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EVALUATION OFFICE

SYNTHESIS REVIEW

Incentive-Based Instruments for Water Management

December 2015

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PACIFIC INSTITUTE

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For this synthesis review, The Rockefeller Foundation provided financial support, the Foundation Center and its IssueLab service were involved in project and technology development, and the Pacific Institute authored the report. Pacific Institute authors included Heather Cooley, Michael Cohen, Matthew Heberger, and Heather Rippman.

Cover: Hudson River, NY. Photograph by Daniel Case.

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Chesapeake Bay, Maryland. Photograph by Bossi.

Table of Contents

Annexes

Acronyms

ARP	Acid Rain Program (US)
AWS	Alliance for Water Stewardship
BIER	Beverage Industry Environmental Roundtable
BMP	Best management practices
CAC	Command-and-control
CDP	Carbon Disclosure Project (former name)
CRP	Conservation Reserve Program (US)
DEG	German Investment and Development Corporation
EPA	Environmental Protection Agency (US)
EPRI	Electric Power Research Institute
GEF	The Global Environment Facility
GPCD	Gallons per capita daily
IID	Imperial Irrigation District (California, US)
IWS	Investment in watershed services
MAF	Million acre-feet
M&I	Municipal and industrial
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MWD	Metropolitan Water District of Southern California (California, US)
MWELO	Model Water Efficient Landscape Ordinance
NRC	National Research Council (US)
NSWDEC	New South Wales Department of Education and Communities (Australia)
NWC	National Water Commission (Australia)
PES	Payment for ecosystems services
PSAH	Programme for Hydrological Environmental Services (Mexico)
PSA	Pagos por servicios ambientales (payment for environmental services)
PWS	Payment for watershed services
RUPES	Rewarding Upland Poor for Environmental Services (Indonesia)
SBP	Socio Bosque Program (Ecuador)
SDCWA	San Diego County Water Authority
SO_2	Sulfur dioxide
SWP	State Water Project (California, US)
TMDL	Total maximum daily load
TWSTT	Transforming Water Scarcity through Trading

UCSB	University of California at Santa Barbara
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USBR	United States Bureau of Reclamation
WEF	World Economic Forum
WfW	Working for Water (South Africa)
WHO	World Health Organization
WQT	Water quality trading
WRI	World Resources Institute
WWF	World Wide Fund for Nature

Foreword

Human transformation of freshwater ecosystems is rapidly exceeding capacity required to sustain the conditions we need to survive and thrive. Water crises are already impacting people around the globe – from river basins in California and China, to the cities of São Palo and Bangkok. Under current population and growth trends, the 2030 Water Resources Group predicts global water demand will exceed available supply by 40 percent by 2030.

Humans have used, benefited from, and shaped the natural environment for the whole of human history. But what we have not done – especially in the course of industrialization and modernization – is find effective ways to integrate natural ecosystems into our economic and social systems. In response to these challenges, The Rockefeller Foundation's work focuses on incentive-based solutions that harness the importance of ecosystems as an asset for smart development, economic and social progress, and long-term resilience. In our work on agriculture and food security, climate change, energy, and fisheries, we seek new approaches to environmental care that will create incentives for the wise use of resources, and preserve their resilience. And in all of our work we place particular emphasis on the effects of these solutions on the poor or otherwise vulnerable members of society, who are most directly dependent on ecosystems to meet their basic needs and are mostly likely to bear the consequences of environmental degradation.

Freshwater crises are representative of the kind of misaligned incentives we seek to correct. Freshwater allocation and management systems often place little value on the benefits of functioning ecosystems. This, in turn, leads to a vicious cycle in which ecosystem degradation and overuse reduce future water supplies, making even more people vulnerable to water scarcity. As water crises continue to capture public attention – in January, the World Economic Forum's *Global Risk Report 2015* named water crises the number one economic risk in terms of impact – and decision makers worldwide scramble for answers, The Rockefeller Foundation is eager to help support the identification of sound solutions by synthesizing the knowledge and lessons from past and current water management interventions.

The synthesis report that follows examines several incentive-based instruments for improving freshwater management for all users, including poor and vulnerable populations and the freshwater ecosystems themselves. The report examines the economic, social, and environmental performance of three tools, which were selected because: there is growing interest in applying these instruments in a range of settings, they are clearly focused on voluntary transactions rather than sanctions or voluntary standards, they can be applied to improve water quality or quantity, and there is an existing body of literature about their implementation upon which we can build. However, one of the key findings is that these transactions are often not voluntary. The report highlights the importance of finding a fit between a community's water goals and the water management tool(s) it might choose and, perhaps most importantly, it characterizes the enabling conditions required for their effective implementation. We hope this synthesis review will serve as an entry point for those exploring opportunities to improve the management of freshwater, and will spark the development of more robust solutions to improve our management and maintenance of freshwater systems.

We hope that you will find this report useful and encourage you to explore the accompanying learning tool at freshwater.issuelab.org and to share it widely with colleagues.

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Learning from Experience – an ongoing collaboration between the Foundation Center and The Rockefeller Foundation

This synthesis review, *Incentive-based Instruments for Water Management*, is part of an ongoing collaboration between The Rockefeller Foundation and the Foundation Center, aimed at helping organizations build more effectively on each other's knowledge, lessons and experience. With financial support from The Rockefeller Foundation, the Foundation Center is engaging in synthesis reviews and the development of supportive technologies and practices that facilitate the collection, synthesis, and sharing of the sector's collective knowledge.

As part of our collaboration, we are committed to sharing all work products from these efforts as public goods. Too often, systematic and synthesis reviews result in a public report but leave future researchers having to duplicate search and selection efforts in order to further build on a synthesis. By collecting and sharing coded search results through an open repository and openly licensing all work products, we hope other researchers can more freely use and repurpose our findings.

Our goal is to contribute to better programmatic and funding strategies by enabling teams and organizations to start with a more inclusive and comprehensive understanding of what has worked, what hasn't, and why.

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Executive summary

Water is one of our most precious and valuable resources and is fundamental for maintaining human health, economic activity, and critical ecosystem functions. Yet, we can see clear signs of the overexploitation of available freshwater resources and the resultant inability to meet basic human and ecosystem needs. Already, some iconic rivers, such as the Colorado in the United States and the Yellow in China, no longer reach the sea. Groundwater withdrawals have tripled over the past 50 years, with groundwater extraction exceeding natural recharge in some areas, causing widespread depletion and declining groundwater levels. More than 660 million people lack access to an improved drinking water source, predominantly in sub-Saharan Africa and Oceania, and some 2.4 billion people lack access to basic sanitation.[1]

At the same time, the world's water quality is becoming increasingly degraded, with water pollution exacerbating the challenges posed by water scarcity. Pressure on water resources is intensifying in response to challenges such as economic and population growth, and, in turn, is having major impacts on our social, economic, and environmental well-being.

With traditional approaches to managing water having proven insufficient to address these challenges, new approaches and policies are needed. Policy makers and water managers are showing increasing interest in incentive-based instruments to reduce pressure on water resources.

In most regions, laws and regulations have been the primary policy tools employed to improve environmental outcomes. However, over the past several decades, the environmental policy "toolkit" has expanded to include incentive-based instruments that use financial means, directly or indirectly, to motivate responsible parties to reallocate water, or reduce the health and environmental risks posed by their facilities, processes, or products.

This report provides a synthesis review of a set of incentive-based instruments that have been employed to varying degrees around the world. It is part of an effort by The Rockefeller Foundation to improve understanding of both the potential of these instruments and their limitations. The report is divided into five sections. Section 1 provides an introduction to the synthesis review. Section 2 describes the research methodology. Section 3 provides background on policy instruments and detail on three incentive-based instruments – water trading, payment for ecosystem services, and water quality trading – describing the application of each, including their environmental, economic, and social performances, and the conditions needed for their implementation. Section 4 highlights the role of the private sector in implementing these instruments, and Section 5 provides a summary and conclusions.

Water trading

Water trading refers to the temporary or permanent transfer of the right to use water in exchange for some form of compensation. It is perhaps the best known and most widely used method of reallocating water. It has proven, in some cases, to be less expensive, more flexible, and less time-consuming than

[1] An "improved" drinking-water source is one that, by nature of its construction and when properly used, adequately protects the source from outside contamination, particularly fecal matter.

developing new water supplies through, for example, constructing new diversion structures or desalination plants. Similarly, water trading is generally a more accepted method of reallocating water than state appropriation or revoking of existing water rights. Today, examples of successful water trading in Australia and other locations – combined with classic economic theory which suggests that market mechanisms can optimize resource allocation – have heightened interest in this instrument in both academic literature and popular media.

Water trading occurs within sectors, from agriculture-to-agriculture and urban-to-urban, across sectors and, less frequently, from either of these to the environment. Water trading exists, to varying degrees, in countries around the world, though the most active water trading markets are in Australia and the western United States. In Australia, the total value of water trading in fiscal year 2012–13 exceeded $1.4 billion, with much of that activity concentrated within the Murray-Darling Basin. While the total volume of water traded via long-term trades within the Murray-Darling Basin decreased slightly in fiscal year 2012–2013, the volume of water traded via short-term trades increased by 44 percent from the previous year, from almost 3.5 to 5.0 million acre-feet (MAF), or about 50 percent of the total surface water use in the basin.[2] In the western United States, where the scale of water trading is considerably lower, there were more than 4,000 water trades between 1987 and 2008. In 2011, the most recent year for which data are available, more than 1.4 MAF of water were traded in California, representing about 4 percent of the total water use that year. Of that amount, 42 percent of the water traded went to municipal and industrial users, 37 percent to agricultural users, 17 percent was used for environmental purposes, and the remainder was for mixed uses.

