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CIVIC LEDGER

Improving Water Markets and Trading through New Digital Technologies

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Mareeba-Dimbulah Water Supply Scheme

Pilot Research Project

CRCNA
DEVELOPING NORTHERN AUSTRALIA

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The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2018),

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ACRONYMS, DEFINITIONS AND TERMS

Account Number	Unique account identity number assigned to a **Customer** by **ROL Holder**
API	Application Programming Interface
ASEAN	Association of Southeast Asian Nations
ASX	Australian Securities Exchange
ACCC	Australian Consumer and Competition Commission
Baseline Program	A baseline schedule for the Pilot Project
Blockchain Technology	An open, distributed ledger that can record transactions between two parties efficiently (peer-to-peer) in a verifiable (time-stamped) and permanent way (immutable)
BRII	Business Research and Innovation Initiative
Civic Ledger	A multi-award winning young Australian technology company with domain expertise in blockchain technology and smart contracts to help governments and industries prepare for the digital economy
CRCNA	Cooperative Research Centre for Developing Northern Australia
CRC Research Agreement	Agreement between CRCNA and Civic Ledger for delivery of the Pilot Project
CRC WiNA	Cooperative Research Centre for Water in Northern Australia
Customer	An identity holding a water **Account Number**
Customer ID	A customer to ROL Holder for purchase of water at MDWSS
DLT	Distributed Ledger Technology founded on a blockchain protocol
Ethereum	An **open source**, **public**, **blockchain-based distributed computing platform** and operating system featuring smart contract (scripting) functionality
ERC	Ethereum Request for Comments
ERC1753	Civic Ledger's Ethereum standard for the issuance of licences, permits and grants
EVM	Ethereum Virtual Machine
FNQ Growers	Far North Queensland Growers
Incentive Mechanism	Something that motivates a buyer or seller to follow a course of action or to change behaviour
Institutional infrastructure	Denotes all the governance and organisational structures that lower the cost of trade and expand the scope for exchange
IoT	Internet of Things
Licence	An identifier allocated to a User in compliance with ERC1753
Market Governance	The range of institutions, rules and processes through which decisions concerning water trade arrangements are made and implemented, and water markets are regulated
MDWSS	Mareeba-Dimbulah Water Supply Scheme
MDWSS Water Ledger	**Water Ledger** trading platform adapted to business and operating rules at **MDWSS**
MVP	Minimal Viable Product
NWI	National Water Initiative
Orion	Information system owned and operated by SunWater for the management of MDWSS trading
Offtake	A unique location at which water is drawn by the holder of a **Water Account**
Participant	A party to a Participant Declaration Agreement with CRCNA
PEP	Project Execution Plan
PRG	Project Review Group

Pilot Project	Improving Water Markets and Trading through New Digital Technologies
Principal	CRCNA
QDNRME	Queensland Department of Natural Resources, Mines and Energy
RDA for Tropical North	Regional Development Authority for Tropical North
RegTech	Regulatory Technology that enables regulatory requirements to be met more effectively and/or efficiently to support compliance
Research Provider	Civic Ledger
Resource Operations Licence	Mareeba–Dimbulah Water Supply Scheme Resource Operations Licence
RMIT	Royal Melbourne Institute of Technology Blockchain Innovation Hub
ROL Holder	SunWater Limited
RaC	Rules as Code
Scheme Operator	SunWater Limited
Smart contracts	Self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code
Stakeholder	A party with interest and / or participation in the Pilot Project
SunWater	SunWater Ltd ABN 131 034 985
Temporary Water Allocation	A **Water Allocation** with a short term
Transaction	The sale of a Temporary Water Allocation from a Water Account Number to another Water Account Number
User	An irrigator at MDWSS who buys or sells Temporary Water Allocation on MDWSS Water Ledger
Water Account	An account for water supply with **SunWater** within a **Customer Account** which is identified by a unique number and is assigned to an **Offtake**
Water Allocation	An entitlement to a share of the available water resource in a catchment and an authority to take the water on a permanent basis
WIS	Water Information System owned and operated by QDRNME
Water Ledger	A blockchain distributed ledger platform developed by Civic Ledger for water markets operation and associated activities
Water Plan	Water Plan (Barron) 2002
Water Right	A right pertaining to ownership and / or use of water that may be on or under the land
Zone	Any of zones A, B, C, D or E in MDWSS
Zone Transfer	A transfer of a Water Allocation from one Zone to another Zone

PROJECT PARTICIPANTS

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EXECUTIVE SUMMARY

The Cooperative Research Centre (CRC) for Developing northern Australia (CRCNA) have identified[1] that a key barrier for securing the Association of Southeast Asian Nations (ASEAN) agricultural opportunity in northern Australia is adequate assurance to potential investors with ready access to water markets and governance instruments that will help facilitate transparent water trading and ongoing water security.

Therefore, CRCNA partnered with Civic Ledger[2] to deliver a research project: ***Improving Water Markets and Trading through New Digital Technologies*** (Pilot Project)[3]. The pilot project contributes to the CRCNA strategic intent:

- To develop new technologies, products, and services to de-risk investment in new, emerging, and established industries by identifying barriers and providing solutions in northern Australia.

The Pilot Project was focussed on the Mareeba-Dimbulah Water Supply Scheme (MDWSS) on the Atherton Tablelands in Far North Queensland, Australia. In the MDWSS over 1,000 water users grow a large diversity of horticulture crops including sugar cane, mangoes, bananas, pawpaw, citrus, avocados, and coffee using over 200GL of issued water entitlements per annum from SunWater (Resource Operations Licence holder).

The Pilot Project was conducted from early 2020 to the end of August 2020 and delivered with participants from Far North Queensland (FNQ) Growers, Queensland Department of Natural Resources, Mines and Energy (QDNRME), our research partners Griffith University and Royal Melbourne Institute of Technology (RMIT) Blockchain Innovation Hub with SunWater as a key stakeholder.

A key element of the Pilot Project was the deployment of Civic Ledger's blockchain enabled peer-to-peer water market and trading platform – Water Ledger – built on the Ethereum blockchain and utilises Civic Ledger's ERC1753: smart contract Interface for Licences standard to handle the issuance of water licences and permits[4]. The Water Ledger trading platform was adapted to the MDWSS business and operating rules to observe how blockchain technology can reduce trading costs, improve the efficiency of trade processes, and increase water market transparency.

Part I: Options for Reducing Trading Costs

Water markets have emerged as a preferred option in Australia for sharing scarce water resources between competing uses and users, meeting both policy objectives, and delivering individual flexibility and benefit. In Australia, the enabling regulations for water trade were introduced in 1994, with the explicit goal of recognising the true value of water and helping it flow towards its highest value use. Despite a greater use of markets for water there continues to be misunderstandings about how they operate[5].

Current mechanisms for trading water are highly complicated which has led to a breakdown of trust between parties, concern over market manipulation and speculation, and market distortions such as information asymmetry, opacity, and high transaction costs[6]. These misunderstandings have given rise to a plethora of research studies and market reviews[7][8], with a significant emerging focus on the potential for digital transformation in water markets.

> The Pilot Project considered the role of institutional infrastructure of water markets and how they may be improved through next generation digital technologies. Institutional infrastructure includes all the governance and organisational structures that lower the cost of trade and expand the scope for exchange including deep and liquid markets, effective information supply chain tracking technologies, and low-cost dispute resolution and court systems.

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[1] CRCNA et al, Northern Australia agriculture investor identification and analysis report, March 2020 Northern Australia agriculture investor identification and analysis report | CRCNA
[2] https://civicledger.com/
[3] https://www.crcna.com.au/research/projects/improving-water-markets-and-trading-through-new-digital-technologies
[4] http://erc1753.org/
[5] Australian Competition and Consumer Commission (ACCC), Inquiry into Murray-Darling basis water markets: interim report (30 June 2020) https://www.accc.gov.au/system/files/Murray-Darling%20Basin%20inquiry%20-%20interim%20report.pdf
[5] Australian Government, Productivity Commission, National Water Reform: Issues Paper, 26 May 2020. https://www.pc.gov.au/inquiries/current/water-reform-2020/issues/water-2020-issues.pdf
[6] Australian Competition and Consumer Commission (ACCC), Inquiry into Murray-Darling basis water markets: interim report (30 June 2020) https://www.accc.gov.au/system/files/Murray-Darling%20Basin%20inquiry%20-%20interim%20report.pdf
[7] *Ibid.*
[8] Australian Government, Productivity Commission, National Water Reform: Issues Paper, 26 May 2020. https://www.pc.gov.au/inquiries/current/water-reform-2020/issues/water-2020-issues.pdf

This focus on institutional infrastructure is important because when someone wants to *buy* a water right or allocation, the Regulator or Operator need to surface as much information as possible from the water market to influence its decision whether to approve a water trade or not.

Box 1: Institutional Infrastructure

An essential component of water markets is a trusted source of who owns what water rights at a given time, and updates over time as water rights are traded. Today these data elements are invariably maintained in a centralised hierarchical way through various schemes including public and private owned exchanges and information systems. Furthermore, Australian water markets are highly regulated with many trading and business rules built on a fragmented set of ledgers that are often opaque and inhibited by inconsistent transaction costs and fees. This situation tends to discourage trade and reduces market liquidity.

By comparison, the Pilot Project suggests that a blockchain enabled water market is likely to address some of the underlying challenges of designing water market governance frameworks. Blockchain can:

Secure water registries by holding an immutable record of sensitive data of entitlements, transactions, and trade behaviour associated with water market and trading activities.

Establish peer-to-peer markets for the trading of temporary water allocations and permanent water entitlements that can be integrated with existing systems of record.

Provide curated water supply chain information that provides assurance through smart contracts that automate (to the greatest degree possible) trade activity which are enforceable to jurisdictional business and operating rules including licensing regimes in real time.

Deliver instantaneous compliance, auditing and reporting of core activities removing data silos, paper-based transactions, and human errors lowering costs of validation and verification of water trades.

Box 2: Blockchain for Designing Water Market Governance

Feedback from Pilot Project stakeholders reinforce the importance of these blockchain characteristics, with expectations that the typical time to conclude a water trade can be reduced from the current 60-90 days to less than a week. Furthermore, stakeholders also noted that these timeframes could be reduced even further through automation of regulatory approvals e.g., hydrology considerations, and potentially simplified as regulation develops to capture the benefits of blockchain directly.

This highlights the potential for blockchain to reshape the role of government as new water markets are being planned for northern Australia. If water markets are designed from the bottom-up, rather than as an add-on or an after-the-fact adjustment, it positions governments as ***providers*** of secure public water market and trading data and orchestrate interoperable information system digital institutional infrastructure that can be reused by others – individuals, the private sector (brokers and exchanges) and government itself – with confidence.

Part II: Opportunities for Real Time Price Discoverability

For water markets to operate efficiently and provide equitable opportunity to participate, market participants need ***access to reliable and transparent market information*** – in real time. Stakeholder feedback highlights that the most important water information includes ***authority***, ***ownership***, ***price***, ***market volume***, and ***trade history***.

The primary source of price discoverability was identified as SunWater – the Resource Operations Licence (ROL) holder. Historical MDWSS water trading data (January 2019 to December 2019) was sourced from SunWater's Orion information system for two purposes. First, to assess recorded data relating to the MDWSS water market; and second, upload the historical data into the Water Ledger trading platform. The data analysis found that the SunWater Orion information system did not capture the buy or sell price from 315 approved water trades (85% water trades between different accounts and 15% "zero-value" water transfers between common water accounts).

Given that the MDWSS water markets did not have water price information available, it was important to find out how irrigators discover at what price to buy or sell. The Pilot Project conducted a workshop with representatives from the FNQ Growers to learn how irrigators currently access the MDWSS water market. During this workshop key community personages were identified as a key source of price information and knowledge. For example, Joe Moro, a mango farmer in Mareeba, shared with the workshop that farmers call him because of his knowledge of MDWSS water markets and ask what price they should be buying or selling water. The Pilot Project would learn through ***feedback from MDWSS irrigators*** that the water price ranged from about AU$70 per ML to approximately AU$200 per ML. The irrigators explained there was an apparent low level of participation in the temporary water allocation markets because of the perception that MDWSS water prices may be subject to manipulation.

Central to the operation of the MDWSS water market are the business and operating rules, which were sourced through public documents including legislation and MDWSS rules. In sourcing and coding these business rules into smart contracts it became necessary to engage with both the Regulator and Operator to secure consensus on a ***common standard*** of terms and definitions particularly on what constituted a customer identity.

The Pilot Project utilised four smart contracts:

Order Book – The Order Book is the primary listing of unmatched orders. It is the smart contract that implements the rules around what is a valid trade. In the current model of orders are listed, whether as a buy or sell order, and the order is then accepted by another licence holder.

Zones – The zones' smart contract stores water account balances for each licence, and the details (such as minimum and maximum balances) of each zone. The zones' smart contract enforces two key rules. One is the storage of the balances of individual water accounts in each zone. The other is the balance of the zone itself - the total hydrological capacity of the catchment. This rule comes with minimum and maximum capacities which may not be overrun by any trade.

History – The History smart contract stores a list of trades which consist of accepted orders as they are created. These trades will automatically appear in the order book under the buy and sell orders, or on a separate webpage dedicated to the fuller trade history.

Licences – The Licence smart contract stores licence and water account details to ensure the Ethereum address has valid access to the Water Ledger trading platform. This smart contract implements the ERC1753 standard for licences.

Stakeholder engagement in the Pilot Project was focussed on understanding whether the application of blockchain technology would significantly change the way the MDWSS water market could operate; and if so, to what cost or benefit. Feedback reinforces that a blockchain enabled platform for the trading of water rights solved three immediate problems to vastly improve the operation of the MDWSS water market:

1. Real time availability of water supply chain information,
2. Reduced barriers to trade, and
3. Market incentivisation through transparency.

Authorisation was solved by SunWater providing all the data to set up water accounts in Water Ledger.
Ownership was solved by SunWater providing all the water account data with each water account having an owner ID number.
Water price was solved by the smart contract capturing this data going forward – historical pricing data was gathered from engagement with the MDWSS irrigators.
Water market volume was solved by the smart contract capturing volume data going forward – for the Pilot Project, SunWater provided historical volume data.
Trade history was solved by the smart contract capturing trade history data going forward – for the Pilot Project, SunWater provided historical trade data.

Box 3: Solving the Problem of Missing Supply Chain Information

Part III: Interoperability Beyond Water Trading

The Pilot Project revealed that, whilst the blockchain enabled water market could embed regulatory technology and programmable code into the platform to deliver an efficient and effective water market, it could not determine water account balances in real time nor could the smart contracts code the hydrological conditions necessary to approve a water trade. Hence, it was necessary to adapt the Water Ledger trading platform to automatically notify SunWater of a pending trade ready for manual assessment and approval.

To gain the full benefit of blockchain and smart contracts, the Pilot Project experience suggests a need for interoperability between the water delivery infrastructure and the operation of the water market. Such interoperability would allow automated evaluation of whether the point of sale and point of purchase are hydrologically connected and whether adequate delivery capacity is available to satisfy the trade. Furthermore, stakeholder feedback also suggests that availability of delivery capacity could be expected to influence market price – prices may be expected to increase to reflect scarce delivery capacity.

Conclusions and further research

The Pilot Project has allowed a thorough examination of the potential of blockchain and smart contract technology to address three fundamental challenges for effective and efficient water markets:

- Reduce transaction costs,
- Real-time price discoverability, and
- Interoperability.

The Pilot Project demonstrated that these next generation technologies offer significant opportunity to reduce transaction costs by reducing trading time from the current 60-90 days to less than a week. A significant element of this time reduction is public visibility of buy and sell offers, and automated approvals via smart contracts. However, as regulation develops to capture the benefits of blockchain directly there is potential for near real time approvals of water trades.

Current MDWSS water market systems do not adequately capture price, either because of zero-value trades or no price information being recorded. In these circumstances water users must resort to a word-of-mouth system to determine market price. The Pilot Project demonstrated that blockchain applications can be designed in such a way as to publicly surface depersonalised information on market price, through open presentation of all buy and sell orders and historical trade patterns and price.

