making contexts. Since water rights are both temporally and spatially relative, being able to query a database based on location as well as other characteristics could enable much more efficient and effective approaches to a wide range of use cases. A handful of the states in our survey have georeferenced data, although their implementation varies in both the details of its functionality and the completeness of its georeferencing.[67]

eWRIMs has GIS capability, but its user interface could be improved to make it more accessible to non-experts (see **Achieving Level 3 data integration in British Columbia's Cariboo Water Tool**, page 39, and **Section 3.1.3**), and the GIS functionality depends on incompletely georeferenced data. While eWRIMS does allow some search functions on a GIS map, it is difficult to generate results. The stream trace tool can be finicky, and the GIS map does not allow for an area search.[68] The current eWRIMS Web GIS system allows for "stream trace" functions to find Points of Diversion that are hydrologically related, though the tool is not easy to use and does not allow for priority sorting. The tabular exports from eWRIMS do allow for easy priority sorting, but it's difficult to see which PODs are connected to each other. Tools built for other areas, such as the Cariboo tool (see **Achieving Level 3 data integration in British Columbia's Cariboo Water Tool**, page 39), one can easily see Priority date directly connected to the POD on the map, and the

tool provides access to extensive watershed PDF reports with diversion points and rights dates listed, but the nature of a PDF means one cannot easily cross-reference stream location against seniority.[69]

Access and Downloading

Public access to documents is essential for trust and transparency in decision making, and permitted by California law. (see **Section 3.2.1** for more discussion). Most states, including California, allow documents to be downloaded directly in PDF form where they are available.[70]

The current system for eWRIMS document retrieval is not intuitive, and navigation often requires specific platform knowledge. Documents that are available are hard to access and find, and only a limited set of documents (incomplete and inconsistently applied) are available for download. The design hinders, rather than enables, information access.

Table 3. Data search functions in western jurisdictions.

	DATA SEARCH FUNCTIONS (BY GIS TOOL OR OTHER DATABASE)												
	Search Function	AZ	BC	CA	CO	ID	MT	NE	NV	NM	OR	TX	WA	WY
METADATA BASED SEARCH	By Priority Date	✓	✓	x [71]	✓	x	✓	✓	x	x	✓	x	✓	✓
	By License/Permit Number	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	✓
	By Status of License/ Permit	✓	✓	✓	x	✓	✓	✓	x	x	✓	x	x	✓
	By Source of water	✓	✓	✓	✓	✓	✓	✓	x	x	✓	x	x	✓
	By Stream Segment	x	x	✓	x	x	x	x	x	x	✓	x	x	x
	By Watershed or Basin	✓	✓	✓	x	✓	✓	x	x	✓	✓	x	x	x
	By Lessee	x	x	x	x	x	x	x	x	x	x	x	x	✓ [72]
	By Owner	✓	✓	✓	x	✓	✓	✓	✓	✓	✓	x	✓	✓
	By Beneficial Use/Purpose	✓	✓	✓	✓	✓	✓	✓	x	x	✓	x	x	✓
	By Quantity/Amount	✓	✓	x	✓ [73]	x	x	✓	x	x	x	x	x	x
	By Timing	x	x	x	x	x	x	x	x	x	x	x	x	x
	By Place of Use (POU) Location	x	x	x	x	✓	x	x	x	x	✓	x	x	x
	By Point of Diversion (POD) Location	x	✓	✓	✓	✓	x	✓	x	x	✓	x	x	x
GEOREFERENCED SEARCH	GIS Map Search	x	✓	✓	✓	✓	x	x	x [74]	x	✓	x	✓	x [75]
	GIS Stream Trace	x	✓ [76]	✓	x	x	x	x	x	x	✓	x	✓	x
	GIS Watershed	x	✓	✓	x	x	x	x	x	x	x	x	✓	x
WITHIN DOCUMENT SEARCH	**Searchable (OCR)** – uploaded documents are searchable by OCR (terms are searchable within a document)	✓	x	x	x	x	x	x	x	x	x	x	x	x
	Searchable (keyword) – documents can be searched by keyword (terms are searchable within the database as a whole)	x	x	x	x	x	x	x	x	x	x	x	x	x
	Searchable database by permit number or other field	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	x	✓	✓

✓	Data or function as described is available.
x	No data or function publicly available.[77]

California stacks up fairly well to other states in terms of how much water-related data is strictly available. However, California could improve its data search functions to take advantage of the electronic resources it does have by including a priority-based search function.[78]

2.3.2 Interoperability

While illustrative of overall demand in a given water basin, water rights data alone cannot effectively inform water decisions. Rather, water rights data are most effective when coupled with other types of information, particularly those which monitor and predict water supply and quality. Interoperability refers to the ability of information technology systems to exchange meaningful information with each other in standard ways that allow for common comparison, aggregation, and analysis.[79] Ultimately, water management is so complex that management tools that analyze and integrate these data sources will be necessary for making sense of, and acting on, current conditions and future expected trends.

Table 4 synthesizes available data and monitoring tools from other states. It illustrates the wide range of tools and functionalities that might be included in a water rights information system beyond water rights data. These tools may currently exist separate from eWRIMS, although ideally a WRIS, along with other activities focused on water data more broadly,[80] would enable users to see a more compete and integrated picture.

Table 4 presents the availability of a publicly accessible management tool that packages and presents raw data on a State platform. Tools vary in terms of usability and effectiveness, though we did not rate or rank them in our survey. For example, Wyoming provides links from its water rights database to snowpack data used in water allocation decisions, but does not actually have a snowpack reporting or observation tool integrated with the State's water data site itself. Some states linked to outside platforms which monitored water conditions in the state but that were not owned and operated by the state. Many state platforms hosted a webpage for stream gage information, but would reroute a system user to the USGS website to view the actual data. We did not include such external resources in our evaluation.

Table 4. Water supply data, quality data, and monitoring tools available in western states.[81]

Monitoring Tool	AZ	BC	CA	CO	ID	MT	NE	NV	NM	OR	TX	WA	WY
Streamflow; real-time – does the platform provide a real-time streamflow monitoring tool (non-USGS)?	X	✓	✓[82]	✓[83]	X	✓[84]	✓	X	X[85]	✓[86]	X	✓[87]	✓[88]
Streamflow; historic – does the platform provide a historic streamflow monitoring tool (non-USGS)?	X	✓	✓[89]	✓	X	✓	✓	✓[90]	✓	✓[91]	X	✓	✓
Streamflow; forecast – does the platform include a streamflow forecast tool?	X	✓	X	X	X	X	X	X	X	X	X	X	X
Reservoir levels; real time – does the platform have a tool that reports real-time reservoir levels?	X[92]	✓[93]	S[94]	X	X	X	X	X	X	X[95]	✓[96]	X	X
Reservoir levels; historic – does the platform have a tool that catalogues historic reservoir levels?	X[97]	✓[98]	S[99]	X[100]	X	S[101]	X	X	X	X	✓	X	X
Precipitation; real time – does the platform include a real-time precipitation tool?	X	✓	S[102]	X	X	X	X	X	X	X	✓[103]	X	X
Precipitation; historic – does the platform include a historic record of precipitation?	X	✓	S[104]	✓	X	X	✓[105]	✓[106]	X	X	✓	X	X
Precipitation; prediction – does the platform include a tool for predicting precipitation, based on historical averages or other data?	X	✓	X[107]	X	X	X	X	X	X	X	X	X	X
Snowpack; real-time – does the platform include a real-time snowpack report, including snowpack water equivalent (SWE) data?	X[108]	✓	✓[109]	✓	X	X	X	X	X	X	N/A	X	S[110]
Snowpack; historic – does the platform include a tool which records historic snowpack conditions?	X	✓	✓	✓	✓	S[111]	✓[112]	X	X	X	N/A	X	S[113]
Snowpack; prediction – does the platform include a tool for predicting snowpack conditions, based on historical averages of other data?	X	✓	X	X	X	X	X	X	X	X	N/A	X	X
Groundwater levels; real-time – does the platform track and report real-time groundwater levels?	✓[114]	✓	X[115]	✓[116]	✓[117]	X	X	X	X	X	✓[118]	X	X
Groundwater levels; historic – does the platform record historic groundwater levels?	✓[119]	✓	X	✓	✓	X[120]	S[121]	✓[122]	X	✓[123]	✓	S[124]	S[125]
Water quality; real-time – does the platform provide water quality updates from the last 24 hours?	X	X	X	X	X	X	X	X	X	X	X	✓[126]	X
Water quality; historic – does the platform provide historical water quality records?	X	✓	✓[127]	X	S[128]	✓[129]	X	✓[130]	X[131]	✓[132]	S[133]	✓	X

✓	Data plus tools for analytics or interpretation support publicly available from the state
S	Only data available from the state
X	No data or tool publicly available from the state

2.3.3 Can California Optimize Water Data?

Water data including information on supply and quality are crucial to water management decisions. Western states address water supply and quality data in different degrees. **Figure 3** provides a conceptual illustration of the levels of investments that states may make in data availability and usability.

LEVEL 1 (BASELINE)	**LEVEL 2** (INTERMEDIATE)	**LEVEL 3** (IDEAL)
✓ State measures and records water data × Raw data are not made public × Data are not incorporated into a useable tool that helps the system user understand and interpret the data × Data are not ineroperable with other data sources	✓ State measures and records water data ✓ Raw data are made public × Data are not incorporated into a usable tool that helps the system user understand and interpret the data × Data are not ineroperable with other data source	✓ State measures and records water data ✓ Effective QA/QC procedures are carried out ✓ Raw data are made public ✓ Data incorporated into a usable tool that helps the user understand and interpret the data ✓ Data are interoperable with other data sources

Figure 3. Conceptual illustration of levels of water data availability and usability.

At the baseline level, a state may simply ensure that data are measured and recorded. While these data may be used internally by state agencies for water management decisions, they are not made available to the public, nor are they interoperable with other data sources.

At an intermediate level, states provide water supply and quality data in an accessible form to the general public. This is the case for many states in our survey. California, for example, maintains a wide variety of water data through the Department of Water Resources' (DWR) California Data Exchange Center (CDEC).[134] While data availability is nominally good at this level, data may be difficult to interpret by a non-expert, and bringing together multiple data sources can require resource investment. Ultimately, California needs a system that tracks natural flows, actual diversions, and permitted diversions on a real-time basis. Currently, California's streamflow datasets aren't linked by a tool that communicates with California's snowpack data – even though snowpack data inevitably impacts streamflow as snow melts and in turn affects water supply decisions.

At the third ideal level in **Figure 3**, data are not only measured, recorded, and publicly available, but are also provided in a useful and usable way to

non-experts, and are interoperable with other data. While California does not yet meet this ideal, the State is well situated to provide this level of functionality. Crucially, all data do not need to live together in a single data platform. Rather, multiple data sets can be maintained and operated independently, but structured to allow exchange and synthesis of the disparate types of data. The State maintains a valuable trove of data through the CDEC – including streamflow, reservoir levels, precipitation, and snowpack. Historical water quality data are available from the California Environmental Data Exchange Network (CEDEN). The challenge for California will be maintaining and completing its water datasets and translating those datasets into actual usable tools that are accessible, useful, usable, and interoperable with other datasets.

Although many challenges exist,[135] we believe California has tremendous advantages on which to build, and that for California, data nirvana is an achievable goal. One of the strongest arguments that California can do this is that Colorado and British Columbia almost have. Even for these leaders in the field, work continues on their efforts to develop interoperability of their data with outside sources. But impressive systems in Colorado and British Columbia come closest to this ideal, and there is every reason to expect that California can learn directly from their efforts and build a WRIS that fully supports decision making by a broad range of actors.

ACHIEVING LEVEL 3 DATA INTEGRATION IN BRITISH COLUMBIA'S CARIBOO WATER TOOL

British Columbia's Cariboo Water Tool provides a useful example of a system that is both rich in functionality and interoperability, and accessible to a non-expert (**Figure 4.**)[136] The system provides historic, current, and predictive monitoring tools for streamflow (**Figure 4** and **Figure 5**), groundwater levels, and climate (precipitation, snowpack, and temperature). It also provides historic surface and groundwater quality data.

The accessibility and ease of use are noteworthy. Clicking anywhere on the Cariboo map generates a watershed report. By clicking on the "PDF" icon, researchers can view a preliminary report on water demand and supply in the selected region. For more information on this function, see **Watershed Reports.**

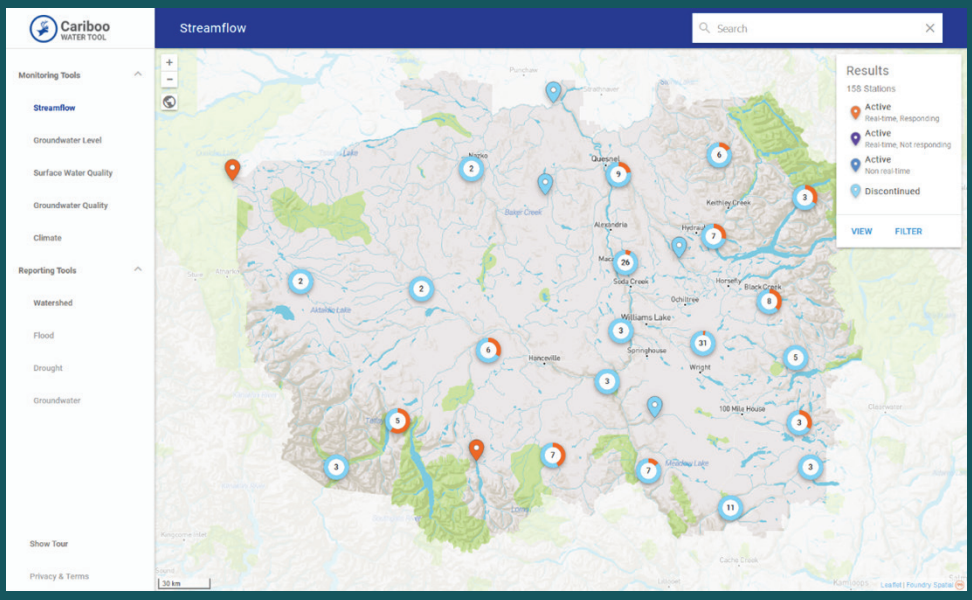

Figure 4. The Cariboo Water Tool's homepage, mapping locations of active and historic stream gages.

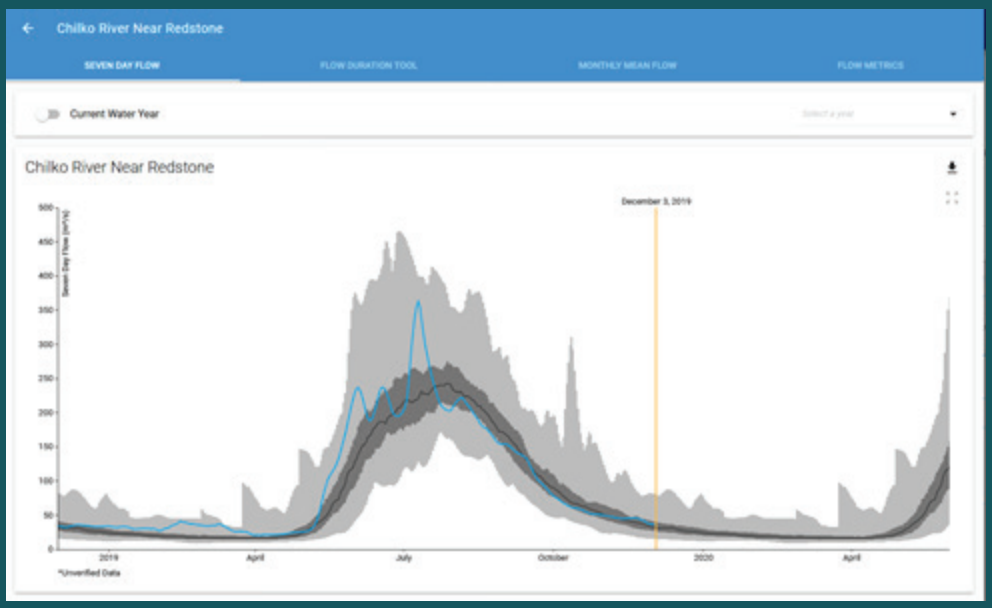

Figure 5. An example of the Cariboo Tool's streamflow monitoring function.

The system also includes a watershed reporting function, which combines information from water rights documents with water supply information. The reporting function delivers an on-demand report for specified watersheds (**Figure 6**), which includes information on hydrology, upstream and downstream water supply and demand, risk management levels, climate and predicted climate trends, and existing water allocations sorted by priority date. The existence of the report generation tool, in particular, reduces transaction costs for individuals by allowing users to quickly obtain a broad view of water supply and demand in a given basin.

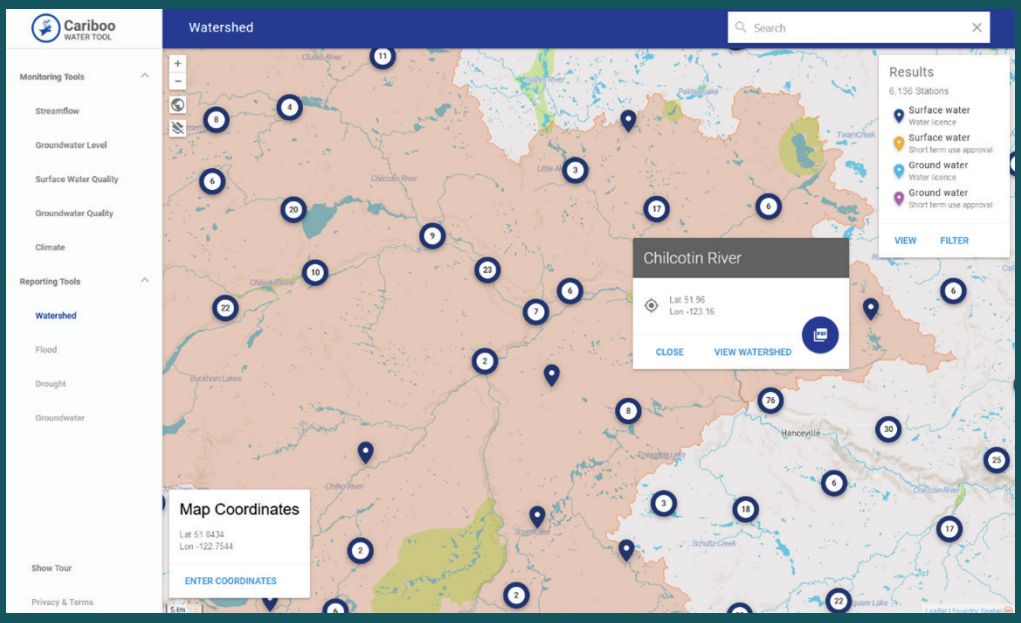

Figure 6. The Cariboo Tool's watershed mapping tool.

3. HOW? PILOT PROJECT AND PROOF OF CONCEPT

Having established that a modern water rights and use information system would be useful for the State of California, and that based on experience in other areas it would be possible to develop, we now describe an empirical example for California, a pilot database in the Mono Basin.

Our pilot focused on one foundational aspect of water rights data, namely scanning and organizing water rights documents and making them searchable. The goal of the pilot was to clarify the potential process and cost for scanning, digitization, and metadata assignment. This section reviews our team's process and concludes that the task is not only theoretically but also practically feasible.

3.1 DEVELOPING AND TESTING A PILOT DATABASE

Our team chose to focus on one aspect of California's water data challenge with foundational importance for water governance – converting water rights documents into digitized and searchable form. In particular, we were interested in whether a sample of paper documents housed in the Records Room could be scanned, uploaded, and made searchable for a reasonable cost, and what we could learn about the potential cost and effort of doing so at scale. This phase of the pilot focused on these elements, and left a crucial next step for future work, namely detailing user interface, front end functionality, and methods for interoperability.

Our team selected the Mono Basin in Eastern California for the pilot project. In one sense, the Mono Basin is a comparatively straightforward pilot because there are only two water rights involving significant diversions for consumptive uses. However, the Mono Basin presents an excellent test case for this phase of the pilot because of the variety of documents associated with those two rights. Years of litigation about these water rights in the Mono Lake Cases, including evidentiary hearings (1993-4) before the State Water Board,[137] have resulted in a trove of over 132,000 pages of records of many types, including hearing exhibits, reports, and public correspondence. And

importantly, the water rights holder – Los Angeles Department of Water and Power (LADWP) – offered to support and fully fund the pilot.

The team scanned and digitized these records, and built a search tool with two search mechanisms, the first using a variety of assigned metadata fields such as owner name, permit or license number, and the second using OCR to enable searching complete document text. The following section describes the scanning and metadata assignment process, as well as relevant costs for this step of building the database.

Scanning the documents took a total of ten days and indexing took two minutes per record, for 5,998 total records, encompassing all 132,000 pages. Scanning the documents in the pilot project cost about $0.20/page, and indexing the documents brought the total cost to about $0.32/page. This exercise provides an important empirical basis for future estimates of cost for a potential statewide application, subject to important caveats. This pilot was conducted by a private firm under a private contract. Were the State of California to fund such an effort, contracting procedures, overhead costs, vendor eligibility, the scale of the project, and other factors may make the per page cost significantly different, and precise estimates of those costs is out of scope for this report.

While this pilot is only a small first step in improving the accessibility of California's water rights data, it demonstrates that it is possible and provides useful information about whether and how the State can bring a WRIS to scale.

OBSERVATIONS AND KEY TAKEAWAYS

- It is possible. 5,998 records, amounting to 132,422 pages, were scanned in ten days using a small team.
- The process is less expensive than previously estimated.
- Multiple options exist, ranging from simpler execution with more limited benefits, to higher upfront costs with potentially greater utility.
- Costs of a full-scale WRIS would be offset in the long term by reduction in costs associated with information processing under the status quo.

3.1.1 Scanning Water Rights Documents

The first challenge in designing the pilot was that most water rights documents had never been systematically scanned and accounted for by the State. A select range of documents had been scanned (typically water permits or licenses), but the majority had not. Many unanswered questions existed about the logistics and process of transforming large volumes of paper records into a searchable repository, and no protocols for the creation of such a system existed. Thus, our team had to design a scanning and organizing protocol from scratch and ensure that the protocol was followed throughout the pilot process.[138]

Perhaps the largest unanswered question concerned cost. At the beginning of the pilot, it was unclear how much it would cost to scan the records, with initial estimates (from university libraries) of over $1.00 per page. The pilot revealed that the cost of scanning, including contractors and equipment, but excluding a modest amount of State Water Board staff time, was around 20 cents per page (**Table 5.**)

Table 5. Cost of scanning records in the pilot.

NUMBER OF PAGES	NUMBER OF RECORDS	TOTAL COST FOR SCANNING TASKS	COST PER PAGE FOR SCANNING TASKS
132,422	5,998	$27,048	$.204

3.1.2 Indexing and Assigning Metadata

To allow for refined searches, metadata were assigned to each record after the development of a systematic structure and process. First, we developed in consultation with State Water Board staff a set of metadata fields based on key characteristics of water right records and searches (*e.g.*, permit or license number, location, amount of right), and on common fields used for similar legal records (e.g., author, title, document date). The details of this assignment schema can be found in **Appendix G**.

Second, we developed a database and entry system consistent with this framework, using the open-source Django web application framework.

Finally, our team assigned values for each metadata field to each scanned document (see **Appendix G**). Fields included title, document type (report, exhibit, etc.), author, and date. Experienced water rights paralegals did the indexing, under the supervision of a water rights attorney. We suggest that this is likely to be an effective and efficient method for metadata assignment – water rights experience is important in understanding how to interpret documents correctly and do so efficiently. Because the team assigning metadata had extensive water rights experience, and in particular because the supervising attorney had deep experience with the Mono Basin litigation, the resulting indexing costs for the pilot are lower (**Table 6**), and its initial accuracy higher, than in a situation with a less specialized team. If California chooses to build a water rights database system, indexing costs may vary depending on the experience of staff hired to complete indexing and metadata assignment tasks. Budgeting for a full-scale effort would need to take this uncertainty into account, along with other uncertainties such as the exact amount, nature, and condition of documents to be scanned.

THE ROLE OF METADATA IN A WATER RIGHTS DATABASE

Metadata are essentially data about data. As opposed to data taken from scanned documents (*e.g.*, priority date, quantity of water right, point of diversion) or from a data source (*e.g.*, the measurements taken by a stream gage), metadata is data about scanned documents or data sources. For example, metadata may tell a system user:

- Who uploaded the data to the system
- What type of data are contained in a given record
- When data was entered or recorded
- Where data was produced, or what location a record refers to
- Whether and how data have been adjusted from their raw state
- The quality of the data, such as any ranking or grading, if it includes a confidence interval or margin of error, or when relevant instruments were calibrated
- Any records of revisions and updates to a record, ideally including a record of old versions

Metadata are critically important for managing data. Proper metadata assignment helps ensure data quality and allows for traceability to previous data versions. Metadata also enables systematic searches. To illustrate, searching for "John Smith" in the "Owner" field could reveal water rights owned by individuals with this name, whereas a general search for "John Smith" could also return documents that were, for example, prepared by a consultant with this name. Ultimately, it will be up to the State Water Board to decide the extent of metadata to include, based on an evaluation of the costs and benefits of exhaustive assignment.

Once established, most metadata would ideally be automatically generated or updated. For example, if a document were determined to be illegible and a new scan were required, a database would automatically keep a time-stamped record of its replacement.

The development and implementation of an indexing protocol is important for the pilot because it enables users to search systematically for documents with specified characteristics. It is also important because the metadata scheme can be leveraged by the State if and when it brings a WRIS to scale.

Table 6. Cost of indexing documents in the pilot.

NUMBER OF RECORDS	INDEXING COST PER RECORD	INDEXING TIME PER RECORD	INDEXING COST PER PAGE
5,998	$2.80	2 minutes	$.113

The text provides important caveats, and indexing costs for other projects would likely depend greatly on a range of factors.[139]

3.1.3. Priority and Geographical Search

One basic need for a WRIS revolves around rapidly answering questions that are foundational to most water rights inquiries: Where are water rights in a given area, and how do they relate to one another in terms of seniority? Our survey of water rights tools in western states (**Section 2.3**) highlights limitations of California's current system, and suggests that a novel tool specifically designed to streamline priority searches would be important to decision makers, and also a useful contribution to water rights information more broadly.

Appendix D discusses search functions and related questions about document integration in more detail, and we summarize key points here.