The actual results of water trading worldwide have been decidedly mixed, due to two key challenges: externalities and transaction costs. In Australia's Murray-Darling Basin, the federal government overcame some of those challenges by investing more than $3 billion to purchase water for the environment, protecting ecological resources and directly addressing one of the major challenges to water trading. This has facilitated trading in the basin and reduced transaction costs by shifting them to national taxpayers. Over the last 30 years, the federal government also implemented significant institutional changes that facilitated trading and reduced transaction costs. Short-term water trading within irrigation districts in the United States, such as within the Northern Colorado Water Conservancy District, occurs smoothly and quickly because intra-district trades undergo very limited oversight, and because the third-party impacts of such trades tend to be small or negligible.

However, these examples of successful water trading regimes are countered by critical arguments and examples of less-successful trades from various parts of the world. Many authors challenge the applicability and efficacy of water trading, contending that externalities and the unique characteristics of water itself pose significant obstacles to trading water. Many of these externalities arise from the physical properties of water: it is heavy, unwieldy, and easily contaminated; varies seasonally and from year to year; and is readily lost through evaporation, seepage, or runoff. Further, externalities may be borne by disparate parties, such as the environment or future generations, challenging efforts to compensate those injured by trading. Questions of externalities, commodification, and the special nature of water

2 An acre-foot, the conventional unit of water measurement in the western United States, is equivalent to 325,851 gallons or 1,233.48 m^3.

itself highlight the challenges faced when seeking to implement or expand water trading. Critics also highlight the many examples of "buy-and-dry" water trades, where water-rich agricultural areas sell their water rights, often to wealthier cities, only to find that rural communities as a whole suffer when agricultural production declines. Critics have pointed to examples around the world where wealthy communities or interests have purchased and withdrawn water from less powerful, poor rural areas.

The environmental performance of water trading has been highly variable, depending on the type of trade and site-specific conditions. Water trading has been used as a mechanism to obtain water for ecological purposes, to augment streamflow, and to address water quality concerns (such as temperature) in threatened reaches. The benefits of voluntary, incentive-based water acquisition include ease of transaction and greater community support, especially relative to regulatory takings,[3] though in most areas, such activity still represents a tiny fraction of total water use in any given area. In California, in the last three decades, environmental water purchases averaged 152,000 acre-feet per year, accounting for about 14 percent of trading activity and less than 0.5 percent of total water use in the state. Conversely, water trades for other purposes can inadvertently harm the environment. They can, for example, change the timing, quantity, and quality of return flows, adversely affecting riparian and wetland habitats and the species that depend upon them.

Water trading has rarely been employed to address equity challenges. Indeed, water trading can exacerbate social and economic inequalities, worsening gender and geographic differences. Unequal access to water markets due to unequal access to information or credit can distort outcomes and reduce market efficiency. On the other hand, water trading that promotes water-use efficiency rather than fallowing of agricultural land can improve socio-economic outcomes for both the area of origin and the destination. Water trading's social impacts vary based on several factors, including the relative economic health of the area of origin and the purchasing area, whether or not the water leaves the area of origin, the process used to trade the water, the relative economic and political power of the parties, gender differences regarding access to and control of water, the amount of trading activity in the area, and the legitimacy of the water rights being traded. Impacts often vary within the same community, as those with water rights or allocations to trade receive compensation, while third parties – such as irrigation equipment suppliers or farmworkers – may suffer a loss of revenue or income as a result of trading.

Institutional arrangements are among the most important factors that determine the ultimate success or failure of water trading. Successful water trading requires secure and flexible water rights that recognize and protect users and others from externalities. Such institutional arrangements also need to be flexible enough to adapt to changing physical conditions as well as changing social norms, such as the growing interest in meeting environmental needs and protecting water quality. Some factors, such as access to timely information about water available to trade, can enable water trading but may not be required. Other factors, such as legal and transferable rights to use water, may be necessary for water trading to occur. Still other factors, such as "no injury" regulations and "area of origin" protection, limit water trading or can function as barriers or obstacles to trading.

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3 A "regulatory taking" occurs when a government regulation limits or infringes upon a private property right to such an extent that it deprives the owner of some or all of the value of that property" (Fischel, 1995).

In a limited number of areas with the necessary legal and technical conditions and with sufficient public investment, water trading has offered a timely, relatively inexpensive, and flexible mechanism to reallocate water between users, or from water users back to the environment. Building a successful water market requires decades of determined effort to measure water flows and use, report transactions publicly, conduct regional water planning, and construct and maintain infrastructure to convey water. In Australia's case, it also required more than $3 billion of public funding to acquire water for environmental purposes, which also called for creating and, in turn, maintaining an environmental baseline above which trading activity could occur. Such significant institutional changes require broad public support and a considerable amount of time to implement. Although water trading can be used to reallocate water effectively, successful implementation requires a clear understanding of existing conditions and a determined, long-term effort to make the necessary changes and minimize externalities.

Payment for ecosystem services

Payment for ecosystem services is an incentive-based instrument that seeks to monetize the external, non-market values of environmental services – such as removal of pollutants and regulation of precipitation events – that can then be used as financial incentives for local actors to provide such services. In practical terms, they involve a series of payments to a land or resource manager in exchange for a guaranteed flow of environmental services. Payments are made to the environmental service provider by the beneficiary of those services, e.g. an individual, a community, a company, or a government. In essence, it is based on a beneficiary-pays principle, as opposed to a polluter-pays principle.

Payments for ecosystems services (PESs) that focus on watershed services, commonly referred to as "payments for watershed services" (PWSs), can take a variety of forms. They may be intended to prevent the degradation of a watershed or to restore a previously degraded one. They may be small, local schemes covering several hundred hectares or large, national schemes covering millions of hectares. Programs may be financed directly by the beneficiary or by third parties acting on behalf of the beneficiary, e.g. governments or institutions, or some combination thereof. They may involve cash or in-kind payments to be paid all at once or periodically.

New York City provides a well-known example. In the late 1990s, New York City was faced with the prospect of building a $4–$6 billion filtration plant with an additional $250 million in annual operating costs to meet new federal drinking water standards. An initial analysis suggested that preserving the upstream rural Catskill watershed would be far less expensive. The city and local farmers came together to develop a plan that could meet both groups' interests. A key element of the plan was the Whole Farm Program, a voluntary effort fully funded by New York City's Department of Environmental Protection whereby farmers would work with technical advisors to custom design pollution control measures to meet an environmental objective while also improving the viability of their farming businesses. By 2006, the city had spent or committed between $1.4 billion and $1.5 billion in watershed protection projects, averaging $167 million in expenditures per year – far less than building a water filtration plant. Participation remains high, with 96 percent of large farms in the watershed participating in the program.

Payments for watershed services are gaining prominence and have been applied in a wide range of settings. Some of the earliest programs were established in Central America but today, such programs can be found in countries around the world. The United States' Conservation Reserve Program pays farmers to take land out of production in order to protect soil and water resources and wildlife habitat. In northeastern France, Vittel-Nestle Waters paid farmers and provided technical support (and some labor) to alter local dairy farming practices in order to reduce nitrate pollution of groundwater – the source of Vittel's bottled water.

The largest PWS programs are in China. China's Sloping Land Conversion Programme, piloted in 1999 and fully implemented in 2002, requires farmers to set aside erosion-prone farmland within critical areas of the watershed of the Yangtze and Yellow Rivers – the two largest rivers in China. In exchange, farmers receive regular cash payments and grain rations. The program promotes forestry and other economic endeavors on the land rather than grain production, in order to prevent sediment from washing into rivers and clogging dams and shipping channels.

The environmental performance of PWS is not well understood. Evaluation of these programs is inherently difficult because the connections between land use practice and watershed services are not always clear, especially as they relate to water quantity, and they are often site-specific. It can also be difficult to attribute change to the program rather than to external factors (e.g. changing commodity prices), and programs may not reach threshold levels for measureable impact, or that impact may occur over a relatively long time period. In addition to these challenges, many programs lack baseline data or monitoring systems. In the absence of scientific information, performance is often based on perceptions of local populations and those operating the schemes. But even based on these sources, the available data suggest that environmental performance of PWS is mixed, with less than 60 percent of programs reaching their environmental objective. As the field has matured, it has increased emphasis on monitoring, which will inevitably help improve environmental outcomes.

Similarly, limited data are available on the social and economic impacts of payments for watershed services. Most studies have focused on increased income or capacity building rather than broader social impacts, such as changes in power dynamics. While participation in a PWS program can boost the income of small farmers, the payments they receive will typically boost their annual incomes only slightly. Several studies have also suggested that there are important non-financial (or non-income) benefits, such as increasing land-tenure security, creating human and social capital through internal organization, and improving the visibility of the community to donors and public entities. Some analysts have argued that because the programs are mostly voluntary, continued participation provides some indication that the programs are cost effective, i.e. that benefits exceed costs and participants are satisfied with the outcomes.

While information on broader social outcomes is limited, there is information on the role of these arrangements in alleviating poverty. However, it is important to recognize that payment for watershed services was conceptualized as a mechanism to improve the efficiency of natural resource management, not as a mechanism to reduce poverty. Several studies have examined the socio-economic status of participants, either as buyers or sellers, and have found mixed results, depending to some extent on land and forest tenure regimes and socio-economic conditions in the targeted areas. While most programs prioritize areas critical for ecosystem services, some have been tailored to meet social objectives through a variety of mechanisms, such as targeting the programs to particular areas or populations, reducing transaction costs, and providing pro-poor premiums and subsidies. While there are often more direct ways of reducing poverty than payments for watershed services (e.g. education or health programs), there is little evidence of these schemes actually doing any harm. Few studies have examined gender representation among program participants.

In general, payments for watershed services are flexible, and the necessary conditions are relatively modest. Small, self-organized schemes between private entities are based on general legal requirements: a legal system recognizing that agreements must be kept and that civil law must provide the contracting parties with legal remedies in case of non-compliance. Expanding these projects to address regional or national water problems would require a more developed policy and legal framework along with incentives or requirements to participate in PES programs, cultural and political acceptance of markets, trust between ecosystem service providers and beneficiaries, and a supply and demand for ecosystem services.