Finally, the Pilot Project has been able to illustrate that it is relatively easy to capture the current business rules of the MDWSS water market, however, there remain challenges of encoding these into a series of smart contracts that can automate trade approvals. It was found that a critical missing element is the interoperability between the water market and the water delivery infrastructure. Furthermore, there is clear scope for the regulatory regime to develop and modify in ways that fully capture the potential of blockchain and smart contract technology. Of note is the potential to deploy ***Rules as Code*** semantic technologies and domain model-based regulation to promote public sector innovation within the water sector.[9]

Therefore, based on the findings of the Pilot Project we have identified three horizons for future work:

1. **Horizon One**: Extending a blockchain enabled water market to all twenty-three Water Supply Schemes operated by SunWater,
2. **Horizon Two**: Interoperating a blockchain enabled water market with irrigation infrastructure design and delivery referring to the Lakelands Irrigation Scheme as an example, and
3. **Horizon Three**: Key considerations when designing a blockchain enabled water market for the emerging northern Australia water markets.

	Theme	Pathways
HORIZON ONE	Interoperability with SunWater Orion Information System	Continue the development of Water Ledger in MDWSS to fully interoperate with SunWater Orion information system.
		In partnerships with SunWater rollout Water Ledger to all remaining SunWater Water Supply Schemes with a focus on northern Australia in the first instance - early discussions with Water Start, a non-for-profit that connects water technology companies that have cutting edge solutions to utilities and large water consumers, have indicated an interest in co-funding the rollout of Water Ledger.
		Engage with QDRNME and SunWater key officers to deliver a series of workshops to uplift knowledge of next generation digital technologies.

[9] James Mohun and Alex Roberts, 2020, Cracking the Code: Rule Making for Humans and Machines, OECD, October 2020, pp. 10.

	Theme	Pathways
HORIZON TWO	**Engagement with Key Irrigation Infrastructure Projects**	Engage with RDA for Tropical North to discuss options for conducting work with the National Water Grid Authority.
		Facilitate consultations with Working Committees which have oversight on current and emerging irrigation infrastructure projects with a focus on northern Australia in the first instance e.g., Lakelands, Bradfield, and Big Rocks Weir, to introduce Water Ledger and why planning for digital infrastructure to support an efficient and effective water market is to be undertaken in parallel with the engineering aspects of the irrigation infrastructure planning.
		Deliver a series of workshops to uplift knowledge of next generation digital technologies to support the design and delivery of new water markets in northern Australia.
HORIZON THREE	**Water Markets in Northern Australia**	Undertake a literature review of the sixteen feasibility studies and three water resource assessments funded through the White Paper to support the design and delivery of a blockchain enabled water market.
		Seek co-funding under the CRCNA EOI Round in early 2021 with partners including but not limited to the CSIRO, the Bureau of Meteorology, James Cook University, the University of New South Wales Global Water Institute, Griffith University and RMIT.
OTHER ACTIONS	**ACCC Inquiry into Murray-Darling Basin Water Markets**	Civic Ledger to make a submission based on the findings from this Pilot Project to the ACCC Interim Report: Inquiry into the Murray Darling Basin Authority due 31 October 2020. The ACCC Final Report is expected to be available to the public at the end of April 2021.

Table 1: Three Horizons

Key priority actions for sector development	Action owner and key partners	Pathways to implementation and timeline	Intended industry impacts
1. Water Ledger Interoperability with SunWater Orion information System	Owner: Civic Ledger Key partners: • SunWater • QDNRME • Water Start • FNQ Growers	• Establish full MDWSS Water Ledger Interoperability with SunWater Orion MDWSS system, • Water ledger platform development for wider northern Australia, and • Civic Ledger / QDNRME / SunWater program of workshops for *Rule of Code* shifting to computer reading of business and operating rules. Timeline: 0 – 12 months Commencement: Immediate future	• Establishment of integrated northern Australia water markets platform model with in built regulatory integrity, • Increased visibility of and access to reliable northern Australia water markets data, • De-risking access to critical supply chain production resource, and • Unlocking investment in northern Australia.
2. Civic Ledger Engagement with key northern Australia Irrigation Infrastructure Projects	Owner: Civic Ledger Key partners: • North Queensland Water Infrastructure Authority • RDA for Tropical North • QFF • Big Rocks Weir • Hells Gate Dam • Bradfield • Hughenden Irrigation Scheme • Lakeland Irrigation Area	• Consultations with emerging irrigation infrastructure projects for digital infrastructure planning in parallel with engineering, • Civic Ledger and Griffith University research interoperability, IoT, digital twinning to support further development of Water Ledger, • Engagement with RDA for Tropical North re options for working with National Water Grid Authority, and • Workshops to uplift knowledge re: next generation digital technologies to support delivery of new water markets in northern Australia. Timeline: 0 to 36 months Commencement: November 2020	• Optimisation of water infrastructure design with digital technology infrastructure, • Extended interoperability of Water Ledger markets with water scheme operations, • Optimisation of Water Ledger interoperability with water industry participants, • Establishment of northern Australia water markets • Increased investment in northern Australia through market certainty, and • Water allocation to highest value production through markets liquidity.
3. Water Markets in northern Australia	Owner: Civic Ledger Key partners: • CRCNA • CSIRO • BoM • JCU • UNSWGWI • Griffith University • RMIT	• Literature review of sixteen feasibility studies and three water resources assessments funded White Paper to support design/delivery of blockchain enabled water market in northern Australia, • Seek co-funding CRCNA round early 2021 with CSIRO, BoM, JCU, UNSWGWI, Griffith University, RMIT, and Timeline: 2021 – 2022 financial year Commencement: July 2021	• Design of institutional governance and regulatory framework for water markets, and • Establishment of northern Australia blockchain enabled water markets.

Table 2: Strategic Recommendations

1. INTRODUCTION

Water is vital to our wellbeing and prosperity, individually and collectively. In times of plenty we give it little thought, while in times of scarcity we recognise its true value, at least momentarily. With advancing climate change impacting water availability, coupled with growing demand there are many headlines all over the world talking of actual and impending water crises.

When water is in the spotlight there is invariably a flurry of activity, a wealth of science and commentary, announcements of initiatives and investments all aimed at addressing the current or future imbalance between supply and demand[10]. This sounds deceptively easy and organised, while we all appreciate a more complex reality of the politics of water, fragmented effort, competition over ideas, and a debate all too often focussed around 'silver bullets' – in many ways Mark Twain's famous quotation "*Whisky is for drinking. Water is for fighting over.*" never held truer.

A key challenge for water markets is the fact that water is an 'uncooperative' commodity whereby its value is derived not only from its quantity, but also its quality, reliability, timing, location, and use[11]. Trade can, and often does, change who, where and how water is used, which can affect subsequent extraction by downstream parties or future use of aquifers. Thus, changes in the location, timing, and technical efficiency of water-use ***matter***.

These uncooperative dimensions of water reinforce that water markets and trade arrangements have developed as '***add-ons'*** to existing water resource management frameworks. As seen in the Murray-Darling basin water markets, the system has been built for water management, but not for efficient water trading. This dimension is further compounded by the fact that water markets in Australia are a relatively new policy approach that has evolved over the past twenty years, while water resources management laws and policies have developed incrementally over a period of a hundred years.

- Water markets are ***a crucial tool*** to achieve sustainable water demand through the voluntary allocation and reallocation of resources between competitive users and uses.
- Water markets ***have evolved*** over the last twenty years as an ***add-on*** to wider water resources management laws and policies.
- There is a ***wide variety of products*** that are tradeable on water markets.
- There is a ***high level of fragmentation*** in water markets, with different jurisdictions developing different rules.
- Data and information systems to support water markets including the water register are ***invariably fragmented, inaccessible***, and ***opaque***.

Box 4: Australian Water Market Characteristics

Drivers for change

Transparent information

One significant driver for change is increasing competition for water, exacerbated by scarcity. This correlation between high water stress and high transparency may sound counterintuitive, but there is evidence that civil society in water-stressed areas is more active and demanding of information, thus forcing government to be more transparent. Further, as water tends to be high on the political agenda in water stressed regions, governments can readily show its commitment to address water-related issues to its constituency. That said, in any call for transparency there is also a need to respect privacy and confidentiality.

Murray-Darling Basin water markets

In the recent ACCC's Interim Report into Murray-Darling basin water markets, it is their view that the current governance of the Basin and the regulatory frameworks for water trading do not meet the standards for a fair and efficient water market, underpinned by an environmentally healthy river system[12]. There are significant deficiencies associated with the settings and governance of water trading, which undermines the efficiency of water markets and their dependent industries.

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[10] https://en.wikipedia.org/wiki/Commodification_of_water
[11] Bakker, K (2004). *uncooperative commodity: Privatising water in England and Wales*. Oxford, U.K: Oxford University Press.
[12] ACCC, Murray-Darling basin water market: Interim report, June 2020, pp. 26-28.

Many of the water market issues outlined in the Interim Report are partly due to issues with the existing governance framework[13]. Governance can be both the source of the problem or can impede the effective and timely resolution of problems. Market governance refers to the range of institutions, rules and processes through which decisions concerning water trade arrangements are made and implemented, and water markets are regulated. In the ACCC's view, digital technologies offer the opportunity to make more substantial improvements, and at the same time enable increased market oversight to improve the integrity of Basin water markets[14].

Emerging northern Australia water markets

According to the Australian Government's: *Our North, Our Future: White Paper for Developing Northern Australia*, the north will never reach its potential without secure, tradeable titles to land and water[15]. Water related initiatives to support the emerging economic benefits to be unlocked in northern Australia include[16]:

National Water Grid Authority	Water Related Initiatives
$200 million to build water infrastructure in the north and tied to developing secure and tradeable water rights as part of the National Water Grid Authority	$15 million to determine available water and best locations for water infrastructure in the Mitchell River catchment (Queensland), West Kimberley (Western Australia) and the Darwin region (Northern Territory).
	Up to $5 million each for detailed examinations of the economic feasibility of Nullinga Dam (Queensland) and Ord Stage 3 development (Western Australia / Northern Territory).

Table 3: National Water Grid Authority Water Related Initiatives

Given the water market governance related challenges in the Murray-Darling basin water markets, how does the Australian Government avoid today's challenges of the Basin water market and design efficient and effective water markets that are guided by governance principles of interoperability, consensus, privacy, and security? More so, how can next generation digital technologies design market mechanisms to increase transparency, reduce costs and regulation burden, improve speediness, and lower barriers to entry?

Digital transformation

Another driver is the expectations of today's digital citizens because of exposure to highly efficient and engaging consumer products to deliver services and process transactions. Consumers have a growing demand to reduce transactional costs, improve response times, and build confidence in the data and trust in the transaction. Equally, governments are seeking reduction of costs, increased transparency, and improving the customer experience. New digital technologies offer the opportunity for governments, and other service providers, to enable a future where the delivery of public value linked services and resources are more personal, immediate, and efficient.

Legacy systems often only work for the policy they were built for.
Inconsistent ways of recording the same data.
Silo working can inhibit progress.
Fragmented environment makes achieving ambitions more challenging.
Achieving ***interoperability*** of data and information systems is very ***challenging***.
Tension between interoperability and technology choices / diversity.
Need to ***maintain public trust*** about use of data.

Box 5: Why Digital Transformation is so Hard

[13] *Ibid*, pp. 37
[14] *ibid*, pp. 28-30
[15] Australia Government, Our North, Our Future: White Paper on Developing Northern Australia, pp. 5.
[16] https://www.nationalwatergrid.gov.au/science/feasibility-projects

The challenges of digital government are not new but are nonetheless daunting. This speaks to the challenges of digital transformation, noting that truly transforming government through the power of next generation digital technologies will be a journey.

Business Research and Innovation Initiative (BRII)

Previously, Civic Ledger researched the potential of next generation digital technologies including blockchain to improve transparency and confidence in the Murray-Darling Basin water markets. In June 2017, Civic Ledger collaborated with the Australian Government's Department of Industry under its Business Research and Innovation Initiative (BRII) Challenge and delivered its Feasibility Report ***"Water Ledger – Increasing the Transparency of Water Markets".***

The premise of the BRII Challenge was that the lack of transparency and reliability of market information was a key impediment to confidence in, and participation by irrigators in the Basin water markets. Civic Ledger's research showed that while the transparency and reliability of water information was an impediment to market participation by irrigators, it was not the most influential impediment.


civic ledger
Australian Government
Department of Industry, Innovation and Science
Business
"Water Ledger" – Increasing the Transparency of Water Markets
Version: Final
30 June 2017

Civic Ledger's research identified several critical barriers to water market participation including complexity of the trading process, lack of price and volume transparency in some "closed" water systems, and some irrigators having no clear understanding of how additional water can increase farm output. Further, intermediaries appeared to hold privileged, valuable contextual information that may impede some irrigators from trading.

In tackling this BRII Challenge, Civic Ledger analysed how a blockchain-based platform, "Water Ledger" could support a "perfect market" for irrigators, which in economics and general equilibrium theory, is defined by several conditions, collectively called "perfect competition".

To test this hypothesis, it was necessary that the Water Ledger platform be trialled in an irrigation scheme.

Before moving to the next section which discusses what was involved in delivering the Pilot Project, let's introduce the blockchain technology, its key benefits, and why it can offer the opportunity to streamline water trading, and at the same time improve water information quality and availability.

What is blockchain technology?

Blockchain technology can be defined as an open, distributed ledger that can record transactions between two parties efficiently (peer-to-peer) in a verifiable (time-stamped) and permanent way (immutable).[17] It is an emerging way for businesses, industries, and governments to make and verify transactions, streamlining business processes, saving money, and reducing the potential for fraud or error almost instantaneously. In the broad environmental context, the potential of blockchain to support water markets and trading comes down to one key feature: its ability to ***provide a verifiable record*** of ***who*** exchanges ***what*** with ***whom*** – and therefore who has what at a given time.

Many of the challenges for how we manage natural resources like water arise because of a lack of trust and confidence in the rules governing exchange and possession. Blockchain's ability to provide a verifiable and transparent record may make it well placed to help answer such questions. By decentralising and digitising the adjudication of what is trustworthy, blockchain also has the potential to empower broader communities of stakeholders and improve the slow, costly intermediation associated with our current models of governing water markets.

What are the benefits of blockchain?

Drawing from Satoshi Nakamoto's White Paper: Bitcoin: A Peer-to-Peer Electronic Cash System[18], there are five key benefits of blockchain technology.

[17] https://en.wikipedia.org/wiki/Blockchain
[18] https://bitcoin.org/bitcoin.pdf

Trust: Blockchains have a decentralised architecture and governance structure, meaning there is no one entity that is solely responsible for the state of the ledger and can make changes. A predetermined set of rules dictate which transactions are valid, and how new information is added to the ledger. Because there is no one owner of the system, and all rules are predefined, this creates a level of trust between unknown parties.

Security: Blockchain duplicate the same information across all its nodes, which in some cases are in the thousands and are distributed geographically. This creates a redundancy of information, which is beneficial in the case of a network outage in a region or a malicious attack on the network. Cryptography is used to secure communications between parties, so that anything that is intercepted is not comprehensible unless sent to an intended recipient with appropriate permissions. Cryptography can also act as a way of authenticating whether communications are in fact from a specific individual or organisation.

Immutability: Information on a blockchain cannot be changed once added to the ledger, making it append-only. Because transactions are batched into blocks which are then cryptographically linked together, information in past blocks cannot be changed. Because information is immutable this makes blockchain ideal for record keeping or when needing to create a single source of truth between multiple parties.

Transparency: Transactions published to a public blockchain are viewable by anyone at any time. All records are accessible through a web-based browser and can be validated. Blockchains create a new level of transparency of information, increasing accountability and reducing the need for third-party verification or audits.

Coordination: Because blockchains create a common set of information across multiple parties, this reduces the need for reconciliation and can expedite the processing of certain actions by using smart contracts that automatically execute if the predetermined conditions are met.

Box 6: Five Benefits of Blockchain Technology

Where can the blockchain help?

Blockchain has three primary use cases: ***record keeping***, ***transfer of value*** and ***automated logic***, increasing from the most basic application to the most complex.