We used existing public data, both from the current eWRIMS system and the USGS National Hydrography Dataset Plus (NHDPlus),[140] to develop a "priority sort" tool that allows for easy searches of Points of Diversion (PODs) by a range of attributes, as shown in **Figure 7.**

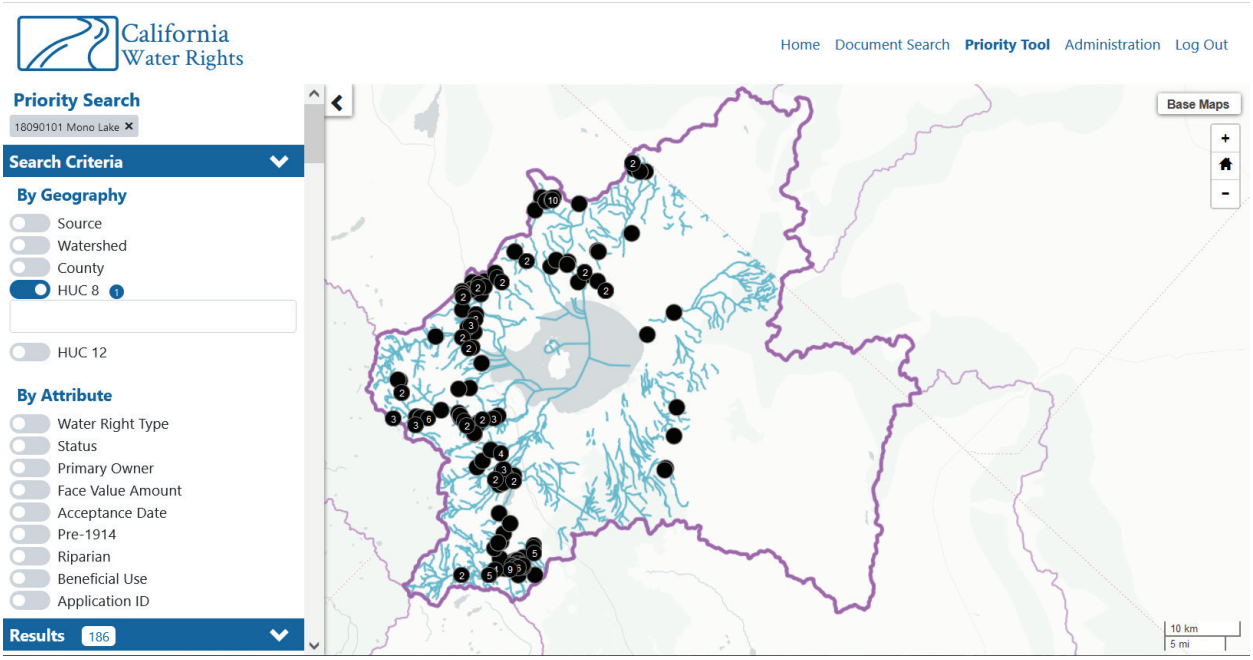

Figure 7. POD search with multiple filter options, including both boundaries and rights types.

As shown in **Figure 7**, the Priority Tool includes a range of options for filtering, including multiple boundary layers (from California or USGS sources) and POD/rights attributes (all derived directly from eWRIMS). A POD is a crucial spatial reference for each water right, but the water right itself is the most important entry. The results present water rights, grouping PODs where a right has multiple diversions. For example, this web address contains a search for all pre-1914 rights within a particular Hydrologic Unit Code Sub-Watershed (HUC12) area: cawaterrights.org/prioritytool/?pre1914=t&divhuc12=3505&z=12&x=-119.20921&y=37.86781.

The heart of the tool, however, is the Analyze button present on each POD. The Analyze button presents all the PODs and rights that are hydrologically connected to that Point of Diversion. This tool allows for rapid querying in the application itself, building on the analysis from each POD.

The priority search tool is a critical first step in understanding which rights are most senior and for how much water within any stream order of PODs and rights. Compared to the current eWRIMS online GIS system, it presents a streamlined, easy-to-use interface focused on helping users find the areas they are interested in and then instantly view any POD in relation to its relevant neighbors, both spatially and temporally.

3.1.4 Implementing Text-based Search of Records

A real-world example illustrated the utility of the newly completed database in an unexpected way. Dust storms have long been a management issue for Mono Lake, due to exceedances of air quality standards. Previously, in order to find all documents referencing "dust storm," the State Water Board would have had to search for all documents by hand – combing through over 132,000 pages of documents related to Mono Lake in order to fulfill the search request. We ran this search on the completed database. In a few seconds, the pilot identified 155 responsive records in the 90-year history of these water rights. This was based on OCR-based full-text search, saving immense effort and enabling the collection of a comprehensive document set that otherwise may not have been possible as a practical matter.

This example is typical of many water rights documents searches. Currently, exhaustive searches for documents by location or keyword is a herculean task, requiring hours and months State Water Board staff or stakeholder time. With a fully implemented WRIS, the same information will be retrievable with a few keystrokes in seconds. This striking increase in search speed will help State agencies and stakeholders across a broad range of interests to access water rights information. The quicker information can be retrieved, the quicker it can be used to help inform our water management decisions.

3.2 TECHNICAL CONSIDERATIONS FOR A WATER RIGHTS DATA SYSTEM

Our team researched a range of additional technical considerations associated with building out a water rights documents database. Engagement with experts and stakeholders, in addition to additional research, helped us to identify three key areas: privacy, chain of custody, and quality control and assurance.

OBSERVATIONS AND KEY TAKEAWAYS

- Although water rights documents are public records, a database of digitized records should appropriately protect certain Personally Identifiably Information (PII).
- An effective Chain of Custody (CoC) for physical water rights documents is necessary for their protection, and will help establish the legitimacy of a water rights and use information system and enable trust among users of the system.
- Quality Assurance and Quality Control processes will be important for, and enabled by, a WRIS. For example, enabling system users to electronically flag data with errors, describe the reason for the flag, and suggest a potential resolution for State Water Board staff will help bring crowdsourcing techniques to increase the quality and legitimacy of water rights records.

3.2.1 Completeness

As discussed above in **Section 2.3.1**, the completeness of a WRIS is an important determinant of its usefulness and legitimacy. Here we describe some considerations for ensuring that a WRIS would be as complete as practicable at its inception, and how it could be designed to encourage increasing completeness over time.

A central element of any digitization effort would be the digitization of records housed by State Water Board, which are the official, and the single largest, repository for the State's water rights. These records are likely the most significant and centralized source of water rights records in California. Without a systematic effort to itemize and analyze these records, their completeness cannot be evaluated. The WRIS would help in this way to surface gaps over time, both through the direct evaluation of Board staff, and through the option for members of the public to flag incomplete records for repair, as discussed below.

A complete WRIS would contain information on all relevant water rights in the State, including records not currently housed by the State Water Board. The Board generally does not hold original records for riparian rights (such as grant deeds for the underlying lands) or appropriative water rights that predate the 1913 Water Commission Act. Many original records, such as notices, were filed contemporaneously in the courthouses of the State's 58 counties. Based on experience with other water rights, it is likely that few of those records have been retained in courthouses across more than century, in paper or digital form.

The State Water Board should ask the holders of pre-1914 and riparian rights (who must file reports on water use) to voluntarily provide records and information associated with their water rights. In drought-related orders in 2015,[141] the State Water Board obtained such information from many water rights holders. Response from claimants was uneven, and all reserved the right to provide supplemental information in defense against future challenges.[142] Going forward, the Board should request similar information under its ordinary authority to assure reasonable and beneficial use of water.[143] Though further exploration would be necessary to clarify the legal, regulatory, and procedural requirements for such requests.

The State Water Board would adopt and apply written procedures to authenticate electronic records and verify reported use data. Such reviews would be done by a water rights engineer, possibly with the assistance of data algorithms discussed above. Based on that review, the State Water Board could request further information from the applicable water rights holder on a non-binding basis. Our pilot does not support an estimate of the cost for such a procedure, although the State Water Board's experience with the 2015 drought orders would be a useful starting point.

On an ongoing basis, a WRIS would need to be designed and managed such that it would tend towards greater completeness over time. One measure would be requiring electronic filing of new water rights, as discussed elsewhere

in this report. Others are described below in **Section 3.2.4**, which describes both Quality Assurance and Quality Control procedures that would help not only with accuracy of existing records, but with identifying and filling gaps.

3.2.1 Privacy

Privacy is an increasingly high-profile concern in the information age, as awareness grows about the consequences of poor stewardship or abuse of personal information. A thoughtfully designed data system will carefully take privacy concerns into consideration, while also respecting the principle that all water is public.

Ultimately, water rights records are public documents. They involve the use of a resource that is by statute public. And the laws and norms of California governance dictate a careful consideration of transparency and openness in decision making. However, the Water Code as administered has recognized the importance of safeguarding certain information, and private parties involved in water rights express understandable sensitivity about potential changes in the availability of information about water rights and water use. Because of the importance of this topic, this section discusses in some depth the privacy considerations related to digitizing water rights information.

Public Information

California's Public Records Act (PRA)[144] provides broad definitions of public information[145] which, when it is in the possession of a State or local governmental agency, must be made transparently available. Water rights documentation and water use records unambiguously fall into this category.[146] Under the PRA, data under the custody of the State Water Board that are relevant to public decisions must be made accessible to any member of the public.[147]

The bulk of California's water rights data are kept in paper form in the State Water Board's Records Room in Sacramento. Access to these records is available to any member of the public, with appropriate controls and safeguards.[148] However, in its 2018 Open Data Resolution,[149] the Board stated that it "strives to make all public data available in machine readable format," consistent with activities in other areas of State government. [150] (See **Recent Data-related Legislation and Policy Changes**, page 15.)

Privacy Standards and Concerns

Privacy concerns about digitizing water rights records stem from concerns about how those records may be used and accessed in new ways because of easier access, not from changes to the information itself. [151] With a modern WRIS, any citizen could remotely access records, which would lower transaction costs relative to physically visiting the State Water Board's offices, or hiring a law firm to do so. In addition, electronically searchable records, with

or without metadata assignment, could enable record searching and sorting in ways that are practically infeasible now (see **Section 3.1.3**).

A WRIS would contain searchable electronic copies of the same documents that are currently publicly available. Digitized water use data would include tabular data that are currently in paper or PDF form. The State's current stance on digital data is reflected in its California Open Data Handbook:

Under the Public Records Act the presumption is that government records shall be open to the public, unless excludable under a narrow set of specific exemptions including such concerns as invasion of personal privacy, impairment of contractual or collective bargaining negotiations, exposure of protected trade secrets, interference with law enforcement or judicial proceedings, endangering life or safety, and others. [152]

Therefore, a judgment is necessary as to whether the potential for easier search, aggregation, and availability of data could trigger any of the specific exemptions under the PRA.

Various types of Personally Identifiable Information (PII) associated with water rights information – such as contact information for water rights holders, agents, reporting agents –could be sensitive. While most of the stakeholders in our engagement efforts were supportive of making records public, some expressed concerns that the availability of names and addresses associated with water rights could compromise personal privacy. However, these data are necessary for the State Water Board's administration, and ownership of water rights is relevant as a matter of law and public interest.[153]

Other information may be viewed as proprietary and sensitive. For example, some have argued that public information about contracts related to sales or leases of water can impair the efficiency and fairness of trading platforms relative to double blind or anonymous transactions, or that these transactions can constitute trade secrets, or that public transparency would change current ways of informally conducting some transactions.[154] But others argue that lack of transparency about these same data could mask consolidation of power, or create unnecessary barriers to exchange.[155]

Many of the benefits of open data would accrue to the public, to specific water rights holders where transparency results in changes in management or allocation that benefit them, and to non-water rights holders, to the extent that more data enable innovation and efficiency. Water rights information accessibility could benefit landowners and others who have an interest in accurate valuation of landholdings to the extent that water rights could more clearly be factored into land values in specific transactions or into global assessments of land values.

Ultimately, as a matter of law, water rights data are public records and, absent legal change to the contrary, should be publicly available when they are held by a public agency. Some privacy concerns may be valid. But ultimately, innovation and change create opportunities and risks[156] that the State must balance in pursuit of progress and transparency.

PRIVACY CONSIDERATIONS IN REAL ESTATE DATA AND OTHER STATES' WATER DATA SYSTEMS

Real estate data provide an instructive example of the privacy effects of making public data available digitally, as do water rights data systems in other states.

Zillow.com has been aggregating and making freely available a wide range of public data about personal property in the real estate setting for years. This data includes physical information such as acreage, square footage and photos; financial information like sales prices and rents; and derivative data such as solar suitability and value estimates. In many areas, these data are available for many or all parcels. Blockshopper.com has similar data, and also includes ownership data for parcels, aggregated from government records.

The availability of these data has arguably benefitted both buyers and sellers of real property by increasing transparency of real estate markets, without, to our knowledge, major controversies or disruptions. Digitizing, georeferencing, and making public data useable has changed access from something that previously required specialized knowledge, a heavy time investment, or engaging with a middleman. The limitations of these analytical tools are also instructive: real estate agents, far from being obsolete, are as important as ever to evaluate the nuance of valuation and transactions – they just have to do less grunt work to access information themselves.

Our cross-jurisdictional analysis revealed that water rights data have been digitized in some other states with a level of openness and functionality analogous to that provided by Zillow. In Colorado, water rights information is posted online and georeferenced to the point of diversion, with all documentation scanned and included on the platform. Oregon has similar availability, with key documents for each water right, along with information on ownership and georeferenced place of use. We are not aware of any claims of privacy violations associated with the publication of this information.

Part of these successes may lie with thoughtful execution. On Zillow, real estate data are parcel-based and anonymized, so they are searchable by classifications such as location or size, but not by the owner's name. Blockshopper.com allows search by property owner's name, reflecting public records, but will entertain exceptions for law enforcement officers, individuals under court protection orders, or other individuals deemed specifically vulnerable.

For water rights, other states' experiences can be more directly informative. In the public database of every Western U.S. state in our analysis, water rights are tagged with the owner's name, often as a searchable field. In about half of these, contact information is also available for water rights.

The key point is that data transparency has had great benefits for innovation in both of the real estate and water sectors, and that where this has been done, privacy considerations have posed no significant disruptions.

Specific concerns and considerations may be presented by the digitization of California water rights data. But these examples illustrate how data transparency in similarly sensitive contexts has been successfully navigated, and may reduce worries about undefined risks of open water rights data.

Privacy Options

In order to ensure legitimacy with water rights holders and other stakeholders, the State should carefully consider privacy tradeoffs when designing a WRIS. We describe several hypothetical options, framed as illustrative extremes, about how to approach privacy decisions in a WRIS.

First, a fully public option could treat all information in publicly held water rights documents as public and fully transparent. This could include making all documents and data fully searchable via OCR and making fully public an exhaustive assignment of metadata fields.

Second, a restrictive option could redact contact information or identifying information for people associated with water rights, such as water rights holders, agents, reporting agents, and others, from the public version. This approach could restrict access to certain metadata fields, and in its most extreme form redact specific fields or information types within scanned forms and documents. This option would severely reduce the utility of a data system for routine administrative functions. It would also likely carry the highest cost.[157]

A third option might better mirror the current state of water rights records, which are all fully viewable by any member of the public, while reflecting the needs of decision makers and the interests of the public. This option would make PII accessible behind a firewall only to agency staff or other authorized personnel as necessary to support decision making and administrative functions.[158] While public access to these metadata fields would be restricted, public OCR searchability would still be maintained.

We suggest an approach that systematically weighs costs, risks, and benefits.[159]

This section has not attempted to exhaustively weigh the privacy implications of greater transparency from various options for implementation of a WRIS. Statutory and practical analysis suggests strong benefits and minimal risks from greater transparency, as does the public interest in making water rights records openly and transparently available. However, privacy concerns deserve careful consideration and engagement with interested parties.

3.2.2 Chain of Custody

Chain of custody (CoC) refers to the control of a set of legal documents and ongoing documentation of their provenance and use. A sufficient CoC will help to establish the legitimacy of a water rights and use information system and increase trust among users of the system.

Currently, no formalized, written CoC procedure exists for water rights records in the Records Room. Of course, the Records Room staff keep records required by rule, such as an application, orders, and hearing evidence. They also have a practice of keeping informal records such as electronic mail or documents provided by Board staff upon retirement or reassignment. All such records, whether formally submitted or not, are coded as being associated

with a given right; and that is the extent of the indexing. The State Water Board does not have a docket that identifies and indexes each record (including metadata) associated with a water right. Our pilot established the first index that identifies each record associated with LADWP's water rights in the Mono Basin.

Developing CoC procedure will require an internal policy change by the State Water Board. This will be particularly important in developing a digital repository, although it will likely be necessary regardless to instill discipline on paper records. The priority and goal of such policy would be to ensure the legitimacy of State records by making sure documents on file are what they proport to be, and also to make sure that records that do not belong in the formal record for a given water right do not appear in those records.

The State Water Board considers the original paper records pertaining to water rights that are housed in the Records Room in the Cal/EPA building to be the central core of the source documentation for water rights. Electronic or paper copies of these records, housed in eWRIMs or elsewhere, can be useful for reference or convenience of access, but are not themselves considered authoritative, let alone exhaustive, representations of the legal record. The need for the paper records would not change, even if the State were to generate a more comprehensive WRIS, and even that WRIS was authenticated and verified to the point its contents themselves were considered legitimate legal records.

Nevertheless, to the extent that the WRIS would form a more exhaustive and useful record of water rights data, the Water Board must consider its CoC to enable the WRIS to be a legitimate and credible reference and resource. In light of this discussion, CoC has two key elements: stewardship of the original paper records, and ensuring accurate reflection of these records in an electronic resource.

For the original paper records, the State Water Board should follow its current, careful procedures for public access.[160] Since these records may in some cases be the only copies of water rights documents, safeguarding them is important. Files are tagged with barcodes, which enable staff to check them out in a library-like system. Any member of the public can check out a limited number of records for viewing. Original files may not be removed from the records room, but SWRCB maintains a viewing room where members of the public may review a limited number of files, and copy up to 20 pages at a time. For larger requests, a Board-approved contractor takes responsibility for CoC, signing documents out and making electronic or paper copies for a fee. The original items are then delivered back to the records room for re-filing by Board staff.

Electronic CoC has not yet been fully established. eWRIMs contains attachments for some water rights, but by no means is it a complete record, nor is it intended to be a reference source. Rather, it is populated in an ad hoc way, and staff have used it as a reference opportunistically to support specific ongoing matters.[161] Still, staff can access some permit and licensing information based on the originating documents in eWRIMs, which contains some

post-1914 surface water diversion rights, but limited information on pre-1914 rights or riparian rights.[162]

During our pilot scanning project, our team, in collaboration with State Water Board staff, established a draft protocol for CoC during digitization of water rights records in the Mono Basin. We believe that the original paper records were successfully safeguarded during this process, and that they were returned in even better condition, because the scanning process provided an opportunity to tag individual records with barcodes that reference their location in files for easier organization and access.

3.2.4 Record Authentication Procedure (True and Correct Copy of Paper Record)

Quality assurance and quality control (QA/QC) are essential components for a WRIS. An electronic system will need to stand alone as legitimate and trustworthy if it is to be useful for agency and stakeholder decision support, regardless of the whether the State Water Board intends to have archived paper records remain the ultimate legally referenced source for water rights information.

A modern WRIS should include a procedure to authenticate that any given digital record is a true and correct copy of the original record, which is typically paper. This authentication procedure stops short of verification of the correctness of the content, which we discuss in the next section below, but nevertheless is a crucial step.

The record authentication procedure includes QA and QC processes. For the purposes of this document, QA refers to processes used during development of the WRIS, including populating it with an initial set of documents. These processes are geared towards minimizing or eliminating errors in the scanned and digitized data, metadata, and database structure and functionalities, and other elements.

QC, in contrast, refers to an ongoing process that begins once the database is populated. This aims to identify and correct errors, omissions, and ambiguities. QC is ideally flexible and adaptive to enable improvements that are not anticipated in early versions.[163]

QA/QC Options and Considerations describes more detailed concepts for QA/QC of water rights data, and the specifics of QA processes will need to be developed and formalized by the State Water Board. These procedures should include document management, error checking of scans (possibly by machine learning), and the development of data dictionaries, valid values, and other pre-submission checks.

Quality Assurance and Quality Control processes will be important for, and enabled by, a WRIS. For example, enabling system users to electronically flag data with errors, describe the reason for the flag, and suggest a potential resolution for State Water Board staff will help bring crowdsourcing tech-

niques to increase the quality and legitimacy of water rights records. It would be important to note that SWRCB staff would control the records, as the legal repository.

3.2.5 Data Verification Procedure (Data Integrity)

Whereas the record authentication procedure focuses on ensuring that digital records accurately reflect the original records or entries from which they are drawn, we recommend an additional substantive procedure by which State Water Board staff would examine the content of water rights data, with some degree of effort to find, flag, and where possible, correct errors.

Water right and use records can contain a range of first-order errors. For example, some statements of water use contain values that are in error, resulting from sources including faulty unit conversion, ambiguous reporting, measurement error, or other causes.[164] Some errors are obvious based on physical impossibility, such as where a reported value for diversion rate would be inconsistent with existing infrastructure. Internal inconsistency within a set of water right records could also reveal a need to clarify records, as could the lack of key documents.

We propose a procedure whereby State Water Board staff would ask water rights holders to verify existing records related to their water rights, fill in missing records, and correct inconsistent or incongruous data. Such a procedure would be valuable with or without digitized data, but having a baseline record of scanned data in a functional WRIS would significantly expedite the procedure. Board staff would have a continuing role in reviewing data use over time by addressing issues flagged by water rights holders and other stakeholders.

The overarching purpose of this procedure would be to improve clarity and transparency about water rights data. Crucially, this procedure would stop well short of adjudication, including the procedures specified by Water Code sections 2000 – 2102 or 2500 – 2850. While adjudication results in a binding determination of claims of right relative to one another, the procedure described in this report is intended to test and clarify self-reported data. The Water Code clearly provides that self-reported data, as well as the Board staff's efforts to validate the data, are not binding evidence with respect to water rights.[165]

Finally, we acknowledge and emphasize that developing an effective data verification procedure, and implementing it, would be challenging, expensive, and require thoughtful and creative planning coupled with ongoing and effective engagement with water right holders and other stakeholders. As with many institutional advances, these challenges are difficult in part because they involve change to a familiar status quo. Nevertheless, they are technically viable, and ultimately crucial if California chooses to bring modern and effective decision making to the fingertips of all with interests in water rights.

3.2.6 Practical Considerations for Record Authentication and Data Verification Procedures

Record authentication and data verification procedures would be labor intensive, technologically advanced, or both. To verify data using currently available methods, a topical expert[166] would review a scanned application, permit, or license for a given water right for critical elements of a water right to ensure a basic level of completeness and consistency. This would be particularly important for non-standard documents.[167]

Technology could be developed to aid these procedures by drawing on existing machine learning software that assists in litigation discovery or extracts information from old records (including real estate, taxes, and genealogy). Such algorithms could flag incomplete, inconsistent, or irregular records, and State Water Board could then request further information from the water rights holder. The Board could emphasize that this procedure is informational and non-binding with regard to any aspect of the water right.

3.2.7 A WRIS is viable from a technical standpoint

We conclude that technical considerations do not pose any obstacles that cannot be overcome with sufficient attention and clear decisions by the State Water Board, informed by stakeholder engagement. Privacy, QA/QC, CoC, and the record authentication and data verification procedures are conceptually significant, and important to address in planning a WRIS. However, water rights data are public records and should be treated as such in the digital age.

Appropriate protections for PII can and should be implemented in accordance with the PRA and other relevant laws. Digitization brings the State Water Board's existing need to address its lack of a formalized CoC into sharper focus. However, doing so is likely to be relatively straightforward. Finally, rigorous record and data review procedures will be important for a WRIS. Implementation of a well-thought out WRIS will improve both access to and content of the State's water records over time.

3.3 TOWARDS ESTIMATING FUNDING REQUIREMENTS FOR DIGITIZING WATER RIGHTS DATA

Our efforts resulted in information that can help the State refine estimates for developing a robust and accessible WRIS. Below, we report on the costs for our pilot project, and suggest ways to develop a budget for statewide implementation.

Our intent in this section is to take a first step towards budgeting based on the rough data we have collected thus far, in order to set the stage for more precise estimates. The discussion that follows is based on incomplete data and approximations, and should be regarded as an illustration in broad brush strokes of how the State could go about developing funding estimates. There are many sources of uncertainty and imprecision, including the fact that we

have not taken State contracting requirements and procedures or other overhead costs into account. Therefore, actual costs may be significantly higher than what we suggest here.

We estimate that the State Water Board physically holds up to 10 million pages of paper records related to water rights. A photo of the Records Room is included as p. 2 (behind the title page). This estimate is a function of the linear feet of boxes held in the Records Room and off-site archives (estimated as 3,100) times the number of pages in a linear foot (2,000 – 3,000 depending upon how tightly a box is packed). We assume that a private vendor would scan at the pilot's rates of $.314/page for scanning and indexing. This is conservative, as the larger volume would justify a discount. We estimate that digitizing all water rights records under the State Water Board's control would cost approximately $3.5 million on a one-time basis, plus the cost of Board staff's supervision.

Our pilot did not include a procedure for verification of use and other data. A scale-up should include such procedure, as we discuss in detail in **Section 3.2.**

In our pilot, the records containing information on the critical elements of the two water rights totaled less than one hundred pages. Some elements derived from a single record (for example, the priority date derived from the application), while other elements required review of several records (the authorized rate of diversion changed between permit and license).

We estimate that a topical expert would review the records for a typical water right in less than two days, in order to establish a first approximation of these elements.[168] The first approximation would be a retrospective review of existing data. It would result in asking users to provide clarification or additional documentation. Given 45,000 water rights in the State, this verification procedure could require 50 - 75 FTE-years to implement with respect to existing data, at a cost of $10 -15 million. The Division of Water Rights could engage a consultant to assist with implementation subject to staff oversight, similar to its approach to California Environmental Quality Act documents.

Databases, like any other infrastructure, also require ongoing maintenance, as well as inevitable addition or modification of features as use cases are refined and change. Currently, State Water Board has a $250,000 annual budget for eWRIMS maintenance, which has not been sufficient to produce a fully useful and useable system. Estimating a sufficient maintenance budget will depend on a better understanding of the eventual data system, and the State should carefully consider and budget for the ongoing operating costs of a WRIS.

THIS IS A CHEAP PROPOSAL

California's perennial budget pressures and its continual underfunding of water infrastructure, exacerbated by the COVID-19 crisis, amplify the question of how to value, and pay for, the activities proposed in this report. From our perspective this is a matter of context – this is a cheap proposal.