Water quality trading

Water quality trading (WQT) is an incentive-based approach for reducing or controlling water pollution. Under such a system, polluters are granted a permit to pollute, and these permits can be bought and sold among polluters. The central idea is that trading puts a price on pollution, encouraging cost savings, efficiency, and innovation. Water quality trading is an adjunct to regulation, not an alternative to it. In fact, its success depends on the presence of a strong regulatory body to enforce water quality standards, and monitor and enforce discharge limits.

Water quality markets have drawn inspiration from the success of the Acid Rain Program (ARP) established in the United States in the 1990s. The popularity of emissions trading for dealing with water pollution in the United States is largely a result of the Clean Water Act of 1972, which made it difficult for governments to handle pollution from farms. Water quality markets have been established in the United States, Canada, Australia, and New Zealand. There is also interest in China and Europe, although no programs are currently in place. To date, most water quality trading markets have been used to control pollution from nutrients that cause excessive algal growth and low dissolved oxygen levels in water bodies, a process referred to as “eutrophication”. Other water quality trading programs have been set up to control salinity, heavy metal, sediment, and temperature or thermal pollution.

The largest WQT market in the United States in terms of transactions, the Connecticut Nitrogen Credit Exchange Program, was created in 2002 to reduce nitrogen pollution that came into Long Island Sound from the Connecticut River. Under the program, which covers 79 sewage treatment plants in the state of Connecticut, a plant can control pollution in excess of its permit requirement and sell excess nitrogen allowances to those plants that exceed their allowances. A 2012 review of the program found that in ten years, the program had helped reduce nitrogen pollution by over 50 percent while controlling costs.

One of the best examples of a successful water quality trading market is on Australia’s Hunter River, where coal mines and other pollution sources are subject to discharge limits to protect water quality and drinking water sources in downstream cities. Under this system, limited discharge is allowed, but permitted dischargers must coordinate their activities so that the total salt concentration in the river never goes above a specified limit. Industries can buy and sell salt credits in real time via a trading website run by the state government. Several years after it began, the trading program remains popular among participants and functions smoothly. Perhaps the biggest marker of the program's success is that, even though new and potentially high-polluting mines have been established, river water quality has met standards nearly 100 percent of the time.

Despite the fact that water quality trading markets have existed for three decades in some areas, it is difficult to determine whether the approach can be considered an overall success. Many of the domestic WQT markets in the United States have not lived up to expectations, seeing few trades or no trades at all. This can be explained by a number of factors: high transaction costs, lack of trust, uncertainty about the future of the market, or simply unfamiliarity and unwillingness to participate. However, paradoxically, despite a lack of trading, the process of creating the market may have contributed to better watershed management. Bringing stakeholders together around a common goal of improving water quality has helped lower resistance to new, more stringent water quality regulations.

In other cases, discussion of the use of "market fundamentals" helped convince some political conservatives to implement a form of environmental regulation, paving the way for improved water quality. A common argument in favor of environmental markets is that they will be smaller, simpler, and lower cost, because they aim to replace regulation with a free market. However, water quality markets require a strong and capable regulatory ability to set a cap on pollutants, to monitor pollution, and to verify the legitimacy of water quality credits that are created. Ironically, this often results in the creation of additional layers of government to perform these functions.

WQT markets are valuable where large price asymmetries exist in water pollution control, and where certain polluters are beyond the reach of a regulatory agency. This is the case in the United States, where states are responsible for preserving water quality but have little authority over agriculture and some other nonpoint sources. On one hand, this has decreased the burden on municipal and industrial sources of pollution, allowing them to save on the cost of installing expensive treatment technologies. On the other hand, it has compelled them to fund projects on farms, often hundreds of miles away. We conclude that water quality trading is not a panacea for solving water pollution problems. However, it can be part of an effective regulatory approach under certain conditions.

Conclusions

In this report, we analyze the potential for incentive-based instruments to reduce pressure on water resources. To date, the primary environmental policy tools to address water challenges have been command-and-control regulations. However, over the past several decades, the environmental policy "toolkit" has expanded to include a host of incentive-based instruments that use financial means, directly or indirectly, to motivate responsible parties to reduce the health and environmental risks posed by their facilities, processes, or products.

While regulations and incentive-based instruments are frequently juxtaposed, they also frequently operate alongside one another. With water quality trading, for example, governments mandate caps on the allowable pollutant levels and issue tradable permits that allow industry groups to allocate polluting activities among themselves, governed by market forces. Similarly, with water trading, governments may allocate water and then institute a framework within which water trading can occur. While incentive-based instruments may work in tandem, they must be integrated within a broader watershed management effort.

Decisions about whether and how to apply a particular instrument depend on the specific objectives, circumstances, conditions, and needs of a given area. These decisions should be based on an open and transparent process, with meaningful participation from all affected parties. This approach will help in crafting a solution that is appropriate for local conditions, and ensure that it is fair and equitable. It will also help to reduce opposition and promote acceptance from those who will be implementing and affected by the program. It is important to recognize that those with the least power may not have the resources to participate, or they may be skeptical of the groups involved. In these cases, there is a need for consistent and rigorous outreach and, potentially, for engaging a trusted intermediary.

Finally, monitoring and evaluation are essential to the success of any instrument. In particular, monitoring and evaluation help ensure outcomes are achieved and allow for adjustments in response to changing social, economic, or environmental conditions. Monitoring should evaluate the "additionality" of the program, i.e. whether the program has an effect when compared with some baseline. It should also examine any potential impacts on surrounding areas (i.e. leakage) and the permanence of the intervention. However, extensive monitoring requirements would increase transaction costs, potentially threatening the viability of the program. Thus, the need for monitoring and evaluation must be balanced with practical considerations of the ability to maintain the viability of the program.

Limari River, Chile. Photograph by Eduardo Robles.

1

Introduction

Water is one of our most precious and valuable resources and is fundamental for maintaining human health, agricultural production, and economic activity as well as critical ecosystem functions. Even as the planet's endowment of water is expected to remain constant, human appropriation of fresh water, already at 50 percent by some measures (Postel *et al.,* 1996), is expected to increase further (Leflaive *et al.,* 2012). We can already see clear signs of the overexploitation of available freshwater resources. For example, some iconic rivers, including the Colorado River in the United States and the Yellow River in China, no longer reach the sea. Groundwater withdrawals have tripled over the past 50 years (UN, 2012), and in some areas, groundwater extraction exceeds natural recharge, causing widespread depletion and declining groundwater levels (Wada *et al.,* 2010; Famiglietti, 2014). Pressures on water resources are likely to worsen in response to continued economic and population growth, climate change, and other challenges. Water pollution exacerbates the challenges posed by water scarcity as the world's water quality is increasingly becoming degraded.

Growing pressures on the availability and quality of water resources have major impacts on our social, economic, and environmental well-being. The failure to provide safe drinking water and adequate sanitation services to all people is perhaps the greatest development failure of the twentieth century. Improving access to water and sanitation has been a key focus of the global development agenda since 2000. Water and sanitation were goals of the 2000–2015 Millennium Development Goals, and now, the Sustainable Development Goals launched in September 2015, also call for insuring access to water and sanitation for all.

"…more than 660 million people still lack access to an improved drinking water source…"

Yet, despite nearly two decades of international attention and tens of billions of dollars invested, more than 660 million people still lack access to improved drinking water, predominantly in sub-Saharan Africa and Oceania, and some 2.4 billion people lack access to basic sanitation (WHO and UNICEF, 2015).[4,5] In even the wealthiest countries, access to water and sanitation

4 Improved water sources include household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collections. Unimproved water sources are unprotected wells, unprotected springs, vendor-provided water, bottled water (unless water for other uses is available from an improved source), and tanker truck-provided water.

5 Improved sanitation includes connection to public sewers, connection to septic systems, pour-flush latrines, simple pit latrines, and ventilated improved pit latrines. Service or bucket latrines (where excreta is manually removed), public latrines and open latrines are not considered improved sanitation.

is not universal. A 2011 UN report (de Albuquerque, 2011) highlighted several areas of the United States, including California, where marginalized populations (e.g. those living in poverty, communities of color, and indigenous groups) lacked the basic rights to water and sanitation. Moreover, access to an improved water source does not necessarily mean that the water is affordable or safe to drink. For example, naturally occurring arsenic pollution in groundwater affects nearly 140 million people in 70 countries (United Nations, 2009).

Freshwater ecosystems are among the most extensively altered systems on earth. Rivers, streams, and lakes have been subjected to chemical, physical, and biological alteration as a result of large-scale water diversions, introduction of invasive species, overharvesting, pollution, and climate change (Carpenter *et al.,* 2011). As a result, an estimated 20 to 35 percent of freshwater fish are vulnerable or endangered (Cosgrove and Rijsberman, 2000). Likewise, about half of the world's wetlands have been lost since 1900, and much of the remaining wetlands are degraded (Zedler and Kercher, 2005). Freshwater ecosystem conditions are likely to continue to decline unless action is taken to address acute threats and better manage freshwater resources.

Traditional approaches to managing water supply and demand are not going to be effective in addressing these challenges. Throughout much of the twentieth century, the emphasis was on developing massive dams and pumping ever increasing amounts of groundwater to satisfy rising water demands. This approach, as noted by Sharma and Vairavamoorthy (2009), "has led to over-use of the resources, over-capitalisation, pollution and other problems of varying severity." The soft path for water has emerged as a promising alternative. The term "soft energy path", coined by Amory Lovins (1977) of the Rocky Mountain Institute, described an alternative path for energy development that emphasized energy efficiency and promoted smaller, decentralized energy systems fueled by renewable sources. The soft path for water, as described by Peter H. Gleick (2002, 2003), is based on integrating several key principles, including improving the overall productivity of water use, matching water quality to users' needs, prioritizing basic human and ecosystem water needs, and seeking meaningful local and community engagement in water management.