Immutable record keeping

As its most basic function, a blockchain serves as an immutable ledger, meaning that once information has been verified and committed to the system, it cannot be edited or deleted – creating a permanent record. Because of the construct of blockchains, different parties can access the same information seamlessly, breaking down data silos that often plague organisations – particularly those with multiple agencies, partners, vendors, etc. When designed properly, blockchain can facilitate data sharing across partners that may not trust each other or may not be able to use a common centralised database.

Transfer of value

Another benefit of blockchain technology is the frictionless movement of value that can occur by leveraging the ledger of blockchain to record the transfer of an asset. By utilising blockchain, third-party processors and clearinghouses play a lesser role, reducing transaction costs and the time delay that typically occurs when moving value between parties. Through links to electronic payment systems the blockchain stores records of “Amount, From, To, Date” in a cryptographically secure, distributed ledger.

Automated rules, smart contracts

Smart contracts are a feature within certain blockchains which automate logic. Smart contracts can be used in the context of an organisation to streamline and expedite administrative processes. Smart contracts use an information source, called an oracle, to determine if conditions have been triggered, and as a result, generate a new transaction which is added to the ledger. Despite the name, smart contracts are not legally binding, therefore doing so usually requires traditional paperwork to accompany the digitised business rules. smart contracts can be used for official sign offs, vendor payments, asset trading, triggering dispute resolution, and asset transfer.

A blockchain enabled water market

It is envisaged that a blockchain enabled water market would have the following characteristics:

A ***peer-to-peer*** market for the trading of temporary water allocations and permanent water entitlements through automation and digital transformation.
A curated ***water information supply chain*** that provides assurance through smart contracts that automate (to the greatest degree possible) trade activity.
Instantaneous ***compliance***, ***auditing*** and ***reporting*** of core activities to regulators and key stakeholders removing data silos, paper-based transactions, and human errors.
Securing of a ***trade ledger*** holding sensitive data of entitlements, transactions, and trade behaviour associated with water sector activities.

Box 7: Blockchain Water Market Characteristics

Trialling the Water Ledger trading platform

In mid-2019, Civic Ledger sought co-funding from the CRCNA to conduct the Pilot Project at the MDWSS located on the Atherton Tablelands in Far North Queensland, Australia. Funding was approved and the Pilot Project was conducted from early 2020 to the end of August 2020.

2. THE PILOT PROJECT: BACKGROUND AND RESEACH METHOD

The MDWSS is situated on the Atherton Tablelands in Far North Queensland, Australia essentially comprises the Tinaroo Falls Dam, Lake Tinaroo, and the Mareeba-Dimbulah Irrigation Area. The Tinaroo Falls Dam also supplies the Barron Gorge Hydro-electric Power Station.

Water from Tinaroo Falls Dam is distributed by gravity through 176km of main channel to the various sections of the MDWSS. A further 189km of subsidiary channels distributes water to farms, dwellings, and townships. Over 1,000 water users grow a huge diversity of horticulture crops including sugar cane, mangoes, bananas, pawpaw, citrus, avocados, and coffee using over 200GL of issued water entitlements per annum from SunWater (ROL holder).

Image 1: Mareeba's Barron Channel

The Mareeba-Dimbulah Water Supply Scheme Efficiency Improvement project is currently underway to modernise the existing water supply scheme, including the replacement and installation of around 14km of pipeline, construction of an off-stream storage and installation of automated control gates**.**

This project will improve water distribution efficiency and increase water availability by up to 8,306ML through reduced losses, enabling irrigators to better manage and meet crop water demands. The $28.1M project is jointly funded by the Australian Government ($11.6M) and the Queensland Government through SunWater ($16.5M)[19]. Also, Mareeba is to benefit from a new 200,000 megalitre dam at Lakeland which would support 8,000ha of high valued crops and contribute $234M to the gross regional product[20].

The Pilot Project considers that the modernising of MDWSS's water delivery infrastructure coupled with its diverse and high valued crops which makes the MDWSS an excellent case study.

Pilot Project research method

The blockchain enabled Water Ledger trading platform is at a Minimum Viable Product (MVP) phase of its software development lifecycle and is now ready for a pilot trial project in an irrigation area environment. The scope of the trial project at the MDWSS is to replicate the transfer of irrigation water allocations on the Water Ledger trading platform and use this as a basis for focussed engagement with stakeholders. Three key phases involved in the Pilot Project included:

[19] https://www.nationalwatergrid.gov.au/program/mareeba-dimbulah-water-supply-scheme-efficiency-improvement
[20] https://www.rdatropicalnorth.org.au/about/initiatives/lakeland-irrigation-scheme/

Phase 1: Planning
Phase 2: MDWSS Trials
Phase 3: Post Trials Analysis and Reporting

The Pilot Project aimed to replicate the buying and selling of temporary water allocations in compliance and as authorised in accordance with all applicable business and operating rules for the MDWSS.

Historical trades would be replicated on the Water Ledger platform involving developing smart contracts and transactions which will replicate trading in accordance with MDWSS rules and restrictions.

Water allocation trading on the Water Ledger trading platform will be mapped and a data set of transaction activity compiled which, along with all other collated data, will be used for the subsequent further research and evaluation with relevance to the growing northern Australia agriculture industry.

	Phase	Scope: Tasks and Activities
Phase One	Planning	Project Execution Plan (PEP) preparation and formation of Project Review Group (PRG).
		Conduct initial Key Stakeholder meetings.
		Collation of SunWater business and operating rules for MDWSS.
		Collation of SunWater historical trading data for temporary water allocation transfers.
Phase Two	MDWSS Trial	Workshops with key Stakeholders.
		Adaptation of Water Ledger blockchain platform to MDWSS business and operating rules.
		Water trading simulation on Water Ledger.
		Trials conclusion and data summation.
		Obtaining user (irrigators) feedback re trials / platform demonstration.
		Determine enhancements to Water Ledger platform.
Phase Three	Post MDWSS Trial Analysis and Reporting	Analysis of historical water trading activity.
		Evaluation of blockchain potential for the underlying governance of emerging northern Australia water markets.
		Compilation of research papers and Final Report.
		Final Report to CRCNA and Participants.

Table 4: Pilot Project Phases and Scope

It is expected that research and development of the Water Ledger platform by Civic Ledger and its partner research organisations: Griffith University and RMIT Blockchain Innovation Hub, will continue after completion of Pilot Project.

Pilot Project Stakeholders

Image 1: Pilot Project Participants and Stakeholders

Pilot Project themes and guiding questions

The Pilot Project's research objective was to inform the understanding of the governance and market mechanisms for the efficient and effective functioning of water trading and the water marketplace based on a mix of conventional and next generation digital technologies including blockchain and smart contracts.

Overall, there were two themes with two guiding questions:

	Theme	Research Questions
Theme One	Governance and Market Mechanisms	How can blockchain technology assist in the design of incentives for irrigators to optimise water allocation usage leading to increased agri-economic outputs and improved environmental benefits?
		From an institutional utility viewpoint, how can blockchain technology help design new regulatory and governance frameworks for emerging water markets in northern Australia (and elsewhere) to deliver reliable and symmetric revelation of information about water prices and market volume to capture the ASEAN agricultural opportunity?
Theme Two	Essential Water Supply Chain Information	Does price and market volume transparency in near real time offered by a blockchain enabled water trading platform, lead to the optimisation of water allocation usage (liquidity)?
		Does a simplified trading process and reduced trading cost, lead to increased water market trading participation?
		Does this approach differ from current methods of water trading using intermediaries?

Table 5: Pilot Project Research Themes

	Guide	Research Questions
Guiding Questions	Theoretical Research Questions	How can the market be designed to maximise incentives for irrigators to efficiently allocate water rights?
		How does a blockchain-based water rights infrastructure differ compared to existing centralised systems (e.g., organisational characteristics such as speed, potential for smart contracts)?
		What benefits does blockchain provide from the perspective of stakeholders within the water ecosystem (e.g., irrigators, operators, governments, regulators, registries, traders)?
		What are the risks of more decentralised blockchain water trading infrastructure, including integration with existing governance and market mechanisms?
		What are the strategic considerations in implementing blockchain infrastructure (e.g., choice of blockchain platform, overcoming potential market barriers)?
		What are the key design methodology and pattern considerations in blockchain-enable platform design for schemes like MDWSS, and for generic application of blockchain technology for water trading and water register maintenance across multiple water supply schemes?

	Guide	Research Questions
		What is an optimal framework for mapping operating and business rules for a water supply scheme or region to inform development of blockchain-enabled systems for water trading functions?
Guiding Questions	Empirical Research Considerations	How are legacy water trading rules (e.g., limits) affected by new blockchain-based water trading infrastructure? Are these regulations fit-for-purpose?
		What other areas of regulation should be considered (e.g., privacy, data rights)?
		How might blockchain-based infrastructure solve existing political problems and challenges (e.g., indigenous water access and rights)?
		What are some export opportunities for new digital infrastructure, particularly into the ASEAN region?

Table 6: Pilot Project Guiding Questions

The research objectives were channelled into three areas of work over the life of the Pilot Project:

Work Area One	Work Area Two	Work Area Three
The performance of the Water Ledger trading platform in correlation to SunWater's Orion information system and engagement with the Pilot Project stakeholders.	The co-authoring of a report with RMIT Blockchain Innovation Hub looking deeper into the socio-economic and regulatory technology ("regtech") correlation between water supply chain information and functioning water markets.	The collaboration with Griffith University exploring Water Ledger's technical architecture beyond water trading and the correlation or co-dependency on other digital technologies such as Internet of Things, sensors, AI, and digital twinning.

Table 7: Pilot Project Areas of Work

Refer to Appendix A, B and C respectively for detailed research methodology, Project Execution Plan and Stakeholder Engagement Plan.

3. PART I: OPTIONS FOR REDUCING TRADING COSTS

Part I of the Final Report considers options for reducing trading costs within the MDWSS water market.

3.1 Introduction

The reliability and efficiency of market-enabling infrastructure is well-understood as a key driver of investment and growth. The term infrastructure tends to conjure images of physical infrastructure such as roads, railways, ports, and electricity lines. While this physical infrastructure supports economic activity it also creates both physical and economic challenges in sparsely populated areas (e.g., northern Australia) where the fixed costs of investment are dispersed across fewer people.

But economic activity relies on more than just physical infrastructure – it also requires institutional infrastructure. Institutional infrastructure includes all the governance and organisational structures that lower the cost of trade and expand the scope for exchange. This infrastructure includes deep and liquid financial markets, effective supply chain tracking technologies, and low-cost dispute resolution and court systems. Each of these infrastructures lower transaction costs and facilitate trade.

While water markets require physical infrastructure to move water, our focus here is on the institutional infrastructure of water markets. We wish to examine how existing water market infrastructure might be improved through new digital technologies. Water markets facilitate the allocation of water rights between a geographically dispersed group of stakeholders including farmers, irrigators, and governments. As with all markets, they can help allocate and coordinate scarce resources – in this case, water – to their most productive uses.

How can we understand the institutional infrastructure of water markets? Water markets are essentially problems of maintaining a ledger – under trading rules – that is a trusted source of who owns what water rights at a given time. That ledger must also be updated over time as water rights are traded. Effective water markets are underpinned by ledger rules that encourage transparency, liquidity, and trust. Today most ledgers are maintained in a centralised hierarchical way through various schemes – public and private owned exchanges and information systems. Unfortunately, ledgers of water trades are often siloed and opaque, and are inhibited by inconsistent transaction costs and fees that discourage trade. Put simply: there is room for improvement.

In 2020 we have available a range of next generation technologies that might improve the governance and maintenance of water market infrastructure. Existing hierarchical and paper-based systems in a range of different industries are fast being replaced through decentralised digital systems. Much of this follows the invention of blockchain technology in 2008 to power the cryptocurrency bitcoin. But in this invention what we received was not just digital money: we were introduced to a new ledger technology. Blockchain technologies facilitate the trade of value and property rights over the internet.

There has been much interest in the application of blockchain technology to govern familiar ledgers of information in new ways: money, property registers, supply chain information, contracts, and so on. Blockchain is also highly complementary to other digital technologies, such as the internet of things, that provide inputs into the ledger.

In this section of the Final Report, we focus on how blockchain technology provides a new mechanism to record and transfer water allocations through markets, with the potential to vastly improve the operation of water markets. Subsequently, as with all radical improvements in infrastructure, we anticipate innovations in water markets through digital technologies to incentivise and encourage investment and growth in related industries, such as agriculture. By improving the efficiency of water markets domestically – for instance through higher trading volumes, greater liquidity and interoperability across schemes – we also expect these improvements to spur investment and, over the longer time, provide an export opportunity: once the foundational infrastructure is built that can be exported to other schemes, and ultimately other international jurisdictions.

Our aims are twofold. Our first aim is to theoretically examine the potential of blockchain and other digital technologies to provide new infrastructure for water markets. How might distributed ledger technologies ameliorate some of the challenges facing existing water markets – such as speed, integrity, and market liquidity? We outline the strengths and limitations of distributed ledger technologies as applied to water market infrastructure, as well as their relationship to other next generation digital technologies.

Our second aim is to introduce and analyse a world-first pilot project of blockchain-based water markets through the MDWSS Pilot Project delivered by Civic Ledger. This Pilot Project helps us to understand the more practical challenges of water trading using distributed ledger technology and smart contracts and gives an indication of the potential for improvements in the speed, liquidity, cost, and security of water markets.

Together these findings provide guidance to policymakers, to water markets stakeholders, and more broadly to other jurisdictions and schemes, on the challenges and opportunities of blockchain-based digital trade infrastructure.

3.2 An Introduction to water markets

The Australian water framework is a fundamental institution that contributes to the Australian economy and conserves the environment. Australian agriculture is a key export industry, making more than 11 per cent of Australian goods and services exports in 2018-19. At the same time, Australia is a dry continent – the second driest, only exceeded by Antarctica – with highly variable water available, where water conservation and distribution plays a core environmental role. The Australian water framework combines a regulatory approach to ensure water is available for the environment with a market driven approach to distribute water to its highest value economic use.

Economists have known since Adam Smith that property rights and exchange allow for economic coordination between producers and consumers to allocate resources in the most efficient way. The Australian water market establishes property rights over water access entitlements and water allocations, allowing holders of those rights the ability to exchange those through market infrastructure. Water users can buy, sell, lease, or use water to fulfil their individual needs.

While some institutional features of Australia's contemporary water market can be dated back to the Federation and earlier, the modern nationally consistent institutional regime developed with the 1994 Council of Australian Governments Water Reform Framework and the 2004 National Water Initiative (NWI). The 1994 regime established the fundamentals of the 'cap and trade' approach to water, where water availability for the economic use was capped by regulation and allocations under that cap were traded. The NWI, which followed the drought of the early 2000s, sought to further develop the legal framework recognising water rights as property and better navigate the balance between the economic and environmental uses of water.

What is interesting about the NWI is that there is no single type of water market. In the case of Queensland, the government notes that the water market comprises of the:

- water allocation market (trading of registered water allocation titles),
- seasonal water assignment market, and
- relocatable water license market (relocation of water licences from one parcel of land to another)[21].

Existing water markets face several challenges that may be ameliorated through new technologies and digital infrastructure. While those challenges differ across schemes and over time, there is a general consensus that common problems include transaction costs and fees (reducing market participation), time delays in the operation of the market (hindering efficient allocation), regulatory complexity and uncertainty over scheme rules (leading to perceptions of differential application of rules) and a lack of interoperability across schemes. Many of these water market challenges might be ameliorated through a digital infrastructure upgrade using blockchain technology, which we introduce in the following section.

3.4 Blockchains as economic infrastructure

Before we examine the potential of blockchain and distributed ledger technology to ameliorate some of the challenges above we must examine the nature of the technology itself. In this section we introduce blockchain technology, explore some of its applications, and examine some of the economic implications of a new digital ledger technology. This understanding provides a theoretical foundation on which to examine blockchain as applied to water markets

Blockchain was invented over a decade ago as a technology to create a decentralised digital currency. In 2008, a pseudonymous inventor(s), Satoshi Nakamoto, released a white paper describing a new cryptocurrency, Bitcoin[22].

Underlying that cryptocurrency was a suite of technologies that came to be known as a blockchain. Blockchain technology is a novel combination of technologies – including cryptography, peer to peer networking, game theory – that when put together facilitate a decentralised and distributed ledger of information. Blockchains enable decentralised networks of computers to come to consensus over a shared ledger of data, and to update that ledger with more information.