California has a trillion-dollar economy, all of which depends on water. Voters have regularly approved bonds of billions of dollars to support water and environmental management. Interest groups from all perspectives advocate for, and succeed in generating, tens or hundreds of millions of dollars of public spending on individual local infrastructure or restoration projects with comparatively narrow and constrained benefits.

A water rights information system geared towards unlocking systemic innovation at a much larger scope and scale would be a bargain even if it cost $20-30 million or more in addition to annual operations and maintenance costs. It would be a drop in the bucket relative to total spending on water, or even to State spending.[169]

The investment in a WRIS would, when fully implemented, generate savings for water users, for the State's necessary regulatory functions, and for all who care about water in California. California cannot afford to move slowly on innovating to fix urgent water management issues, or address long-term challenges. Better information on water rights is achievable and invaluable. It will be a bargain for California.

4. WHAT NEXT?

In Part 3, we describe the feasibility and affordability of scanning, digitization, and metadata assignment for water rights documents. Yet, as highlighted in Part 2, water rights documents and their associated data are but one part of a larger ecosystem of water data that feed into water management decisions. Likewise, the ability to scan and digitize water rights documents is not inclusive of all technical considerations for building a data system. In Part 4, we describe a vision for a new water data system. We consider the utility of some functionalities from other western water data systems and discuss additional data needed to support those functionalities, including improving both water supply and water demand data. We also address some additional technical considerations for building a data system, including privacy, chain of custody, and quality control.

This section lays the groundwork for realizing a robust system for water rights information for California. Ultimately, State Water Board should articulate, endorse, and act to implement a vision for the water rights information system. This vision can include technical functionalities, logistics, governance, and funding, articulate a plan and process to avoid future obsolescence, and be based on how an information system can contribute to improved water management to enhance the economy, productivity, and environmental quality of our State. We offer the following discussion for consideration by State Water Board members and staff, as an option for how they might choose to lead California into a new era of information-based water management.

4.1 VISION: A MODERN WATER RIGHTS AND USE INFORMATION SYSTEM FOR CALIFORNIA

This section presents a vision for a new data system, based on our research and experience with the pilot process. **Section 4.1.2** describes proposed functions for a WRIS and their benefits. **Section 4.2** highlights aspects of other State water platforms which may serve as an example for an improved California system. Finally, **Section 4.3** addresses data needed to support a wide range of functionalities in a broader information ecosystem of which water rights documents are only one element.

OBSERVATIONS AND KEY TAKEAWAYS

- If California is to achieve real time management of its water resources in accordance with water rights law, a robust WRIS will be an essential component of the State's governance infrastructure.
- We have a strong conceptual and operational basis for the design of a robust WRIS. Nevertheless, it will need to be designed and executed carefully as befits its broad potential uses.
- To refine and realize such a vision, process will be key. In particular, continued engagement with stakeholders will be crucial.

4.1.1 A WRIS Should Be Designed as a Useful Element for Water Decisions

California can and should invest in a robust WRIS so that water decisions can be grounded in foundational legal information. The previous sections have described why this is the case, and how it can be achieved.

Thoughtful execution will be crucial to the success of a WRIS. A haphazardly developed WRIS could have limited functionality, or even become a stranded asset. The broad applicability of a WRIS provides strong justification for its need, but also highlights the importance of building a tool capable of serving diverse user groups. The potential broad user base also suggests that it may be unwise, unlike in more niche areas of public data provision, to produce a tool geared for specialist users who are willing to invest heavily in developing new skills to access its data. Thinking carefully through how a WRIS will be used, and by whom, and using that to design a system that meets those needs, will be an important part of the State's investment.

In the following sections, we offer a preliminary set of characteristics of an idealized WRIS, as a starting point for conversations about its scoping and development. Naturally, actually producing an effective WRIS to meet California's unique needs would involve structured stakeholder engagement. Ideally, such engagement would involve facilitated discussions that reflect the opinions and use cases of representative users and beneficiaries, and also would employ methods from the state of the practice for data system and user interface design, such as surveys, focus groups and design charettes.

Core Functionality of a WRIS

A range of features and functions would be useful to fully support the wide range of decisions relevant to water rights information. Broadly speaking, these functions fall in two classes: those that will be developed internally to the WRIS itself, and those that will rely on interoperability with other data sources and tools. **Table 7** outlines the basic, core functionalities of a water rights data system, including housing data, searchability, and electronic filing.

Our pilot demonstrates both an electronic library and structured and unstructured search functions. The pilot serves both as proof of concept and as a jumping off point for refinement. Interoperability with other data sources is also a crucial element.

Table 7. Foundational elements of a water rights data system.

FUNCTION OR FEATURE	DESCRIPTION	BENEFIT
Electronic library of water rights records	All legal records associated with water rights will be publicly available for viewing or downloading.	Complete library of legal records, including statements of use and permits, will facilitate compliance reviews, transfers, resolution of disputes between or about water rights, and many other areas in which clarity is important for decision making.
Statements and other Reports of Use	Availability of legacy and current statements and other reports of use for each water right.	These data will permit analysis of trends in reported use across time, by water right. This will also permit comparison of reported use with monitoring databases, including evapotranspiration and streamflow, to evaluate accuracy and correct any errors in reports.
Searchability	Search may occur through structured data via metadata assignment (*e.g.*, application ID, author, title, document type, and date) or for any word in the record text via OCR.	Searchability alone arguably justifies the production of a WRIS. Carefully designed and executed searchability will increase access to water rights data and enable increased understanding of how California's water system should work from a legal perspective.
Electronic filing	Support for electronic filings and payments. Any new filing of a document or report will be entered into the electronic library for the applicable water right.	Electronic filing will improve efficiency, accuracy, and accountability, and reduce cost of participation in water rights proceedings.
Interoperability with other data sources	Interoperability will enable linkage with other data, including, monitoring data from environmental databases.	Interoperability will permit integrated analysis of water use and associated environmental quality.
Case management functionality	Ability to connect with eWRIMS, or replace its case management functionality as currently exercised by SWRCB staff.	eWRIMS enables more efficient administrative actions, and any new system should either support eWRIMS through interoperability, or replace it with improved functionality.

4.1.3 Electronic Library of Water Rights Data

Water Rights Records

The core function of a WRIS is to house, organize, and make accessible data pertaining to water rights, including water rights documents, water rights data, and water use data (as defined in the **Key Terminology: What do we mean when we say "data"?**, page 16). These data should include foundational information including basic fields on applications, licenses, and permits, as

well as ideally all legal and administrative records that substantiate claims of right.

Records of water use are essential information for establishing the ongoing validity of water rights, and, in aggregate form, for evaluating watershed conditions and water availability.

Statements of water use are submitted annually through State Water Board's Records Management System (RMS), which is separate from eWRIMS.[170] Water use data has been reported through RMS since approximately 2009.

We recommend that historical water use data from RMS and pre-RMS water use reports be integrated into a new WRIS and attached to water rights records to enable system-scale planning and analysis.

Further, SB 88[171] presents the possibility that State Water Board can require electronic reporting of water use reports for some classes of users. The benefits of such reporting in efficiency for users and effectiveness and accuracy of data are potentially immense. As a practical matter, a WRIS should be designed to readily accept electronic reporting of water use.

Much of the data in eWRIMS has been populated in an ad hoc, opportunistic way, and is not a complete or reliable record of any of the types of water rights data.

4.1.4 Basic Search Functions

Structured Search via Metadata

As discussed above, thorough and credible metadata assignment can enable specific queries based on data characteristics of interest to decision makers and stakeholders. Key factors such as priority, water source, amount, and location are all of interest, particularly to the extent that they can enable rapid evaluation in the context of California's relative water rights system. Another example would be to enable search for water rights by conveyance structure. This is of particular importance in California, where a large portion of water is delivered by the Central Valley Project (CVP) and the State Water Project (SWP).

eWRIMs has limited metadata assigned to its records, and as a result its structured search functions are neither complete nor reliable.

WATER USE DATA

Our pilot project and this report focus on water rights records and their accompanying metadata, which are particular subsets of water rights information as defined broadly (see **Key Terminology: What do we mean when we say "data"?** page 16). Water use data are critical for understanding and managing water resources in California, based on legal first principles and on empirical evidence from our use cases. Although our report focuses on other types of water rights data, water use data are also extremely important.

We consider two main classes of water use data. First, data reported by users in the water rights context generally focuses on the relevant legal aspect of water use, namely reported diversions. Second, physical measurements and estimates can be made of various elements of water use, including applied water, evapotranspiration, infiltrated water, or other aspects of the hydrologic cycle. Open ET (evapotranspiration) is a prime example of the latter, and a prime example of a co-produced method.[172]

Each of these data are useful for specific aspects of water management, and interoperability and inter-comparability would increase the value of each for decision making.

Unstructured search via Optical Character Recognition

As discussed above, optical character recognition (OCR) gives a database user the ability to search scanned documents for a particular word or phrase. Only one State database in our survey, Arizona's, has this capability. However, while Arizona's database allows a user to OCR search within a selected document, it does not allow a user to conduct an OCR search across the entire database of documents. Our pilot project took this next step, allowing a user to search for documents based on a simple term or keyword of interest (*e.g.* "dust storm," see **Section 3.1.4**). This allows a user to quickly find documents concerning a particular topic, which is especially important in cases where a water right may have a long history of conflict and thousands of pages of hearing records.[173]

eWRIMs does not have the capacity for unstructured search via OCR.

Electronic Filing, Billing and Payments

Electronic filing can help streamline data integration by allowing users to directly input data or upload documents. Idaho provides a wide variety of forms related to water management and water rights, all which can be e-filed.[174] Users can submit forms to report, among other things, an address change, beneficial use, changes in use, and to claim an existing water use, file an instream stockwater notice, or to file a new water right or protest. Once submitted, an electronic version of the completed form is often available to view within a short period of time, which can be useful for those interested in new water right transfers and new water rights permits.[175]

eWRIMS does not currently offer any e-filing. However, RMS offers limited filing of some required reports and electronic billing payments.

4.1.5 Interoperability

The legal and policy structures governing water resources are complex and interconnected, and water rights information divorced from its context is of limited utility. Therefore, consistent with the conceptual foundations being developed for water data at the statewide scale,[176] a WRIS should be designed and developed to be readily and easily interoperable with a wide range of relevant data sources. This theme is reflected within our analysis and observations throughout this report.

eWRIMS does not currently support interoperability with other water data sources.

4.2 ADDITIONAL USEFUL WRIS CHARACTERISTICS

Our survey reveals that water databases and platforms in other states exhibit a wide range of functionalities, from e-filing of water rights applications to integration of real-time streamflow monitoring. These systems demonstrate the potential for California to build and implement a highly useful system. As California considers how it can manage its water data in a usable, transparent, and accessible way, it can look to these other states for examples of potential database functions, cherry-pick the functionalities that best suit California's needs, and leapfrog the other examples to produce a best-in-class system.

Below we enumerate a range of functions that illustrate what is possible. Decision makers can draw from the list below to develop a conceptual basis for the design of California's WRIS.

4.2.1 Search Functions and Document Availability

GIS Map Area Searchability

A map with georeferenced data can be immensely helpful for finding water rights in a particular area. Without a map search, local knowledge such as previous information on permit numbers or owner names is needed to develop a picture of water rights. Washington's Water Rights Map,[177] for example, enables a user to draw a shape on a map area, within which it generates visual indicators for points of diversion, as well as a corresponding table of water rights. The table can then further be sorted by water right number, owner, priority date, and water right status to refine a search. The ability to conduct a GIS map area search that accurately and reliably identifies water rights in the selected area can be of particular use for applicants for new water rights. By conducting a preliminary search of existing water rights in the area where the applicant wishes to apply for a diversion, the applicant can view water rights already in existence and weigh the feasibility of obtaining a new water right in the same area.[178]

eWRIMS' current map function does allow users to see the location of a diversion point and view all of the diversion points for a particular basin together but does not allow more precise map searches. eWRIMS also does not have a second step sorting feature, such as Washington's, which would allow a user to further organize selected diversion points by priority date or use.

GIS Stream Trace

A stream trace allows searching upstream or downstream of a point on a particular waterway. This function can be particularly helpful, for example, when determining which water rights would be affected by a decision to grant a change petition or a new water right. Oregon's Water Rights Mapping Tool exemplifies this function.[179] Given a selected point on a stream, Oregon's stream trace function allows searches for all water rights upriver, downriver,

or within the particular reach. The search can also include tributaries of the selected waterway. An advanced search allows users to narrow search results to only the type of water right (groundwater, surface water, or storage) or by water use (*e.g.,* agriculture, irrigation, wildlife, power, municipal, etc.). Search results are generated in a table below the mapping tool and allow users to sort results by a variety of factors, including water right identification number, owner name, water use type, and priority date. Oregon's search results are further linked to available water rights documents and other information.

The ability to stream trace potentially aids both the State Water Board and stakeholders in multiple situations. Granting a new water right, determining environmental flows, or facilitating water transfers all require the ability to understand where existing water rights are located, and how they interact with each other, and it is often critical to understand how a transferred or new water right will impact existing rights downstream.

eWRIMS also has a stream trace function, but its functionality is not nearly as powerful as Oregon's. For example, eWRIMS only maps points of diversion for water rights, and does not generate a sortable table of results, nor a link to associated water rights documents.

Priority

Finding and ordering water rights based on their priority date is a crucial function in a prior appropriation system. This function is important because relative claims on the right to use water on a particular stream helps accurately determine seniority (see **Table 3**).[180] Colorado's Decision Support System does this particularly well.[181] Here, a search can be honed by various fields, including location, water division, structure type, decreed use, or source. Once a user has selected search parameters, they can generate a list of applicable water rights. The results are generated in a table, with the option to sort by priority or other factors.

The ability to find and order water rights based on their priority date can be helpful in a range of use cases, including for example understanding the broader landscape of water rights relationships when negotiating Voluntary Settlement Agreements among multiple parties.

eWRIMS does allow some sorting by priority in its Water Rights Records Search but does not allow for water rights to be sorted by priority in the GIS map feature. Further, incomplete information may undermine the accuracy of such priority lists.

4.2.2 Connecting to Physical Data

Streamflow Monitoring

Improving access to streamflow data could help increase clarity about water availability**.** Participants in our December 2018 workshop flagged the lack of streamflow data as one of the biggest gaps in water data.[182] Linking real-time streamflow data to water rights data would remove a bottleneck to more agile decisions that reflect current conditions. Doing so in practice could require additional institutional capacity.[183]

Streamflow monitoring helps water managers and water users determine real-time stream conditions. Managers may use this information to determine whether administrative action is necessary. Water users may similarly monitor this information to help determine whether or not they might be able to withdraw water from a stream, and when. Streamflow monitoring information is available from USGS and CDEC, but a few states also incorporate the data directly into their water management platforms.

Nebraska, Colorado, and British Columbia do this particularly well. Nebraska's simple system provides an interactive map of all stream gages in the state.[184] A system user can select a particular gage and then select the station identification number. The station identification number takes the water user to a series of graphs, which track current streamflow, daily data, measurement data, hydrographic reports, and a station description. System users can select a particular timeframe for which they would like to view reported streamflow data.

Colorado maps its stream gage information along with other water data.[185] A user can map all active gages in the state, then select a particular gage and view additional details such as discharge at the gage in cubic feet per second (cfs), along with historic average.[186] The graph data can be adjusted to display data on gage height, precipitation, and water temperature, or to view data over a particular time period.

Montana's stream gaging functionality maps state and USGS gages.[187] Gage reports include a discharge, stage, and temperature graph, and a site summary of minimum, average, and maximum stage and temperature measurements for the period of record or a selected period of time.[188]

British Columbia's stream gaging functionality is the most user friendly.[189] It is worth visiting as an example of how powerful a thoughtfully designed user interface can be. Its Streamflow function maps all stream gages in a selected region, including all active and discontinued gages. From here, a system user can select a gage of interest and view an automatically generated report that charts seven-day flows recorded at the site, flow duration, monthly mean flow, and flow metrics. A user can choose to limit results to a particular year or time period, including the current water year. Data in the seven-day flow chart include current measurements, and the maximum, median, and minimum

flows for the selected time period. The flow duration charts monthly flow statistics, flow duration, and total runoff.

Streamflow monitoring can be particularly helpful when establishing water markets and facilitating transfers and groundwater recharge. Having a more refined and accurate picture of how much water exists in a stream or system at a given time allows managers to act quickly to move water from where it is available to recharge ponds or transfer to others in a water market.

eWRIMS does not have this function. However, California already houses much relevant data that could be leveraged for these purposes.[190]

Raw data alone do not generate a clear picture of water conditions in complex watersheds. In addition to streamflow data, workshop participants highlighted the need for new models to accurately synthesize and reflect California's hydrological conditions. A circularity exists, however – without data, models cannot be accurately parameterized and calibrated, and without models, data alone are of limited utility. Data provision is a useful first step, but a data system should be designed for interoperability such that models and data can communicate and together provide useful information.

Ideally, these models would be spatially expansive and include connections between California's streams and groundwater supplies, but also precipitation and snowfall, impaired flow analysis, streamflow, and reservoir and conveyance system operations. Models should be vetted ahead of time with stakeholder input to be effective when they are needed (for example, during times of water shortage it will be too late to argue about the credibility of a model, so it should be developed and considered a legitimate tool before it is needed).[191] These models, and the assumptions that went into creating them, should be published and revised ahead of the next drought.

Hydrological models are particularly helpful when deciding whether or not to grant new water rights. They can help both applicants and the State Water Board determine whether water will realistically be available for the new water right. State Water Board has its own sources for hydrological models used for decision making. eWRIMS does not internally serve modeling data or support interoperability with these or other external models.

Historical Precipitation

Historical precipitation records (rain and snow), in conjunction with use of climate projections from General Circulation Models, can help generate estimates of future weather patterns and water supply availability. In the British Columbia Cariboo Water Tool,[192] a "Climate" function allows users to view the location of all weather stations in a region, manually search for stations of particular interest, and view real-time and historical precipitation data, in graphical and downloadable form.

Colorado has developed a similar tool. The CWCB Snowpack Assessment view provides daily snowpack information, organized by sub-basin and in map form.

It includes data on Mean Snowpack Water Equivalent (SWE), SWE Volume, Change in SWE, and percent snowpack for time of year.[193]

Historical precipitation, like other historical data, help users observe historical trends, which in turn informs stakeholders and the State Water Board in situations such as the granting of new water rights. eWRIMS does not have this function.

Real-time Precipitation Reports and Reservoir Conditions

Real-time data can help water managers and water users understand current hydrology and water availability. Water Data for Texas, a site created by the Texas Water Development Board, provides this data in an interactive GIS map.[194] System users can select a given reservoir and view current and historical reservoir conditions in both graph and chart form. System users also have access to TexMesonet, a tool developed by the Texas Water Development Board which reports real-time precipitation and includes current weather satellite data.[195] TexMesonet also includes historical precipitation data and forecast reports.

Real-time precipitation reports and reservoir conditions, like real-time streamflow reporting, are helpful in cases where close to real-time decisions must be made in order to increase efficiency in California's water systems. By understanding real-time participation and reservoir conditions, water managers can more quickly decide whether to transfer water or to divert water for groundwater recharge.

eWRIMS does not have this function, although such data are available in California and interoperability would be useful.

Watershed Reports

Watershed reports can help water users and the public understand current and projected future conditions in their basin. British Columbia's Cariboo Water Tool allows system users to generate reports for specified watershed. Users can click anywhere on a map to define a particular watershed. From there, a user can choose to generate a downloadable PDF report for the selected watershed. The report shows 1) a map of the watershed upstream of the selected point and its location relative to the surrounding area; 2) the hydrology of the watershed (both upstream and downstream of the selected point, including volume of runoff and volume of allocations); 3) the hydrology of the watershed, including mean annual discharge; 4) risk management levels and response measures; 5) a list of all existing allocations in the watershed; 6) land cover and topography of the area, by area and percent of the watershed dedicated to that topography; and 7) the historical normal conditions and projected future change of the watershed's climate for temperature, rainfall, and snowfall.

Watershed reports are useful when establishing a baseline of conditions and facts in negotiating settlement agreements among water rights holders and other stakeholders.

eWRIMS does not offer this functionality.

4.2.3 Additional Lessons and Guiding Principles for a WRIS

Ensuring Information Accuracy

Some errors are inevitable in records as voluminous as the water rights data for California. One of the crucial advantages of an electronic system is the potential for ongoing, transparent quality control (see **Appendix H**). Crowd-sourcing QC functions carries potential benefits as well as pitfalls. Members of the public and their representatives may have greater familiarity with local water rights situations than agency staff, and thus a system by which they can flag potential errors for review could leverage a partially crowdsourced approach to QC. Public comments on water rights records can be valuable for increasing the accuracy of a WRIS over time if they direct State Water Board staff attention to correctable errors, and we recommend that members of the public who want to annotate or flag electronic records should be required to do so non-anonymously so Board staff can track comments to specific users. This would both enable State Water Board to contact commenters for clarification where necessary and woul help to reduce pollution of the database with spurious or malicious comments.

Engagement

Data collection and system design must involve input from water users. A broad range of stakeholders, including water users, environmental interests, and agency managers should be included in these conversations. Participants at our workshops emphasized the broad interest in involvement among many water users, as well as the importance of that involvement. Articulating the purposes for which the State plans to use a WRIS will be particularly important.

Timing for data collection

The State should determine how refined water supply and demand data should be to serve the needs of all the parties who will use the data system, and how frequently data should be collected. Diversions and supply data can be reported at different time intervals. Some data are reported yearly, others monthly. Use cases and engagement can inform these determinations, such as whether daily or real-time data are needed to make certain decisions, or whether weekly, monthly, or yearly reporting is sufficient. Use cases and engagement can also help create plans for collecting more refined data as those needs arise. A passive data collection system, subject to crowd correction and user verification, would be an ideal system.

Usability

The user interface for a WRIS will be a key function that determines whether it is a tool for trained specialists, or a broadly impactful and practically useful tool. A high degree of usability is possible – British Columbia and Colorado demonstrate powerfully that this is the case. The State should conduct the design process to emphasize usability and functionality.[196]

Interoperability and Availability

The WRIS will be more powerful to the extent that it can interoperate with other databases through an Application Programming Interface (API). Relatedly, the WRIS will be more accessible to the extent it allows the public to download copies of water rights documents, ideally in batches based on searches.

Currentness

Users will want to know how up to date the system is. Ideally, uploaded documents would be available with little lag time. Idaho in particular does this well by making water rights transfer applications available nearly the same day that they are filed.[197] At minimum, a WRIS should indicate in some way how current its data, or the data in a given search, are.

Metadata Complement Data

Effective metadata assignment will be a crucial element of a functional WRIS. Our pilot effort has produced a proposed metadata standard that the State Water Board can refine, adopt, and update as it needs for additional fields change (see **Appendix G**). Once legacy water rights data have been assigned, we propose the State Water Board require metadata assignment be automated within a WRIS such that applicants must assign metadata to new records. A perjury penalty would encourage reporting accuracy, but developing a system in which users have a stake in the output and an interest in its accuracy would be an equally important measure. A vetting and QA/QC process should be developed to enable systematic State oversight.

Metadata Assignment Requires Skill and Oversight

In our pilot, experienced paralegals applied metadata fields to scanned records under the supervision of an experienced water rights attorney, and we recommend the State take the same approach. Indexing involves judgment calls with respect to these fields, such as how to date a record with an origination date different that the date of introduction as a hearing exhibit. The indexers should follow standard protocols in making these judgments. **Appendix G** describes the protocols used in this pilot and can serve as a starting point for the State to develop official metadata tools.

Completeness

Populating the WRIS with the complete set of digital water rights records will be partially easy, and partially challenging. For the records held by State Water Board, a systematic scanning and organization effort will be relatively straightforward, although it will need to be done with a substantial and careful mobilization effort. Records in county courthouses are in unknown condition and completeness. Greater completeness would also involve expanding the types of documents that are included in the database, particularly change petitions, transfers, and pending water permit applications.

To maintain a complete database, the State Water Board will need to request information from water rights holders, who arguably have the ultimate responsibility for documenting their claim of right to water. Although important for broader clarity and the collective benefit of a complete public record, such a request would likely be an area of contention. Because claims of right can be exercised absent any effort to document a claim, the current incentive for water right holders is to hold information private until it is required by legal challenge.

Chain of Custody

The State Water Board should adopt a procedure for filing a document into the record of a given water right. Public agencies with mature information systems link them to a filing procedure.[198] Records now held in the Records Room should be grandfathered.

Improving Water Demand Data

Water use reporting must be improved. Consistent with SB 88 rules,[199] water use data should be standardized so that they are reported using the same metric. For example, some water rights report the quantity of the water right in terms of flow, or cubic feet per second. Others report water quantity by volume, usually acre-feet. Although both metrics are important, and both should be required, it can be difficult to determine actual water demand when two different demand metrics are used. Water use data should also be reported at the same intervals of time, *e.g.,* daily, weekly, or monthly. More frequent and consistent reporting, or improved monitoring and data collection processes, should be consistent with the scale and impacts of given diversions. The benefit will be higher resolution data and a better picture of the State's actual water demands.

4.3 KEY NEXT STEPS AND UNANSWERED QUESTIONS

Our findings strongly support the need for a modern water rights and use information system for California, and provide concrete information about its design, feasibility and affordability. Developing the ideal process for actualizing the vision presented here will involve further investigation building on the

work we present here. In this section, we enumerate some recommendations about process and function emerging from our research, and point to some key unanswered questions.