A key element of the soft path for water is shifting from a near exclusive supply-side orientation to one that seeks to manage water demand. Numerous studies have found significant opportunities to reduce water demand in all sectors using a variety of conservation and efficiency measures (e.g. Gleick *et al.,* 2003; Cohen *et al.,* 2013; Heberger *et al.,* 2014). These measures can be applied in countries at varying levels of economic development, although the types of measures employed and implementation strategies may differ (Sharma and Vairavamoorthy, 2009). Brooks (2006) argued that demand management is more than a set of techniques; rather, it is a governance approach linked to equity, environmental protection, and public engagement goals. Additional information on demand management can be found in Annex 1.

"...the environmental policy "toolkit" has expanded to include "incentive-based" instruments..."

New policy tools are also needed. In most places, regulations have been the primary tool employed to improve environmental outcomes. However, over the past several decades, the environmental policy "toolkit" has expanded to include "incentive-based" instruments. Incentive-based instruments use financial means, directly or indirectly, to motivate responsible parties to reallocate water or reduce the health and environmental risks posed by their facilities, processes, or products. These instruments have emerged for several reasons, but mainly because they are believed to be more cost effective than regulations, as they provide greater flexibility for the individual or firm to meet the environmental objective in the least costly manner. Incentive-based instruments are also thought to lower administrative costs and promote innovation by rewarding those who exceed their targets (Harrington and Morgenstern, 2004). Furthermore, Koplow (2004) suggests that these instruments can support self-enforcement by creating "groups of firms and individuals with vested interests in the proper use of resources and in emitting only as much pollution as allowed."

This report provides a synthesis review of a set of incentive-based instruments that have been employed in varying degrees around the world to reduce pressure on water resources. It is part of an effort to understand the full potential, and limitations, of these instruments in managing both the quantity and quality of freshwater. We have divided this review into five sections. This Section 1 introduces the synthesis review. Section 2 describes the research methodology. Section 3 provides background on policy instruments and detail on three incentive-based instruments that have been used in the United States and abroad – water trading, payment for ecosystem services, and water quality trading. For each instrument, we describe its application, its environmental, economic, and social performance, and the conditions needed for its implementation. Section 4 highlights the role of the private sector in implementing these instruments, and Section 5 provides a summary and conclusions.

Colorado River, Texas. Photograph by Leaflet.

2

Research methodology

The freshwater synthesis review is based on a five-step approach to making better use of existing evaluative knowledge. This approach, modeled by The Rockefeller Foundation to help inform its investment and programmatic decisions, has already been used in a review of success factors in small-scale coastal fisheries management in developing countries (The Rockefeller Foundation, 2013). Throughout the project, the project team held bi-weekly calls with The Rockefeller Foundation to review progress on the project, discuss key findings, and dive into specific case studies that could further support learning. The following steps were taken.

1. **Refine project scope.** The first step was to work with the Foundation Center and The Rockefeller Foundation to refine the scope of work and develop research questions.
2. **Undertake literature search and review.** The second step was to review the peer-reviewed literature and law reviews on the key topics for the research. We supplemented this formal literature search with a review of the gray literature, including government and other institutional reports, from organizations working to evaluate or implement these instruments. To identify the relevant literature, we used Web of Science (formerly Web of Knowledge) Internet-based search engines, and institutional website search engines. The literature on these incentive-based instruments is extensive. For example, a Google Scholar search of "water trading" returned nearly 1 million results. Given the need to review a large amount of information in a relatively short time, we prioritized articles published since 2000. We further refined our study by limiting our scope to articles and reports on the state of practice, rather than the state of theory. In total, we reviewed approximately 500 articles and reports.
3. **Conduct expert interviews.** The third step was to obtain the knowledge of experts working to address the study's key questions. It was designed to fill in any gaps in the literature. We developed the interview list based on the academic and grey literature search and from the research team's experience in the sector.
4. **Compile initial analysis and synthesis.** The fourth step included an initial analysis and synthesis of the knowledge gained from the first three steps, which was compiled into a detailed presentation and supporting materials, and formally presented to the Foundation Center and The Rockefeller Foundation Team in an interactive discussion in March 2015. The Rockefeller Foundation also reviewed the draft report in July 2015, providing additional input on the synthesis.
5. **Conduct further analysis and develop final knowledge product.** The fifth step was to conduct further analysis of the published and expert knowledge based on the discussions with the Foundation Center, The Rockefeller Foundation, and other parties. We worked closely with the Foundation Center to develop the final knowledge products, including this summary report and online components, such as a visualization of key findings and a public collection of cited research. All of the knowledge products are openly licensed and free to be used and repurposed.

Murray River, Australia. Photograph by Mattinbgn.

3

Environmental policy instruments

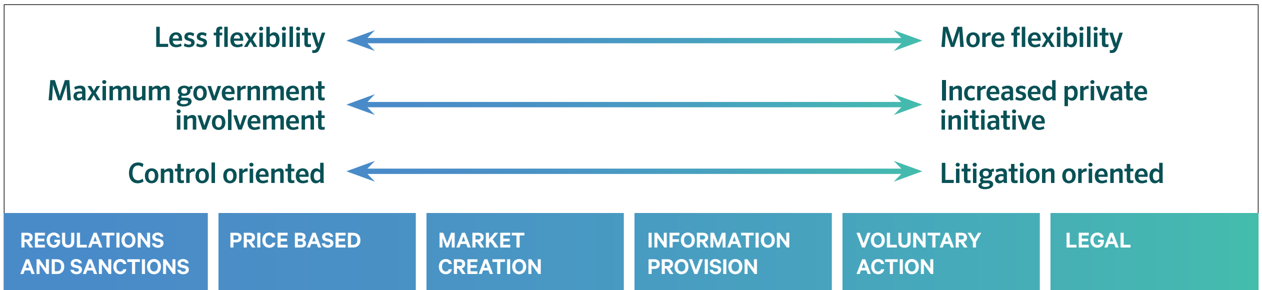
The objective of environmental policy is "to modify, slow, or stop resource extraction; to reduce or eliminate emissions of concern; and to shift consumption and production patterns towards greater sustainability" (Koplow, 2004). In most places, regulations have traditionally been the primary environmental policy instrument employed to achieve environmental outcomes. This approach, often referred to as command-and-control (CAC), relies on some governmental or similar body to establish a standard or target (the "command") that must then be complied with to avoid negative sanctions, such as fines or prosecution (the "control").

Over the past several decades, the environmental policy "toolkit" has expanded to include incentive-based instruments, also referred to as economic instruments or market-based instruments. While definitions vary, we use the term "incentive-based instruments" to refer to a set of tools that use financial means, directly or indirectly, to motivate responsible parties to reallocate water or reduce the health and environmental risks posed by their facilities, processes, or products. While CAC and incentive-based instruments are often juxtaposed with one another, a United Nations Environment Programme (UNEP) report (Koplow, 2004) noted that "in reality the two often operate alongside each other. Governments may, for example, mandate caps on allowable pollution for a region or country and use market-oriented approaches such as tradable permits to allocate the allowable emissions in an efficient manner."

Figure 1 provides a depiction of the range of environmental policy instruments currently applied around the world. These include the following.

- **Regulations and sanctions** – mechanisms that rely on guidelines, permits, or licenses, and often include a legal or financial penalty for non-compliance. Examples include pollution standards, water use quotes, and building standards.
- **Price-based instruments** – mechanisms that impose i) higher costs through fees, charges, or taxes on pollution or the use of a natural resource, making them more expensive and discouraging their production or consumption, or ii) lower costs through the use of subsidies for environmentally friendly activities or products. Examples include abstraction fees, pollution charges, grants, low-interest loans, and favorable tax treatment.
- **Market creation** – mechanisms that include i) tradable permits whereby user or polluter rights are assigned according to desirable use levels or historical practices, and compliance can be achieved by trade, or ii) deposit refund systems that create a market to buy back inefficient or polluting products. Examples include water trading and water quality trading.
- **Information provision** – mechanisms that use the provision and disclosure of information on environmental performance to incentivize producers to reduce their water use or emissions of pollutants,

FIGURE 1. Incentive-based policy instruments



WATER MANAGEMENT EXAMPLES:

Regulations and sanctions	Price based	Market creation	Information provision	Voluntary action	Legal
Pollution standards	Cost recovery tariffs	Water quality trading	Eco-labels	UN CEO Water Mandate	Criminal penalties
Water use quotas	Pollution taxes	Water trading	Corporate reporting	AWS International Water Stewardship Standard	Performance bonds
Building codes	Payment for watershed services		Environmental certification		Civil liability statutes

Source: adapted from Huber *et al.*, 1998; UNEP, 2009.

or to incentivize consumers to select products with superior performance. Examples include corporate reporting, product labeling (e.g. WaterSense),[6] and environmental certification schemes.

- **Voluntary action** – mechanisms that use voluntary agreements between the government and private firms and/or commitments made independent of government requirement. Examples include the UN CEO Water Mandate and the Alliance for Water Stewardship's International Water Stewardship Standard.
- **Legal instruments** – mechanisms for compensating victims when pollution causes human or environmental harm, and encouraging compliance with existing environmental regulations. Examples include criminal penalties, civil liability statutes, and performance bonds.

[6] WaterSense is an environmental program designed to encourage water efficiency in the US, through use of a special label on consumer products.

As shown in Figure 1, these instruments exist along a continuum, from "very strict command approaches to decentralized approaches that rely more on market or legal mechanisms" (Huber *et al.*, 1998). As noted, there are varying definitions of incentive-based instruments and the types of tools that would qualify. All definitions identify price-based instruments and market creation as incentive-based instruments. Some, however, use a broader definition that includes information provision, voluntary action, and liability instruments (see, e.g. Stavins, 2001; UNEP, 2001; Anderson, 2004). Product labeling schemes, such as the United States' "Energy Star" or Thailand's "Green Label", allow companies meeting environmental standards to place a recognized label on their product, boosting sales by making the product more appealing to consumers and providing a financial incentive to improve environmental performance (Stavins, 2001). These products may also be sold at a higher price than less environmentally-friendly models. Likewise, voluntary programs may reward meeting environmental outcomes with, e.g. public recognition which, in turn, increases sales.