As mentioned above, the first application of blockchain technology was to update a new ledger of digital money, Bitcoin. But the application of blockchain extends far beyond ledgers of money, and now includes registries, licences, health

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[21] https://www.business.qld.gov.au/industries/mining-energy-water/water/water-markets
[22] http://satoshinakamoto.me/bitcoin.pdf

records, supply chain information, betting markets. Indeed, an economy is made of different ledgers of information that record economic, political, and social facts. Ledgers are needed to record not only who owns what property, but where products are going next, who has management power, who has voting rights, and so on.

One of the major applications of blockchain technology has been in the governance of supply chain information. Global supply chains today are not primarily hindered by the costs of moving goods (e.g., transportation technologies), or even the regulatory costs of moving goods across borders (e.g., tariffs and quotas). The underlying problem today is a ledger problem of how to ***coordinate trusted supply chain information***.

Today global supply chains face a different type of problem: how to record and update information about goods as they move. Supply chain infrastructure must not only carry physical products, but it must also coordinate information about those products too. That information includes their location, destination, finance, ownership, provenance, and so on.

Today supply chain information is recorded in often a paper-based manual way in siloed hierarchies (e.g., ledgers kept by individual companies, or by governments as goods cross borders). Blockchain technology, however, provides a new digital infrastructure for storing supply chain infrastructure in a decentralised way. Supply chain participants can now create digital representations of physical products in a decentralised and tamper-resistant blockchain ledger, updating the blockchain with new information as the product moves (e.g., its location).

Applying blockchains in supply chains promises to enable more granulated, trusted, and cheap information about global supply chains, leading to various other benefits. Today many major companies – from IBM to Walmart – are using this technology to increase the efficiency of supply chains and trade, particularly around error and fraud in the recording of supply chain information. We will return to blockchain-based supply chains later in this report because it has strong parallels to the challenges of creating blockchain-based water markets – namely the relationship between a digital ledger and the physical location of what that ledger represents.

The field of institutional economics was pioneered throughout the twentieth century by several Nobel Prize winners to understand the different ways that information and trust problems are solved in economies. From this perspective an economy isn't just made of physical things – like machines or people – but rather is made of different types of organisations and institutions – hierarchical firms, governments, market mechanisms – that lower barriers to trade (i.e., lower transaction costs).

Blockchain technology is best understood within this institutional context. Blockchain and other distributed ledger technologies are not conventional industrial technologies (e.g., the aeroplane or the 3D printer) that help humans do production tasks faster, better, and cheaper. Rather, blockchains are institutional technologies. They are a technology for solving governance problems. In this way blockchains are more analogous to the invention of the joint stock company or the nation state than the steam engine. What this means is that when we seek to analyse the application of blockchain technology we should examine how it changes the boundaries of existing institutions – including firms, markets, governments – and how the technology might better facilitate mutually beneficial trade and coordination.

The nature of blockchain as an institutional technology has raised many policy questions. Rather than blockchain creating policy challenges at the boundaries of existing legislation, many applications go to the heart of regulatory frameworks. For instance, the application of smart contracts – self-executing agreements or parts of agreements executed on blockchain networks – make entirely new decentralised organisations possible, creating challenges both for how existing frameworks are designed (assuming that the regulations are enforced on centralised firms) and how those regulations are to be enforced (how to enforce a rule on a decentralised network).

What we have seen in this section is that blockchains should not be confused with cryptocurrencies. Rather, they are a foundational new institutional technology within our economy. They compete and complement existing institutions and organisations that we use (such as firms and governments) to solve information coordination problems by enabling value to be transferred digitally in a tamper-resistant way. In the following section we turn more specifically to the opportunity of blockchain technology underpinning water markets, before outlining the Pilot Project as a case in point.

3.5 Water Markets and blockchain infrastructure

This section examines some of the opportunities that blockchain technology (and other digital technologies) presents for improving water markets. Before focusing on a specific application or type of blockchain technology (as we do in the following section through the Pilot Project) our aim here is to give a more general understanding of the potential of digital technologies to improve the operation of water markets, including their costs, efficiency, and liquidity.

In theory water markets are simple. Parties are allocated water rights. Those water rights are property rights, including who owns the allocation, the size of the allocation, the time horizon and where that water may be drawn from. All of those rights are recorded in a ledger, generally helped by a centralised scheme operator. Water demands change over time – initial allocations do not necessarily meet demands as conditions change. Some parties require more water, others less. Water markets solve this problem by enabling the trading of water rights.

The basic microeconomics of water markets suggests that, with clearly defined water property rights (who has rights to what), and low transaction costs (few fees and barriers to trade), market exchanges will tend scarce water resources to their most valuable use. Clearly visible market prices send signals to those in the market about the efficient allocation of resources and the scarcity of water at that time.

But water markets do not live up to this efficiency-enhancing seamless reallocation ideal in practice. There are several reasons for this. As we saw previously, water allocations are not always clearly defined and transparent. If you are a person who wants to buy more rights it can be difficult to see where you might buy water rights and at what possible prices. Some of this problem is because of the centralised recording of water market trades (a lack of visibility). Furthermore, many schemes charge transaction fees to transfer rights. The costly manual process of updating a water rights ledger must be defrayed somewhere in the trade (ultimately crowding out some low value and small transfers that would otherwise be efficiency-enhancing). Such poorly managed opaque water markets prevent the reallocation of water rights to their best use. Indeed, as the Productivity Commission has noted, for these markets to operate efficiently "traders require access to reliable and timely information, including about prices."[23]

The complexity of water markets is also exacerbated by the multitude of operational and trading rules that transfers must abide by. Water markets are heavily regulated. Those thousands of rules must be adhered to. Those rights are also subject to regulations and trading rules stipulating not just initial allocations, but how those rights might be traded.

This complexity not only comes with a direct paper burden or compliance cost for those who want to trade but empower intermediaries and brokers – experts in the complex rules – within the market process. These complexity challenges are exacerbated even further with overlapping jurisdictions and a lack of transparency and interoperability across schemes. We touch on some of these regulatory and legal challenges later in this report. But the often-non-discretionary nature of those rules also presents an opportunity – they can be incorporated into the code itself to ensure that all participants are legitimately abiding by the same rules.

How would such a blockchain-based water market work? Our aim here is not to present any specific blockchain-based water market model, but to provide a broad understanding of how this technology can be applied, and the opportunities that present. Much like the digital representation of goods in supply chains as outlined above, water market rights can be digitally represented on a blockchain-based ledger. Holding a digital representation of a water allocation gives the holder various rights, such as the ability to withdraw that allocation from a particular source within a particular time period, as well as the right to sell that allocation through a water market (of course given various trading and business rules).

The fundamental difference here compared to the status quo is that, rather than water market rights being recorded manually through a scheme operator, those rights are recorded and transferred on a shared distributed ledger. Given the tamper-resistant nature of the distributed ledger, stakeholders have more confidence in the ledger. A blockchain-based water trading system might also lower the various transaction costs that make water markets less liquid and efficient. For instance, those who are buying and selling water can have greater visibility over the available quantity and market prices of water trades, helping them to reduce their search costs. The opaque characteristics of existing water markets raises search costs that can be partly ameliorated through expensive intermediaries, such as brokers. In a blockchain-based water market the problem of search costs is lowered through visibility across the entire scheme via the digital platform. Through self-executing smart contracts, blockchain-based water markets also reduce the enforcement costs associated with exchange. That is, transfers of rights are automatically executed in real time.

The lower transaction costs enabled through blockchain-based water markets, including both search costs and enforcement costs, theoretically improve the efficiency of water markets in different ways. The lower costs of entering and participating in water markets improves market liquidity and extends the scope of potentially beneficial trades.

Furthermore, the visibility of prices and trades improve market coordination – allocating scarce water resources to their most valued use – by signalling to market participants the conditions of the market. It is important to note here that more effective water markets can not only incentivise those who have spare unused water allocations to sell them, expanding the effective supply of water on the market, but also encourage water users to use their water rights more efficiently (because unused rights can be sold) leading to possible new products been offered in the market.

There are also broader benefits of blockchain-based water market infrastructure as a form of ***Regulatory Technology*** (regtech). It is well-understood that regulatory constraints impose costs on market participants. These costs discourage

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[23] Productivity Commission National Water Reform Inquiry, p. 111. https://www.pc.gov.au/__data/assets/pdf_file/0007/228175/water-reform.pdf

market participants and affect the liquidity of the market. Water markets are highly regulated markets with many trading and business rules at different levels. Rather than those rules being applied manually by a scheme operator – for instance determining whether each individual transaction is compliant – those rules can be directly integrated into the digital platform itself. This ensures that all transactions are being made under the same set of rules and helps to discourage fraudulent activity or biased activity towards market actors.

Of course, the application of any new technology has potential challenges and downsides. Blockchains are not a perfect technology and will not miraculously meet the conflicting needs of modern web applications together with customer expectations.

There are several strategic considerations, however, that policymakers and stakeholders should consider in the deployment of this technology. We outline some of these here. Our aim is not to provide answers to these questions, but to raise them as strategic considerations.

Given that water markets are ***highly regulated with many trading and business rules***, policymakers should consider the capacity for various trading rules to be hard coded into the platform.

How can changes in the regulatory environment and new trading rules, at various levels of government be ***coded*** into the Water Ledger trading platform?
Should developers and policy makers consider the potential of ***interoperability*** between various water supply schemes (that is, how can the water delivery infrastructure interoperate with other Water Supply Schemes)?
How can water supply chain information recorded in Water Ledger's trade ledger ***integrate*** with state owned water registers or other information systems?

Box 8: Strategic Considerations for Policy Makers and Stakeholders

It is also worth noting that the deployment of such digital infrastructure may clash with entrenched interests. To the extent that individuals and groups are benefitting from the inefficiencies of existing water markets (for instance, by taking advantage of asymmetric information in their bargaining position, or a lack of transparency enabling some fraudulent activity) we can expect those actors to resist the movement towards a more tamper-evident and transparent water market.

3.6 Legal frameworks

Legislative and regulatory frameworks establish water rights as property rights, including who owns the allocation, the size of the allocation, the time horizon and where that water may be drawn from. These frameworks also establish how water rights can be transferred and exchanged. As the MDWSS Pilot Project is located on the Atherton Tablelands in Far North Queensland, Australia, it is purpose of this section is to outline the legislative and regulatory frameworks that apply in that jurisdiction.

Broadly, the legal framework consists of three separate levels - legislation, regulation, and water supply scheme rules.

The *Water Act 2000 (QLD)* is the principal legislation. Section 2 of the Act provides, amongst other things, that a main purpose of the Act is to provide a framework for "the sustainable management of Queensland's water resources ... by establishing a system for the planning, allocation and use of water" and "the effective operation of water authorities." Relevantly, section 2(g) of the Act notes that "sustainable management" includes "promoting the efficient use of water" through "the establishment and operation of water markets" (in addition to other considerations such as water demand, water conservation, and water volume and quality).

Specifically, the Water Act provides an overarching framework for allocating water and registering those interests, and how those allocations can be dealt with and registering those dealings. There is a complex governance structure over water allocations consisting of:

- A "Water Plan" (see Part 2 of the Water Act) that provides a framework for establishing water allocations. A Water Plan has legal force as subordinate legislation (see section 48 of the Water Act). In the case of the MDWSS, the relevant Water Plan is the Water Plan (Barron) 2002,
- A ROL that provides the holder - the owner of the water infrastructure - with the authority "to take water or interfere with the flow of water to distribute water under water allocations" in relation to a Water Plan (see section 176 of the Act). In the case of the MDWSS, SunWater is the ROL and a partner of the research Pilot Project, and
- A "Water Licence" (authorisation to take water from the land) or a "Water Entitlement" (allocation separate from the land and capable of being registered and traded).

In terms of water trading, there is a system of registration. Section 168(1) provides that “for registering water allocations and interests and dealings with water allocations, the registrar must keep a water allocation register.” Significantly for the present study, the Act ***does not dictate what form the register should take***. Instead, the section 169 provides that “the register may be kept in the form the registrar considers appropriate” and that “the registrar may change the form in which a register or a part of a register is kept.”

Further, the Queensland regulatory and governance frameworks ***do not require information on allocation trade prices*** to be captured or published. This is consistent with their legislative framework which does not require allocation trades to be registered.

As such the *Water Act 2000 (Qld)* was amended in December 2018 to provide for a ROL – SunWater – to include conditions, such as a requirement ‘*that the licence holder collect and publish the sale price for each seasonal water assignment of a water allocation managed under the licence*’. As discussed in Part I of this Final Report, the Pilot Project found that water price data was not included in the 2019 calendar year of MDWSS historical trades. Water price information was sourced directly from the MDWSS irrigators through a face-to-face workshop in late June 2020.

Other relevant aspects of the Queensland Regulatory framework include:

- Water Regulation 2016 (Qld),
- Supply Contracts, and
- Water Supply Scheme Rules.

The important legislation relating to the Australian agriculture water market is the *Water Regulations 2008 (Cth)* which specifies the data reporting requirements for trades of irrigation rights.

3.7 The Pilot Project

The blockchain enabled Water Ledger trading platform codified the rules (business logic) to enable irrigators to lawfully interact with each other in the MDWSS water market without intermediaries. These peer-to-peer interactions were then recorded on a public ledger in near real time, reducing regulatory burden as each interaction was automatically compliant. The act of codifying rules that can be understood and used by a computer is a transformational shift in how governments create rules and how third parties consume them just as Water Ledger demonstrated during the execution of the Pilot Project.

The aim of this section is to build on the above discussion by introducing two new terms that were central to the Water Ledger trading platform’s functionality: ***regulatory technology*** and ***programmable code***. It aims to highlight factors that policy makers and regulators should consider for adopting blockchain technology in the context of regulatory technology and programmable code enabling the greater use of it within the wider Australian water market ecosystem and beyond.

3.7.1 What is regulatory technology and why is it of interest?

Recently, the Australian Government’s Productivity Commission released its Information Paper: Regulatory Technology[24]. It positions itself as a “discussion starter”, targeted at policy makers and regulators and raises the question of whether there is a gap in regtech adoption less than some optimal level given the opportunities, and if so, what is causing it?

According to the paper, ***regtech*** “refers to technology that enables regulatory requirements to be met more effectively and/or efficiently” (Wang 2019: p5). It goes further to explain that the greater use of regtech to support regulatory compliance has, in part, been enabled to reduce costs of technology and the proliferation of data. Those sectors that are dealing with many rules and/or dealing with large number of customers, transactions and data can benefit from regtech to reduce the cost burden of compliance.

Over time, advances in technology have shown to help with reducing compliance burden by substantially lowering costs and speeding up transactions. Whilst next generation technologies such as the cloud, artificial intelligence (AI), data analytics and blockchain are improving the agility of digital information processing; they have also opened new areas for policy and regulation. According to the paper there are four reasons for this driver for change:

1. The increased complexity (and quantity) of regulatory requirements in some areas, and resulting compliance burdens,
2. The greater possibilities offered by technology to tackle areas where the costs of regulatory non-compliance are high (financial and/or detriment to individual or community outcomes),

[24] Productivity Commission, Information Paper: Regulatory Technology, October 2020, pp. 3-7

3. Reduced costs of, and associated increased reliance on, technology in business operations, and
4. Growing recognition of the usefulness of some data collected during business operations in also demonstrating compliance with regulatory requirements.

How does the use of blockchain technology support regulatory compliance? What has driven the need for the convergence of regulation and technology? Is the current water market regulation "fit-for-purpose" as described in the previous section to encourage such technologies to be adopted?

Prime facie there is a strong case that blockchain offers significant benefits in delivering effective and efficient water markets. However, up to now there has been no practical evidence to support this. Thus, the Water Ledger trading platform was deployed in the MDWSS to test the hypothesis that:

> *From an institutional utility viewpoint, how can blockchain technology help design **new regulatory and governance frameworks** for emerging water markets in northern Australia (and elsewhere) to deliver reliable and symmetric revelation of information about water prices and market volume to capture the ASEAN agricultural opportunity?*

3.7.2 Current State of Regulatory and Governance Frameworks

The water market in Australia is the world's only large-scale system of water trading estimated to be worth $22 billion per annum. Despite the relatively large size of water markets, its full potential has not been materialised due to a lack of robust market mechanisms: ***regulation*** and ***governance***. According to the ACCC Interim Report into the Murray-Darling basin water markets[25], '***market governance'*** refers to the range of institutions, rules and processes through which decisions concerning water trade arrangements are made and implemented, and water markets are regulated.