4.3.1 Recommendations and Next Steps

- Move forward with developing a WRIS. Our research, and new State policy,[200] support the importance of developing a WRIS. The State should prioritize this effort.
- Look to build on what exists already, recognizing that California is unique. California is an acknowledged national and global leader in technology innovation, and its Governor has written about the importance of data for next-generation advances in governance.[201] Yet California should take advantage of the fact that other states have done more on water rights data. The opportunity to learn from, build upon, and ultimately leapfrog other states' systems provide the path for California to vault rapidly from laggard to leader in this space.
- Recognize the value of pilots. There is no stronger way to evaluate whether or not something works than to actually test it, as our focused pilot clearly demonstrated. We recommend two new pilots to develop a WRIS: First, a pilot in a basin with more complex water rights, such as a larger basin with numerous diversions. This will enable developing and testing features such as priority logic and mapping functionality. Second, pilots of user interface designs and methods such as APIs that enable interoperability will begin to stress test our recommendations and build the ingredients for a detailed specification of a final complete system.
- Privacy concerns are relevant to water rights holders and users of the system. Ultimately, water rights data, as public information, should be available to users who want to view WRIS data and access WRIS functionality for their evaluation of water rights information and records. Determinations about what elements of records constitute PII will rest on legal definitions and policy determinations. Since the water rights system serves to allocate a public asset, and implies public responsibility for stewardship and accountability. The default for relevant information would ideally be complete transparency about its use and users. Evaluating the costs and benefits of various options, and determining the details of a final system, remains a question for decision makers to evaluate with input from stakeholders.
- Evaluate the feasibility of record authentication and data verification procedures. Ensuring the legitimacy of a WRIS will require data verification at some stage. Developing options for specific procedures to ensure data quality, and weighing these options to best address the needs of agencies, water right holders, and other stakeholders will require effort, but will be an essential part of a successful WRIS.
- Stakeholder engagement will be crucial. The present report builds on a multi-year process, including workshops, focus groups, interviews, and informal conversations with many dozens of stakehold-

ers representing water users, environmental groups, disadvantaged communities, legal counsel, technical consultants, academia, and State agencies. Continuing this engagement is essential to develop a water system that works for their needs, addresses their concerns, and ultimately is viewed as both useful and legitimate.

- Harness collective innovation. Building on the need for general stakeholder engagement, a WRIS will need to harness the best ideas from all relevant sectors. One way to encourage this would be to use the California Department of Technology Request for the Innovative Ideas (RFI2) process, a flexible approach to State technology procurement.[202] RFI2 will help involve top technology industry professionals with the technical development of the new WRIS, and will provide multiple opinions on how the software architecture should be structured.
- Connect to and build on other California water data efforts. Attention to water data, emerging thought leadership, and momentum for recognizing the importance of water data has never been greater in the history of California. As described above (see **Recent Data-related Legislation and Policy Changes,** page 15.), multiple parallel efforts can both contribute to, and need to draw on, a modern WRIS. Links to these processes and their products should be made and sustained for the sake of mutual benefit.
- Examine approaches to contracting and procurement. Past attempts to develop large-scale technology systems have not always mapped well onto State procurement procedures. Considering the potential for more flexible approaches to State technology procurement could be an important element of implementation.[203]
- Now is the time. The potential to harness momentum on water data represents a generational opportunity. Pursuing a WRIS needs to be a central part of the State's efforts on water data. The stakes go far beyond a WRIS: the usefulness of a wide range of water data for a wide range of purposes hinges on its ability to leverage water rights data. We hope that California will take the opportunity to unlock water rights data, and in so doing open the potential for unprecedented levels of effective and efficient water management.

4.3.2 Unanswered Questions and Topics for Further Research

- How to fund it? As with any infrastructure, funding is an essential gate to implementation. Planning for capital costs as well as ongoing operations, maintenance, and improvement should all be conducted up front. Evaluating options, including bonds, general fund, user fees, or non-State sources like grants from foundations or other sources, or some combination, should be part of next steps.
- Who should lead? The State of California has a well-deserved reputation as a national leader in many areas of environmental policy, but it has a weaker track record for successfully developing databases and data systems for public information. While the State Water Board is the logical lead agency, it has for years been understaffed and under-resourced, both relative to its administrative responsibil-

ities and relative to its sister agencies. The State should consider whether there would be ways to partner with others, such as academic organizations, consultants, or even other states. It will be important to evaluate up front how any partnership could produce a product that complies with State requirements, and that the State can ultimately adopt.

- How should a WRIS be governed? The standard model for ownership is that the State builds and maintains these types of data systems. However, it might be worth considering new models. For example, a WRIS could be housed at an external organization (*e.g.*, nonprofit organization, public benefit corporation, or Joint Powers Authority). That organization which would handle database design, population, and maintenance, in active collaboration with State Water Board, while State Water Board would lead on substantive issues of reporting, verification, and dispute resolution.
- How to fully populate a WRIS? Some segments of water rights data, such as the paper records housed in State Water Board's records room, will be relatively straightforward to digitize. However, other classes of records are less centralized, including documents housed in county courthouses, those held solely by water rights holders themselves, or missing or misplaced documents. During the 2015 drought the State issued an information order for records it does not have regarding the Russian River.[204] The State could consider issuing such information orders in the future to support fully populating a WRIS. It is the responsibility of water rights holders to file documentation to support their water rights, and to file annual water use reports through RMS.[205] Questions remain about exactly how to operationalize records acquisition, including how to handle riparian and pre-1914 water rights. Nevertheless, the State should prioritize developing sufficient electronic infrastructure to make filings organized, clear, and efficient.
- Standardization or translation.[206] Interoperability and long-term usability of a database require either data standards or the ability to translate multiple non-standard formats into a unified data language. For example, water diversions can be measured and reported using different temporal resolutions and units (*e.g.*, cubic feet per second, acre feet per month). One way to achieve interoperability is to require unifying reported data into a common framework.[207] Another is to develop software to translate differently measured values into intercomparable metrics. Either option should include clear indications of uncertainty and the limits of interoperability. The State will need to evaluate these approaches and decide how to employ both in a WRIS.
- How best to avoid analysis paralysis? Our report contributes concrete observations and recommendations and a pathway for moving forward. It also points to these and other unresolved issues. However tempting it might be to use these questions as reasons to delay progress, we strongly emphasize that that would be a mistake. We believe that a WRIS can and should be developed as soon as possible. As our pilot shows that learning by doing is by far the most effective way to make progress. The State should build on our work, on learning from other states, on expertise that already exists in California and nationally, on momentum on California water data, and on the well-placed faith that by building thoughtfully upon a strong conceptual foundation California will be able to develop a WRIS to effectively serve the cause of better water decision making.

CONCLUSION

This report asked several simple questions: Does California need a more robust and accessible water rights and use information system? Is it feasible and affordable for California to develop such a system? If so, what should the key elements of such a system be, and how can it be actualized? Through a combination of legal and empirical research and an extensive stakeholder engagement process, we find clear answers to these questions.

California will need to modernize how it manages water rights and use data, if it is to manage its increasingly complex and stressed water resources in accordance with State law, let alone respond effectively to the suite of pressures that are emerging with global environmental change. We find that the current system for managing water rights data, namely reliance on paper records supplemented by a very limited online system, does not meet the needs of users.

The need for a new approach is acute.

We conclude that developing such a system is clearly feasible. First, other western states have developed electronic water rights management systems with characteristics that are far superior to California's, without California's reputation for technical sophistication and innovative leadership in natural resources management. Second, most or all of the necessary data already exist. The task, therefore, is not generating new data, but putting existing data into useful and useable form. Third, we have shown directly that it can be done. Our pilot project scanned, digitized, and made searchable records for two of the most litigated water rights in California's history. This pilot demonstrates the feasibility of moving from musty paper to instant searchability, and that it could be more affordable than previously estimated. Clearly, there are technical hurdles to overcome, decisions to make about functionality, and potential tradeoffs to navigate. But our report lays the groundwork for these decisions.

A modern WRIS can be designed to meet the needs of a range of decision makers and the general public. We recognize that the designers of a WRIS will not be able to anticipate every current use for such a system, let alone the novel and creative future uses that may emerge once these data are available. Our research suggests both a preliminary set of functions based on legal needs and examination of user preferences, and a process for refining and detailing these functions.

Ultimately the decision facing the State is not about whether California needs a modern WRIS, or whether a WRIS can be developed. The key question is whether the State can summon sufficient will, funding, and leadership to make it happen. A modern WRIS will be an essential ingredient in generating clarity for water rights holders, State agencies, and everyone in the State who has an interest in good decisions about water resources management. We believe that California can rise to the challenge for the sake of its most fundamental natural resource, and everyone who depends on it.

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REVIEWERS

The authors solicited review of a draft version of this report from workshop participants and others with a range of perspectives and technical expertise. Reviewers remain anonymous and their comments confidential to protect the integrity of the deliberative process. Reviewers were not shown, nor were they asked to endorse, the final report. Naturally, the authors take full and final responsibility for the content of this document, including any remaining errors.

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GLOSSARY OF TERMS

AB 1755: The Open and Transparent Water Data Act, legislation passed in 2016 that requires the creation, operation, and maintenance of a statewide integrated water data platform.

Authentication: An assurance that any given digital record is a true and correct copy of the original paper document or electronically submitted record, and as accurate and formally useable as that original record would be (see Verification).

Consumptive Use: The amount of water which has been consumed through use by evapotranspiration, has percolated underground, or has been otherwise removed from use in the downstream water supply as a result of direct diversion or use of stored water.

Data: Quantitative or qualitative representations or measurements of basic properties of the world.

Database: An electronic collection of data organized for rapid retrieval by computer.

Data system (or information system): A software or hardware system that supports the collection, processing, analysis, synthesis, archiving, distribution, or integration of data so they can be used to answer questions. A data system will involve one or more databases, plus the electronic infrastructure to access or modify the data contained therein.

Decision support system: A modelling or analytic tool used to help guide decisions by processing and synthesizing data into information.

Environmental Flows: ecological flow prescriptions adjusted to consider and *balance* other competing human uses to produce flow regime that balances human and ecological needs.

eWRIMS: Electronic Water Rights Information System is California's current water rights management system. It contains a basic Water Rights Records Search and GIS mapping system.

Georeferencing: Associating data with locations in physical space.

Information: Data that have been processed, analyzed, or synthesized so they can be used to answer questions.

Information system (or data system): A software or hardware system that supports the collection, processing, analysis, synthesis, archiving, distribution, or integration of data so they can be used to answer questions. A data system will involve one or more databases, plus the electronic infrastructure to access or modify the data contained therein.

Interoperability: The ability of diverse computer systems or software to exchange and make use of common data.

Metadata: Data that describes and gives information about other data.

Open data: The provision of access to data using open- source and open-architecture protocols and methods.

Report Management System (RMS): RMS allows owners of water rights to file statements of use and other reports required by statute or by a specific water right

Report of Water Use: All water users, whether appropriative or riparian, are required to file an annual report with State Water Board detailing their water use for the previous year. Reports include beneficial use, the amount of water directly diverted, diverted to storage, and used.

Stakeholder: For this report, defined as those with an interest in the outcomes of California's progress on water data, including data users and data producers from a variety of sectors.

State Water Resources Control Board (SWRCB): the state agency tasked with overseeing water rights and water quality in California.

Statement of Use: A report used to establish a claim of right by riparian or pre-1914 water users.

Timing: Permits commonly contain parameters which establish that water can only be diverted during certain months or seasons. Water users cannot legally divert water outside the permitted season or month of use of their right.

Usability: Data that meets the needs of decision-making processes in practice. Data that are readily available in formats that suit users' needs for making decisions.

Use case: For this report, defined as an example of a water decision making process and the data needs associated with that process. An answer to the set of questions of *who* needs *what data* in *what form* to make *what decision*.

Verification: Ensuring data integrity by examining the content of water rights data with some degree of effort to find, flag, and where possible correct errors by State Water Board staff. As discussed in the text, such verification would be distinct from, and stop well short of, an adjudication-type procedure (see Authentication).

Water data: Water data encompasses both water rights data and water use data. It also includes other types of water information, including supply information (*e.g.* precipitation, streamflows) and quality information.

Water rights data: Refers to specific legal information which determines who gets to use what water and when. Water rights data refers to data which can be gathered from looking at a water rights document (*e.g.,* a permit, license, change petition), and includes such information as: owner, priority date, timing,[208] quantity of water permitted under the right, point of diversion, place of use, and purpose of use.[209]

Water rights documents: The formal legal documents associated with water rights. They include permits, licenses, change petitions, and many other documents that directly define water rights, as well as supporting information such as maps, figures, environmental reports, and so forth that are formally attached to water rights records.

Water use data: Refers to data which tracks how water is used and consumed. Such data includes consumptive use data, return flows, and how much water is diverted.[210]

TABLE OF ACRONYMS

API: Application Programming Interface

CDEC: California Data Exchange Center

CEDEN: California Environmental Data Exchange Network

CFS: Cubic Feet per Second

CLEE: Center for Law, Energy and the Environment

CoC: Chain of Custody

CVP: Central Valley Project

DWR: Department of Water Resources

ET: Evapotranspiration

eWRIMS: Electronic Water Rights Information System

GIS: Geographic Information Systems

HUC12: Sixth-level Hydrologic Unit Code (sub-watershed)

NHDPlus: National Hydrography Dataset Plus

OCR: Optical Character Recognition

POD: Point of Diversion

PDF: Portable Document Format

PII: Personally Identifiable Information

POD: Point of Diversion

POU: Place of Use

PRA: Public Records Act

QA/QC: Quality Assurance, Quality Control

RMS: Report Management System

SWE: Snowpack Water Equivalent

SWP: State Water Project

SWRCB: State Water Resources Control Board

TNC: The Nature Conservancy

USGS: United States Geological Survey

WPLG: Water and Power Law Group, PC

WRIS: Water Rights Information System

APPENDIX A: METHODS

Given the range and complexity of the topic and questions motivating this research, we adopted an interdisciplinary, mixed-method approach.

The goal of Part 2 was to examine the rationale for a modern water rights and use information system. To do so, we blended legal and regulatory research, research on data systems, and analysis of publicly available records and published materials, with ongoing engagement with stakeholders and agency staff. This engagement incorporated expert interviews, focus groups, and formal facilitated workshops, conducted over a period of more than four years. To develop a comparative picture of the state of practice, our empirical research combined document analysis and interviews to analyze water data systems in California, other western states and British Columbia.

The goal for Part 3 was to empirically develop a pilot to demonstrate two key elements of a complete water rights and use system. First, we piloted the scanning and digitization of water rights documents. We developed methods and workflow to organize, steward, and prepare paper water rights records for scanning and OCR assignment, while safeguarding their integrity. Second, we piloted metadata assignment for these records. For this process, we used legal research and engaged with agency staff to develop and implement a generalizable metadata template for California.

The goal for Part 4 was to develop a conceptual vision for a next generation WRIS. This effort built directly on the experience and lessons learned from Parts 2 and 3, augmented by additional qualitative research including interviews, focus groups, and workshops, plus traditional document analysis and a multi-disciplinary literature review.

Permissions. In order to utilize water rights records held by the State Water Resources Control Board, the team worked under a legal agreement with the State which required the team to follow certain privacy and data standards. These standards included encryption of the received records and password protecting the prototype database.

Stakeholder Input. Throughout the process of researching and writing this report, our project team relied heavily on stakeholder input. Stakeholder input was gathered at a December 2018 facilitated workshop in Sacramento and an October 2019 facilitated listening session. Both events were facilitated by Joseph McIntyre (Ag Innovations) and included participants from State Water Board, DWR, consulting and law firms, and outside data experts (*see* **Acknowledgements**, above).

Cross-Jurisdiction Tables. Research synthesized the functions and characteristics of water rights databases on selected Western jurisdictions, using publicly available material.

Database Development. The technical design of the pilot water rights document database was done by a team from GreenInfo Network led by Dan Rademacher. Smooth Solutions scanned the paper documents and transformed them into optical character recognition text.

Proper preparation of paper records is critical to scanning efficiency. In the pilot, the paper records were in widely varying condition - some loose-leaf, and others bound by staples and clips. While most of the records were 8.5 x 11 inches, some were non-standard sizes. The records were in 51 separate boxes. Approximately 75% of the on-site work went into preparation, and specifically, creating discrete stacks of paper ready for scanning.

Protocols to protect the paper records. In the pilot, the paper records were the original legal records for these water rights. The vendor adopted and followed protocols to assure that the paper records were returned in their original order and to their original storage boxes, with the only changes being the addition of separator sheets with barcodes.

Research and Interviews. Research for this report included a cross-jurisdiction analysis conducted by the team at WPLG and CLEE. The analysis involved reviewing the publicly available databases and platforms from thirteen western jurisdictions, including California. The team conducted additional informational interviews with data experts.

APPENDIX B: ILLUSTRATION OF EWRIMS DATABASE SYSTEM SEARCH FUNCTIONS

eWRIMS contains basic information on water rights in California, such as location, primary owner, and reported statements of use. It offers the ability to find some (but not all) water documents.[211] This appendix describes the process of searching for a water right in eWRIMS, by way of illustrating its capabilities and areas for possible improvement.

Step 1- Initial Search. To begin a water rights documents search using the current eWRIMS system, the first step is to access the Water Rights Records Search tool from the eWRIMS Public Data Access Menu (**Figure 8**). Users can search for a water right by multiple fields.

Figure 8. Public water rights rec ords search function from eWRIMS. Source: SWRCB.

Step 2 – Search Results. Searching "S006311" in the Application ID field in **Figure 8** generates information for a water right held by the California Department of Water Resources (**Figure 9**). From here, a user can view reports, available documents, or open the water right in a GIS map.

CIWQS

e-WRIMS Water Right Search Results

Criteria: Displaying Water Rights where Application Number like "S006311".

Search Results: previous 1-1 of 1 next

Appl ID	Permit ID	License ID	Water Right Type	Status	Holder Name	Date	Face Amt	County	Source	View Reports	View Document	Open in GIS	Export to Excel
S006311			Statement of Div and Use	Claimed	DEPARTMENT OF WATER RESOURCES	01/01/1980	0 acre-ft/yr	San Joaquin	GRIZZLEY SLOUGH	View Reports	View Document	Open in GIS	Download to Excel

Return to Water Right Public Search Form | Download to Excel

Figure 9. Table generated for a water right with the Application ID "S006311". Source: SWRCB.

Step 3 – Viewing Reports. If a user chooses to click "view reports," the database will generate a list of statements of use, or, in the case of this particular water right, a list of Supplemental Statements of Water Diversion and Use (**Figure 10**). Statements of Use are only available online from report years 2007 onwards. The statements themselves contain summary information. Rate of diversion, amount of water stored, and amount of water beneficially used are typically reported by month (**Figure 11**).

CIWQS

e-WRIMS RMS Reports

Restart Search

Reports Submitted for S006311

Year	Type	Date Received	Action
2018	Supplemental Statement of Water Diversion and Use	06/27/2019	View
2017	Supplemental Statement of Water Diversion and Use	08/07/2018	View
2016	Supplemental Statement of Water Diversion and Use	03/16/2017	View
2015	Supplemental Statement of Water Diversion and Use	03/21/2016	View
2014	Supplemental Statement of Water Diversion and Use	08/16/2016	View
2013	Supplemental Statement of Water Diversion and Use	03/21/2016	View
2013	Supplemental Statement of Water Diversion and Use	04/14/2014	View
2012	Supplemental Statement of Water Diversion and Use	04/14/2014	View
2011	Supplemental Statement of Water Diversion and Use	04/14/2014	View
2010	Supplemental Statement of Water Diversion and Use	03/14/2012	View
2009	Supplemental Statement of Water Diversion and Use	03/14/2012	View
2008	Supplemental Statement of Water Diversion and Use	03/14/2012	View

Figure 10. Table of available reports for Water Right S006311. Source: SWRCB.

[SUMMARY OF FINAL SUBMITTED VERSION]

SUPPLEMENTAL STATEMENT OF WATER DIVERSION AND USE FOR 2011

Primary Owner: DEPARTMENT OF WATER RESOURCES
Statement Number: S006311
Date Submitted: 04/14/2014

1. Water is used under	Pre-1914 Claim
2. Year of first use	1946

3-4. Maximum Rate of Diversion for each Month and Amount of Water Diverted and Used

Month	Rate of diversion (GPM)	Amount directly diverted or collected to storage (Gallons)	Amount beneficially used (Gallons)
January	0	0	0
February	0	0	0
March	0	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total		0	0
Comments	land was dry-farmed		

5. Water Diversion Measurement

a.	Measurement	Direct measurement using a device listed in Section 1 is "not locally cost effective" for water directly diverted and/or diverted to storage
b.	Types of measuring devices used	
c.	Additional technology used	
	Description of additional technology used	
d.	Who installed your measuring device(s)	
e.	Make, model number, and last calibration date of your measuring device(s)	
f.	Why direct measurement using a device listed in Section 1 is "not locally cost effective"	Diversions are infrequent No power at diversion point
	Explanation of why use of devices and technologies listed in Section 1 are "not locally cost effective"	cannot bring power to the site
g.	Method(s) used as an alternative to direct measurement	Crop duty estimates/consumptive use estimates
	Explanation of method(s) used as an alternative to direct measurement	

6. Purpose of Use

Other	n/a

7. Changes in Method of Diversion

8. Conservation of Water

a.	Are you now employing water conservation efforts?	
	Describe any water conservation efforts you have initiated	
b.	Amount of water conserved	Acre-Feet
	I have data to support the above surface water use reductions due to conservation efforts.	

9. Water Quality and Wastewater Reclamation

a.	Are you now or have you been using reclaimed water from a wastewater treatment facility, desalination facility, or water polluted by waste to a degree which unreasonably affects such water for other beneficial causes?	No
b.	Amount of reduced diversion	
	Type of substitute water supply	
	Amount of substitute water supply used	
	I have data to support the above surface water use reductions due to the use of a substitute water supply	

10. Conjuctive Use of Surface Water and Groundwater

a.	Are you now using groundwater in lieu of surface water?	No
b.	Amount of groundwater used	
	I have data to support the above surface water use reductions due to the use of groundwater.	

11a. Additional Remarks

Attachments

File Name	Description	Size
No Attachments		

Contact Information of the Person Submitting the Form

First Name	juan
Last Name	mercado
Relation to Water Right	Diverter of Record
The information in the report is true to the best of his/her knowledge and belief	Yes

Figure 11. 2011 Supplemental statement of water diversion and use for Water Right S006311. Source: SWRCB.

Step 4 – Viewing Documents. Clicking on "View Document" from the table shown in Step 2 generates a PDF file of scanned documents associated with water right S006311. For this water right, documents include a scanned Statements of Use from 1971 and 1989, and a letter from the State Water Board to a private individual in 1991, confirming receipt of a letter notifying the State Water Board of the sale of land associated with the water right. Other documents associated with the water right are not available.

Step 5 – Opening a Water Right in GIS. Clicking on "Open in in GIS" from the table shown in Step 2 activates eWRIMS Web Mapping Application. The map shows the location of water right S006311, along with other nearby water rights (**Figure 12**). Limited information (owner, geographic information, and status of the water right) is available on the left-hand search window.

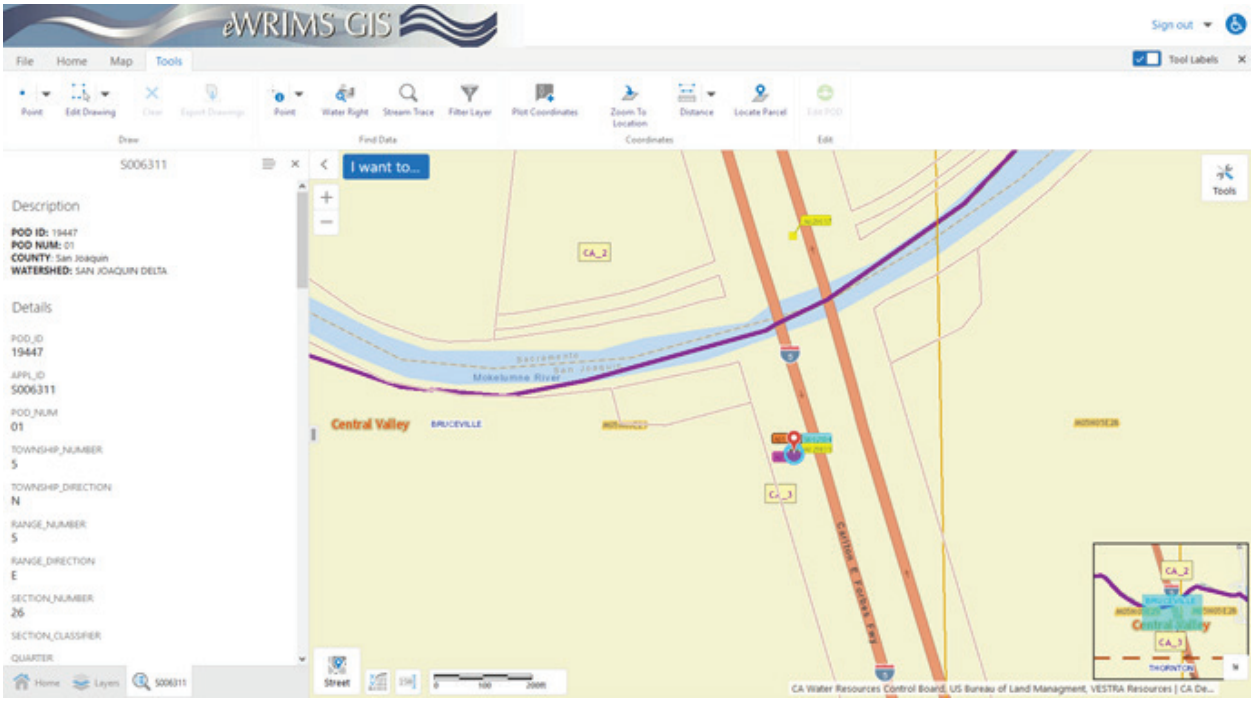

Figure 12. Location of Water Right S006311, shown in the eWRIMS Web Mapping Application. Source: SWRCB.

APPENDIX C: SEARCH FUNCTIONALITIES OF eWRIMS

SEARCH CRITERIA	CURRENT SYSTEM	LIMITATIONS
Water right ID	Indexes water rights by number that the State Water Board has assigned to application, permit, license, or other right for which a Statement of Use has been filed.	Must be complemented by other search methodologies.
Name of diverter	Indexed by primary owner.	Cannot search for water rights based on the names of parties holding the water right. This could hinder a number of functions, including leases or transfers.
Status of right	Indexed to show active, adjudicated, cancelled, and other status categories.	Not consistently updated for all rights.
Priority Date	The dates shown in eWRIMS is the date when the license was granted.	Under the Water Code, the application date determines priority, not the date that the license was granted.
Point of diversion	Water rights indexed by county, source, and HUC. Includes GIS coordinates; permits mapping of a right in isolation and relative to adjacent rights in a given source. Lacks precision or verification – in many cases the map is manually "pinned" based on user reports, rather than having a detailed georeferenced location.	Mapping function is driven by geographic criteria. eWRIMS does not permit mapping of rights based on seniority, status, reported or actual quantity of use, or similar non-geographic criteria. Not consistently included.
Place of Use	Not included.	Water rights are not indexed or searchable by place of use.