The application and market activity of these instruments are not well understood. Several organizations track the application of some of these incentive-based instruments (IIED, 2015 and Forest Trends, 2015a).[7] However, there is no comprehensive list of the programs that have been implemented globally. Additionally, programs are sometimes poorly defined, fall into multiple categories, or change over time. Moreover, data on the activity of these instruments, including the number and value of transactions, are not collected or made available publicly. Despite these challenges, Forest Trends has been tracking the activity of five market and market-like instruments for watershed investments for several years.[8] It estimates that the market activity of watershed investments was $12.3 billion in 2013 (Table 1). The majority of this activity ($11.6 billion, or 94 percent) was associated with payment for watershed services, and 98 percent of that activity was in China. Collective action funds – which pool contributions from multiple investors to support coordinated interventions within a watershed – had the second highest transaction value at $563 million. We note, however, that the distinction between payment for watershed and collective action programs is sometimes unclear.[9] The market activity of instream buybacks – programs that purchase or lease water to augment instream flows – was considerably less ($97 million), followed by water quality trading ($22 million), and voluntary compensation ($320,000). It is of note that instream buybacks likely represent a modest fraction of the market activity of water trading programs, although comprehensive data on the latter are not readily available.[10] While the data suggest a rapid expansion in the application of these instruments since 2008, Ecosystem Marketplace's Genevieve Bennett (personal communication, 2015) noted that much of the increase is actually an outcome of better reporting.

7 See, for example, Watershed Markets (watershedmarkets.org), maintained by the London-based International Institute for Environment and Development, and Watershed Connect (watershedconnect.com), an online platform maintained by the Washington, D.C.-based Forest Trends.

8 Forest Trends is an international "non-profit organization with three principal roles: convening market players to advance market transformations, generating and disseminating critical information to market players, and facilitating deals between different critical links in the value chains of new forestry." See forest-trends.org.

9 Water funds are sometimes categorized as payment for watershed services and other times as collective action funds.

10 California, for example, has an active trading market but no centralized repository of data on the number and value of transactions.

TABLE 1. Transactions (in millions of US$) by type, 2008–2013

	2008	2009	2010	2011	2012	2013
Payment for watershed services/undefined	$ 7,950	$ 6,950	$ 7,470	$ 8,000	$ 9,600	$11,600
Collective action funds	n/a	n/a	n/a	n/a	$ 137	$ 563
Voluntary compensation	n/a	n/a	n/a	n/a	$ 0.230	$ 0.320
Water quality trading	$ 10.7	$ 8.30	$ 8.30	$ 7.70	$ 14.9	$ 22.2
Instream buybacks	n/a	$ 19	$ 390	$ 164	$ 144	$ 97.0
Total	$ 7,960	$ 6,980	$ 7,870	$ 8,170	$ 9,890	$ 12,300

Note: Numbers shown are nominal values. All values rounded to three significant figures. Numbers may not add up due to rounding. Based on data provided by Bennett (personal communication, 2015) and included in Bennett and Carroll (2014).

In this review, we evaluate three of the major incentive-based instruments that have been employed to improve water management: water trading, payment for ecosystem services, and water quality trading. These instruments are employed in developed and developing countries, and there is growing interest in expanding their application.

3.1 Water trading

Description

Water trading is perhaps the best known and most widely used method of reallocating water. In some cases, purchasing or leasing water from existing users has proven to be less expensive, more flexible, and less time-consuming than developing new water supplies, such as constructing new diversion structures or desalination plants. Similarly, water trading is generally a more accepted method for reallocating water than state appropriation or condemnation of existing water rights. Successful examples of water trading in Australia and other locations – combined with classic economic theory suggesting that market mechanisms can optimize resource allocation – have heightened interest in this instrument in both academic literature and popular media.

"...water trading provides a mechanism to improve the economic efficiency of water..."

As noted in Box 1, the peer-reviewed and gray literature employ several terms (e.g. water transfers, water markets, and water banks) to refer to a variety of sometimes overlapping instruments and methods for conveying and reallocating water. In this paper, we use the following terms:

- **water trading** – the temporary or permanent transfer of the right to use water in exchange for some form of compensation
- **informal water trading** – the sale of a specified volume of water for a limited period of time, which does not involve actual contracts or occurs outside of a recognized legal or administrative framework (e.g. the sale of groundwater to an adjacent irrigator)
- **water banks** – the institutions or agencies that i) broker or otherwise facilitate water trading (Culp *et al.*, 2014) or ii) are established for a specific objective, such as a trust created to obtain water rights for instream augmentation (Clifford, 2012). Water banks offer expertise and information for improving communication between buyers and sellers, and often provide a centralized repository or clearinghouse of information on current and historical transactions, including volumes, pricing, and locations.

There is an extensive body of literature suggesting that water trading provides a mechanism to improve the economic efficiency of water through its reallocation from lower to higher value uses (Glennon, 2005; Dellapenna, 2000; Bjornlund and McKay, 2002). The germinal study entitled *Water and Choice in the Colorado Basin* (NRC, 1968) recommended that water in the western United States be transferred from irrigation, which generates relatively low returns per unit of water, to high-value non-agricultural uses. More recent research has continued to emphasize the potential value created by water transfers. For example, models used to project California's economic costs under a dry climate change projection, (Medellín-Azuara *et al.*, 2008) found significantly increased benefits with market-based reallocations. Newlin *et al.* (2002) and Jenkins *et al.* (2004) asserted that water trading could dramatically reduce Southern California's water scarcity costs.

Water trading is attractive because it tends to minimize the impact on existing rights holders by providing compensation and, in many cases, additional security, for existing water rights, while providing opportunities to those with new or increasing demands (NRC, 1992).

A large number of experts challenge the applicability and efficacy of water trading. Freyfogle (1996) asserted that externalities, intrinsic to the very nature of water itself, pose such an insurmountable obstacle that water trading does not and cannot work. Many of these externalities arise from the physical properties of water: it is heavy, unwieldy, and easily contaminated; it sometimes has dramatic seasonal and year-to-year variability; and it can be easily lost through evaporation, seepage, or runoff (Salzman, 2006). Further, these externalities may be borne by disparate parties, such as the environment or future generations, challenging efforts to compensate those injured by trading (Freyfogle, 1996). Moreover, Salzman (2006) argued that custom, history, and religion in many parts of the world treat drinking water as a common property resource, rather than a tradeable commodity. Similarly, Zellmer and Harder (2007) asserted, "Water is a uniquely essential resource with uniquely public attributes," unlike other resources typically treated as property. Questions of externalities, commodification, and the special nature of water itself highlight the challenges faced by implementing or expanding water trading.

In some cases, water trading is effectively zero-sum, simply shifting water use and economic productivity from one area or sector to another. In other cases, it can

BOX 1

A note on terminology

Water transfers. The National Research Council (NRC) of the United States National Academies defines water transfers as changes in the point of diversion, type of use, or location of water use (NRC *et al.*, 1992). The term "water transfers" encompasses a broad range of market-based and non-market water reallocation mechanisms of varying periods, geographic scales, and arrangements. Water transfers can range from short-term leases or conditional arrangements to the permanent transfer (i.e. sale) of a water right. They can range in scale from i) change in type of use on an existing parcel of land, such as when a water right shifts from irrigation to municipal use when agricultural land is purchased and converted to housing, to ii) inter-basin transfers, such as when a city purchases or leases water from a different watershed.

Water bank. A water bank is a mechanism for changing the time or location of water use. Water banking, as with water transfers, can refer to market-based or non-market activities. The term "water bank" can refer to an actual institution or to the physical storage of water. Water banks as institutions may function as i) brokers that connect buyers and sellers of water rights or leases, providing an important communication function; ii) clearinghouses that directly purchase or lease water from willing sellers and aggregate supplies for subsequent sale to other buyers; iii) facilitators that expedite water transfers using existing storage or conveyance facilities (Culp *et al.*, 2014); or iv) trusts that hold or otherwise manage water rights or entitlements for a specific purpose, such as streamflow augmentation (O'Donnell and Colby, 2010). When serving as facilitators, water banks may perform various administrative and technical functions, including the confirmation of water rights and screening of potential buyers (Clifford, 2012). Water banks may also refer to physical storage, either in surface reservoirs or in aquifers, which, in turn, may be a component of a larger water transfer or simply a mechanism enabling an entitlement holder to store water for its own future use, but we do not use this definition in this review.