> "*Regulatory or governance gaps can lead to the opportunity for misconduct to occur or mean that third party impacts (externalities) are not being adequately addressed*"[26].

One explanation is that water markets have developed at different times across different regions as an adjunct to broader water management reform. This has resulted in an extremely complex, fragmented and sometimes inconsistent system. An inconsistent system which has been built for water management, but not for efficient water trading. It is now understood that many of the historical market settings and governance arrangements are no longer suitable to deliver the potential benefits of water trading.

1. Trade processing needs:
    - Improve consistency of terminology across the states.
    - Simplify trading rules.
    - Reduce administrative burdens, both on applicants and trade approval authorities.

2. Need to reduce and harmonise transactions costs:
    - Improve trade processing times, particularly for interstate trade.
    - Streamline trade processing and reduce scope for errors.
    - Harmonise trade approval fees for the same trade type across jurisdictions.

3. Transparency needs:
    - Improve the quality of public information (for example, via automated error checking).
    - Improve access to public information.
    - Improve timeliness of information.
    - Address information asymmetries (limiting the potential negative impacts of private information).

4. Need to improve regulatory oversight:
    - Improve potential to monitor trader and water market intermediary behaviour.
    - Reduce cost of obtaining market information and increasing the cost of deliberately misreporting information, thereby reducing the scope and incentive for traders or intermediaries to engage in misconduct.

Box 9: Four Key Areas which RegTech Solutions for a Water Market need to Address

[25] Australian Competition and Consumer Commission, "Murray-Darling basin water markets inquiry: Interim report, 30 June 2020, pp 18, 483.
[26] Ibid.

3.7.3 Programming code or "Rules as Code"

The Water Ledger platform's use of smart contracts to execute the codified rules when prescribed conditions were met in the interaction between irrigators represented a strategic, systemic, and deliberate approach to changing the way rulemaking works within government. This evolution is called ***Rules as Code***[27].

> **Rule as Code** (RaC) is about changing when, how, by and for whom rules are made. It moves beyond enhancing existing workflows and processes and requires deeper and deliberate examination of the rulemaking process. It positions government as the creator of a machine-consumable version of rules from the outset, rather than after the fact.

Box 10: Rules as Code

As the Pilot Project will discuss in Part II, it bought participants from the existing rules making process – QDNRME (regulator), SunWater (operator) and FNQ Growers (irrigators) – together to agree on common definitions and data to create a machine consumable version of the existing MDWSS water trading rules. This shift to RaC reduced the need for the MDWSS water market participants to manually interpret or translate the rules as the Water Ledger trading platform was able to perform this workflow automatically in compliance with the policy makers and regulators' objectives.

Could the Pilot Project be an example of what an efficient and effective water market could possibly be? The Water Ledger trading platform was able to demonstrate that it was technically feasible to solve the challenge of rulemaking and enforcement. Through examining the rulemaking process, it showed that:

- MDWSS rules were numerous and interconnected without consistency increasing the difficultly faced by water market participants, operators and even government seeking to comply with the requirements,
- These inconsistencies position individuals – lawyers, intermediaries – for interpreting the rules defraying the cost burden to prove compliance to water market participants, and
- When rules are only available in "human-readable" format, water market participants, businesses and governments are to separately interpret and implements a version of the rules within individual systems limiting policy makers and regulators to model and test the impacts of changes to the rules.

In an era of digital transformation of government, the Water Ledger trading platform could present a case study to government for the design and development of new water markets in northern Australia for two possible reasons:

1. Water market and trading "Rules as Code" are ***digital institutional instruments*** designing the mechanisms of water markets from the bottom-up, rather than as an add-on or an after-the-fact adjustment, and
2. It rethinks governments as ***providers*** of public data and shared information systems infrastructure that can be used by others – individuals, the private sector and government itself – with confidence.

3.8 Conclusion

As we approach the limits of meeting water demands by increasing supply, governments are evaluating ways of managing water demand to signal the scarcity value of water. This has resulted in increasing attention on water markets and what they can deliver in terms of efficiency and balancing water supply and demand. Despite a greater use of markets for water there continues to be misunderstandings about how they operate. For water markets to operate efficiently and provide equitable opportunity to participate, market participants need ***access to reliable and transparent information***.

A blockchain enabled peer to peer water market and trading platform that allows for the secure and transparent trading of water entitlements and temporary allocations could increase participation by irrigators and increase the overall allocative efficiency of this scarce water resource. Designed to be interoperable between government departments, authorities, and operators, including by way of multiple party direct access through API abstraction of functionality to a common and immutable water market ledger offers the potential to create a ***one source of truth*** for water market trade data.

Therefore by removing complexity from the act of water trading, by its very design frees up resources that are normally tied-up with regulatory compliance activities because the essential water information required for a legal water trade to occur cannot be omitted or occluded in any way.

[27] James Mohan and Alex Roberts, Cracking the Code: Rule Making for Humans and Machines, OECD, October 2020, pp 2-6.

More specifically the Pilot Project found that:

A blockchain-based water trading system shows significant potential to lower various transaction costs that make water markets less liquid and efficient. For instance, those who are buying and selling water can have greater visibility over the available quantity and market prices of water trades, helping them to reduce their search costs.

Through self-executing smart contracts, blockchain-based water markets also reduce the enforcement costs associated with exchange. That is, transfers of rights are automatically executed in real time.

The lower transaction costs enabled through blockchain-based water markets can improve the efficiency of water markets in different ways. The lower costs of entering and participating in water markets improves market liquidity and extends the scope of potentially beneficial trades.

The visibility of prices and trades improve market coordination – allocating scarce water resources to their most valued use.

Box 11: Part I Findings

4. PART II: OPPORTUNITIES FOR REAL TIME PRICE DISCOVERABILITY

Part II of the Final Report identifies opportunities to enhance real time price discoverability if water supply chain information is broadcasted in real time to the water market participants and third parties. This Part of the Final Report was authored by Civic Ledger.

4.1 Water trading business and operating rules

The MDWSS business and operating rules are drawn from a range of publicly available information including legislation, regulations and documents relating to the specific operating nature of the scheme itself. Whilst, the Pilot Project did not have difficulty is sourcing these key documents, where there were challenges was in navigating and evaluating the differences in language, terms, and definitions cited across the literature.

Legislation

Water Act 2000 (Qld)
Water Regulation 2016 (Qld)
Water Plan Barron 2002 (revised version 6 December 2002) (*"Water Plan"*)
Provisions of the Barron Resource Operations Plan taken to be included in the Water Plan (Barron) 2002 – Act ss. 1259 and 1264
MDWSS Resource Operations Licence – Water Act 2000 (*"ROL"*)

Regulation

Barron Water Management Protocol 2017

MDWSS Operating Rules

Barron Operations Manual
Current Location of Water Allocations
SunWater Transfer Conditions

Box 12: Legislation, Regulation and Operating Rules

Central to the efficient and effective operation of a water market is the ability to identify a customer and assign it an authority so it can participate in trading activity. Taking into consideration that the Water Ledger trading platform would need to interoperate with QDNRME's Water Information System (WIS) and SunWater's Orion information system, the Pilot Project engaged with its Stakeholders to better understand its respective business systems and workflow processes.

4.2 Customer identification

Engagement with QDNRME and SunWater was undertaken to determine the MDWSS rules that define unique water customer identification for the purposes of water trading.

On the one hand, QDNRME protocols refer to a Customer as the holder of one or more licences or entitlements in MDWSS. QDNRME identifies Customers as the recipients of entitlements issued, or a Buyer or Seller of an entitlement in terms of water trading. Such a Customer is an *identified entity*.

On the other, SunWater protocols designate an entitlement holder, a Buyer or a Seller, were consistent with QDNRME protocols. However, as relates to water trading ***an additional level of user identification*** is employed to reflect the operational requirements and the hierarchy of water supply contracts at MDWSS.

At the scheme level SunWater's Orion information system allocates a unique Account Number to a Customer. In both instances, a Customer (or Account Number) may hold multiple licences or entitlements. At MDWSS however, each licence or entitlement is allocated a Water Account Number for each water supply contract / offtake.

Customers (i.e. Account Numbers) at MDWSS are also allocated a unique Water Account Number for each water supply contract entered as between the Customer and SunWater. In turn, each Water Account Number corresponds with a unique delivery point or offtake, and each offtake is metered.

Further, the issued entitlements at the scheme level are reportedly broken down (for each Customer / Account Number) to a Water Account Number / water supply contract / offtake level. The greater level of detail employed at MDWSS required full mapping to design the correct Water Ledger smart contract functionality to automate these rules ***and*** to maintain consistency with SunWater's Orion information system.

It is important to note that whilst QDNRME (the Regulator) and SunWater (the Operator) were consistent with each other's customer identification protocols; the Operator goes further by allocating a unique Water Account Number for each water supply contract. The Pilot Project was able to eventually map these different layers of customer identity.

Temporary Water Allocation Transfers and Term

- MDWSS Temporary Water Allocation transfers occur between Water Accounts and between Water Accounts with common ownership, and
- MDWSS Temporary Water Allocation Transfers term is always for the remaining balance of the financial year.

Water Zones

The identification of MDWSS Supplemented Surface Water Zones (*"Zones"*) was determined by the Provisions of the Barron Resource Operations Plan included in the Water Plan (Barron) 2002 – Act ss. 1259 and 1264. Maximum water use volumes for the MDWSS Zones A to E are described in the Barron – MDWSS Operations Manual. Consistent requirements for limitation of water allocation transfers between Zones are also identified in:

- Barron Water Management Protocol 2017,
- Business Queensland - Current location of water allocations in the MDWSS, and
- SunWater Transfer Conditions MDWSS.

Engagement with SunWater operations personnel further determined that applications for a water allocation transfer between Zones, as well as compliance with the above Operations Manual requirements, also undergoes a further evaluation at SunWater to determine hydraulic capacity for MDWSS infrastructure to deliver water in accordance with applicable water supply contract(s) to the intended buyer offtake location(s).

1. A Buyer ***identifies*** a Seller with acceptable terms offered
2. One or more of the intended transaction parties ***notifies*** SunWater that the trade is sought between the parties and the quantity of water
3. SunWater ***evaluates***:
    a. Bona fides of parties e.g. water licence and a water account
    b. Compliance with Zone allocation limit restrictions
    c. Capacity of infrastructure to deliver water to the intended Buyer
4. SunWater ***notifies*** parties as to the outcome of evaluation (i.e. trade is approved or not approved)
5. ***If*** trade is *approved* the parties ***complete*** the trade
6. The parties then ***notify*** SunWater of transfer date
7. SunWater ***amends*** the local register that is established to manage temporary transfers

Box 13: SunWater Seven Steps to Transfer Temporary Water Allocations

Data recorded

SunWater records data relating to Temporary Water Allocation Transfer as follows:

1. Transacting Water Accounts,
2. Quantity of water,
3. Zone transfer details, and
4. Date.

The trade price is not presently recorded in SunWater's Orion information system.

Codifying business and operating rules

After completing the engagement with QDNRME and SunWater to reach consensus on MDWSS's business and operating rules, the Pilot Project was now ready to adapt the Water Ledger trading platform to the operate the MDWSS water market through the creation of four smart contracts:

- ***Licence smart contract***: Rules that confirm that intending buyer has necessary licences or customer credentials,
- ***Order Book smart contract***: Rules that implement what is a valid water trade e.g., a valid licence, sufficient water balance in the Zone,

- ***Zone smart contract***: Rules that validate that water transfers between zones at MDWSS do not violate established Zone allocation limits, and
- ***History smart contract***: Rules that create an immutable record of history of successful trades between parties.

The adaptation process identified thirteen steps to prepare the Water Ledger trading platform for coding.

1. ***On-boarding*** of Accounts and Water Accounts into Water Ledger:
    a. Account ID
    b. Water Account IDs
    c. Applicable Zone/s
    d. Respective water allocation/s
2. Buyer or a Seller ***locating*** a counterparty
3. ***Authentication*** of intending parties to a trade:
    a. Required Account and Water Account held
    b. Water allocation is available (i.e. unused) to trade
4. Buyer or Seller ***accepting*** an offer or a bid (quantity, price)
5. ***Notification*** of intended trade data to scheme operator
6. Scheme operator ***validating infrastructure capacity*** to deliver water to the intended Buyer
7. Scheme operator providing ***approval*** for the trade
8. Buyer and Seller ***entering contracting*** to complete the trade
9. ***Notification*** to scheme operator that trade has been entered into
10. ***Notification*** to scheme operator of water allocation transfer quantity, date
11. Seller ***accepting*** liability to settle transaction
12. ***Settlement*** of transaction
13. ***Notification*** to scheme operator that trade has been settled

Box 14: 13 Steps Codified to Adapt Water Ledger to MDWSS Water Market

Once a Buyer or Seller are ready to either place a bid or an offer, the Water Ledger trading platform's smart contracts automatically execute the business and operating rules completing the workflow for a compliant trade in seconds rather than days or weeks ready for SunWater's review.

This efficiency is due to the Water Ledger trading platform surfacing all the trade-related data in real time – authorisation, ownership, quantity, zone, and price – to SunWater. Once SunWater receives notification from the Water Ledger trading platform of an intended trade (Step 5), the water delivery infrastructure and other information such as water account balance (Step 6) is to be assessed reducing SunWater's time and steps (from 7 down to 2) to validate and approve the trade.

What did we learn from evaluating and codifying the MDWSS business and operating rules?

The key takeaway from codifying the MDWSS business and operating rules was that once consensus was secured from QDNRME and SunWater on what constituted "identity", programming the rules was relatively straight forward. The reason for this ease was due to information readily obtainable in the public domain.

Coupled with Civic Ledger's in-house water industry expertise, proactive input from relevant stakeholders with a special mention to SunWater, and the Pilot Project's early planning focus on this area ensured an expeditious completion of this important requirement. As to be discussed in greater detail in Part III Civic Ledger's research with Griffith University, planning the business and operating rules to codify the smart contracts showed that when the Trial Phase was completed, the Water Ledger trading platform was adaptable to suit the MDWSS water trading requirements.

At the conclusion of this phase of the Pilot Project it was possible for the Water Ledger trading platform could create marketplaces for all SunWater operated Water Supply Schemes as each share common sets of business and operating rules.

Adapting the Water Ledger trading platform to replicate the MDWSS water market demonstrated the potential for next generation digital technologies to shift from the human reading of water trading steps to the adoption of programmable code resulting in a savings in time and costs for water market participants.

It is proposed that further research be undertaken into ***Rules as Code***[28] semantic technologies and domain model-based regulation to consider its potential to rethink rulemaking to design and deliver next generation water markets in northern Australia.

[28] James Mohun and Alex Roberts, 2020, Cracking the Code: Rule Making for Humans and Machines, OECD, October 2020, pp. 10.

4.3 Water trading data collection

Securing the historical temporary water allocation trading data from SunWater's Orion information system (from a Water Account to a Water Account for the period from January 2019 to December 2019) was managed through the PRG's governance processes to ensure that privacy provisions were met. Once the datasets were received it was necessary to cleanse the data firstly, prepare the data for uploading into the Water Ledger trading platform, and secondly, analyse the water trading activity to understand the key components of the water supply chain information present in the data.

As SunWater's Orion information system to manage MDWSS's temporary water allocation trades did not capture price, the Pilot Project used water trading price information based on ***anecdotal inputs from MDWSS irrigators*** at the workshop reportedly ranging from about AU$70 per ML to approximately AU$200 per ML. The pricing appeared to vary according to time of year (i.e. period of temporary transfer remaining until 30 June next) and rainfall patterns.