SEARCH CRITERIA	CURRENT SYSTEM	LIMITATIONS
Type of Use	Included (*e.g.*, municipal or agricultural).	None.
AVAILABLE DOCUMENTS AND FUNCTION		
Statements of Use	Includes statements filed since 2007, in scanned and downloadable form, typically as PDF files.	Does not include Statements of Use filed prior to 2007. Does not calculate or display reported use data across years, or provide comparison between reported and authorized uses.
Legal documents	Includes scanned copies of application, permit or license if any; some decisions or orders by the State Water Board; and post-2006 Statements of Use.	Sporadically populated with data.[212] There has been no systematic effort to include documentation of this kind in eWRIMS. Rather, data of this sort included in eWRIMS is the result of staff using the system to store records as they work through cases. Available documents are not searchable.
Electronic filing and service in water rights proceedings	None.	State Water Board permits filing documents by mail or email, but this filing procedure is not directly linked to eWRIMS.
SYSTEM FUNCTION		
Interoperability, including the ability to share data from water rights documents and reported data to eWRIMS to other state data systems, as required by AB 1755.[213]	None.	eWRIMS does not currently have the ability to automatically exchange data from water right (either from documents themselves or reported data from water rights holders) to a broader state water data system.

Table 8. Search abilities and limitations of eWRIMS.

APPENDIX D: DOCUMENT AND PRIORITY SEARCH FUNCTION DETAILS

As discussed in **Section 4.2.1** one of the crucial elements of a WRIS will be searchability based on water rights priority and other specific aspects. This appendix details the development of the elements of our prototype tool that enable searching on water rights spatially and sorting them both hydrologically and by seniority.

The pilot database described in this document can be found at cawaterrights.org.

Document Search System

The document search system provides methods to search, sort, and tag the 6,000 documents associated with two water rights in the Mono Basin. The system combines the open-source database Postgres with Amazon's S3 storage server to provide access to scanned documents, in PDF format with text converted via optical character recognition, and to metadata assigned to each document or group of documents. We developed many parts of the system as indexers were actively using the system, which is an ideal workflow to ensure we produce a system that answers to the real complexity of the document archive.

The pilot search system reflects the physical documents as found in the State Water Board records room, storing the scanned documents in electronic "folders" and "boxes" in the same organization as in the records room. To the extent that similar types of documents from similar times are grouped together by records room staff, this reflects a logical system, and it also may allow the electronic documents to better be found in physical form. For that reason, we include links from each document to its containing box and folder. However, we found that records room organization is not always thorough and systematic.

Naturally, a digitized, searchable database allows documents to be connected in new ways, and those groupings can be saved and shared. The search system thus allows users to query by text string, date, author, document type, or some combination. For example, a user interested in progress on a particular aspect of a specific water right can save a search and return to the documents, obviating the need to download them. If and when a WRIS is implemented such that documents are updated as progress is made on water rights, this user could use their saved search periodically to check for updated records.

As an example (see **3.1.4 Implementing Text-based Search**), a search for a phrase like "dust emissions" produces the document list and thumbnails (**Figure 13**). Each thumbnail is an image of the first page of the document, which links directly to that document itself in the database.

Search-based URLs make storing or sharing a search as easy as copying a URL, which can be shared or stored for later use. For example, the above simple search is represented by the URL cawaterrights.org/?keywords=dust%20emissions. Searches can contain any number of desired parameters but are still easily represented as portable URLs.

Water rights documents are anything but simple. They have a wide range of both individual and institutional authors, multiple authors per document, and multiple dates of different types (submittal, approval, etc.). For example, for the two water rights in our Mono Basin pilot, we have 6000 documents, >500 authors, and many dates. As noted elsewhere, this heavily litigated system is an outlier in this respect, but nevertheless each water rights document can have multiple authors and multiple dates. Some authors are known by multiple names.

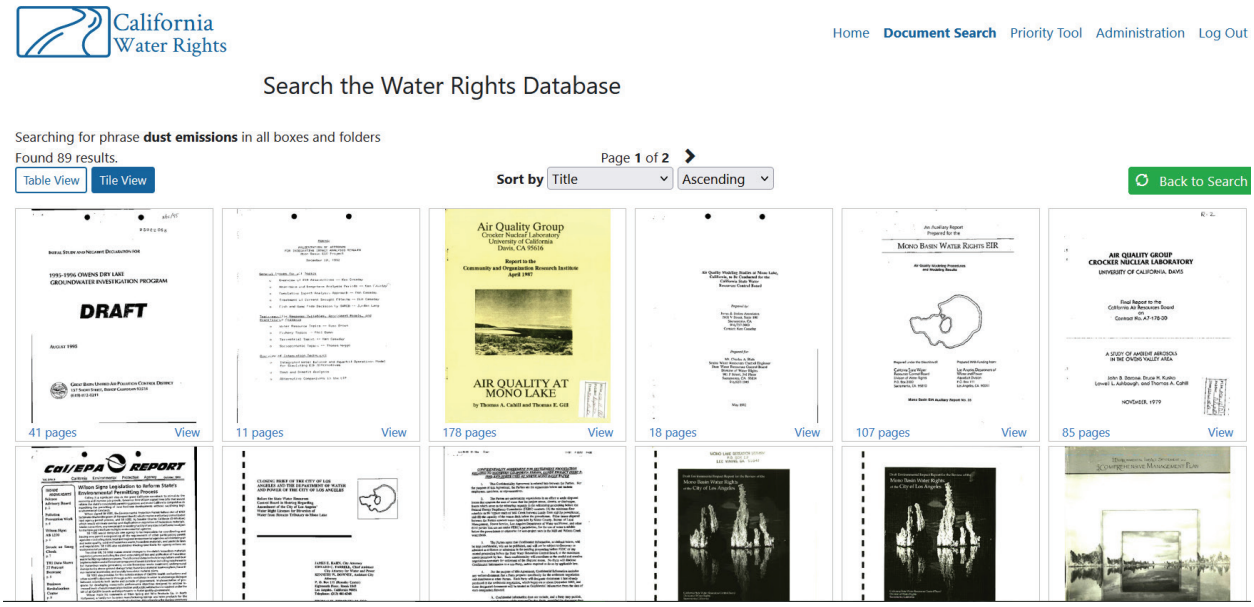

Figure 13. Document search results.

Managing and digitizing an archive of old paper documents that range from photocopies of thermal faxes to actual Statements of Use is a challenge.

To maintain reliability and consistency for both authors and dates across a diverse range of documents, we implemented some sophisticated data models beyond the typical approach of a record having a single author and a hard-coded set of date fields.

To properly catalog authors, we developed a related "Author" table. This is typical, but often means defining authors ahead of time. Instead, we also want to make it easy to add new authors as documents are being indexed.

The indexing form suggests existing authors, but also allows new authors to be created on the fly. This approach speeds indexing and allows for flexibility, but it sometimes produces duplicate authors (*e.g.*, LADWP, LA Water and Power, Los

Angeles Department of Water and Power). To address that, we developed tools to quickly and easily combine authors, associating documents from multiple "authors" to a single new author and pulling over alternative names to that master record to maintain searchability.

As shown in **Figure 14**, we also have multiple methods for database users to suggest changes, including a menu to solicit suggestions for the correct document type, date and author. This is not immediately accepted but rather is saved as a related record for review.

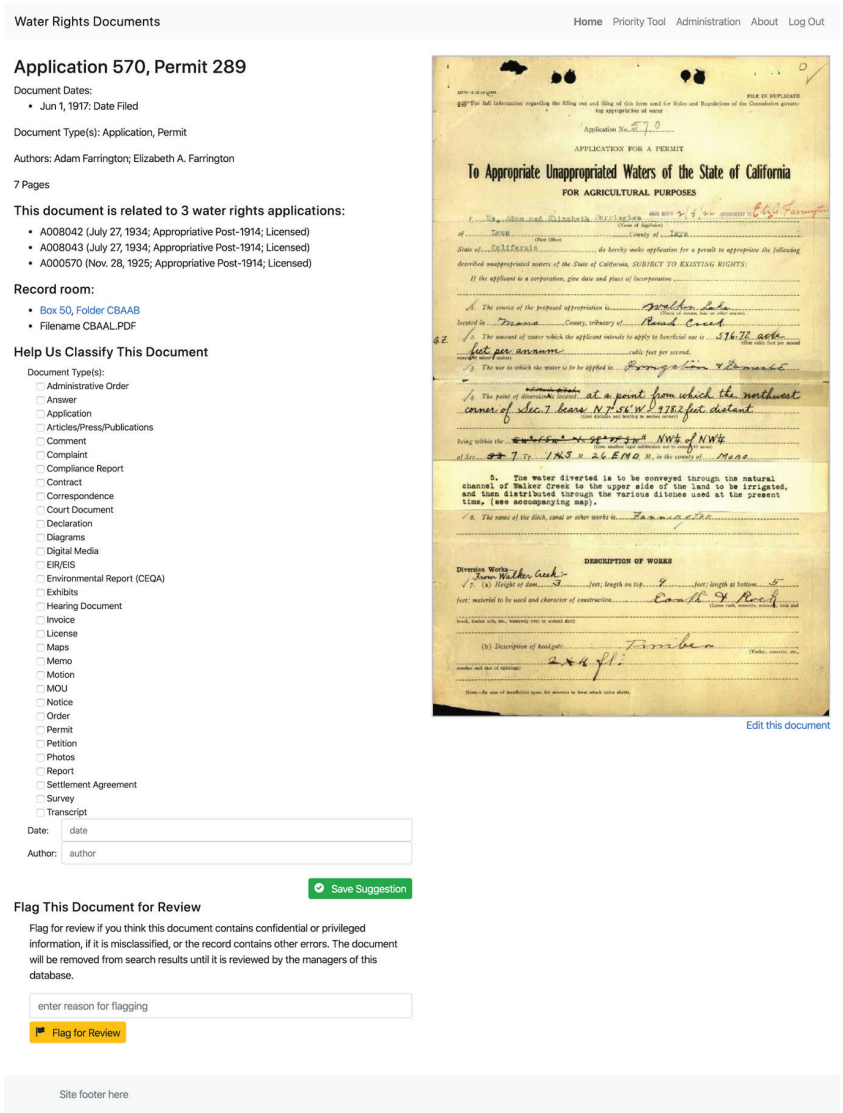

Figure 14. Document with forms for metadata suggestions.

The system also provides a general "flag" with free text to allow users to comment on any other concerns they might have about the accuracy of a document's tagging or its availability to public searches.

Note that an electronic system for filing new documents could easily be designed to eliminate this ambiguity for new or newly modified records. This is yet another argument for the rapid and thoughtful development of an WRIS.

Priority Search

One basic need for a WRIS revolves around rapidly answering questions that are foundational to most water rights inquiries: Where are water rights in a given area, and how do they relate to one another in terms of seniority?

Our survey of water rights tools in multiple western states suggested that a novel tool specifically designed to streamline priority searches would be important to decision makers, and also a useful contribution to water rights information more broadly.

The current eWRIMS Web GIS system allows for "stream trace" functions to find Points of Diversion that are hydrologically related, though the tool is not easy to use and does not allow for priority sorting. The tabular exports from eWRIMS do allow for easy priority sorting, but it's difficult to see which PODs are connected to each other. Tools built for other areas, such as the Cariboo tool cited elsewhere in this report, one can easily see Priority date directly connected to the POD on the map, and the tool provides access to extensive watershed PDF reports with diversion points and rights dates listed, but the nature of a PDF means one cannot easily cross-reference stream location against seniority.[214]

Our approach here is to use existing public data, both from the current eWRIMS system and the USGS NHDPlus hydrography database,[215] to develop a "priority sort" tool that allows for easy searches of Points of Diversion (PODs) by a range of attributes, as shown in **Figure 15**

.

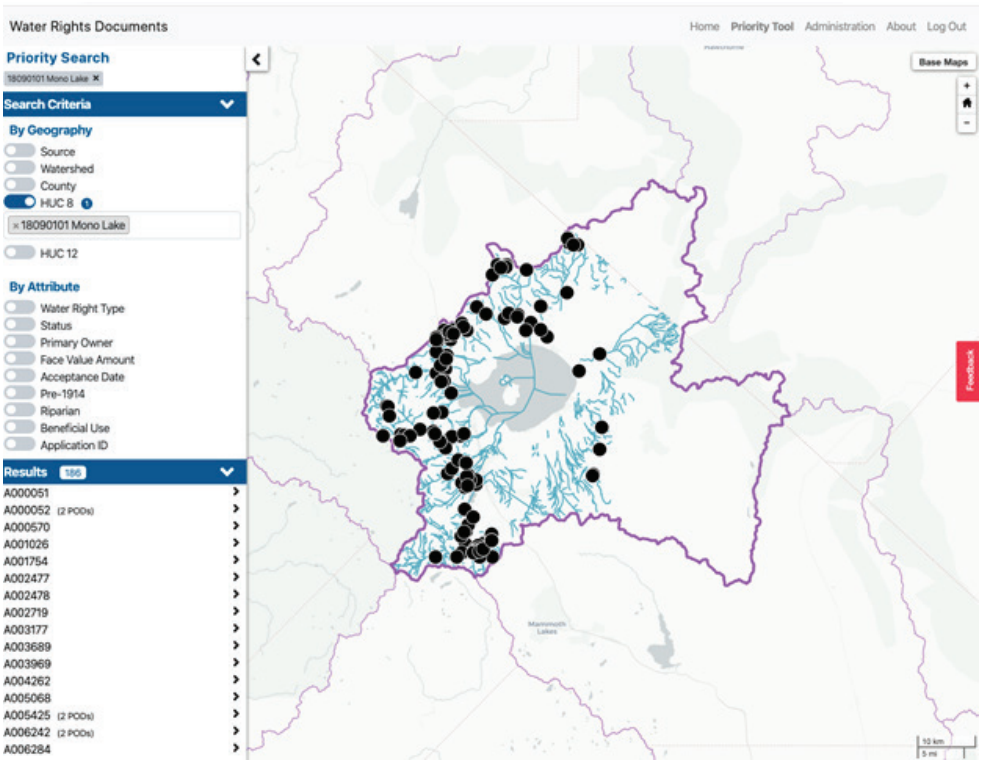

Figure 15. POD search with multiple filter options, including both boundaries and rights types.

As shown in **Figure 15**, the Priority Tool includes a range of options for filtering, including multiple boundary layers (from CA or USGS sources) and POD/rights attributes (all derived directly from eWRIMS). A POD is a crucial spatial reference for each water right, but the water right itself is the most important entity. The results present water rights, grouping PODs where a right has multiple diversions. For example, this URL contains a search for all pre-1914 rights within a particular HUC12 area: cawaterrights.org/prioritytool/?pre1914=t&divhuc12=3505&z=12&x=-119.20921&y=37.86781

Selecting a single result in the POD list shows basic information about that POD and the associated right. Clicking the map achieves the same thing (**Figure 16**).

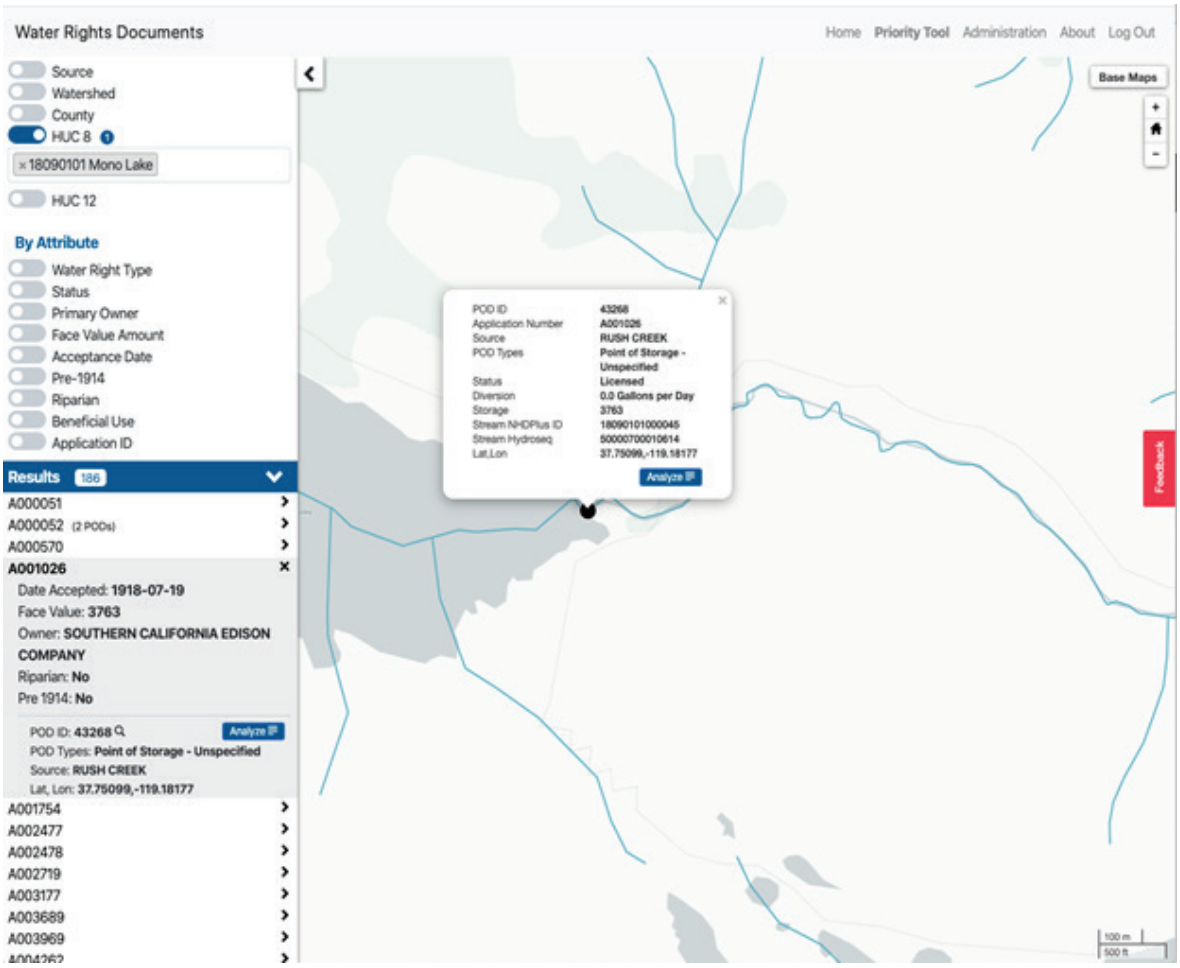

Figure 16. A single POD, showing metadata about that POD, plus the Analyze option for that POD.

The heart of the tool, however, is the Analyze button present on each POD. The Analyze button presents all the PODs and rights that are hydrologically connected to that Point of Diversion.[216] The connection to NHDPlus allowed us to use the HydroSeq attributes[217] to conduct a scripted network analysis and cache the upstream and downstream relationships of each POD to all other PODs. This allows for rapid querying in the application itself, since the analysis from the perspective of every POD has already been done.

Figure 17 shows a stream-order sort with the selected POD and water right highlighted on the map and in the left bar.

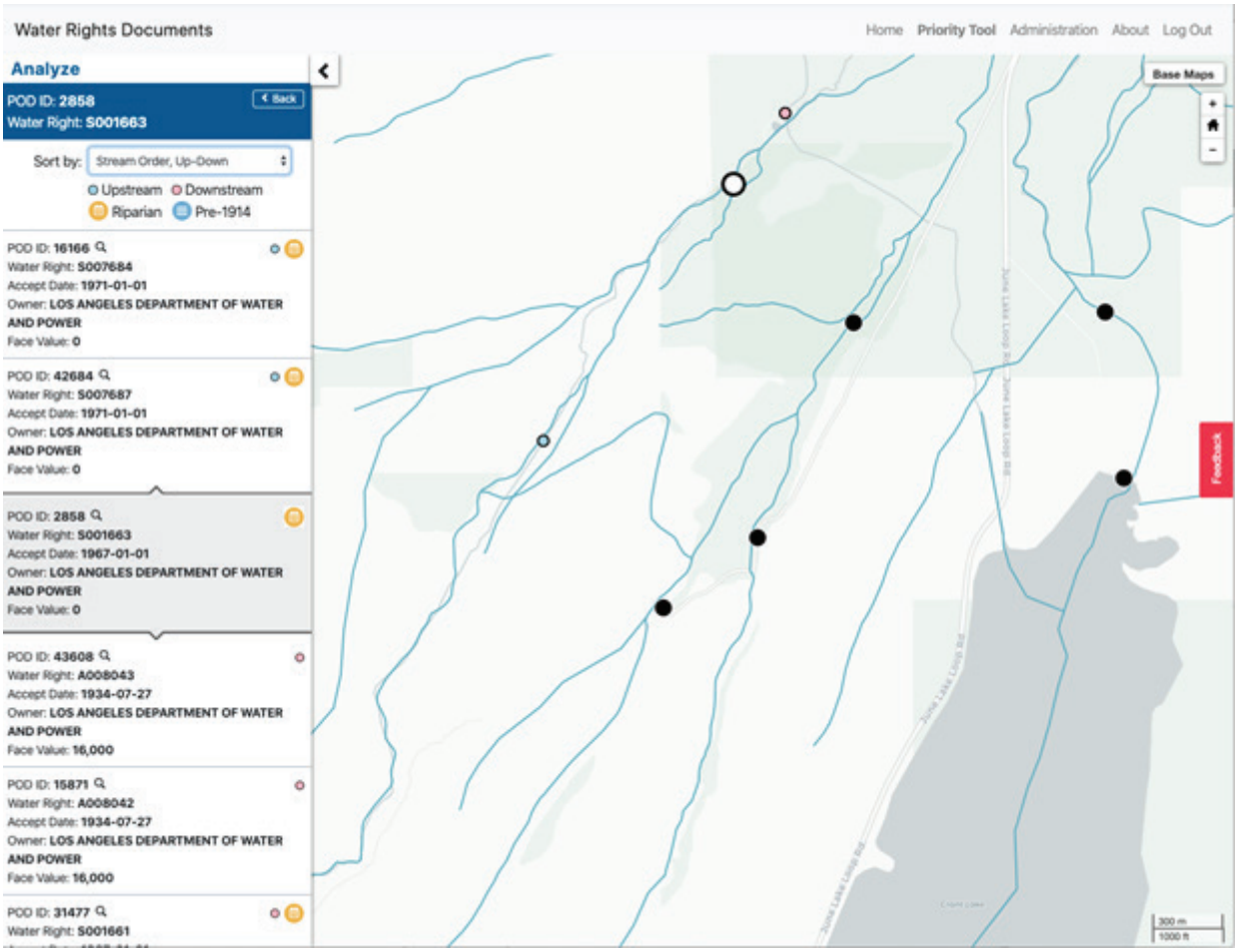

Figure 17. Stream-order sort with selected POD and water right highlighted on the map and left bar.

This POD has just two other rights upstream of it, but a number more downstream. Now, simply selecting the "sort by" option and choosing a date sort then reorders the same list of PODs by the acceptance date of each one's right, with special treatment for Riparian and Pre-1914 that put those to the front of the line (**Figure 18**):

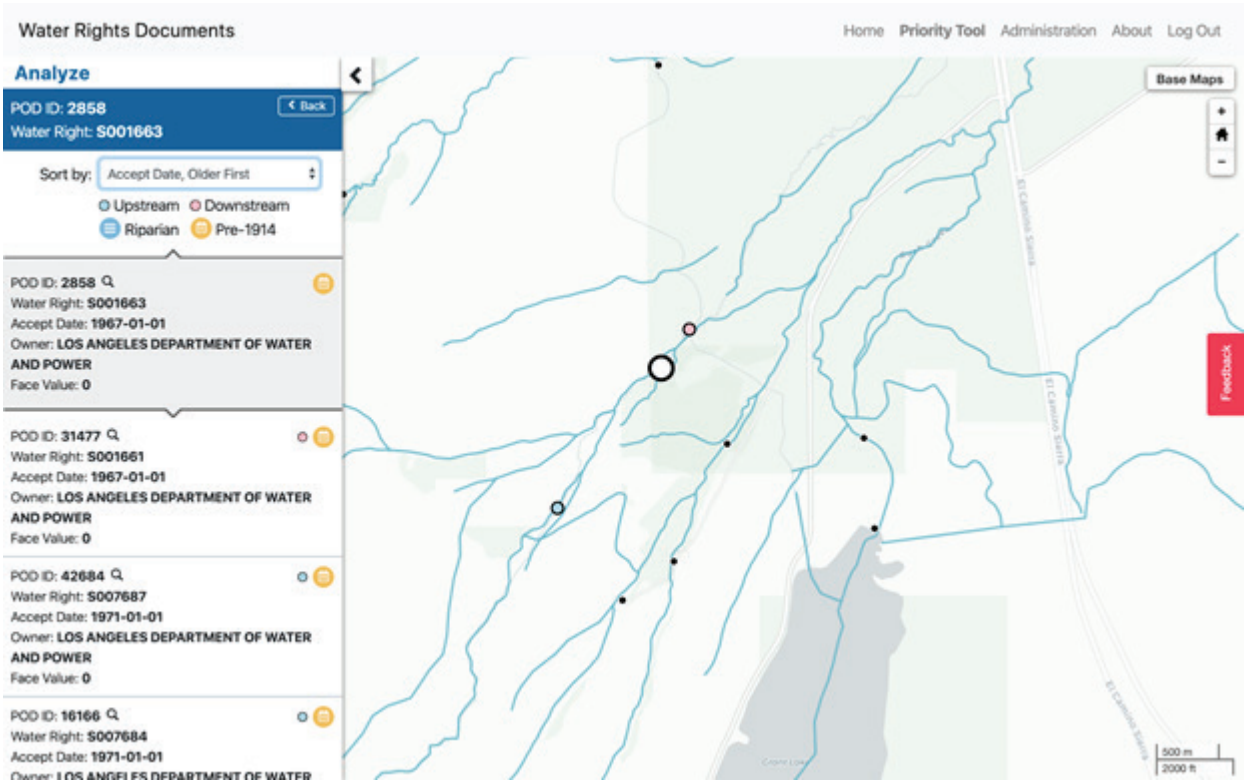

Figure 18. Date-sorted list of hydrologically connected PODs, with selected POD highlighted.

The priority search tool is a critical first step in understanding, within any stream order of PODs and rights, which rights are most senior and for how much water. Compared to the current eWRIMS online GIS system, it presents a streamlined, easy-to-use interface focused on helping users find the areas they are interested in and then instantly view any POD in relation to its *relevant* neighbors, both spatially and temporally.

APPENDIX E: EXAMPLE USE CASES FOR A WRIS

The tables in this appendix contain supporting details for the use cases described in **2.2.2 Use Cases: Water Rights Data in Practice**.