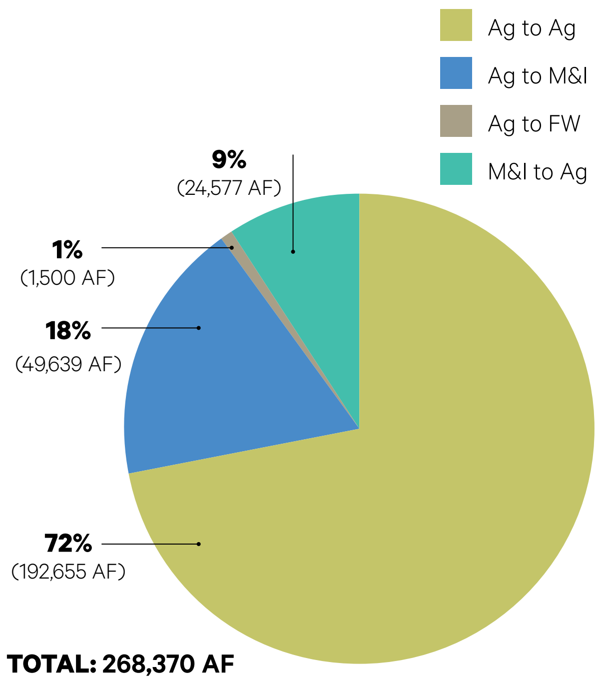
Water market. The term water market refers to a range of different market-based practices, typically referring to water trading. According to Brown (2006), the term water market lacks a precise definition, "but once a few voluntary trades of water of relatively common physical and legal characteristics occur, it is said that a water market exists." A water market may also refer to informal transactions involving the direct sale of water that does not involve the lease or sale of water rights. Informal water transactions can include purchasing bottled water or water from a tanker truck, a common practice in many parts of the developing world that lack a reliable, piped water supply. While a "water contract" can refer to a one-time voluntary water exchange between two actors, a water market is where many actors come together and make trades; a market also includes some formalization of the transactions (Brown *et al.*, 2015).

increase system-wide water efficiency, by providing the area of origin with funds for investing in improved efficiency, maintaining local productivity with lower water use, and then transferring the conserved water. Water can be made available for trading from a variety of activities, including fallowing fields, crop shifting, and in some cases, a shift from surface water diversions to groundwater pumping. Water trades can also be linked to water conservation and efficiency efforts, including increasing irrigation efficiency and decreasing system losses that generate surplus water by, e.g. lining canals or constructing operating reservoirs. However, increasing demand for greater efficiencies in irrigation can challenge the flexibility of existing institutions (Hundley, 2001), such as irrigation districts and water courts, which often do not recognize a legal property right to this "new" water created by conservation or efficiency. Additionally, existing institutions often impose significant costs on those attempting to dedicate water to non-traditional uses such as instream flows (Getches, 1985). These changes have tested the resilience of water institutions, which have shown some flexibility in adapting to new values and goals but often impose high transaction costs (Colby *et al.*, 1991).

"The most active water trading markets occur in Australia and the western United States."

Water trading can occur within sectors, from agriculture-to-agriculture and urban-to-urban, across these sectors, and, less frequently, from either of these to the environment (Brewer *et al.*, 2007). Figure 2, from the California Department of Water Resources, shows the relative proportions of water trading within and between different sectors. Although water trading is often considered a means to move water from agriculture to urban uses, nearly three-quarters of the 270,000 acre-feet of water traded in California in 2013 occurred between agricultural users. Interestingly, nearly 25,000 acre-feet of water were traded from municipal and industrial (M&I) uses *to* agriculture, which was nearly half of the volume of water traded from agriculture to M&I uses.

FIGURE 2. Non-project water transfers within the Sacramento-San Joaquin watersheds in 2013



Note: Ag – agriculture; FW – fish and wildlife; M&I – municipal and industrial; AF – acre-foot.

Source: California Department of Water Resources.

Application

Water trading exists, to varying degrees, in countries around the world. When Grafton *et al.* (2010) assessed water trading in two wealthy countries (Australia and the United States), two low- to middle-income countries (Chile and South Africa), and one poor, rapidly developing country (China), they found that differing levels of information availability, legal rights structures, institutional constraints, and management goals had resulted in very different levels of activity and performance.

The most active water trading markets occur in Australia and the western United States. Within Australia, water trading includes both short-term trades (referred to as allocation trading) and long-term trades (referred to as entitlement trading). The total value of water trading in Australia in fiscal year 2012–13 exceeded $1.4 billion

(NWC, 2013). Trading within the Murray-Darling Basin, which has an active and well-documented water market first established more than 30 years ago (Grafton *et al.,* 2012), accounts for 98 percent of all allocation trades and 78 percent of all entitlement trades within Australia, by volume. Indeed, the Murray-Darling Basin figures prominently in discussions about water trading, as an example of a thriving incentive-based system that successfully transitioned from a non-market system (Grafton *et al.,* 2012). In fiscal year 2012–13, the total volume of short-term (allocation) trading within the Murray-Darling Basin increased 44 percent from the previous year, from almost 3.5 million acre-feet (MAF) to 5 MAF, or about 50 percent of total surface water use in the basin. The total volume of long-term trades, however, decreased by about 14 percent over that period, to about 0.85 MAF. A national study found that these permanent entitlement trades often offset the temporary allocation trades, as irrigators planting perennial crops, such as grapes or almonds, purchased entitlements to meet expected future demand, but then sold a portion of the temporary allocations associated with these entitlements to generate revenue (Frontier Economics and Australia National Water Commission, 2007). For more information on Australia's water market, see Annex 2.

In the western United States, the scale of water trading is considerably lower. A database compiled by the University of California Santa Barbara (UCSB) Bren School shows notifications for more than 4,000 water trades in 12 states in the western United States from the years 1987–2008.[11] Brewer *et al.* (2007) documented the large variability in the volume, price, and duration of water trades in the western United States, both within and between sectors. In 2009, the most recent year for which data are available, the database reports almost 640,000 acre-feet of water traded in California, through 36 trades with a total value of about $234 million (all values adjusted to 2014$). More than 80 percent of the water was leased rather than sold. According to the database, 15 of these trades, accounting for about 88,000 acre-feet of total volume, occurred within one agricultural district. However, the Bren School database only records the initial year a water trade is reported, and thus does not reflect the volume of multiyear trading agreements. That means that a review of 2009 trading activity does not reflect previous multi-year trades that may still have been active in 2009, so the values reported above understate trading activity in 2009.

A comprehensive review of water trading in California reports about 1.5 MAF of water were traded in 2009, a dry year (Hanak and Stryjewski, 2012). Volumes reported for 2011, a wet year and the most recent year for which data are available, were about 5 percent lower, at 1.4 MAF. In 2011, 42 percent of the water traded went to municipal and industrial users, 37 percent to agricultural users, 17 percent for environmental purposes, and the remainder to mixed uses. Because of limited data, the study does not include trading activity within irrigation districts or similar users associations, although some estimates suggest that such intra-district activity accounted for several hundred thousand acre-feet of water, a third of total water supplies within some of the larger irrigation districts. Hanak and Stryjewski (2012) did not provide total dollar values associated with the California water market, though they noted that prices of temporary water transfers had increased from an average of $30–$40 per acre-foot in one region in the mid-1990s to $180 per acre-foot in 2011, while average prices in another basin rose to an average of $400 per acre-foot. The authors noted the shifting trend from short-term to longer-term leases and permanent trades, pumping restrictions in the Bay-Delta, and rising transaction costs that had slowed market activity in the past decade.

California is also home to the largest United States water trade to date. The San Diego County Water Authority (SDCWA) entered into a 45-year contract

[11] The database summary notes that "The data are drawn from water transactions reported in the monthly trade journal the Water Strategist and its predecessor the Water Intelligence Monthly from 1987 through February 2010." These data reflect published reports that in some cases do not reflect final transfer agreements. For example, the database reports that the Imperial Irrigation District-San Diego County Water Authority water transfer began in 1997, although the final transfer agreement was not actually signed and the transfer did not begin (at different volumes than the database reports) until October 2003. The Bren School water transfer database is available at bren.ucsb.edu/news/water_transfers.htm.

in 2003, with an option for a 30-year extension, with the Imperial Irrigation District (IID), one of the largest irrigation districts in the country.[12] Under the terms of the agreement, the SDCWA pays the IID to reduce its diversion of Colorado River water, while the Authority diverts a like amount farther upstream. After a 15-year period intended to create time to address ecological and public health impacts resulting from the trade, the IID will shift to efficiency-based methods (such as lining canals and constructing regulating reservoirs) to generate the water to be conserved. In essence, the Authority is paying the District to improve the efficiency of its operations and receiving the water conserved. The trade is ramping up to a maximum volume of 200,000 acre-feet per year by 2021, representing about 25 percent of the region's total water supply. In 2014, the price for the water was $594 per acre-foot, plus an additional $445 per acre-foot to a different agency to convey the water through its facilities. This total, which does not include additional payments to offset the environmental impacts of the trade, is about half what the Authority has contracted to pay for water generated by a new desalination plant on the coast.

In Central and South America, Chile and Mexico have active water trading markets. Chile's Limarí Basin enjoys water rights trading and water transfers, enabled by three large state-built reservoirs and robust local water organizations. The actual number of water trades in Chile's Limarí Basin has averaged about 33 each year (Romano and Leporati, 2002), although water trading has been more limited in the rest of the country (Bauer, 1997). Mexico's National Water Law of 1992 established a formal water market with tradable concessions that formed the basis for active markets in several parts of the country (Thobani, 1997), with nearly 3,700 registered water transfer requests in 2006 alone (CONAGUA, 2012).

Water markets have also been established in parts of Europe, Asia, and Africa. In Spain, informal trades, sales, and short-term exchanges of water are common, while formal transfers of long-term water rights are generally limited to groundwater (Albiac *et al.*, 2006). In Spain's Alicante basin, several irrigation districts auction their annual water allocations to district farmers (Albiac *et al.*, 2006), creating a strong incentive to improve water-use efficiency and shift toward higher value crops. England has encouraged water trading for more than a decade, although only about 60 trades have occurred to date (TWSTT, 2014).

"Water banks are generally less widespread than water trading..."

South Africa has more extensive water markets that continue to be plagued by conflict and inadequate institutional support (Grafton *et al.*, 2010). South Africa's Water Act of 1998 has provided a framework for water trading. Historically, agricultural irrigators traded water rights within their sector, mediated by the national Department of Water Affairs and Forestry (Farolfi and Perret, 2002). In 2001, mining companies seeking to expand operations in northern South Africa successfully negotiated a temporary trade of some 10,000 acre-feet of water (13 million m^3) from neighboring farmers – representing more than 70 percent of their annual allocation – in exchange for the current equivalent of about $1 million. These funds, used to help rehabilitate the local irrigation infrastructure, represented less than 0.1 percent of the mines' development costs, reflecting a significant economic disparity between the two interests (Farolfi and Perret, 2002).