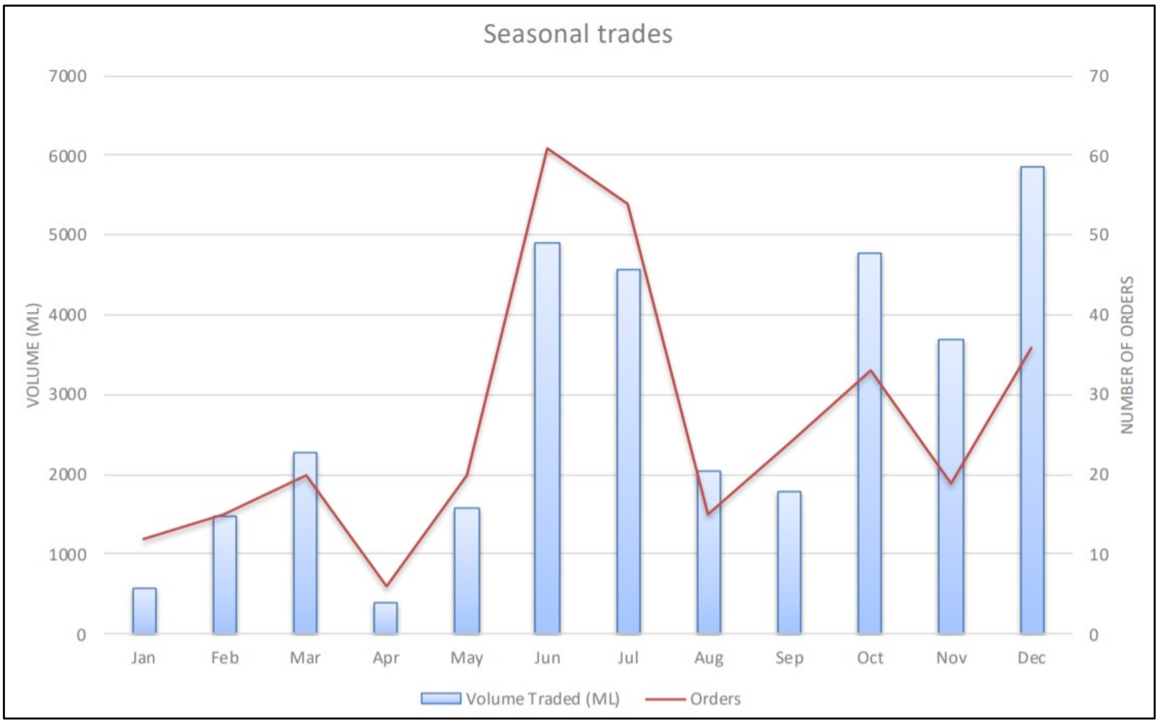


Chart 1: MDWSS Seasonal Trades January 2019 to December 2019 (Source: SunWater)

This absence of water price recorded by SunWater's Orion information systems resulted in a changed approach from analysing water trading activity from "***price related***" to analysing "***market participation***".

4.4 Water trading data analysis

The MDWSS customer base comprises of the following:

- Total Customer Accounts: 2,068
- Total Water Accounts: 2,703

The Pilot Project analysed MDWSS water market participation: activity and transactions relating to the transfer of temporary water allocations for the period from January 2019 to December 2019. Our analysis of the water market data found the following:

- Of 2,068 Customers, 168 (or 8.1%) participated in temporary water allocation trades during 2019,
- Of these, 109 (or 64.9%) traded water just once or twice in the period, and
- Active market traders (more than two trades in the period) are limited to fewer than 60 irrigators (or 2.9% of all MDWSS irrigators) for the 2019 period.

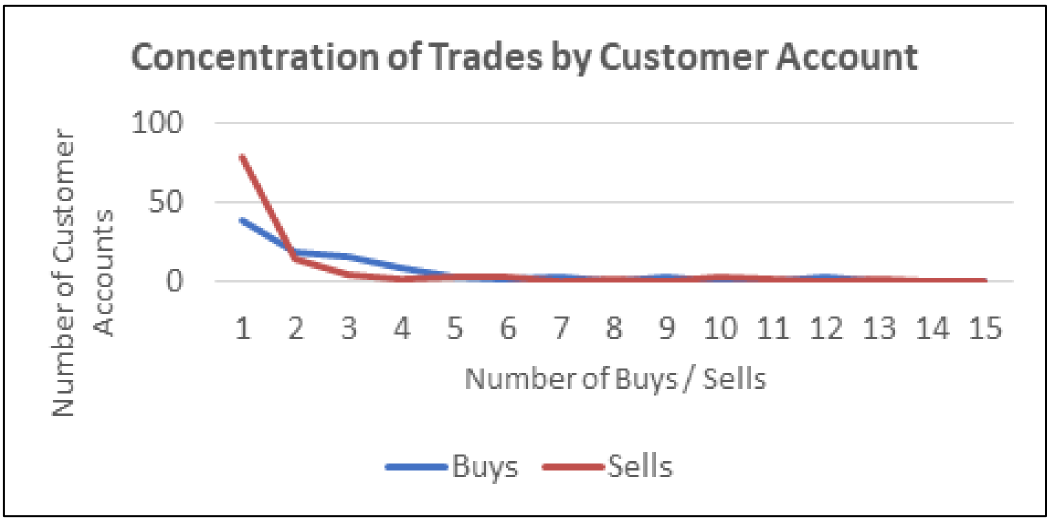


Chart 2: Concentration of Trades by MDWSS Customer Account (Source: SunWater)

Of 315 transfers from water account to water account, approximately 85% of temporary water allocation transfers between MDWSS irrigators represented trades for SunWater's financial consideration. Whereas, approximately 15% of temporary water allocations were transfers as between commonly owned Water Accounts, and (reportedly) for no financial consideration or "zero value" trades – that is, a MDWSS irrigator transferring water allocations between their own water accounts.

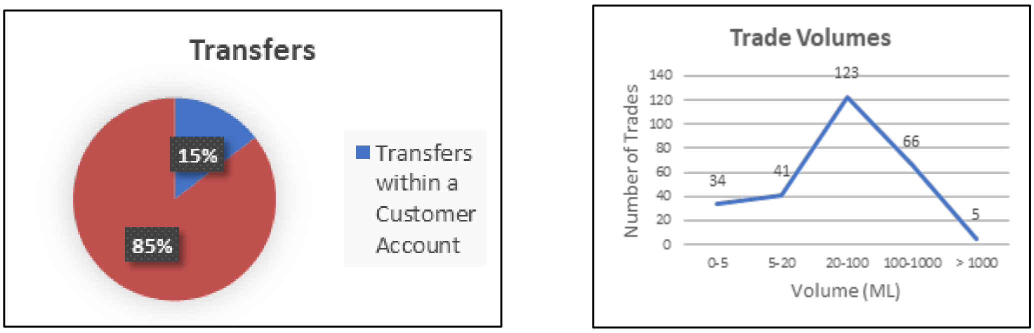


Chart 3: Transfers from Water Account to Water Account and Trade Volumes (Source: SunWater)

Most trades between MDWSS irrigators were for volumes less than 1,000 ML, with 123 trades between 20ML and 100ML, and only five of 269 trades exceeding 1,000 ML.

4.5 Water trading data analysis feedback: MDWSS irrigators

The Pilot Project sought feedback on the water trading data analysis from the MDWSS irrigators. According to the MDWSS irrigators via workshop and follow up interview with Joe Moro[29], the apparent low level of participation in the temporary water allocation markets is understood to derive from a combination of current market aspects including:

1. Sellers are often not aware of current market pricing.
2. Buyers are not always readily found.
3. Water trading is time consuming.
4. Water trades can take weeks or longer to complete.
5. Brokers are expensive.
6. Water market prices may be manipulated.
7. Time, cost, effort compared with the corresponding benefit renders the nett marginal return.

Box 15: Reasons for Low Level Participation in MDWSS

[29] Recorded Interview with Joe Moro via Zoom, 19 August 2020, 2.00 pm - 2.30 pm.

The irrigators held the view that MDWSS market pricing generally is subject to manipulation. Regardless, the water trading data analysis conclusions coincided with reported irrigator feedback that market participation would increase with more accessible and more visible water market information being available[30].

4.6 Development of the Water Ledger trading platform

Two key challenges presented during the Water Ledger's trading platform adaptation and development:

1. Current SunWater Orion information system did not capture trade price data, and
2. Validation of engineering hydraulic capacity rules for irrigation infrastructure to deliver additional water following a transfer could not be coded into a smart contract.

To solve the first challenge, the Pilot Project consulted with the MDWSS irrigators for anecdotal trade price information. On the matter of water delivery infrastructure capacity, infrastructure capacity could be addressed through a combination of engineering and technology methods e.g. digital twin, sensors, Internet of Things (IoT) or may remain as a binary incoming oracle to the smart contract should interoperability with other data sources be achieved. Further discussion on interoperability between a water market and water delivery infrastructure can be found in Part III.

4.7 Pilot Project stakeholder engagement

4.7.1 Far North Queensland Growers

The FNQ Growers (previously Mareeba-Dimbulah Fruit and Vegetable Growers) is an industry group representing growers across Far North Queensland from Lakeland north of Mareeba, south to Tully, and west to Dimbulah. Throughout the Pilot Project, Civic Ledger engaged with FNQ Growers through its President Joe Moro to gain insights into MDWSS irrigator preferences and particular requirements for a water trading platform.

Engagement with FNQ Growers included a face to face workshop at Mareeba in late June 2020 due to travel restrictions being lifted in Queensland. The workshop was well attended by MDWSS irrigators including Joe Moro and Craig Cahill, Operations Manager, SunWater's Mareeba office.

The workshop included a demonstration of the Water Ledger trading platform adapted to the MDWSS water market and involved detailed dialogue about existing water trading markets for MDWSS in comparison with the MDWSS Water Ledger trading platform. Key feedback from the MDWSS irrigators was received as a result from the workshop.

A Buyer is not readily able to locate a Seller for an intended trade.
A Seller is not readily able to locate a Buyer for an intended trade.
Options to locate a buyer or a seller include:
- Word of mouth
- Industry group awareness
- SunWater
- Brokers

Neither Buyers nor Sellers have access to reliable market information.
Brokers are perceived as expensive.
More Sellers would reportedly participate in the MDWSS water market if they could more readily do so.
Costs to trade should be met by the Buyers rather than the Sellers.

Box 16: MDWSS Irrigator Feedback on Existing Water Trading

Ease of access.
Access to real time market information including:
- Water available for transfer
- Pricing for bid to buy water or offered for sale of water
- Historical water sales information

Potential Sellers may be more inclined to list water for sale.
Ease of trade execution on workstation or on device.
Completeness of water market information.

Box 17: MDWSS Irrigator Feedback on the Water Ledger Platform

[30] Recorded Interview with Joe Moro via Zoom, 19 August 2020, 2.00 pm - 2.30 pm.

Image 2: MDWSS Irrigator Workshop, Mareeba 24 June 2020

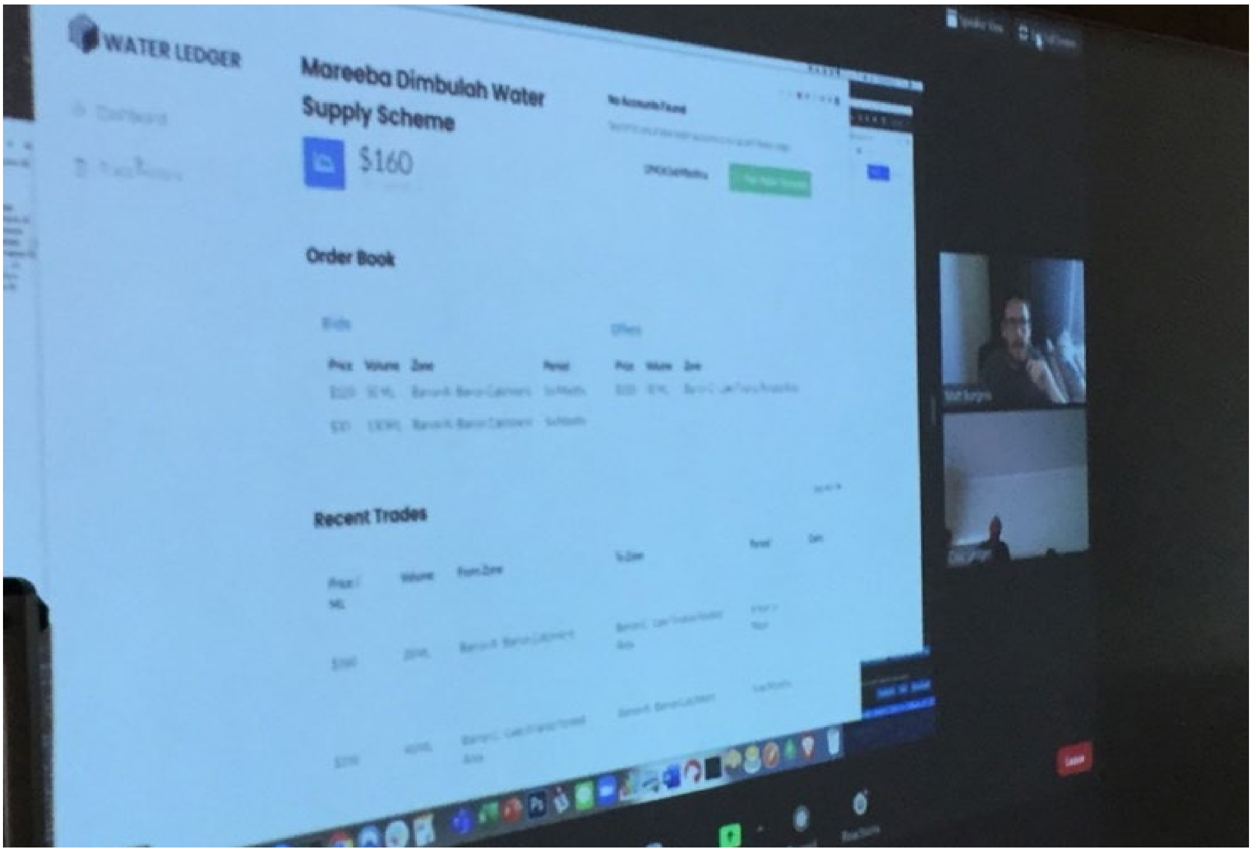


Image 3: Demonstrating Water Ledger, MDWSS Irrigator Workshop, Mareeba 24 June 2020

4.7.2 Queensland Department of Natural Resources, Mines and Energy

The QDNRME was a key stakeholder and its contribution to the Pilot Project included the regulatory framework and emergent water market policy considerations, attending all PRG meetings, and seeking out engagement with Civic Ledger when required. At all times, QDNRME remained actively engaged and supportive during the Pilot Project providing previous research and valuable insights into the status of water market operations and where some areas could be optimised going forward.

4.7.3 SunWater

As the operator of the MDWSS system, SunWater was also a stakeholder to the MDWSS Pilot Project. During the Pilot Project, Civic Ledger continually liaised with SunWater in relation to several key areas including:

- Obtaining water trading historical data,
- Mapping current MDWSS business and operating rules in relation to water trading, and
- Gaining appreciation of current MDWSS systems and process through the provision of Orion's technical architecture and business process workflows.

SunWater was very supportive of the Pilot Project and was proactive including attending all PRG meetings (Brisbane), MDWSS irrigator workshops (Mareeba), available to answer questions relating to current MDWSS systems and making available key resources to assist with the MDWSS business and operating rules. On Wednesday, 12 August 2020, Civic Ledger presented the Pilot Project to SunWater's Board and key Executives and was well received.

4.7.4 Royal Melbourne Institute of Technology Blockchain Innovation Hub

The RMIT Blockchain Innovation Hub provided valuable research into the Pilot Project through co-authoring with Civic Ledger a report looking deeper into the socio-economic and regulatory correlation between water market supply chain information and functioning water markets through the lens of blockchain technology.

This research work was completed through in-person and virtual meetings optimising various on-line platforms resulting in **Part I: Options for Reducing Trading Costs.** Civic Ledger and RMIT considered the water market governance framework from the point of view of core principles or goals of the water market in relation to using blockchain technology.

4.7.5 Griffith University

Griffith University's Information, Communication and Technology Unit at its Gold Coast campus contributed to the Pilot Project by working with Civic Ledger to explore Water Ledger's technical architecture beyond water trading and the correlation or co-dependency on other digital technologies such as IoT, sensors, AI, and digital twinning.