DECISION OR ACTION	DECISION MAKER	INFORMATION NEEDED BY DECISION MAKER	INFORMATION AVAILABLE FROM WATER RIGHTS DOCUMENTS [218]	INFORMATION NEEDED FROM OTHER SOURCES
CAN A PARTICULAR WATER USER DIVERT WATER?	SWRCB	Current quantity of water available for diversion		Streamflow or other monitoring to calculate real-time conditions
		Current demand in the watershed	Existing water rights location, amount, and timing	Real-time diversion measurements
		Forecast of water available in the watershed		While water rights information may help develop predictive models, other data such as streamflow, snowpack, and precipitation will be required for an accurate forecast
		Order of priority of all water rights in the applicable watershed	Priority dates of all water rights	
SHOULD A CHANGE PETITION BE GRANTED FOR PLACE OF USE, POINT OF DIVERSION, OR BENEFICIAL USE?	SWRCB	Priority order of all water rights in the applicable area	Priority dates of water rights affected	
		Point of diversion of all water rights in the applicable area, sorted downstream	Location of diversion points	
		Forecast of downstream return flows and water availability	Beneficial use of water right, which can be used for calculating return flows[219]	
		Downstream water demand	Quantity, timing, and priority of downstream water rights	

DECISION OR ACTION	DECISION MAKER	INFORMATION NEEDED BY DECISION MAKER	INFORMATION AVAILABLE FROM WATER RIGHTS DOCUMENTS [218]	INFORMATION NEEDED FROM OTHER SOURCES
SHOULD A PARTICULAR WATER RIGHT BE REVOKED FOR NON-USE?	SWRCB	Historical records of water availability in the watershed or on the applicable stream[220]		Historical water availability information
		Quantity of water that right is for	Quantity from water right	
		Whether full amount of water was used, if physically available	Reported statements of use	
SHOULD A LICENSE BE GRANTED?	SWRCB	Does the project meet the agreed terms of the original permit?	Original permit application; inspection records of project site	
		Was water used and applied to the permitted beneficial use?	Statement of use records and original permit application	
SHOULD A STREAM BE DECLARED FULLY APPROPRIATED (FAS)?	SWRCB	Total water supply of stream[221]	N/A[222]	While water rights information may help develop predictive models, other data such as streamflow, snowpack, and precipitation will be required for an accurate forecast
		Historic yearly and seasonal averages of water supply		Historical data including streamflow, snowpack, and precipitation
		Total water demand of stream (amount diverted)	Timing, quantity, priority, and point of diversion for all water rights	Diversion data reported by water users
		Total water demand of stream (amount consumed/not returned to stream as return flows)	Place of use, beneficial use, quantity, timing; must also be combined with streamflow measurements to verify consumptive use	Consumptive use data reported by water users
		Calculated return flows for stream or stream segment	Timing, quantity and beneficial use of all water rights	Streamflow measurement which verify return flows

DECISION OR ACTION	DECISION MAKER	INFORMATION NEEDED BY DECISION MAKER	INFORMATION AVAILABLE FROM WATER RIGHTS DOCUMENTS [218]	INFORMATION NEEDED FROM OTHER SOURCES
CAN A NEW WATER RIGHT BE ISSUED ON A CERTAIN STREAM? WHAT IS THE MAXIMUM AMOUNT OF WATER AVAILABLE FOR THAT NEW RIGHT?	SWRCB	Existing locations of public trust resources		
		Current unappropriated water on a specific stream (by year and month) (supply – demand)	Supply: N/ADemand: Quantity, timing, beneficial use, amount of all water rights	Supply: requires data from streamgages, precipitation, and snowpack monitoring systemsDemand: diversion data
		Current water demand on a stream (yearly total and by month)	Quantity, timing, beneficial use, amount of all water rights	Diversion and consumptive use data
QUANTIFY AND ENFORCE ENVIRONMENTAL INSTREAM FLOW REQUIREMENTS	SWRCB	Stream segments with environmental instream flow requirements	N/A	
		Forecasted water supply	N/A	Requires modeling and real-time streamflow, precipitation, and snowpack data
		Forecasted water demand	Quantity, point of diversion, beneficial use, timing	Diversion and consumptive use data
		Priority of water rights on stream	Priority	
		Current water supply	N/A	Will require modeling and real-time streamflow, precipitation, and snowpack data
		Current water demand	Quantity, POD, beneficial use, timing, priority	Diversion and consumptive use data
CAN A WATER USER SELL OR TRADE THEIR WATER RIGHT THIS YEAR?	Water rights holder	Relative priority of the water right compared to other rights on the stream	Priority dates of water rights affected	
		Amount of water available in the basin (to determine whether a water rights holder will receive water this year)	N/A	Requires modeling and real-time streamflow, precipitation, and snowpack data
		Amount of water demand in the basin, and when demand occurs	Quantity and timing of all rights in the basin	Diversion and consumptive use data

DECISION OR ACTION	DECISION MAKER	INFORMATION NEEDED BY DECISION MAKER	INFORMATION AVAILABLE FROM WATER RIGHTS DOCUMENTS [218]	INFORMATION NEEDED FROM OTHER SOURCES
NEGOTIATING SETTLEMENT AGREEMENTS TO MANAGE WATER ALLOCATION AND RESOURCES	SWRCB, water rights holders, other interested stakeholders	Order of priority of all water rights in the applicable area	Priority dates of all affected water rights	
		Point of diversion of all water rights in the applicable area	Location of points of diversion	
		Quantity of water that right is for	Quantity from water right	
		Historic yearly and seasonal averages of water supply		Historical data including streamflow, snowpack, and precipitation
		Existing locations of public trust resources		
		Forecasted future water supply	N/A	Requires modeling of long-term future streamflow, precipitation, and snowpack data
		Forecasted future water demand	Quantity, point of diversion, beneficial use, timing	Diversion and consumptive use data
		Total current water supply of stream[223]	N/A[224]	While water rights information may help develop predictive models, other data such as streamflow, snowpack, and precipitation will be required for an accurate forecast. While this data may not reflect future conditions, it allows decision makers to pinpoint current areas of conflict and tailor agreements to resolving those conflicts
		Current water demand on a stream (yearly total and by month)	Quantity, timing, beneficial use, amount of all water rights	Diversion and consumptive use dataWhile this data may not reflect future conditions, it allows decision makers to pinpoint current areas of conflict and tailor agreements to resolving those conflicts

Table 9. Summary of example use cases for a WRIS. The table is illustrative and non-exhaustive.

WHAT WATER RIGHTS DATA ARE NEEDED?	HOW DO WATER RIGHTS DATA SUPPORT THE DECISION?
Face Value	Face value is the maximum peak amount of water that can be diverted under the water right.[225] It factors into estimated water demand for a particular stream segment or watershed. Combined with modeling and streamflow monitoring, it helps provide an overall picture of water available for appropriation. If available water supply is less than the amount requested in the application, granting the water right would impermissibly harm existing water users.
Timing	Water rights often have temporal condition, such as limitation to a specific season or date range. Therefore, unappropriated water may only be available in certain months of the year. Understanding how the proposed timing of an application interacts with streamflow conditions is necessary to determine water availability.
Beneficial Use	Knowing the beneficial uses of existing water rights helps determine whether water is available, by aiding the calculation of return flows from consumptive vs. non-consumptive uses.
Place of Use	Understanding where existing water rights are used helps to determine where and when return flows may occur, which factor into calculations of water availability. Also helps verify water diversion reports, and will be helpful for SGMA mass balance calculations to GSAs as they develop their water budgets. Helps support valid riparian claims.
Point of Diversion	Both calculation of water availability and a "no injury" determination rely on point of diversion data. For water availability, points of diversion factor into calculating how much water is available for appropriation and where that water is located. For a "no injury" finding, it is critical to understand what water rights exist below the proposed application's diversion point. For example, an existing senior water right could have different implications if downstream or upstream of a proposed application. SWRCB uses relative points of diversion to consider whether and how existing rights and the environment will be impacted by granting an application.

Table 10. Data needs for use case: Can the State Water Board approve a new water rights permit?

WHAT WATER RIGHTS DATA ARE NEEDED?	HOW DO WATER RIGHTS DATA SUPPORT THE DECISION?
Priority	In the prior appropriation system, priority determines the legal order of claims on use of available water. Junior rights must wait for senior rights to be fulfilled before they may divert water.
Timing	Permits commonly contain parameters which establish that water can only be diverted during certain months or seasons. Water users cannot legally divert water outside the permitted season or month of use of their right.
Face Value	If a water user has already diverted the maximum amount of water allowed under their permit for a particular time period, they are, in concept and subject to other more nuanced considerations, no longer allowed to divert water.
Point of Diversion	Point of diversion is important for determining the spatial component of supply availability. For example, if supply is available on the same stream, but only downstream of a point of diversion, water user may not be able to physically divert water.

Table 11. Data needs for use case: Can a current water right holder or claimant divert water?

WHAT WATER RIGHTS DATA ARE NEEDED?	HOW DO WATER RIGHTS DATA SUPPORT THE DECISION?
Name of permit or license holder	Ownership of water by the seller or lessor must be confirmed.
Priority	Priority is necessary to determine how a temporary transfer or sale of a water right will affect other water users or the environment.
Quantity	Quantity bounds the amount of water potentially available for sale or lease. For short term transfers requiring State Water Board approval, a sale or lease can only be for the amount of water that otherwise would have been consumptively used or held in storage.
Timing	Timing – the months or season in which a water right may be exercised - helps State and federal regulators determine when and where a lease or sale will affect other existing water rights and other management goals.
Beneficial Use	Beneficial use may factor into calculating the consumptive use of a water right, and thus, how much water is available for transfer under an appropriative water right. Beneficial use also factors into determining how a change in use as a result of a sale may impact return flows, and thereby affect water users and the environment.
Place of Use	The new proposed place of use must be compared against the existing place of use to determine if the transfer will affect other water users or fish, wildlife, and instream uses.
Point of Diversion	The new proposed point of diversion must be compared against the existing point of diversion to determine if the transfer will affect other water users or fish, wildlife, and instream uses.

Table 12. Data needs for use case: Can a water user sell or trade surface water this year?

WHAT WATER RIGHTS DATA ARE NEEDED?	HOW DO WATER RIGHTS DATA SUPPORT THE DECISION?
Amount	The amount of water needed to fulfil each existing water right is necessary for determining how much water can reasonably be expected to be available in a stream or watershed.
Timing	The seasonality of individual water rights may have a large effect in aggregate on the amount of water that may be diverted, and thus on estimates of watershed conditions at any time. For example, more water rights may be exercised during certain months such as summer irrigation season, so face amount alone is not sufficient. Timing is important in considering whether a stream segment faces higher demands during one season than another, and how those demands might impact ecosystems.
Beneficial use	Beneficial use of water rights can indicate expected consumptive use, and thus how much water is returned to the stream after diversion.
Point of diversion	Point of diversion helps determine where competing demands for water exist between habitat and ecosystem needs and water rights holders. For dams and reservoirs, location data are important to understanding where water is held and can be released from storage.
Place of use	Place of use can help determine where return flows will take place or illuminate synergies. For example, applied water could have multiple simultaneous benefits, such as supporting groundwater dependent ecosystems.
Permit terms	Some permits have specific terms dealing with environmental conditions. [226]

Table 13. Data needs for use case: What is the environmental water balance by stream segment and system?

APPENDIX F: DETAILS OF SCANNING AND DIGITIZATION PROCESS FOR THE MONO BASIN PILOT

LADWP engaged a vendor that specializes in on-site scanning of public documents, including tax records, birth and death certificates, and others.[227] This vendor is Smooth Solutions based in Lodi, New Jersey. The State Water Board provided workspace sufficient for the vendor's team of four people within its Records Room.

The records related to these water rights were in 51 separate boxes. None of the boxes or records had been previously indexed. In cooperation with State Water Board staff, the vendor followed protocols to process the boxes one at a time.

A team of three people was responsible for preparation of records for scanning. This task involved multiple steps. Records were removed from a box. Each record was assigned a unique identity, as the team overlaid a separator sheet with a barcode. The team then removed staples and paperclips, smoothed folded pages, taped torn pages, and assembled records into a stack for scanning.

The vendor used one Kodak I660 scanner, capable of scanning 120 pages per minute in ideal conditions. The vendor used dual-string mode: the scanner created both black and white and color scans simultaneously. Dual-string mode decreased scanning speed to roughly 80 pages per minute. It also significantly reduces issues with illegibility (associated with paper up to 100 years old), and consequently, the probability of rescanning. One person scanned the records, though the supervisor took over scanning during breaks to keep the scanner in continuous operation. The scanner produced images in Tiff Group IV and JPEG.

After scanning, the team returned all records in the original order into the original boxes, recognizing that this order may or may not represent any level of organization or searchability. Following the completion of the on-site tasks, the vendor converted the resulting images into pdf format permitting Optical Character Recognition (OCR).

The team completed the on-site work in ten days. Back in the home office, one employee spent two days overseeing the post-scanning conversion into OCR.

Smooth Solutions provided the scanned documents and associated metadata as directories of PDFs and text files (derived using Adobe Acrobat's Optical Character Recognition) and an Excel table of minimal metadata (pages, box ID, folder ID) that was later enriched and extended by WPLG. GreenInfo stored all files and data on secure Amazon Web Services resources, in a Postgres database running on RDS (Relational Database Services) and files stored on S3. Amazon's resources provide some of the most consistent uptime available in the industry, at very cost-effective prices. A password-protected application, built in Python using the Django application framework, provides password-protected access to the files, with several levels of permissions (view, edit, full admin).

APPENDIX G: METADATA ASSIGNMENT PROCESS AND PROTOCOLS

This section describes the proposed metadata process protocols for a workable documents database. These protocols were developed by Water and Power Law Group in collaboration with GreenInfo Network while building the database.

Our database schema included the ability to assign multiple document types, multiple dates (including partial year, or year-month dates), and multiple authors, as well as indexes keywords and additional notes. Documents can also be related to multiple rights, and of course a right can and will be related to multiple documents. Documents will be queryable by right, author, dates, and free text search, along with information about location in the records room (box and folder IDs).

The system allows for non-editor users to suggest changes in metadata using a form on each document's detail page. Editors can then review and decide whether such changes should be accepted or rejected. The standards and protocols are expected to develop over time, as a wider range of documents are indexed and database user needs become clearer. That said, the system below was developed diligently over the course of the pilot in response to issues raised. Usability and flexibility remain the highest priorities.

Below are the metadata standards as used for indexing the pilot water rights database. Due to the nature of the pilot database, which focused on two water rights and their extensive records, the categories for #1: Water Right have had far less use than #2: Record.

1. Water Right
   - **a. Type** (extracted from eWRIMs)
     - (1). Adjudication
     - (2). Appropriative
     - (3). Pre-1914
     - (4). Post-1914
     - (5). Cert. of Right – Power
     - (6). Correlative
     - (7). Federal Claims
     - (8). Federal Stockponds
     - (9). Groundwater Recordation
     - (10). Non-jurisdictional
     - (11). Not Determined
     - (12). Registration Domestic
     - (13). Registration Irrigation
     - (14). Registration Livestock
     - (15). Riparian
     - (16). Section 12 File
     - (17). Stockpond
     - (18). Temporary Permit
     - (19). Waste Water Change
   - **b. Status** (extracted from eWRIMs)
     - (1). Active
     - (2). Adjudicated
     - (3). Cancelled
     - (4). Certified
     - (5). Claimed
     - (6). Claimed – Local Oversight
     - (7). Closed
     - (8). Completed
     - (9). Inactive
     - (10). Licensed
     - (11). Non-jurisdictional
     - (12). On Hold
     - (13). Pending
     - (14). Permitted
     - (15). Registered
     - (16). Rejected
     - (17). Reports to Watermaster
     - (18). Revoked
     - (19). State Filing
     - (20). Withdrawn
   - **c. Location**
     - (1). Point of Diversion (extracted from eWRIMs mapping tool)
       - APN
       - County
       - Source
       - HOC – name and number
       - Quad Coordinates
       - Source

- Watershed

(2). Place of Use

d. Use (extracted from eWRIMs)

(1). Aesthetic
(2). Aquaculture
(3). Domestic
(4). Dust Control
(5). Fire Protection
(6). Fish and Wildlife Preservation and Enhancement
(7). Frost Protection
(8). Heat Control
(9). Incidental Power
(10). Industrial
(11). Irrigation
(12). Milling
(13). Mining
(14). Municipal
(15). Other
(16). Power
(17). Recreational
(18). Snow Making
(19). Stockwatering
(20). Water Quality

e. Amount of use

(1). Storage
(2). Diversion
- Volume, and/or
- Rate

f. Time of use

(1). Beginning of use
(2). End of use

g. Owner (extracted from eWRIMs)

(1). Corporation
(2). Estate
(3). Federal Government
(4). Government (State/Municipality)
(5). Individual
(6). Joint Venture
(7). LLC
(8). Limited Partner
(9). Organization/Association
(10). Partnership or Co-Owners
(11). Receivership/Fiduciary
(12). Trust

2. Record

a. Title

b. Type of Document

(1). Administrative Order
(2). Answer
(3). Application
(4). Articles/Press/Publications
(5). Comment
(6). Complaint
(7). Compliance Report
(8). Contract
(9). Correspondence
(10). Court Document
(11). Declaration/Testimony
(12). Diagram/Table
(13). Digital Media
(14). EIR/EIS
(15). Environmental Report (CEQA)
(16). Exhibit
(17). Hearing Document
(18). Invoice
(19). License
(20). List
(21). Map
(22). Memorandum
(23). Memorandum of Understanding (MOU)
(24). Motion
(25). Notice
(26). Order
(27). Permit
(28). Petition
(29). Photo
(30). Report
(31). Rule
(32). Settlement Agreement
(33). Survey
(34). Transcript

c. Author(s)

d. Keywords

e. Date

(1). Date Authored
(2). Date Filed
(3). Date (Other)

f. Other Notes

g. Related Water Rights

h. Record Room

(1). Box number, folder
(2). Scan filename

i. Flag & Save

(1). Tag document as duplicate of another
(2). Flag for review

METADATA PROTOCOL DISCUSSION

#1: Water Right

As the pilot's focus was to index all records for two water rights, all documents provided by the State Water Board were automatically indexed with Applications A008042 and A008043. GreenInfo Network is developing a "priority tool" prototype using models derived from existing eWRIMS data (see **3.1.3. Priority and Geographical Search** and **Appendix D**). The core data for water rights remain the same, though the interface will be significantly different.

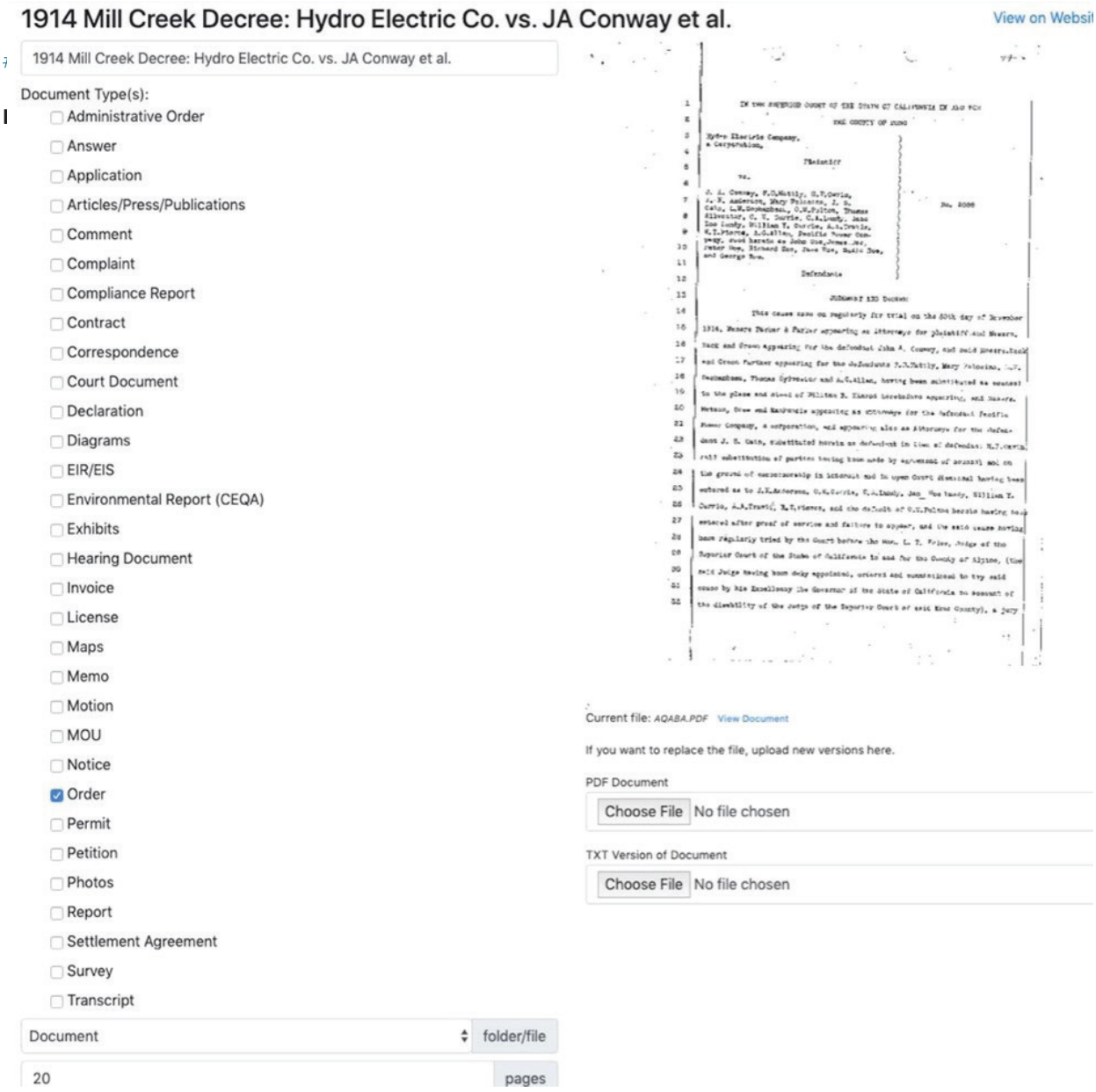

Figure 19. Screenshot of the indexing process.

a) **Title**: Use the document's title to the greatest extent possible. Titles are generally visible from the document snapshot. It is easier to type the document title than to copy and paste – despite the good quality of the OCR, there are enough kerning and capitalization issues to make re-typing the faster, more accurate option. Exceptions to directly re-typing the titles apply:

Correspondence: "Letter to First Surname (Employer) Dated Month DD, YYYY re: Subject Line." Example: "Letter to Jane Doe (SWRCB) Dated January 1, 1992 re: Rush Creek Restoration Progress Report."
Exhibits: "Exhibit Party-##: Title." Example: "Exhibit SWRCB-1: Report on Rush Creek Restoration, 1990-1992."

b) **Type of Document**: Check all applicable document types. Examples: a memo with an attached report would be both "Memorandum" and "Report;" an exhibit including photos submitted to the SWRCB hearings would be "Exhibit," "Hearing Document," and "Photo."

c) **Author(s**): Provide the primary author(s)'s full name(s) and the relevant organization(s). Separate the name and organization into two entries. This allows greater flexibility to account for job or name changes. Example: "Mary B. Jones" is an employee of State Water Board during the 1990s but later becomes a consultant. For documents she authored in the 1990s, the pilot would read: "Mary B. Jones," "SWRCB." The author tag "Mary B. Jones" would also include any documents written by her during her consulting years. Authorship organizes alphabetically.

Aliases: The Authors section is set up to allow aliases, which gives flexibility to record the many acronyms and abbreviations used by parties. Example: if "CalTrout" is the listed author in a given document, a search for "California Trout, Inc." would still provide results with "CalTrout" and vice versa. The current, official name should be the primary author, with outdated and abbreviated names as aliases. Example: "California Department of Fish and Wildlife" is the primary author; "California Department of Fish and Game" (its former name), "DFG, "CDFW", etc. are aliases. If Mary B. Jones later becomes Mary B. Jones-Miller, her author name would be accordingly updated and "Mary B. Jones" would become an alias. Aliases may be added at any time. Though providing the official name as the listed author in a given document is best practice, it does not affect the quality of search results.

It is, however, crucial to include the trial/hearing abbreviations of a given party as an alias and is appropriate to leave the abbreviation as the author for exhibit or other trial/hearing documents. For example, for the document titled "Exhibit SWRCB-1...," leave the author as "SWRCB." Similarly, National Audubon Society and the Mono Lake Committee submitted exhibits together as "NAS&MLC." The exhibit titles are marked as such, and the authors should be "NAS&MLC," "NAS," "MLC." The combined "NAS&MLC" author allows a researcher to quickly find all indexed documents

submitted jointly. "NAS" and "MLC" are aliases for National Audubon Society and the Mono Lake Committee respectively, so searches will include the abbreviated aliases. This is helpful for a beginning researcher who might not yet know to look for the joint author or who is simply interested in only one of the parties.

Exhibits: For authorship of exhibits, record the party submitting said exhibit as well as the original author. To extend the example above, assume that "Exhibit SWRCB-1: Report on Rush Creek Restoration, 1990-1992" was written by John Smith of Smith and Associates, and then submitted as an exhibit by the SWRCB. It would have the authors listed as "SWRCB," "John Smith" and "Smith and Associates."

d) **Keywords**: Include larger themes that would not necessarily appear in a strict text search. The point of the Keywords section is to group documents with similar themes in order to help researchers. Example: "Exhibit SWRCB-1: Report on Rush Creek Restoration, 1990-1992" could have the keywords "Mono Lake Hearings" and "Stream Restoration." New Keywords may be added at any time.