In Asia, India and Pakistan have informal water trading, in which well-owners may sell some of the water they extract to neighboring farms or residents (Easter *et al.*, 1999). In a report published by the Nepal Water Conservation Foundation and the Institute for Social

[12] With the exception of "water conservancy districts", to the best of our knowledge there is no strict naming convention for water agencies. The ability to create conservancy districts is established by statute, enabling state district courts or other authorities to establish conservancy districts with the power to impose property taxes to support district functions (Howe, 2011). Water authorities tend to serve municipal areas, and irrigation districts primarily serve agricultural users. However, the San Diego County Water Authority has agricultural customers (fewer than before, as they have phased out subsidies for irrigation water), while the Imperial Irrigation District sells water to all of the cities within its service area, serving more than 170,000 people. Similarly, water conservancy districts usually serve agriculture, although some districts may also serve municipal customers.

and Environmental Transition, Moench *et al*. (2003) described an active but largely unregulated water trading system in Chennai, India, where private companies meet as much as 35 percent of urban water demand by delivering raw or purified well water purchased from farmers in surrounding areas or extracted from the companies' wells. This private sector engagement helps meet a demand for water that the intermittent municipal water supply cannot meet, though the price is much higher. Moench *et al*. (2003) reported that the price of water for urban customers can be 1,000 times higher than the price paid to the peri-urban farmers supplying the water. Also in Asia, in a rare international water trade, the Bishkek Treaty of 1998 committed Kyrgyzstan to deliver water via the Syr Darya to Uzbekistan and Kazakhstan in exchange for compensation (Ambec *et al.,* 2013). China reportedly has small, local water markets (Grafton *et al.,* 2010). In Oman, the local *falaj* irrigation systems purchase short-term allocations of water based on units of time rather than volume (e.g. a certain duration of water delivery) in a village-based auction (Al-Marshudi, 2007).

Water banks are generally less widespread than water trading because they require additional expertise, funding, and governance structures. Water banks appear to be most prevalent in the western United States, although there are examples in several other countries. The presence of three reservoirs in Chile's Limarí Basin facilitates the large number of water trades in the region (Bauer, 1997), meaning that, in this case, the physical storage rather than an institutional bank facilitates the water trades. In Australia, brokerage-type water banks are active in both the Murray-Darling Basin and in northern Victoria, where the banks post information about pricing and availability (O'Donnell and Colby, 2010). Mexico's National Water Commission reported that the 13 state-based water banks in the country broker thousands of water trades annually (CONAGUA, 2012). In three basins in Spain, water banks operated by local water agencies, known as "exchange centers", have successfully brokered water trades that have lessened groundwater overdraft (Garrido and Llamas, 2009).

In 2003, nine states in the western United States had functioning state-operated water banks, although their level of activity varied dramatically and several are no longer active. From 1995–2003, for example, Texas' water bank only reported one transaction (Clifford, 2012). California's Drought Water Bank functioned for a limited period in the early 1990s, providing a mechanism to facilitate and expedite water trading between agriculture and cities during a multi-year drought, while also ensuring minimum instream flows and providing limited groundwater recharge. The Drought Water Bank purchased, held, and sold water, primarily from northern agricultural users to southern municipal and industrial users, though about half of the more than 800,000 acre-feet purchased in 1991 was dedicated to instream flows (20 percent) and to recharge aquifers (32 percent) (Dinar *et al*., 1997). Idaho operates water banks to manage storage in reservoirs, and in Oregon, river conservancies operate as water trusts to purchase or lease water rights to supplement instream flows (Clifford, 2012). The Northern Colorado Water Conservancy District maintains a webpage that functions as an online bulletin board connecting those seeking to acquire water with those who have water to rent, an example of a brokerage-type water bank. The very active water trading within the Conservancy District is attributable to the equal volume and priority of each share available for trade, the absence of any requirement to preserve return flows or protect downstream or junior priority users, and the fact that trading only requires the approval of the district itself, not a water court, as is the case for most other trades within Colorado (Howe and Goemans, 2003).

The Colorado River basin, shown in Figure 3, boasts a large number of creative approaches to water banking. In 1998, the federal government adopted a new rule permitting interstate banking agreements within the basin. To date, Arizona has diverted and stored more than 600,000 acre-feet of Colorado River water for southern Nevada, and a southern California water agency has diverted and stored more than 161,000 acre-feet for southern Nevada, representing creative methods of skirting state prohibitions of interstate water trading. In 2007, the seven basin states adopted a new set of rules for managing the river that, among other key developments, permitted entitlement holders in Arizona, California, and Nevada to invest in various water efficiency projects within their own states and store a percentage of the conserved water in Lake Mead for later use. To date, more than 1.1 million acre-feet have been stored in Lake Mead under this new program. More recently, four large municipal water agencies in the basin, in cooperation with the federal Bureau of Reclamation, agreed to invest $11 million in fallowing and efficiency improvements, and to dedicate the conserved water to the Colorado River Basin system as a whole, rather than claiming it for themselves. In this instance, the Bureau of Reclamation acts as a water bank by obtaining water through a reverse auction process, augmenting system storage for the benefit of the system as a whole.

Environmental, economic, and social performance

The primary goal of water trading is usually to promote economic efficiency by reallocating water from lower to higher value uses. However, in some cases,

FIGURE 3. The Colorado River Basin

Source: Cohen *et al.*, 2013.

water trading has been used for environmental or recreational purposes, reflecting the increasing societal value ascribed to instream flows. In this section, we evaluate the environmental, social, and economic performance of water trading. While much of the literature on water trading tends toward theoretical assessments or recommendations about trading (Newlin *et al.*, 2002) or specific elements of trading, such as property rights regimes or institutional capacity (Culp *et al.*, 2014), we examine the literature on actual impacts to evaluate the state of practice.

"...the number of detailed economic assessments of existing water trades is surprisingly limited."

ECONOMIC PERFORMANCE

Although there are a large number of articles and studies modeling the potential economic benefits of water trading, the number of detailed economic assessments of existing water trades is surprisingly limited. Some studies on local impacts suggest positive net economic performance, but these studies typically do not describe changes in the distribution of impacts, and they rarely describe broader economic impacts. Assessing the economic performance of water trading is frequently as simple as documenting trading activity and quantifying the number, volume, and value of reported water trades. A more comprehensive analysis would require surveys to estimate the number and volume of additional water trades that users would like to make, as a means to assess the disparity between availability and demand. An even more robust analysis would compare the ability of different instruments – such as water trading, demand-side management, and supply augmentation – to meet specific water demands, and the cost of those instruments. While water agencies seeking to improve their water supply reliability may perform such analyses within their service area, these assessments are often not publicly available.

The large number of trades and the significant volumes traded, especially in Australia, indicate that water trading can be an effective means of reallocating water, where the appropriate conditions exist. The application section of 3.1 of this report describes the range of countries where water trading occurs in general terms. In most of these regions, limited data precludes detailed assessment of the number or volume of water trading activities. In several locations, such as the Murray-Darling Basin and the Northern Colorado Water Conservancy District, water trades occur frequently, often for small volumes, suggesting a robust and active market with low transaction costs (Howe and Goemans, 2003). In other areas, there tend to be fewer but larger transactions, suggesting higher barriers to trading.

The largest agriculture-to-urban water trade in the United States has been successful for San Diego County, which currently receives about 25 percent of its water supply from the rural Imperial Valley,[13] at a unit cost of water that is less than half the contracted price of water from a desalination plant that will soon be operational on the San Diego coastline. The long-term water trade appears to be cost effective from San Diego's perspective but, due to significant externalities, may not be from the broader society's perspective. Total transaction costs for this water trade have exceeded $175 million in attorney fees, plus an additional $171 million in mitigation fees to offset public health and environmental impacts. In addition, the State of California agreed to cover all direct mitigation costs in excess of a pre-determined financial cap for the water trade parties. The magnitude of these additional mitigation costs – primarily for managing dust emissions – will not be known for many years but are expected to run into the hundreds of millions of dollars (Cohen, 2014). As suggested by the Imperial Valley-San Diego example, a narrow focus on direct economic performance may ignore trading's broader economic impacts.

Although there are thousands of peer-reviewed articles on the economic potential of water trading, robust economic analyses of specific water trades do

[13] Roughly 15 percent of San Diego County's current water supply comes from the water trade with the Imperial Valley, while an additional 10 percent comes from water conserved via the lining of the All-American Canal, a project funded primarily by the state of California.

not appear to exist. For example, despite its size and importance, there do not appear to be any economic analyses of the Imperial Valley-San Diego County water trade that assess revenues, agricultural production lost due to fallowing, value of transfer payments, relative value of the water in San Diego, or employment impacts. There are, however, general regional or district-level assessments of water trading, as well as an extensive body of literature on macro-economic trends, and expected or modeled benefits of water trading. Yet, assessments of "net" economic benefit at the state or regional level, expressed in terms of net increase in employment or revenue, can mask disparities between areas of origin and importing areas, and even within the areas of origin themselves.

"In Australia, water trading has enabled the expansion of the wine industry and other high value crops, such as almonds."

In one study, the income and employment gains found in regions in California that imported water via trades exceeded the net losses (total compensation often failed to cover foregone crop revenue) in exporting areas (Howitt, 1998). In 1991, trading activity generated an average net income loss in water-exporting areas equivalent to about 5 percent of net agricultural activity, though this varied within different parts of the state. However, agricultural areas importing water saw total gains greater than the losses in exporting areas: net agricultural water trading activity was positive, as water moved from lower-value crops to higher-value crops (Howitt, 1998). In another example, an agricultural community in California exporting water to urban areas saw a 26 percent decrease in the number of farms overall, but this masked a 70 percent loss in the number of small farms and the loss of almost half of the number of produce firms in the area (Meinzen-Dick and Pradhan, 2005).