Like RMIT, this research work was completed through both in-person and virtual meetings resulting in **Part III: Interoperability Beyond Water Trading.** Civic Ledger and Griffith University considered three horizons including:

1. ***Horizon One***: Extending the MDWSS Water Ledger trading platform to all Water Supply Schemes operated by SunWater,
2. ***Horizon Two***: Interoperating Water Ledger trading platform with irrigation infrastructure planning referring to the Lakelands Irrigation Scheme as an example, and
3. ***Horizon Three***: Key considerations when designing Water Ledger trading platform for the emerging northern Australia water markets.

4.8 Water Ledger and the Blockchain technology

This section of the Final Report will now turn to discussing the application of blockchain technology in the development of the Water Ledger trading platform and its performance during the delivery of the Pilot Project. Specifically, three areas for discussion include:

1. What problems did the blockchain technology solve using specific example in the Pilot area?
2. What specific improvements does the Water Ledger trading platform-offer compared to current water trading platforms such as private water exchanges?
3. Are there demonstrable benefits including market liquidity attributable to the blockchain enabled platform?

4.8.1 Problems solved by the Blockchain technology

According to RMIT in their report featured in Part I, water markets are essentially problems of maintaining a ledger – under trading rules – that is a trusted source of who owns what water rights at a given time. That ledger must also be updated over time as water rights are traded. Effective water markets are underpinned by ledger rules that encourage transparency, liquidity, and trust. Today most ledgers are maintained in a centralised hierarchical way through various water supply schemes, the many registers and private exchanges and brokers. Unfortunately, ledgers of water trades are often siloed and opaque, and are inhibited by transaction costs and fees that discourage trade.

What problems did the application of a blockchain enabled platform for the trading of water rights solve in the MDWSS?

During the delivery of the Pilot Project, it was found that a blockchain enabled water market could solve three immediate problems to vastly improve the operation of the MDWSS water market:

1. Water market supply chain information,
2. Reduce barriers to trade, and
3. Market incentivisation.

As mentioned elsewhere in this Final Report, for an efficient and effective water market to operate, it is necessary that the essential ***supply chain information*** be discoverable by water market participants in real-time: ***authority***, ***ownership***, ***price***, ***volume***, and ***trade history***.

> ***Authorisation*** was solved by SunWater providing all the data to set up water accounts in Water Ledger.
> ***Ownership*** was solved by SunWater providing all the water account data with each water account having an owner ID number.
> ***Water price*** was solved by the smart contract capturing this data going forward – historical pricing data was gathered from engagement with the MDWSS irrigators.
> ***Water market volume*** was solved by the smart contract capturing volume data going forward – for the Pilot Project, SunWater provided historical volume data.
> ***Trade history*** was solved by the smart contract capturing trade history data going forward – for the Pilot Project, SunWater provided historical trade data.

Box 18: Solving the Problem of Missing Supply Chain Information

Having the right incentivisation elements in any market will increase the facilitation of trade resulting in liquidity. In the context of water markets, incentivisation can help allocate and coordinate water to its most productive and higher value uses.

4.8.2 Specific improvements in comparison to current systems

What were the ***specific improvements*** the Water Ledger trading platform offered in comparison to current water trading platforms such as private water exchanges?

As discussed above, for irrigators to have confidence in MDWSS water markets, they need access to the most important pieces of information in real time including, for example, how much available water is there to buy and for how much? The way irrigators currently access MDWSS water markets is through a mix of public state systems and registries, and private commercial systems: water brokers and exchanges.

The current mix of public and private water systems and registers contain siloed data, have different transaction times, and is stored on un-interoperable centralised information systems. Where prices of water trades are not captured in real time by either public or private systems and registers, this is a problem for MDWSS irrigators as it masks the value of water resulting in reduced confidence in market participation.

The Pilot Project designed the Water Ledger trading platform to be interoperable between government departments, authorities, and operators, including by way of multiple party direct access through API abstraction of functionality to a common and immutable water market trade ledger.

Could next generation digital platforms which are designed to be interoperable with other water market information systems reduce the water information discovery costs currently defrayed to the water market participants? Is it possible to challenge the boundaries of existing institutions including public and private information systems and registers that support the Australian water market? Could blockchain technology better facilitate mutually beneficial trade and coordination if the water market governance goals included interoperability and immutability?

4.9 Conclusion

The Pilot Project reinforces that a blockchain enabled peer to peer water market and trading platform offers the potential to create a one source of truth for water market trade ledger data. Stakeholder feedback highlights this as vitally important given the number of organisations who capture elements of the water information supply chain, often using different rules and standards.

More specifically the Pilot Project found that:

Current information systems do not adequately capture price information.
Irrigators have developed a sophisticated, but time consuming, word of mouth system to elicit price information.
The irrigator developed system of price discovery is heavily dependent upon key community authorities.
A blockchain platform can explicitly display of all buy and sell orders to all participants, and further enforces the capture of price data as no trade can take place without price disclosure – *"no price, no trade"*.

Box 19: Part II Findings

5. PART III: INTEROPERABILITY BEYOND WATER TRADING

Explore Water Ledger's technical architecture beyond water trading and correlation or co-dependency on digital technologies such as Internet of Things, sensors, AI, and digital twinning.

The Part III of the Final Report is written by Griffith University with Civic Ledger to consider three possible horizons:

1. ***Horizon One***: Extending the MDWSS Water Ledger trading platform to all Water Supply Schemes operated by SunWater,
2. ***Horizon Two***: Interoperating Water Ledger trading platform with irrigation infrastructure planning referring to the Lakelands Irrigation Scheme as an example, and
3. ***Horizon Three***: Key considerations when designing Water Ledger trading platform for the emerging northern Australia water markets and beyond.

During the delivery of the Pilot Project in MDWSS, Griffith University explored the Water Ledger trading platform's technical architecture beyond water trading and correlation or co-dependency on digital technologies such as IoT, sensors, AI, process mapping and analysis, and digital twinning. This exploration was important for the Pilot Project as the Water Ledger trading platform handles the trading of the licence to a water allocation right – not the actual transfer of the water itself. Without access to data that tracks water usage – sensors, water meters, IoT for example – the Water Ledger trading platform's account balances can only ever be a theoretical maximum, rather than a true reflection of the water account's current state.

The Water Ledger trading platform can handle the licensing issuing process in a simple single step approval, yet this functionality and specification was not developed as firstly, it was outside the Pilot Project's remit and secondly, for the licensing issuing process to execute there is a need for the differing but complementary information systems to interoperate - the Regulator which in this case is QDNRME and the Operator being SunWater.

5.1 Key components for a robust water ledger

Griffith University's detailed investigation of the blockchain enabled water trading platform piloted at the MDWSS revealed that for the water market to operate efficiently and securely five main technical areas need to be considered as shown in the figure below. These five areas are in addition to the regulatory, governance, and societal dimensions as explored in the previous section by RMIT.

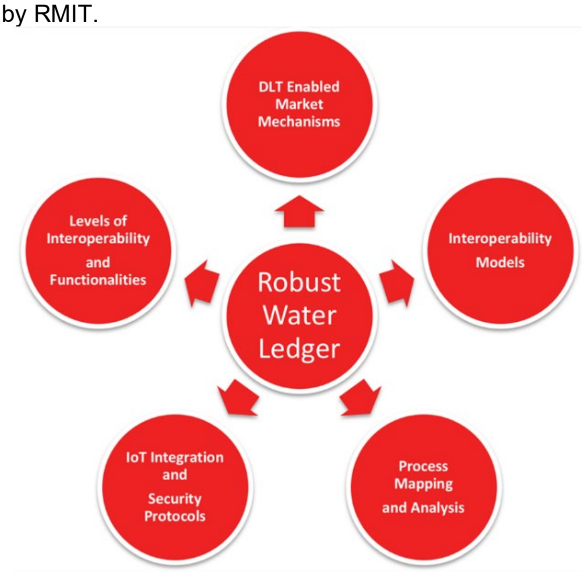


Figure 1: Key Components of Robust Water Ledger System

Blockchain enabled market mechanisms: For the efficient and effective operation of the water market it is essential to have appropriate *incentive mechanisms* designed and incorporated within to overcome critical barriers to participation. A strict definition of an incentive mechanism is something that motivates a buyer or seller to follow a course of action or to change behaviour. At its commencement, the guiding principles or "technology goals" of the Water Ledger trading platform's incentive mechanisms were threefold: ***accountability***, ***transparency***, and ***trust***.

Accountability: The goal was to maximise participation requiring users to have something approximating "perfect" water market information and in real time:

- Perfect information requires, amongst other things, access to state-controlled water trading data and broker / exchange information, and
- An effective system should also consider all factors including storage trend data, water storage and delivery, weather, seasonal agricultural trend data, etc.

Transparency: The goal was to offer a simple, intuitive user interface to increase uptake by users:

- A simpler interface, backed up by appropriate levels of information to encourage more direct trading and greater participation, and
- Improved capacity to support appropriate data transparency, transfer, and openness for third party contribution and reuse.

Trust: The goal was to increase user confidence in the operation of the water market.

The motivation to embed these technology goals as the Water Ledger trading platform was adapted to the MDWSS water market was for two reasons: one, to be a ***trusted*** and two, ***open sourced*** for water market information. At the conclusion of the Pilot Project's retrospective of the performance of the Water Ledger trading platform's technology stack, the original technology goals were revised to include:

- Interoperability through common standards,
- Consensus systems to reach an agreement,
- Confidentiality to deliver consumer confidence, and
- Security over water ownership and entitlement.

The key reason for this readjustment: ***interoperability***.

If the digitalised system is to move beyond water trading, interoperability between the authorities and registers, the brokers and exchanges must be the goal. Equally important is the ability to securely transmit data, seamlessly interface with other connected information systems, automatically execute rules when agreed conditions have been met, and publish water market information to a publicly accessible water trade ledger, whilst protecting the privacy of all stakeholders.

Interoperability models: For the efficient functioning of the digitalised system, appropriate interoperability models are to be designed and implemented.

Levels of interoperability and functionalities: When blockchain and traditional systems are interconnected and integrated, appropriate interoperability levels and the required associated functionalities can be determined. Once these parts are identified, interoperability mechanisms to support such levels and functionalities in terms of technical and conceptual aspects can be designed and implemented.

These levels of interoperability and functionalities are valuable from the point of view of water market governance: regulatory oversight, and enforcement and compliance activity. As to be discussed below, interoperability between blockchain and traditional information systems could be achieved without significant amendment of stakeholders' business requirements, practices, and processes.

Process mapping and analysis: The water market operates with complex rules and reduced transparency. To get the best efficiency and to ensure that the digitalised system operates as expected, a formal process mapping needs to be carried out. The correctness of this mapping is then needed to be analysed and verified.

IoT integration and security protocols: For the ultimate digitised Water Ledger trading platform beyond water trading, IoT devices are to be integrated with the blockchain enabled system. The data feed to and from these devices need to be securely connected to the Water Ledger trading platform which requires the selection of appropriate hardware and software modules to operate in a secure protocol environment.

To get the full-scale digitisation of a water market, IoT integration is an essential part. This may involve sensors from various locations of the supply chain, integration of sensed data and other forms of data such as metrological and field-specific information. This requires wide range of data feed options to be accommodated with suitable authentication and integrity mechanisms built in. In this case, digital twinning of water delivery infrastructure is essential so as water markets can be designed to optimise engineering considerations for the delivery of water once the trade has been authorised without the approval needing to be deferred to the water operator.

For automation, these devices also need to have appropriate built-in communication facilities. This may include a combination of wired and wireless communications. The figure below depicts a possible sequence diagram between various generic participants in blockchain-enabled water trading systems. The figure also indicates the integration point of market mechanisms to match orders, and validation process before incorporating the data on to the chain. IoT agent is shown to represent any generic device or data feed point.

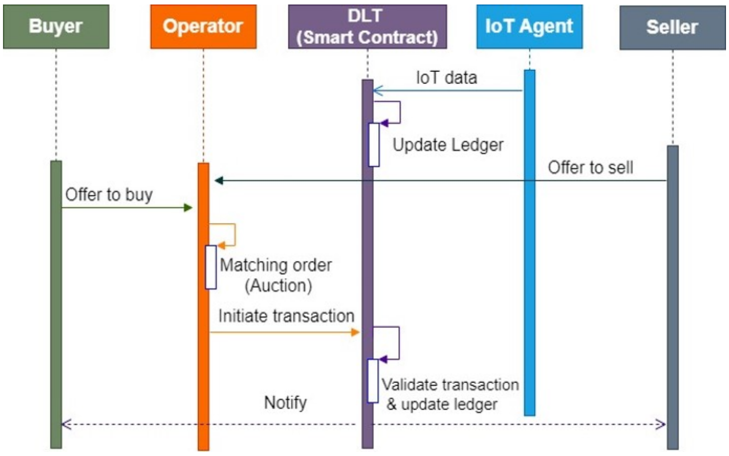


Figure 2: Sequence Diagram of Data Flow from IoT Agent, Buyer and Seller

A fully digitised water trading system – water market + delivery infrastructure – will not only gather information through IoT devices, but response from the water market can be sent back to actuators as well. This approach enables the opportunity to build a fully automated bidirectional end-to-end operational system. The IoT sensor and actuators will need to be compatible in terms of software, hardware with unified protocols architecture and security mechanisms.

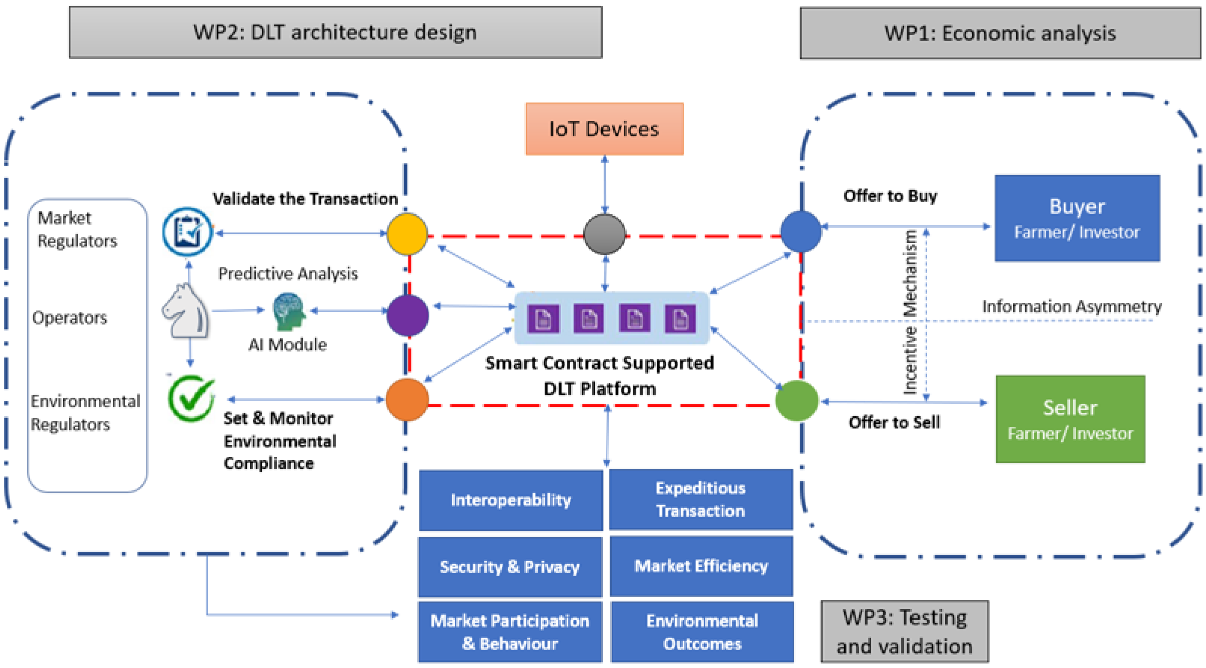


Figure 3: Overall DLT-Enabled Water Trading System and Its Interconnections

Overall, Part III has identified different components for moving beyond water trading and have grouped each for further investigation:

- ***Market participation:*** This includes Buyers, Sellers (both can be irrigators and / or investors), and Brokers. The offer to buy and offer to sell with any other related information is captured and integrated with market mechanism to determine the matching orders.