Keywords also includes the option to "Exclude This Document from Keyword Searches (only visible in whole box/folder searches)." Check this box for documents deemed "non-records" – documents that are not a part of official records and that clutter search results. For example, file folders should be excluded from keyword searches. The pilot occasionally included scans of road maps or blank pages (often torn-off back covers) that should be excluded from keyword searches. Excluded documents do not need to be indexed in other categories.

e) **Date**: Record dates as either i) date filed (using the State Water Board file stamp), ii) date authored, or iii) other. The State Water Board's file stamp date is the primary date to record. If there is no file stamp or a significant difference in the file stamp date from other dates in the document, record those date as needed. File stamps are generally on the first page of a document, but sometimes on the second or the last. For example, if "Exhibit SWRCB-1: Report on Rush Creek Restoration, 1990-1992" is accepted as an exhibit on "1/11/94" and the report itself is dated "May 1993," give "Jan. 11, 1994" as "Date Filed" and "May 1993" as "Date Authored." If there is any ambiguity, fill in the "Additional Info as Needed" bar with an explanation. The Dates section can record as many dates as needed or as few: just the year of a document is sometimes the only available information.

f) **Other Notes**: Record administrative issues with a given document, such as illegibility, mis-ordered pages, misaligned text, etc. Some documents are separated that should be combined or vice versa. Example Note: "AAAAA is missing its last appendix – combine with AAAAB."

g) **Related Water Rights**: Tag related water rights to this section. In the pilot, all documents were automatically tagged with A008042 or A008043.

h) **Record Room**: Automatically populated with the box number from the State Water Board record room, as well as the folder number and five-digit file name.

i) **Flag & Save**: Tag documents as duplicates of others to avoid repetitive search results. Tagging is a less drastic alternative to deleting documents. For example, the State Water Board received one original and nine copies of a report on Mono Lake water levels. If the original report is BBBBB, mark all copies as duplicates of BBBBB instead of indexing the other sections. If BBBBC is one of the copies, it will no longer show in the search results for "Mono Lake water levels," but will appear in box or folder searches. This tool goes a long way to reducing clutter, but the database also contained many of the same documents that could not be tagged. For example, if the report was originally submitted in 1992 but a party submitted it as an exhibit for the trial in 1993 and the hearing in 1994, the 1993 and 1994 versions must be kept as independent, fully searchable documents (though any copies of the exhibits can, of course, be tagged as duplicate).

Tagging documents as duplicates suppresses all other metadata but Notes and the snapshot image. *e.g.* if BBBBC were titled before being tagged, its title would no longer appear. In lieu of the suppressed content, a hyperlink is presented which opens the original document (*e.g.* BBBBB) in a new tab/window. Documents can be un-tagged and fully indexed, however, if they are not true duplicates. Notably, duplicates are mainly an artifact of scanning paper copies. Tagging duplicates should become superfluous when new documents are uploaded directly to the database.

The Flag & Save section also includes a box titled "Flag for review." Check the box for documents with marginalia, confidential information, or copyrighted material. After checking, a window appears asking for the reason for review. Provide a succinct explanation, *e.g.* "private handwritten notes on p. 2." Of course, public handwritten documents (*e.g.* letters from school children) and unimportant notes (*e.g.* "Have you seen this article?") should not be flagged. Flagged documents do not appear in any search results and are accessible only to Editor level users on the database. Flagged documents must be reviewed by State Water Board staff before being returned to the public database.

APPENDIX H: QA/QC OPTIONS AND CONSIDERATIONS

In spite of best efforts and thoughtful design of the QA process, some errors are inevitable, whether introduced by algorithms or human error. Thus, the QC process would benefit from labeled data with quality indicators. For example, metadata could be assigned by a range of methods, each of which has potential error associated with it. Data production methods for any given record could range from very accurate (*e.g.*, formal approval by Board legal staff in a publicly vetted process), to fairly reliable but not certified (*e.g.*, initial, un-vetted assignment by generalist paralegals), to potentially error prone (*e.g.*, unauthenticated OCR of non-standard documents). Developing a schema that estimates and assigns data quality to each entry could help prioritize both QA processes before public launch, and QC processes after it. This schema will also include versioning that flags data as preliminary or finalized in cases where non-vetted data are released as part of a public product. A system that notified rights holders when their rights were flagged could be helpful for transparency, with the caveat that it could also create additional communications challenges.

QC processes will need to be accounted for in design of the WRIS system, and appropriate functionality should be built into the WRIS to support QC. For example, system users will ideally be able to electronically flag data with errors, describe the reason for the flag, and suggest a potential resolution. Ultimately, the State Water Board will need to take responsibility for addressing reported errors by updating scans, revising metadata, and so forth. A time-stamped record of flags and corrective actions in the database will help to minimize duplicative actions and signal when substantive disputes in the record need to be elevated.

Both QA and QC will benefit from automated assignment of electronic signatures that identify data provenance and track versioning history. Identity and access control will ensure accountability for State Water Board staff and authorized contractors submitting and modifying data in the system. Further, we recommend that users be required to register non-anonymously in order to flag data. In combination with requirements that data produced by State Water Board and data submitted by users could require legal statement by the contributor attesting to its accuracy, this basic accountability will help to cut down on spurious activities that can disrupt any web platform. State Water Board will need to assign dedicated staff to the QA/QC functions.[228]

ENDNOTES

1 Alida Cantor, Michael Kiparsky, Rónán Kennedy, Susan Hubbard, Roger Bales, Lidia Cano Pecharroman, Kamyar Guivetchi, Christina McCready, and Gary Darling. 2018. Data for Water Decision Making: Informing the Implementation of California's Open and Transparent Water Data Act through Research and Engagement. Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA, *available at* https://www.law.berkeley.edu/research/clee/research/wheeler/data/ (last accessed February 18, 2020); Alvar Escriva-Bou, Henry McCann, Ellen Hanak, Jay Lund, and Brian Gray. 2016. Accounting for California's Water. Public Policy Insitute of California. Available at: https://www.ppic.org/content/pubs/report/R_716EHR.pdf (last accessed September 21, 2020). Redstone Strategy. 2018. Governance and Funding for Open and Transparent Water Data Implementing Assembly Bill 1755. Available at https://www.redstonestrategy.com/publications/ca-open-water-data/ (last accessed September 21, 2020); Moran, T., A. Saracino, Z. Sugg, B. Thompson and J. Martinez, Evaluating the Use of Data Platforms for Water Management Decisions. Water in the West. Stanford Digital Repository. Available at: https://purl.stanford.edu/cb612zf3515 (last accessed September 21, 2020); Kiparsky, M., and Cantor, A. 2020 (*in press*). Civic engagement and water data: How can California make data work for decision makers? Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA.

2 Gavin Newsom, *Citizenville: How to Take the Town Square Digital and Reinvent Government*. Penguin Books. 2014.

3 Cantor et al. 2018, supra note 1.

4 Cal. Water Code §100.

5 People v. Gold Run D. & M. Co., 1884, 66 Cal. 138 [4 P. 1152], pp. 151-2, stating that: "the rights of the people in the navigable rivers of the State are paramount and controlling. The State holds the absolute right to all navigable waters and the soils under them .... The soil she holds as trustee of a public trust for the benefit of the people; and she may, by her legislature, grant it to an individual; but she cannot grant the rights of the people to the use of the navigable waters flowing over it ...."

6 National Audubon Society v. Superior Court, 1983, 33 Cal.3d 419 [658 P.2d 709] at 441: "Thus, the public trust is more than an affirmation of state power to use public property for public purposes. It is an affirmation of the duty of the state to protect the people's common heritage of streams, lakes, marshlands and tidelands, surrendering that right of protection only in rare cases when the abandonment of that right is consistent with the purposes of the trust."

7 Cal. Water Code §1840 (c).

8 *Annual Water Use Reporting Requirements for Water Right Holders*, California State Water Resources Control Board, *available at:* https://www.waterboards.ca.gov/waterrights/water_issues/programs/diversion_use/water_use.html (last updated June 8, 2018).

9 Cal. Water Code § 12400 et seq; see also Cantor et al. 2018, supra note 1.

10 California Department of Water Resources, *Open and Transparent Water Data Act — Implementation Journal, available at* https://www.arcgis.com/apps/MapJournal/index.html?appid=50323246e8d148a0a504038a0d40fb7f (last accessed September 21, 2020).

11 Cal. Water Code §144.

12 California Department of Natural Resources, California Environmental Protection Agency, California Department of Food and Agriculture (July 2020), *2020 Water Resilience Portfolio, available at* https://waterresilience.ca.gov/wp-content/uploads/2020/07/Final_California-Water-Resilience-Portfolio-2020_ADA3_v2_ay11-opt.pdf (last accessed September 21, 2020).

13 California Exec. Order No. N-10-19 (April 2019), *available at* https://www.gov.ca.gov/wp-content/uploads/2019/04/4.29.19-EO-N-10-19-Attested.pdf (last accessed September 21, 2020).

14 The portfolio states the goals to "Develop data management training for state agencies that aligns protocols for water data access and management under the Open and Transparent Water Data Act of 2016 (AB 1755)" and "Support state water data compliance with AB 1755." And it calls upon state agencies "Build upon implementation of SB 19 of 2019" (p. 23).

15 2020 Water Resilience Portfolio, supra note 14. See action 22.7, stating "Explore ways to make water rights information easily available to the public by rebuilding the state's water right data base to include digital place of use, diversion, and case history information, made available on an easy-to-use geospatial platform." See also other relevant actions under priority 22.

16 See, for example: Governor Newsom's Water Resilience Portfolio (https://waterresilience.ca.gov); Governor Brown's California Water Action Plan (https://resources.ca.gov/Initiatives/California-Water-Action-Plan); a number of reports by the Little Hoover Commission (*e.g.*, https://lhc.ca.gov/report/clearer-structure-cleaner-water-improving-performance-and-outcomes-state-water-boards).

17 1913 State Conservation Commission Report, *available at:* https://waterpowerlaw.sharefile.com/share/view/s5d2567a20ca4f0c9 (last accessed October 2, 2020).

18 Generally, timing refers to the specific months the water right may be exercised if water is available, although this varies (some water rights may list a season or more specific dates).

19 This is frequently referred to in the legal community as "beneficial use."

20 Diversion data can be reported at different granularities, including hourly, daily, weekly, or monthly.

21 Cantor et al 2018, supra note 1.

22 See, for example, Green Nylen, Nell, Michael Kiparsky, Dave Owen, Holly Doremus, Michael Hanemann. (University of California, Berkeley). 2018. Addressing Institutional Vulnerabilities in California's Drought Water Allocation, Part 1: Water Rights Administration and Oversight During Major Statewide Droughts, 1976–2016. California's Fourth Climate Change Assessment, California Natural Resources Agency. Publication number: CCCA4-CNRA-2018-009. 193 pp. Available at: https://www.energy.ca.gov/sites/default/files/2019-12/Water_CCCA4-CNRA-2018-009_ada.pdf (last accessed September 21, 2020) or https://www.law.berkeley.edu/research/clee/research/wheeler/drought-water-allocation/ (last accessed September 21, 2020); Green Nylen, Nell, Michael Kiparsky, Dave Owen, Holly Doremus, Michael Hanemann. (University of California, Berkeley). 2018. Addressing Institutional Vulnerabilities in California's Drought Water Allocation, Part 2: Improving Water Rights Administration and Oversight for Future Droughts. California's Fourth Climate Change Assessment, California Natural Resources Agency. Publication number: CCCA4-CNRA-2018-010. 72 pp. Available at: https://www.energy.ca.gov/sites/default/files/2019-12/Water_CCCA4-CNRA-2018-010_ada.pdf (last accessed September 21, 2020) or https://www.law.berkeley.edu/research/clee/research/wheeler/drought-water-allocation/ (last accessed September 21, 2020).

23 **Appendix B** contains more details of eWRIMs capabilities and includes a walk-through of how a current water rights documents search is done on the system.

24 Documents included are permits, licenses, and orders modifying a previously granted water right. Statements of use are also included, but only after 2009. For statements of use before 2009, a searcher must contact the SWRCB. Cal. Water Code § 5101 has generally required statements of use for all water rights without permits and licenses (that is, for pre-1914 and riparian rights holders) since January 1, 1966. This is important because riparian and pre-1914 water rights holders make up a significant amount of water used in California and often hold the oldest water rights.

25 SWRCB has recently produced a Fresno River Investigation Geodatabase as part of its proceedings pertaining to a Petition for Statutory Adjudication of Water Rights in the Fresno River Watershed. This new tool, while geographically limited and designed for a specific purpose, has far more detailed information and functionality than eWRIMS. The Fresno River Investigation Geodatabase can be found at https://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/fresno_riv_adjud/ (last accessed September 1, 2020).

26 This category also includes "subterranean streams," which are treated as surface water and permitted by the State Water Board. For more information on the differences between appropriative and riparian water rights, *see* Barton H. Thompson et al., *Legal Control of Water Resources* (6th Edition. 2018).

27 *See https://www.waterboards.ca.gov/waterrights/board_info/faqs.html#toc178761093* (last accessed Aug 5, 2020).

28 *See https://www.waterboards.ca.gov/waterrights/board_info/faqs.html#toc178761093* (last accessed Aug 5, 2020).

29 *See https://www.waterboards.ca.gov/waterrights/board_info/faqs.html#toc178761093* (last accessed Aug 5, 2020).

30 *See https://www.waterboards.ca.gov/waterrights/board_info/water_rights_process.html* (last accessed Aug 5, 2020).

31 *See* https://rms.waterboards.ca.gov/login.aspx (last accessed February 18, 2020).

32 *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/docs/ewrims2010_factsheet.pdf (last accessed February 18, 2020).

33 *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/ewrims/docs/ewrims_30nov06workshop.pdf (last accessed September 21, 2020).

34 Cantor et al. 2018, p. 9, supra note 1.

35 In the field of computer science, use cases are employed in software and hardware development to describe system requirements for a user's perspective. Daryl Kulak. & Eamonn Guiney. *Use cases: requirements in context*. Addison-Wesley. 2012.; Cantor et al. 2018, supra note 1.

36 Cantor et al. 2018, supra note 1.

37 Data sources for necessary parameters vary widely even within a given use case. For example, demand and priority can be gleaned from existing water rights information. Calculations of available water supply rely more heavily on real-time data reporting from instruments such as stream gages. However, some aspects of water supply (such as return flows) may be roughly estimated based on water rights data (*e.g.,* point of diversion, place of use, beneficial use) but still require actual measurement or reporting of water flows to verify the amount of water returned to the stream. These observations again support the importance of data system interoperability.

38 Cantor et al. 2018, supra note 1; Cantor, A, and M Kiparsky. 2020. Civic Engagement and Water Data: How Can California Make Data Work for Decision Makers? Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA. 8 pp. https://www.law.berkeley.edu/research/clee/research/wheeler/civic-engagement-and-water-data/ (last accessed June 10, 2021).

39 Cantor et al. 2018, supra note 1.

40 Other examples of key considerations include:

- Is water available for appropriation? If so, when and under what circumstances is water available?
- Will the proposed appropriation injure the exercise of water rights by other legal users of water? If approved, what terms and conditions should be included to prevent injury to the exercise of water rights by other legal users of water?
- Will the water be put to reasonable and beneficial use? If approved, what terms and conditions should be included to ensure that the diversion and use of water is reasonable and beneficial?
- Will the proposed appropriation cause adverse impacts to water quality or public trust resources? If approved, what terms and conditions should be included to protect water quality and public trust resources?
- Is the proposed appropriation in the public interest? If approved, what terms and conditions should be included to ensure that the diversion and use is in the public interest?

41 Groundwater Sustainability Agencies may be interested in this information in order to determine whether to apply for a new water right permit to use surface water for groundwater recharge or to monitoring interactions between surface and groundwater resources.

42 Nell Green Nylen, Michael Kiparsky, Dave Owen, Holly Doremus, Michael Hanemann, 2018. Addressing Institutional Vulnerabilities in California's Drought Water Allocation, Part 2: Improving Water Rights Administration and Oversight for Future Droughts. California Natural Resources Agency, *available at* https://www.law.berkeley.edu/research/clee/research/wheeler/drought-water-allocation/ (last accessed March 17, 2020).

43 See, *e.g.*, Mike Young and Bryce McAteer. 2017. *Sharing Groundwater: A Robust Framework and Implementation Roadmap for Sustainable Groundwater Management in California*. NI WP 17-02. Durham, NC: Duke University, *available at:* https://nicholasinstitute.duke.edu/sites/default/files/publications/ni_wp_17-02.pdf (last accessed February 26, 2020); Ellen Hanak and Elizabeth Stryjewski. 2012. California's Water Market, By the Numbers: Update 2012. Public Policy Institute of California, *available at* https://www.ppic.org/content/pubs/report/R_1112EHR.pdf (last accessed March 17, 2020); Ellen Hanak, Jelena Jezdimirovic, Gokce Sencan, 2019. California's Water Market. Public Policy Institute of California, *available at* https://www.ppic.org/wp-content/uploads/jtf-water-market.pdf (last accessed March 17, 2020), Scott Sellers, Matthew Zaragoza-Watkins, Ph.D., Christina Babbitt, Ph.D., Ana Lucía García Briones, Ann Hayden, David Festa, 2016. Better Access. Healthier Environment. Prosperous Communities. Recommended Reforms for the California Water Market. Environmental Defense Fund, *available at* https://www.edf.org/sites/default/files/california-water-market.pdf (last accessed March 17, 2020).

44 Required approvals vary depending on the water right or contract being traded or sold. For example, transfers between CVP and SWP contractors must be approved by SWRCB. Cal. Water Code § 1725. Transfers within the CVP require approval from the U.S. Bureau of Reclamation (*see* FONSI-15-018: Accelerated Water Transfer and Exchange Program for Friant Division and Cross Valley Contractors – Contract Years 2016-2020, *available at* https://www.usbr.gov/mp/nepa/includes/documentShow.php?Doc_ID=24376 (last accessed February 18, 2020).

USBR "has historically acknowledged water transfers and/or exchanges between CVP contractors geographically situated within the same region and who are providing water service through the same CVP facilities under an accelerated water transfer program." (FONSI 15-018, p. 1). As operator of the SWP, DWR must find that proposed transfers within the SWP conveyance system do not "harm any other legal user of water, will not unreasonably affect fish and wildlife, and will not unreasonably affect the overall economy of the county from which the water is transferred," (*see* https://water.ca.gov/Programs/State-Water-Project/Management/Water-Transfers (last accessed February 18, 2020)).

For water rights not within the CVP or SWP system, SWRCB approval is required by a transfer (*see* https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/docs/transproginfo.pdf (last accessed February 18, 2020). Transfers within either the CVP or SWP system generally do not require approval from the SWRCB, unless a change in the point of diversion, purpose of use, or place of use within the system is needed for the transfer. A majority of water transfers within California take place within the CVP or SWP systems, between contractors in the same project (*i.e.,* CVP to CVP transfers or SWP to SWP transfers). By state estimates, 95% of water transfers in California are water transfers between SWP contractors or transfers between CVP contractors. *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/docs/transproginfo.pdf (last accessed February 18, 2020).

SWRCB oversees all other post-1914 water right transfers which occur outside of the CVP and SWP systems. For pre-1914 rights, SWRCB approval is not required for changes in point of diversion, purpose of use, or place of use so long as other water users are not injured by the change. *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/docs/transproginfo.pdf (last accessed February 18, 2020).

45 Environmental flows must consider and balance other competing human uses to produce flow regime that balances human and ecological needs. Environmental flows include system water needed to transport the appropriate quantity of water to its diversion point, and water needed to maintain adequate water quality and salinity levels. Setting such flows is inherently difficult and contentious. See generally, Decision 1631, https://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1631.pdf (last accessed October 2, 2020); National Audubon Society v. Superior Court, 33 Cal.3d 419 (1983).

46 *See, for a conceptual discussion,* Jeffrey Mount, Brian Gray, Karrigan Bork, James E. Cloern, Frank W. Davis, Ted Grantham, Letitia Grenier, Jennifer Harder, Yusuke Kuwayama, Peter Moyle, Mark W. Schwartz, Alison Whipple, and Sarah Yarnell. 2019. A Path Forward for California's Freshwater Ecosystems. Public Policy Institute of California. Available at https://www.ppic.org/publication/a-path-forward-for-californias-freshwater-ecosystems/ (last accessed October 2, 2020).

47 Yarnell, Sarah M., Eric D. Stein, J. Angus Webb, Theodore Grantham, Rob A. Lusardi, Julie Zimmerman, Ryan A. Peek, Belize A. Lane, Jeanette Howard, and Samuel Sandoval Solis. "A functional flows approach to selecting ecologically relevant flow metrics for environmental flow applications." River Research and Applications 36, no. 2 (2020): 318-324. Available at https://onlinelibrary.wiley.com/doi/abs/10.1002/rra.3575 (last accessed October 2, 2020); https://californiawaterblog.com/2018/12/09/functional-flows-for-developing-ecological-flow-recommendations/ (last accessed October 2, 2020).

48 See the text and appendices for more detailed description of methods.

49 Cal. Water Code § 5101.

50 Naturally, a digital record can be authenticated as a faithful reproduction of an original paper record, while the facts in the document could still not be accurate with respect to any claims of right. The section on QA/QC, and discussion of authentication and verification procedures discusses these distinctions in greater detail.

51 California lacks statements of use before 2009's Delta Reform Act. Although they have been required reporting since January 1, 1966, there was no positive incentive offered for reporting, and no penalty for lack thereof (Cal. Water Code § 5101).

52 While Arizona's database does provide original scans of water rights permits, those documents are included in a broader file. The permit documents themselves are not singled out by a search, but must be found manually within a larger set of documents.

53 Documents are available, but require creation of an online account with password, name, and driver's license. Public to an extent, but still require login and registration with the system.

54 Documents made available in Montana include original scanned statements of claim (along with documents filed in support of the statement of claim, such as maps and historical records) and ground water certificates.

55 Nevada's water documents search is not unified. That is, water rights documents other than permits are not in the same search system. Additional documents, including pending applications, and hearing orders (curtailment orders, finding of violation of curtailment, and finding of other violations) are found within separate databases.

56 New Mexico includes some additional documents, such as change of ownership, applications, and permit, and some court orders, but not correspondence.

57 Oregon includes recent applications, application documents, orders, and official correspondence from the state.

58 As a partial list, Washington includes applications and supporting documents for permits.

59 Wyoming has one of the most extensive "other" documents available, including, application documents, maps, and correspondence, but not court documents.

60 Availability or lack thereof of data and functions was determined at the time of our survey in January 2019. Online databases may have changed since.

61 Depending on the state, permits, license, application, or claim are all terms that can be used for analogous documents.

62 Statements of Use are generally available only from 2008 onward.

63 See https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_transfers/ (last accessed February 18, 2020); https://ciwqs.waterboards.ca.gov/ciwqs/ewrims/EwMonthlyReportingServicesServlet?action=waterTransferPetitionSearch&rptId=23

64 Similarly, pending and new water rights applications are stored on a separate webpage and are not complete.

65 For example, in Idaho's system, documents, including correspondence, are added to the system as they are received. We were able to find documents submitted to the database as recently as the same day as our test searches.

66 In eWRIMs, when a change of ownership form is submitted, all the past reports are renamed to the new owner. Thus, it takes specialized research to reconstruct the history of ownership.

67 We analyzed the search functions across states. Some states allowed users to search by particular fields, which would generate a table of results (table). Other had a GIS system, which allowed a user to search for water rights data based on location (GIS). Other states used both a Table and a GIS Output – these were either separate systems, or integrated (that is, a table generated in one system was also viewable in the GIS system and vice-versa).

- Table only: Arizona, Montana, Nebraska, Nevada, New Mexico, Texas, Wyoming
- GIS only: None
- GIS and Table, Separate: British Columbia, California, Colorado, Idaho,
- GIS and Table, Integrated: Oregon, Washington

Search functions here are limited to fields available for search in the first search step, but data may be further sortable once a table is generated. For instance, Colorado's water rights search function does not allow a user to initially search by priority dates, but once a table was generated, the user could sort the results by priority date by selecting "appropriation date" at the top of the generated table.

68 Washington's system provides a helpful example of this functionality. A database user can draw a rectangle or other shape on a GIS map, which quickly generates an interactive table of all water rights in that area.

69 Example PDF available at: bcwatertool.ca/nwwt/pdf/index.php?lat=54.445689581211404&lng=-128.470001220703 12&wfi=8467529&wfname=Unnamed%20Basin&fwa=400-174068-982133&key=8362b_ (last accessed March 17, 2020).

70 Currently, documents are only available to download one by one – it would be more helpful if documents were available for download in batches.

71 The California Water Rights Database allows you to sort by priority once results are generated, but priority is not a preliminary search field.

72 Includes "Associated Individuals" in search, including: Agent, Applicant, Driller, Party of Interest, and Surveyor.

73 Listed as "volumetric limit" or "max decreed rate" in Colorado's Decision Support System (the CDSS).

74 Can search map for permit only with the permit number.

75 Shows locations of points of diversion, places of use, but not the information associated with the water right (i.e., can't get from the GIS Map to any useful data).

76 Generates a report of all water rights above a certain point by clicking on a stream in the GIS mapping application.

77 See note 51.

78 Some examples illustrate basic search functions that are crucial for turning these data resources into useable information. Including priority date as a search function would be a foundational improvement. California's data are searchable by priority date, but only after first generating a search table with a set of water rights. This works for some use cases, but not for other basic ones. Similarly, allowing water rights to be searchable by lessee or other interested parties, as is the case in Wyoming, could reduce transaction costs for effective water markets.

79 *See*, for example, California DWR (2019), Protocols for Assembly Bill 1755, the Open and Transparent Water Data Act. Available at: https://water.ca.gov/Programs/All-Programs/AB-1755 (last accessed December 8, 2020).

80 Cantor et al., 2018, supra note 1; Cantor and Kiparsky, 2020, supra note 38.

81 See note 51.

82 Although not incorporated into eWRIMS (the current California water rights database and GIS mapping tool), this information is available through the CDEC, maintained by DWR. *Available at* https://cdec.water.ca.gov/river/rivcond.html (last accessed February 18, 2020).

83 Streamflow data are found via the CDSS Map View (https://gis.colorado.gov/dnrviewer/Index.html?viewer=mapviewer (last accessed February 18, 2020)) or CDSS datasets (https://www.colorado.gov/cdss/surface-water-all-stations (last accessed February 18, 2020)) and (https://www.dwr.state.co.us/surfacewater/default.aspx (last accessed February 18, 2020))

84 *See* http://dnrc.mt.gov/divisions/water/management/training-education/water-commissioner-information/streamflow-data (last accessed February 18, 2020) and http://data.mbmg.mtech.edu/mapper/mapper.asp?view=Swamp& (last accessed February 18, 2020).

85 *See* http://meas.ose.state.nm.us/ (last accessed February 18, 2020).

86 Tool available at: https://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/ (last accessed February 18, 2020).

87 *See* https://fortress.wa.gov/ecy/eap/flows/regions/state.asp (last accessed February 18, 2020).; https://waecy.maps.arcgis.com/apps/Viewer/index.html?appid=832e254169e640fba6e117780e137e7b (last accessed February 18, 2020).

88 *See* http://seoflow.wyo.gov/Data/Map/Parameter/NoParameter/Interval/Monthly/Calendar/CALENDAR-YEAR/2019/06 (last accessed February 18, 2020).