- ***IoT Integration and Security Protocols:*** This includes a wide range of sensors, actuators, and other authorised data entry points.

- ***Process mapping and analysis:*** It is important to properly capture the business processes involved in water trading ecosystem and codify them into the smart contract logic and in other components of the blockchain-enabled system. Formal testing and validating are essential due to the complexity of the rules and regulations, checking for end-to-end consistency of common data standards (customer identity for example).

- ***Interoperability:*** Interoperability within a blockchain-enabled water trading system includes technical, conceptual, and contextual aspects.

5.2 Conclusion

Different sets of data and associated business rules are capable of being codified into a rules engine ensuring consistent ways of working. When a market activity event occurs, it is possible to show that any required notifications performed are automatically reported in real time to the water market trade ledger, the Regulator, and the Scheme Operator or elsewhere as required.

The result being a simplified and automated workflow process that improves timeliness, consistency and efficiency of water trade data and market service delivery. Interoperability across different information systems reduces duplication of effort such as work arounds or the need for manual intervention by the water market and its partners – Registers, Operators, Regulators, Exchanges – offering a more granular management of water resources.

More specifically the Pilot Project found that:

Whilst the blockchain enabled water market could embed regulatory technology and programmable code into the platform to delivery an efficient and effective water market, it could not determine water account balances in real time nor could the smart contracts code the hydrological conditions necessary to approve a water trade.

it was necessary to adapt the Water Ledger trading platform to automatically notify SunWater of a pending trade ready for manual assessment and approval.

There is a need for interoperability between the water delivery infrastructure and the operation of the water market. Such interoperability would allow automated evaluation of whether the point of sale and point of purchase are hydrologically connected and whether adequate delivery capacity is available to satisfy the trade.

Stakeholder feedback also suggests that availability of delivery capacity could be expected to influence market price – prices may be expected to increase to reflect scarce delivery capacity.

Box 20: Part III Findings

6. CONCLUSIONS AND FURTHER RESEARCH

The Pilot Project suggests that a blockchain enabled water market is likely to address some of the underlying challenges of designing water market governance and institutional frameworks. Blockchain can:

Delivery a secure water market trade ledger by holding an immutable record of sensitive data of entitlements, transactions, and trade behaviour associated with water market and trading activities.

Establish peer-to-peer markets for the trading of temporary water allocations and permanent water entitlements that can be integrated with existing systems of record.

Provide curated water supply chain information that provides assurance through smart contracts that automate (to the greatest degree possible) trade activity which are enforceable to jurisdictional business and operating rules including licensing regimes in real time.

Deliver instantaneous compliance, auditing and reporting of core activities removing data silos, paper-based transactions, and human errors lowering costs of validation and verification of water trades.

Box 21: Blockchain for Designing Water Market Governance

Feedback from Pilot Project stakeholders reinforce the importance of these blockchain characteristics, with expectations that the typical time to conclude a water trade can be reduced from the current 60-90 days to less than a week. Furthermore, stakeholders also noted that these timeframes could be reduced even further through automation of regulatory approvals e.g. water delivery, and potentially simplified as regulation develops to capture the benefits of blockchain directly.

This highlights the potential for blockchain to reshape the role of government as new water markets are being planned for northern Australia. If water markets are designed from the bottom-up, rather than as an add-on or an after-the-fact adjustment, it positions governments as ***providers*** of secure public water market and trading data and orchestrate interoperable information system digital institutional infrastructure that can be reused by others – individuals, the private sector (brokers and exchanges) and government itself – with confidence.

For water markets to operate efficiently and provide equitable opportunity to participate, market participants need ***access to reliable and transparent market information*** – in real time. Stakeholder feedback highlights that the most important water information includes ***authority***, ***ownership***, ***price***, ***market volume***, and ***trade history***.

The primary source of price discoverability was identified as SunWater – the ROL holder. Data analysis found that the SunWater Orion information system did not capture the buy or sell price from 315 approved water trades (85% water trades between different accounts and 15% "zero-value" water transfers between common water accounts).

Given that the MDWSS water markets did not have water price information available, stakeholder feedback identified key community personages as a key source of price information and knowledge. For example, Joe Moro, a mango farmer in Mareeba, shared with the workshop that farmers call him because of his knowledge of MDWSS water markets and ask what price they should be buying or selling water. The Pilot Project would learn through ***feedback from MDWSS irrigators*** that the water price ranged from about AU$70 per ML to approximately AU$200 per ML. The irrigators explained there was an apparent low level of participation in the temporary water allocation markets because of the perception that MDWSS water prices may be subject to manipulation.

Central to the operation of the MDWSS water market are the business and operating rules, which were sourced through public documents including legislation and MDWSS rules. In sourcing and coding these business rules into smart contracts it became necessary to engage with both the Regulator and Operator to secure consensus on a ***common standard*** of terms and definitions particularly on what constituted a customer identity.

The Pilot Project also revealed that, whilst the blockchain enabled water market could embed regulatory technology and programmable code into the platform to deliver an efficient and effective water market, it could not determine water account balances in real time nor could the smart contracts code the hydrological conditions necessary to approve a water trade. Hence, it was necessary to adapt the Water Ledger trading platform to automatically notify SunWater of a pending trade ready for manual assessment and approval.

To gain the full benefit of blockchain and smart contracts, the Pilot Project experience suggests a need for interoperability between the water delivery infrastructure and the operation of the water market. Such interoperability would allow automated evaluation of whether the point of sale and point of purchase are hydrologically connected and whether adequate delivery capacity is available to satisfy the trade. Furthermore, stakeholder feedback also suggests that availability of delivery capacity could be expected to influence market price – prices may be expected to increase to reflect scarce delivery capacity.

Given the outcomes of the Pilot Project including its research findings, Civic Ledger considers the following as the next steps for the ongoing development and delivery of the pathway to build efficient and effective water markets in northern Australia:

	Theme	Pathways
HORIZON ONE	Interoperability with SunWater Orion Information System	Continue the development of Water Ledger in MDWSS to fully interoperate with SunWater Orion information system.
		In partnerships with SunWater rollout Water Ledger to all remaining SunWater Water Supply Schemes with a focus on northern Australia in the first instance - early discussions with Water Start, a non-for-profit that connects water technology companies that have cutting edge solutions to utilities and large water consumers, have indicated an interest in co-funding the rollout of Water Ledger.
		Engage with QDRNME and SunWater key officers to deliver a series of workshops to uplift knowledge of next generation digital technologies.
HORIZON TWO	Engagement with Key Irrigation Infrastructure Projects	Engage with RDA for Tropical North to discuss options for conducting work with the National Water Grid Authority.
		Facilitate consultations with Working Committees which have oversight on current and emerging irrigation infrastructure projects with a focus on northern Australia in the first instance e.g., Lakelands, Bradfield, and Big Rocks Weir, to introduce Water Ledger and why planning for digital infrastructure to support an efficient and effective water market is to be undertaken in parallel with the engineering aspects of the irrigation infrastructure planning.
		Deliver a series of workshops to uplift knowledge of next generation digital technologies to support the design and delivery of new water markets in northern Australia.
HORIZON THREE	Water Markets in Northern Australia	Undertake a literature review of the sixteen feasibility studies and three water resource assessments funded through the White Paper to support the design and delivery of a blockchain enabled water market.
		Seek co-funding under the CRCNA EOI Round in early 2021 with partners including but not limited to the CSIRO, the Bureau of Meteorology, James Cook University, the University of New South Wales Global Water Institute, Griffith University and RMIT.
OTHER ACTIONS	ACCC Inquiry into Murray-Darling Basin Water Markets	Civic Ledger to make a submission based on the findings from this Pilot Project to the ACCC Interim Report: Inquiry into the Murray Darling Basin Authority due 31 October 2020. The ACCC Final Report is expected to be available to the public at the end of April 2021.

Table 8: Three Horizons

Key priority actions for sector development	Action owner and key partners	Pathways to implementation and timeline	Intended industry impacts
1. Water Ledger Interoperability with SunWater Orion information System	Owner: Civic Ledger Key partners: • SunWater • QDNRME	• Establish full MDWSS Water Ledger Interoperability with SunWater Orion MDWSS system, • Water ledger platform development for wider northern Australia, and • Civic Ledger / QDNRME / SunWater program of workshops for *Rule of Code* shifting to computer reading of business and operating rules. Timeline: 0 – 12 months Commencement: Immediate future	• Establishment of integrated northern Australia water markets platform model • Increased visibility of and access to reliable northern Australia water markets data • De-risking access to critical supply chain production resource • Unlocking investment in northern Australia
2. Civic Ledger Engagement with key northern Australia Irrigation Infrastructure Projects	Owner: Civic Ledger Key partners: • North Queensland Water Infrastructure Authority • RDA for Tropical North • Big Rocks Weir • Hells Gate Dam • Bradfield • Hughenden Irrigation Scheme • Lakeland Irrigation Area	• Consultations with emerging irrigation infrastructure projects for digital infrastructure planning in parallel with engineering, • Civic Ledger and Griffith University research interoperability, IoT, digital twinning to support further development of Water Ledger, • Engagement with RDA for Tropical North re options for working with National Water Grid Authority, and • Workshops to uplift knowledge re: next generation digital technologies to support delivery of new water markets in northern Australia. Timeline: 0 to 36 months Commencement: November 2020	• Optimisation of water infrastructure design with digital technology infrastructure, • Extended interoperability of Water Ledger markets with water scheme operations, • Optimisation of Water Ledger interoperability with water industry participants, • Establishment of northern Australia water markets • Increased investment in northern Australia through market certainty, and • Water allocation to highest value production through markets liquidity.
3. Water Markets in northern Australia	Owner: Civic Ledger Key partners: • CRCNA • CSIRO • BoM • JCU • UNSWGWI • Griffith University • RMIT	• Literature review of sixteen feasibility studies and three water resources assessments funded White Paper to support design/delivery of blockchain enabled water market in northern Australia, • Seek co-funding CRCNA round early 2021 with CSIRO, BoM, JCU, UNSWGWI, Griffith University, RMIT, and Timeline: 2021 – 2022 financial year Commencement: July 2021	- Design of institutional governance and regulatory framework for water markets, and - Establishment of northern Australia blockchain enabled water markets.

Table 9: Strategic Recommendations

APPENDICES

APPENDIX A PROJECT RESEARCH OBJECTIVES

The Pilot Project's research objectives were to inform the understanding of the governance and market mechanisms for the efficient and effective functioning of water trading and the water marketplace based on a mix of conventional and next generation digital technologies including blockchain and smart contracts.

	Research Objective	Research Objective Questions
Governance	By exploring the conditions required for the successful application of blockchain technology in water trading within MDWSS, the Pilot Project considered the following key market governance questions	How can blockchain technology assist in the design of incentives for irrigators to optimise water allocation usage leading to increased agri-economic outputs and improved environmental benefits?
		From an institutional utility viewpoint, how can blockchain technology help design new regulatory and governance frameworks for emerging water markets in northern Australia (and elsewhere) to deliver reliable and symmetric revelation of information about water prices and market volume to capture the ASEAN agricultural opportunity?
Essential Information	Further, the Pilot Project's research objectives were to understand what essential information is necessary for to operate an efficient and effective water market. Some guiding questions included:	Does price and market volume transparency in near real time offered by a blockchain enabled water trading platform, lead to the optimisation of water allocation usage (liquidity)?
		Does a simplified trading process and reduced trading cost, lead to increased water market trading participation?
		Does this approach differ from current methods of water trading using intermediaries?
Theoretical Considerations	The Pilot Project's theoretical research was informed by Civic Ledger's Feasibility Report (June 2017) and then extended to explore answers to the following specific issues:	How can the market be designed to maximise incentives for irrigators to efficiently allocate water rights?
		How does a blockchain-based water rights infrastructure differ compared to existing centralised systems (e.g. organisational characteristics such as speed, potential for smart contracts)?
		What benefits does blockchain provide from the perspective of stakeholders within the water ecosystem (e.g. irrigators, operators, governments, regulators, registries, traders)?
		What are the risks of more decentralised blockchain water trading infrastructure, including integration with existing governance and market mechanisms?
		What are the strategic considerations in implementing blockchain infrastructure (e.g. choice of blockchain platform, overcoming potential market barriers)?
		What are the key design methodology and pattern considerations in blockchain-enable platform design for schemes like MDWSS, and for generic application of blockchain technology for water trading and water register maintenance across multiple water supply schemes?

	Research Objective	Research Objective Questions
		What is an optimal framework for mapping operating and business rules for a water supply scheme or region to inform development of blockchain-enabled systems for water trading functions?
Empirical Considerations	The Pilot Project's empirical research considerations extended to including a detailed case study analysis including its successes and challenges, placing these considerations within the context of the theoretical research. The Pilot Project's policy research matters included the following:	• How are legacy water trading rules (e.g. limits) affected by new blockchain-based water trading infrastructure? Are these regulations fit-for-purpose?
		• What other areas of regulation should be considered (e.g. privacy, data rights)?
		• How might blockchain-based infrastructure solve existing political problems and challenges (e.g. indigenous water access and rights)?
		• What are some export opportunities for new digital infrastructure, particularly into the ASEAN region?

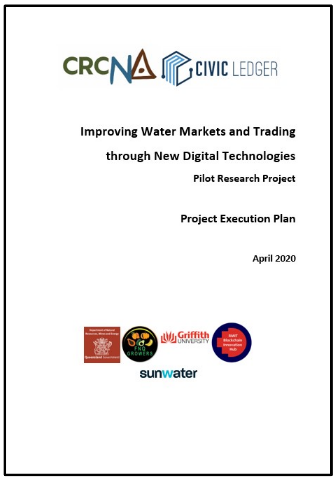
Table 10: Pilot Project Research Objectives

APPENDIX B PROJECT EXECUTION PLAN

The delivery of the Pilot Project was guided by its Pilot Project Execution Plan (PEP) prepared by Civic Ledger. The PRG comprising of Principal, Lead Participant, other Participants, and key stakeholders was formed to overview:

- Overall Pilot Project progress,
- Material issues arising,
- Significant decisions to be resolved,
- Potential changes that emerge,
- Risk issues, and
- COVID-19 issues.

Overall, the Pilot Project's progress against the PEP schedule was well maintained despite the impacts of COVID-19. Initially, COVID-19 greatly restricted interaction with many stakeholders. To overcome restrictions on meetings and travel, Civic Ledger planned and implemented a remote engagement model that proved to be quite effective in mitigating impacts. As a result, the Pilot Project was duly executed and completed in compliance with its planning, objectives, and schedule.


Improving Water Markets and Trading
through New Digital Technologies
Pilot Research Project

Project Execution Plan

April 2020

APPENDIX C PROJECT STAKEHOLDER ENGAGEMENT PLAN

COVID-19 constraints:

As of March 2020, the following limitations apply:

- Travel to perform essential work or business is possible but is being discouraged,
- Social distancing limits remain applicable, and
- Indoor gatherings limited to 2 persons.

Pilot Project Workshop Objectives:

The Project Plan includes for workshops with irrigators for the following purposes:

- Obtain irrigator inputs about preferences how to improve water trading,
- Demonstrate simulation of water trades on Water Ledger,
- Obtain feedback from irrigators about Water Ledger visual user experience,
- Obtain suggestions from irrigators about options to change the user interface, and
- Seek input from irrigators to assist with research about water trading being done by Griffith University and Royal Melbourne Institute of Technology.

Previously Planned Workshops:

Previously it was planned to have three workshops at Mareeba to involve irrigators in both Water Ledger demonstration and discussions re: the above, as well as other issues that would arise. Due to the corona virus constraints the workshops at Mareeba are not feasible.

Revised Plan for Workshops:

A revised approach involving participation by irrigators is proposed as follows:

- 4 or 5 remote sessions (Zoom or Team internet meetings),
- Specific issues designed for each remote meeting e.g.,
    - Current water trading issues and overview of Pilot Project for the first remote session
    - Demonstration of Water Ledger and feedback about visual experience for second session
- Agenda for each planned session to be sent round prior, and
- Feedback from sessions to be invited after each session.