89 Available through the CDEC. *See* https://cdec.water.ca.gov/river/rivcond.html (last accessed February 18, 2020).

90 *See* http://water.nv.gov/SpringAndStreamFlow.aspx (last accessed April 10, 2020).

91 *See* https://apps.wrd.state.or.us/apps/sw/hydro_report/ (last accessed February 18, 2020).

92 The State of Arizona does not have a state-wide tool for this; however, the Salt River Project (SRP) does maintain a reservoir operations tool for some portions of the state. *See* https://streamflow.watershedconnection.com/Map (last accessed February 18, 2020).

93 Separate from the BC Cariboo Water Tool and maintained by Environment Canada. Available at: https://wateroffice.ec.gc.ca/google_map/google_map_e.html?search_type=province&province=BC (last accessed February 18, 2020).

94 California maintains data on current reservoir storage levels. It also reports scheduled releases from reservoirs. Available through the CDEC. *See* https://cdec.water.ca.gov/reservoir.html (last accessed February 18, 2020).

95 Data available from USBR, but not integrated into state system.

96 *See* https://www.waterdatafortexas.org/reservoirs/statewide (last accessed February 18, 2020). Although a .org website, the maps and data are maintained by the Texas Water Development Board, a state agency.

97 *See* the SRP tool: https://streamflow.watershedconnection.com/Map (last accessed February 18, 2020).

98 *See* https://wateroffice.ec.gc.ca/google_map/google_map_e.html?search_type=province&province=BC (last accessed February 18, 2020).

99 Available through the CDEC. Historic hourly, daily, and monthly reservoir levels and outflow is available. *See* https://cdec.water.ca.gov/reservoir.html (last accessed February 18, 2020).

100 Colorado does not include current storage levels but does include yearly diversions and releases from reservoirs.

101 *See* https://mslservices.mt.gov/geographic_information/maps/watersupply/statewide/StatewideReservoirLevels.aspx (last accessed February 18, 2020).

102 Available through the CDEC. *See* https://cdec.water.ca.gov/snow_rain.html (last accessed February 18, 2020).

103 *See* https://www.texmesonet.org/ (last accessed February 18, 2020). Maintained by the Texas Water Development Board, a state agency.

104 Available through the CDEC. *See* https://cdec.water.ca.gov/snow_rain.html (last accessed March 17, 2020).

105 *See* https://nednr.nebraska.gov/NeRain/ (last accessed February 18, 2020).

106 Hydrology data are available on a map, including precipitation data, here: http://webgis.water.nv.gov/Html5Viewer/Index.html?configBase=http://webgis.water.nv.gov/Geocortex/Essentials/REST/sites/Hydrology/viewers/NV_Hydrology/virtualdirectory/Resources/Config/Default (last accessed February 18, 2020).

107 Basin-wide precipitation averages are available, but not by individual station. *See* https://cdec.water.ca.gov/snow_rain.html (last accessed February 18, 2020).

108 All Arizona snowpack data can be found on the federal USDA SNOTEL network, *available at* https://www.wcc.nrcs.usda.gov/snow/ (last accessed February 26, 2020).

109 Available through the CDEC. *See* https://cdec.water.ca.gov/snow/current/snow/ (last accessed February 18, 2020).

110 State snow data for Wyoming available at http://www.wrds.uwyo.edu/wrds/nrcs/nrcs.html (last accessed February 18, 2020).

111 *See* https://mslservices.mt.gov/geographic_information/maps/watersupply/statewide/StatewideSWE.aspx (last accessed February 18, 2020).

112 *See* https://nednr.nebraska.gov/NeRain/ (last accessed February 18, 2020).

113 *See* http://www.wrds.uwyo.edu/wrds/nrcs/nrcs.html (last accessed February 18, 2020).

114 Groundwater levels are available at: https://gisweb2.azwater.gov/gwsi. Detailed well information, including ownership and imaged document records, available at https://gisweb2.azwater.gov/WellReg (last accessed February 18, 2020).

115 Not available on the California Data Exchange Center (CDEC), but some groundwater level data are available from USGS here: https://waterdata.usgs.gov/ca/nwis/gw/ (last accessed February 18, 2020).

116 Updates include depth reports received. *See* https://dwr.state.co.us/Tools/GroundWater/WaterLevels (last accessed February 18, 2020).

117 Updates include depth reports received; tracked most frequently during the winter recharge season. *See* https://maps.idwr.idaho.gov/agol/GroundwaterLevels/ (last accessed February 18, 2020).

118 *See* https://www.waterdatafortexas.org/groundwater (last accessed February 18, 2020). Owned and maintained by the Texas Water Development Board, a state agency.

119 Groundwater levels are available at: https://gisweb2.azwater.gov/gwsi (last accessed February 18, 2020). Detailed well information, including ownership and imaged document records, can be found at https://gisweb2.azwater.gov/WellReg (last accessed February 18, 2020).

120 Not available from state, but available from USGS groundwater tool: https://nwis.waterdata.usgs.gov/mt/nwis/gwlevels?search_criteria=county_cd&submitted_form=introduction (last accessed February 18, 2020).

121 Groundwater data available at: https://dnr.nebraska.gov/data/groundwater-data (last accessed February 18, 2020).

122 Hydrology data are available on a map, including precipitation data, here: http://webgis.water.nv.gov/Html5Viewer/Index.html?configBase=http://webgis.water.nv.gov/Geocortex/Essentials/REST/sites/Hydrology/viewers/NV_Hydrology/virtualdirectory/Resources/Config/Default (last accessed February 18, 2020).

123 Tool available at https://apps.wrd.state.or.us/apps/gw/gw_info/gw_map/Default.aspx (last accessed February 18, 2020). Select well to view hydrograph.

124 Trends and data from 2016 here: https://waecy.maps.arcgis.com/apps/MapSeries/index.html?appid=dc75a9754ed442c2a2c0ac0098124a27 (last accessed February 18, 2020).

125 Some state data for groundwater levels available here: https://sites.google.com/a/wyo.gov/seo/documents-data/groundwater-hydrographs (last accessed February 18, 2020).

126 *See* https://fortress.wa.gov/ecy/eap/flows/regions/state.asp (last accessed February 18, 2020).

127 Historical water quality data available at CEDEN, maintained by the SWRRCB. *See* https://ceden.waterboards.ca.gov/AdvancedQueryTool (last accessed February 18, 2020).

128 Data available for groundwater quality, but not surface water quality.

129 Historic water quality reports available at http://svc.mt.gov/deq/wmaDST/default.aspx?requestor=DST&type=CWAIC&CycleYear=2016 (last accessed February 18, 2020) and http://svc.mt.gov/deq/wmadst/ (last accessed February 18, 2020). Select "Water Quality Monitoring Sites."

130 Tool available here, though of limited usability: https://nevadawaterquality.ndep.nv.gov/ (last accessed February 18, 2020).

131 The state has mapped water quality stations, but actual water quality data from those stations is not readily searchable. Map of stations can be found here: https://gis.web.env.nm.gov/oem/?map=swqb (last accessed February 18, 2020).

132 Data and tool available at: https://orwater.deq.state.or.us/DataAnalysisDetail.aspx?type=22 (last accessed February 18, 2020). It can generate searchable map with results.

133 Some tools are available for coastal water quality stations but are not available statewide. Data can be found here: https://www.waterdatafortexas.org/coastal (last accessed February 18, 2020).

134 CDEC includes precipitation, river forecast, river stage, reservoir level, snowpack, and weather data. https://cdec.water.ca.gov/index.html (last accessed February 18, 2020).

135 Many details will need to be addressed during full implementation. For example, absent existing quantification of riparian and pre-1914 rights, the state will need a method to assign to them the same sets of data that are present in post-1914 rights, so as to make global analysis possible. Further, as with any change in system and process, there will be a need for business modification analysis and change management to support a staff transition to new business rules and requirements. These and other facts do not detract from the usefulness of even an incomplete implementation of a WRIS.

136 The Cariboo Water Tool is available at https://cariboo.bcwatertool.ca/stream (last accessed February 18, 2020).

137 John Hart, *Storm Over Mono: The Mono Lake Battle and the California Water Future*. University of California Press, 1996 (available at https://johnhart.com/books/storm-over-mono/) (last accessed February 18, 2020).

138 For the scanning protocol, see **Appendix G**.

139 The budget for indexing is $15,000, and the budget appears to be sufficient for this task (which is underway as of this report's date).

140 *See* usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution (last accessed March 17, 2020).

141 See 23 CCR § 879 (now repealed), providing such authority with respect to riparian and pre-1914 rights; https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/informational_orders.html (last accessed October 2, 2020).

142 It could be possible to retrieving at least partial records of pre-1914 rights by seeking records retained by county courts. The quality and completeness of these records is unknown, as are the logistical and resource requirements of such an approach.

143 Cal. Water Code § 275.

144 Cal. Gov. Code, § 6250 et seq.; Stats 1968, Ch. 1473, *available at* https://leginfo.legislature.ca.gov/faces/codes_displayText.xhtml?division=7.&chapter=3.5.&lawCode=GOV&title=1.&article=1 (last accessed February 26, 2020).

145 For example, California's Attorney General has offered this interpretation: "This definition is intended to cover every conceivable kind of record that is involved in the governmental process and will pertain to any new form of record-keeping instrument as it is developed. Only purely personal information unrelated to 'the conduct of the public's business' could be considered exempt from this definition, i.e., the shopping list phoned from home, the letter to a public officer from a friend which is totally void of reference to governmental activities" Assembly Committee on Statewide Information Policy, California Public Records Act of 1968. 53 Ops. Cal. Atty. Gen 136, 140-143 (1970).

146 Cal. Gov. Code, § 6253.4 (b), supra note 145.

147 Cal. Gov. Code, § 6250 et seq.; Stats 1968, Ch. 1473, supra note 145. See also https://www.waterboards.ca.gov/resources/public_records/public_recordsact_guidelines.pdf (last accessed February 18, 2020).

148 For example, the Records Room is a locked facility supervised by SWRCB staff. ID is required for entry, and strict protocols are followed for copying more than a *de mimimus* number of pages. See 3.3.2 Chain of Custody, Section for more details.

149 *See* https://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2018/rs2018_0032.pdf (last accessed February 18, 2020).

150 Any SWRCB notes or internal assessments regarding claims of right could be included in an internal database such as eWRIMS, but would most likely not be included in a public version of the data, per General Code 6254(k).

151 *See* Loukissas Y. (2018) All the Homes: Zillow and the Operational Context of Data. In: Chowdhury G., McLeod J., Gillet V., Willett P. (eds) Transforming Digital Worlds. iConference 2018. Lecture Notes in Computer Science, vol 10766. Springer, Cham. Available at https://link.springer.com/chapter/10.1007/978-3-319-78105-1_31 (last accessed February 18, 2020).

152 *See* California Open Data Handbook, available at https://handbook.data.ca.gov/disclosures/ (last accessed February 18, 2020):

> Under the Public Records Act the presumption is that government records shall be open to the public, unless excludable under a narrow set of specific exemptions including such concerns as invasion of personal privacy, impairment of contractual or collective bargaining negotiations, exposure of protected trade secrets, interference with law enforcement or judicial proceedings, endangering life or safety, and others. Organizations should confer with their PRA officers for advice as to whether data might cause the harms described in the PRA law, and therefore would not constitute "publishable state data" for an open data portal.

153 *See* 23 CCR § 915 (requiring notice of any change in ownership).

154 See, *e.g.*, Mike Young and Bryce McAteer. 2017. Sharing Groundwater - A Robust Framework and Implementation Roadmap for Sustainable Groundwater Management in California. Working Paper NI WP 17-02, available at https://digitalcommons.csumb.edu/hornbeck_research_rel/4 (last accessed September 21, 2020); Sarah Heard. 2019. A case study of the Fox Canyon Groundwater Market. Maven's Notebook, November 20, 2019, available at https://mavensnotebook.com/2019/11/20/groundwater-markets-a-case-study-of-the-fox-canyon-groundwater-market/ (last accessed September 21, 2020):

155 Green Nylen, Nell, Michael Kiparsky, Kelly Archer, Kurt Schnier, and Holly Doremus. 2017. Trading Sustainably: Critical Considerations for Local Groundwater Markets Under the Sustainable Groundwater Management Act. Center for Law, Energy & the Environment, UC Berkeley School of Law, Berkeley, CA. pp. 90, available at https://www.law.berkeley.edu/research/clee/research/wheeler/trading-sustainably/ (last accessed September 21, 2020); Tom Tietenberg & Lynne Lewis, Environmental & Natural Resource Economics (10th ed. 2016).

156 Note that incumbent resistance to change may be rational, but also does not necessarily benefit the broader interests of society. See Hunziker, Travis (2017) Real Estate Agents' Favorability of Zillow's Marking Services, available at https://cache.kzoo.edu/handle/10920/35717 (last accessed February 18, 2020).

157 A fully redacted version would likely be highest cost, since redacting specific fields from scanned records could prove expensive to design, implement, and control for quality, especially since many non-standard documents exist. Even if automating a redaction process were possible it could require human evaluation for accuracy and completeness. Assuming that metadata would be required for agency uses, the assignment costs would remain whether or not these data were made public.

158 Note that such "hidden" PII would still need to be made available if affirmatively requested under the PRA. This would be similar to the current situation – where water rights records contain PII, those data are available to those who specifically seek them out.

159 Examples of costs and benefits, and to whom they would accrue, could include:

- In spite of the lack of specific demonstration of risk from transparency, sensitivity among water rights holders to the potential exposure of PII is understandable.
- Stakeholders in our workshops and focus groups have indicated a perception that the perceived risks of open data may fall primarily on specific individual water rights holders who currently benefit from lack of transparency – the water rights system is currently opaque in crucial ways, which benefits some stakeholders and impacts others. Risks from transparency may include reputational damage and exposure of confidential or proprietary information.
- Conversely, many of the benefits of open data would accrue to the public, to some specific water rights holders, and to non-water rights holders, to the extent that more data enable innovation and efficiency.

- To the extent that water rights could more clearly factored into land values in specific transactions or assessments of land values, transparency could benefit landowners and others who have an interest in accurate valuation of landholdings.

- A fully redacted WRIS described in the third option would be the most expensive - even if automating a redaction process were possible it could require labor-intensive evaluation for accuracy and completeness. Assuming that metadata would be required for agency uses, the assignment costs would remain whether or not these data were made public.

160 We have not documented the degree to which SWRCB resources its records room for these procedures and stewardship tasks, so simply note the importance here. Regardless, to the extent that paper records are inevitably subject to some decay over time, depending on actively accessed paper records for long term foundational water rights information carries some risk.

161 See endnote 151.

162 Statements of Water Diversion and Use are available for some pre-1914s/riparians, if they are required to report. See, *e.g.* https://ciwqs.waterboards.ca.gov/ciwqs/ewrims/EWServlet?Page_From=EWWaterRightSearchResults.jsp&Redirect_Page=EWPublicAppSummary.jsp&Purpose=getEwrimsPublicSummary&wrWaterRightID=53484&applicationID=53284 (last accessed February 18, 2020).

163 We also note a distinction between QA/QC for digitized records that are the primary focus of this report, and the issue of poorly reported data such as water use reports that are purposefully or carelessly inaccurate. These issues are partly addressed in following sections, but also warrant more detailed exploration. Similarly, QC of existing data such as historical scanned records will have different challenges from the ongoing QC for newly generated and submitted records, once the database is populated.

164 Throughout the current system there are many opportunities and incentives to misrepresent data. Even conscientious and well-resourced users may report on a basis supportive of their claims. We have no basis for judgement about the extent to which such misrepresentation may have occurred to date. Therein lies a major justification for a WRIS with robust verification.

165 Water Code §§ 5105, 5106.

166 The ideal staffing for this function would be determined by SWRCB, but options could include staff engineers, scientific aides under supervision of a data scientist with water rights training, or other classifications.

167 Critical elements include: priority date, point of diversion, rate of diversion, annual amount, season, water source, and purpose of use (beneficial use).

168 Any such first approximation is not legally binding. It would have the same status as the corresponding information in eWRIMS today: the information represents staff's understanding and is not legally binding.

169 Ellen Hanak, Brian Gray, Jay Lund, David Mitchell, Caitrin Chappelle, Andrew Fahlund, Katrina Jessoe, Josué Medellín- Azuara, Dean Misczynski, James Nachbaur, Robyn Suddeth. 2014. Paying for Water in California. Public Policy Institute of California. Available at: https://www.ppic.org/publication/paying-for-water-in-california/ (last accessed August 20, 2020).

170 *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/diversion_use/water_use.html (last accessed September 21, 2020).

171 Sen. Bill 88, 2015-2016 Reg. Sess. (Cal. 2015) § 1840 et seq.

172 Open ET is a prime example of a co-produced method for estimating a key physical parameter in the water cycle. Open ET is an external, authenticated, independent, non-biased source of "rebuttable presumption" information on evapotranspiration.

173 For example, our pilot allowed a user to search for the word "dust" in all of the documents surrounding the Mono Lake – and within 1 second, pulled up 634 documents which included "dust."

174 Forms from the Idaho Department of Water Resources are available at: https://idwr.idaho.gov/forms/water-rights.html (last accessed February 18, 2020).

175 New water right transfers available at: https://research.idwr.idaho.gov/apps/waterrights/querynewtransfers (last accessed February 18, 2020).

176 Cite to AB 1755 website, progress report, strategic plan docs; Cantor et al. 2018, supra note 1.

177 The Washington Water Rights Map can be accessed at: https://fortress.wa.gov/ecy/waterrighttrackingsystem/WaterRights/Map/WaterResourcesExplorer.aspx (last accessed February 18, 2020).

178 While we leave an exhaustive discussion of the potential uses of GIS-enabled water rights records for another report, we note that there are many. For example, connecting Point of Diversion with Point of Use would be another useful GIS feature, as would connecting water rights information with data identifying fully appropriated streams (see, *e.g.*, Note 223).

179 The Oregon Water Rights Mapping Tool is available at: https://apps.wrd.state.or.us/apps/gis/wr/Default.aspx# (last accessed February 18, 2020). The relevant command is Search: Water Right by River Mile.

180 As noted in the **California water rights**, California's dual system of appropriative and riparian rights presents particular challenges for allocation, which we do not address in depth in this report.

181 From the Decision Support System menu, a user can search existing water rights by selecting "Water Rights: Net Amounts."

182 See also Kathleen Miller, Nell Green Nylen, Holly Doremus, Andrew Fisher, Graham Fogg, Dave Owen, Samuel Sandoval Solis, Joshua Viers, and Michael Kiparsky. 2018. California's Streamflow Monitoring Is Essential for Water Decision Making. Center for Law, Energy & the Environment. Available at https://www.law.berkeley.edu/research/clee/research/wheeler/stream-monitoring/ (last accessed September 21, 2020).

183 *See* endnote 22.

184 The Nebraska Interactive Streamgage Map is available at https://nednr.nebraska.gov/RealTime/ (last accessed February 18, 2020).

185 Colorado's streamgage information is accessible through the Decision Support System map, available at https://gis.colorado.gov/dnrviewer/Index.html?viewer=mapviewer (last accessed February 18, 2020).

186 From its Decision Support System map, a system user can select "Surface Water Current Conditions," which maps all active gages in the state. From there, a user can select a particular gage and click on "view additional details." From there, the system user can select a link which will take the user to a chart showing discharge at the gage in cubic feet per second (cfs), along with historic average.

187 Montana's stream gage data are available at: http://data.mbmg.mtech.edu/mapper/mapper.asp?view=Swamp& (last accessed February 18, 2020).

188 Data can be viewed for the last seven days, last thirty days, for a selected period of time, or the entire period of record.

189 British Columbia's water rights platform for the Cariboo region and associated stream gage information is available at: https://cariboo.bcwatertool.ca/stream (last accessed February 18, 2020).

190 See Cantor et al. 2018, supra note 1.

191 Green Nylen, Nell, Michael Kiparsky, Dave Owen, Holly Doremus, Michael Hanemann. (University of California, Berkeley). 2018. Addressing Institutional Vulnerabilities in California's Drought Water Allocation, Part 1: Water Rights Administration and Oversight During Major Statewide Droughts, 1976–2016. California's Fourth Climate Change Assessment, California Natural Resources Agency. Publication number: CCCA4-CN-RA-2018-009. 193 pp. Available at: https://www.energy.ca.gov/sites/default/files/2019-12/Water_CCCA4-CN-RA-2018-009_ada.pdf (last accessed September 21, 2020) or https://www.law.berkeley.edu/research/clee/research/wheeler/drought-water-allocation/ (last accessed September 21, 2020).

192 Supra note 137 and Sidebar in section .

193 The Snowpack Assessment Tool is available at: https://gis.colorado.gov/dnrviewer/Index.html?viewer=cwcbsnodas (last accessed February 18, 2020).

194 Water Data for Texas can be viewed at: https://www.waterdatafortexas.org/reservoirs/statewide (last accessed February 18, 2020).

195 TexMesonet can be accessed at: https://www.texmesonet.org (last accessed February 18, 2020).

196 Note that this pilot does not consider ADA accessibility, which would also be an important component of a state-sponsored WRIS.

197 *See* https://research.idwr.idaho.gov/apps/waterrights/querynewtransfers (last accessed February 18, 2020).

198 Federal Energy Regulatory Commission is an example. Its online system links filing, service, and docket, by hydropower license or other proceeding. *See* https://www.ferc.gov/docs-filing/ferconline.asp (last accessed September 21, 2020).

199 23 CCR §§ 904 *et seq., see* https://www.waterboards.ca.gov/waterrights/water_issues/programs/measurement_regulation/docs/measure_reg_oal_approve.pdf (last accessed September 21, 2020).

200 *2020 Water Resilience Portfolio* supra note 14.

201 Newsom, Citizenville, 2014, supra note 2; Cantor and Kiparsky, 2020, supra note 38.

202 See https://www.govtech.com/computing/California-CIO-Amy-Tong-Tech-Efforts-Are-Yielding-Returns.html (last accessed September 21, 2020).

203 See RFI2 Information for background on a flexible approach to state technology procurement (https://www.govtech.com/computing/California-CIO-Amy-Tong-Tech-Efforts-Are-Yielding-Returns.html)

204 *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/russian_river/rr_fact_sheet.pdf (last accessed September 21, 2020); *see also https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/rrtribs_faq.html* (last accessed September 21, 2020). Other previous information orders issued by SWRCB include a 2014 Information Order to 1,061 statement holders in the Sacramento and San Joaquin River watersheds, which requested information from riparians and pre-1914 water rights holders after allegations of illegal water diversions. *See https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/2015sacsjinfoorder.pdf* (last accessed September 21, 2020). For additional information and documentation about the 2014 order, *see also* https://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/informational_orders.html

205 *See* https://www.waterboards.ca.gov/waterrights/water_issues/programs/diversion_use/water_use.html (last accessed Aug 5, 2020)

206 For broader discussion, see Cantor and Kiparsky, 2020, supra note 38.

207 This may be a more challenging effort than appears on its face. Old water rights documentation sometimes includes arcane measurements such as a "miner's inch", which needs to be translated into a more modern standard but still remains as the term used in a binding contract. However, generating a controlled vocabulary and tools to make water data intercomparable has been attempted and is possible. See, for example, http://wamdam.org/ (last accessed July 29, 2020).

208 Generally, timing refers to the specific months the water right may be exercised if water is available, although this varies (some water rights may list a season or more specific dates).

209 This is frequently referred to in the legal community as "beneficial use."

210 Diversion data can be reported at different granularities, including hourly, daily, weekly, or monthly.

211 *See* Endnote **13**.

212 For our pilot in the Mono Basin, we estimate that > 99% of the paper records which the State Water Board holds in its Records Room are not available in eWRIMS. The unavailable records include the exhibits, transcripts, and related hearing records associated with Decision 1631 (1994), as well as subsequent compliance orders.

213 For more information on AB 1755, *see* Cantor et al. 2018, supra note **1**.

214 *See* bcwatertool.ca/nwwt/pdf/index.php?lat=54.445689581211404&lng=-128.47000122070312&wfi=8467529&wfname=Unnamed%20Basin&fwa=400-174068-982133&key=8362b (last accessed March 13, 2020).

215 *See* usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution (last accessed March 13, 2020).

216 A SWRCB Points of Diversion geodatabase has already tied each POD in California to a "reach code" in the National Hydrography Database maintained by the US Geological Survey. Over 98% of PODs in the statewide SWRCB database have already had a reach code assigned, so extending this feature to a statewide application of a WRIS would take minimal additional effort.

217 *See* usgs.gov/core-science-systems/ngp/national-hydrography/value-added-attributes-vaas#HYDROSEQ (last accessed March 13, 2020).

218 While water rights may provide information, it's important to note that the information listed here may not be inclusive all of the information needed to make the decision.

219 **For instance, a water right with a beneficial use of "environment" = that water is available downstream; Water right with beneficial use of "irrigation" = most water will be consumed by crops and won't be available downstream.**

220 If water was not available for use in a particular year, a user's non-use will not be counted against them for that year.

221 See the Fully Appropriated Stream Systems tool for more details. Available at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/ (last accessed September 4, 2020).

222 Although beneficial use records may help to determine return flows of the stream.

223 See the Fully Appropriated Stream Systems tool for more details. Available at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/ (last accessed September 4, 2020).

224 Although beneficial use records may help to determine return flows of the stream.

225 Face amounts can be reported in various units (i.e., acre-feet per year or cubic feet per second).

226 For example, SWRCB requires the Bureau of Reclamation to operate Keswick and Shasta Dams, as well as the Spring Creek power plant to meet temperature requirements downstream on the Sacramento River. *See* https://norcalwater.org/wp-content/uploads/2012/01/remanaged-flows-nov2014.pdf (last accessed February 18, 2020), pp. 1-2.

227 The vendor was Smooth Solutions, based in Lodi, New Jersey.

228 A range of questions will require decisions from SWRCB, including:

- When data are required should we control data quality? If data are voluntary, shouldn't we lower the bar for data entry?
- Should we make elements of data entry easier?
- When should data be collected by end users and when should they be the responsibility of WB/agencies?
- Which agencies can we look to for data quality estimations? USGS vs. CDEC… perhaps falls into the metadata conversation.
- Incorporation of AI into the data review. If flows/diversion are wildly different from normal/statistical/reasonable flag for human review
- How far back should we go back to search for data errors? Cost/benefit of data errors catches
- How do we use changing status of sibling agencies data such as USGS provisional data flipping to finalized? Do we go back and download everything or just compare and update individual values?

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