The Northern Colorado Water Conservancy District, introduced in Section 3.1, has a very active water market in part because of low transaction costs. Much of the trading activity in the district is short term and low volume, especially in comparison with trading activity in the same water basin but outside of the district. Municipal and industrial (M&I) users buy district water rights to meet expected future demand and then lease some of this water back to district irrigators. This rising M&I demand has increased the price of imported water rights (known as allotments) within the district (Howe, 2011). Within the relatively prosperous district, this has improved economic performance. However, in other regions, particularly in economically depressed rural areas, selling water out of the area has exacerbated economic decline, causing property values to fall and the local tax base to shrink (Howe, 2011).

In Australia, water trading has enabled the expansion of the wine industry and other high value crops, such as almonds. Over time, the dairy industry in one part of the Murray-Darling Basin transitioned from a small purchaser of water entitlements to a net seller of entitlements, primarily to the expanding wine and nut producers in other parts of the basin. These expanding industries have also exhibited a shift from the former model of shared irrigation infrastructure (such as common canals) to direct extraction from the river by individual irrigators – in other words, from a communal to a more flexible individual approach to irrigation (Frontier Economics and Australia NWC, 2007).

Water trading within the Murray-Darling Basin grew and matured within the context of the devastating drought that afflicted the region from 2006 through 2010. The national water trading assessment noted the challenge of disentangling the economic impacts of the drought from those of water trading itself, generally concluding that trading offered irrigators an additional revenue stream, plus additional flexibility and resilience within the face of a severely limited water supply. Without water trading, some sectors, such as the dairy industry, would have seen even greater losses. Trading also offered a mechanism to adjust for historic water apportionments, facilitating the voluntary sale of water from less productive to more productive lands and uses (Frontier Economics and Australia NWC, 2007).

The active participation of the Australian government in water trading increased prices and participation but may also have increased total water use within the basin. A large survey (n=520) of those selling entitlements or allocations to the Australian environmental water program found that sellers believed they received a higher price from the government than they would have from other private agents, or that the government was the only purchaser in the market. The survey also found that sellers reportedly used 69 to 77 percent of their water allocations prior to trading it to the government (Wheeler and Cheesman, 2013). That is, survey respondents reported selling portions of their allocations that they would not have used otherwise. Selling unused water allocations is not a reallocation so much as an expansion of total water use.

"Water trading can also generate large environmental externalities, adversely affecting either natural habitats or downstream users, or both"

Water trading occurs in a variety of forms. Howe (2011) noted that, in practice, many water trades reflect a change in type of use rather than a change in location. For example, in the Northern Colorado Water Conservancy District, developers have purchased farmland and its water rights and then converted the land and water to residential or commercial use, often generating a significant increase in revenue per unit of water while limiting some of the social and environmental externalities that would occur if the water were physically moved to a different location.

ENVIRONMENTAL PERFORMANCE

Water trading has been used as a mechanism to obtain water for ecological purposes, to augment streamflows, and to address water quality concerns (such as temperature) in threatened reaches. The environmental performance of water trading is highly variable, depending on the type of trade and site-specific conditions. The benefits of voluntary, incentive-based water acquisition include ease of transaction and greater community support, especially relative to regulatory takings. However, water trading can also generate large environmental externalities, adversely affecting either natural habitats or downstream users, or both (NRC, 1992). For example, when water for trading is generated by efficiency or by fallowing land, the trade may reduce the amount of runoff supporting local habitat and may diminish instream flows.[14] On the other hand, some water trades may improve local instream flows by decreasing diversions and contaminant loadings. Where water is traded to downstream users using the existing stream as a conveyance, trading could offer measurable environmental benefits. Where water is traded out of the basin or alters the timing and magnitude of flows, adverse impacts are likely to occur. Unfortunately, there do not appear to be published assessments of the relative impacts of water trading on streamflow.[15] In the following, we discuss the environmental performance of several examples of water trading.

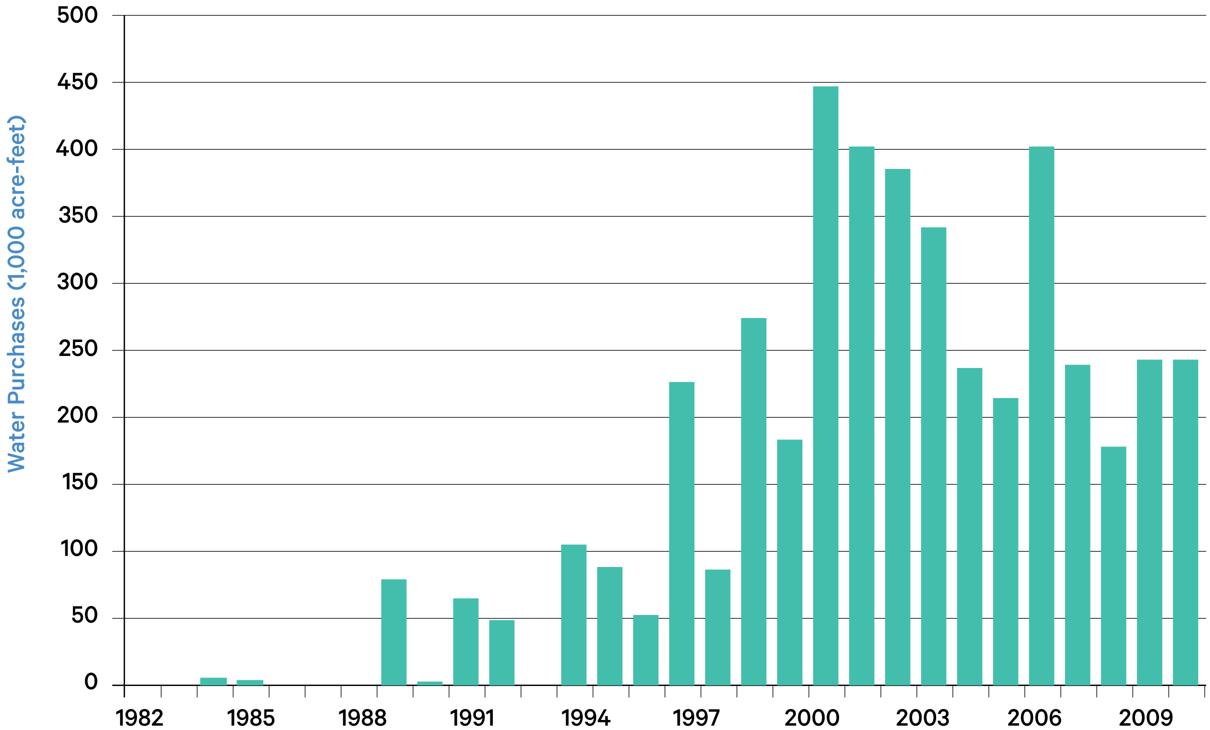
Water trading is now used in some areas to return water to river channels, in order to support listed species or threatened habitats, and for general ecosystem restoration (Tarlock, 2014). However in most areas, such activity still represents only a tiny fraction of total water use in any given area.[16] For example, the Colorado Water Trust (CWT) brokered a lease agreement between two state

[14] In efficiency-based agricultural water trades, the buyer typically pays the irrigator to install more efficient irrigation equipment or methods, such as hiring additional irrigation management staff, installing pump-back systems, lining canals, or constructing new regulatory reservoirs. The water conserved by these new practices would then be available for transfer to the buyer/investor. Efficiency-based trades keep agricultural land in production and can increase total employment in the area of origin, but they require additional monitoring and measurement to document or calculate the volume of water conserved. In fallowing-based trades, also known as "buy-and-dry", the buyer simply pays the irrigator not to irrigate and, in exchange, receives the volume of water historically used by the parcel. This requires less effort and less time to implement, but takes land out of production and typically generates significant adverse impacts on rural communities.

[15] For example, the various water trading agreements between Imperial Valley and urban Southern California will have the direct effect of reducing the volume of water flowing down the lower Colorado River between Parker Dam – the new diversion point – and Imperial Dam, about 150 river miles downstream, by more than 300,000 acre-feet per year, equivalent to roughly 5 percent of the historic average annual flow between these two diversion points.

[16] Such instream flows typically require additional legal conditions, such as explicit recognition of instream flow rights, improved monitoring and measurement, and the acceptance of local entitlement holders.

FIGURE 4. Water purchases for the environment in California, 1982–2011



Source: Hanak and Stryjewski, 2012.

agencies, increasing low-season flows in the White River by 3,000 acre-feet of water three times over a 10-year period to lower the temperature of river flows and, in turn, benefit fish (CWT, 2015). Similarly, the Columbia Basin Water Transactions Program, active for more than a decade, works with partner organizations in four western states to acquire and dedicate water for instream flows within the basin. In 2013, 45 transactions led to the acquisition of more than 48,000 acre-feet of water, costing about $13.9 million and benefiting some 276 miles of streams, the fish and wildlife, and the communities that depend on them (National Fish and Wildlife Foundation, 2014). Bonneville Power Administration, in cooperation with the Northwest Power and Conservation Council, provides some of the funding for the program due, in part, to concerns about endangered species. In California, environmental water purchases averaged 152,000 acre-feet, accounting for about 14 percent of trading activity between 1982 and 2011, but less than 0.5 percent of total water use in the state (Figure 4).

In Australia, the federal government has invested more than $3 billion to date to purchase entitlements and allocations for environmental water, protecting ecological resources to enable and expedite water trading between non-governmental users. In 2008–2009, for example, the government purchased nearly 880,000 acre-feet of long-term water entitlements and 1.4 million acre-feet of short-term allocations, at a total cost of about $2 billion (adjusted to 2014$). The price for this water ranged from about $269 to $377 per acre-foot. Local interest in this environmental water buyback program, known as "Restoring the Balance", has been strong, with the Australian government receiving nearly 7,600 applications to sell water from 2007 to early 2012. Water entitlement sales for the environment account for roughly 25 percent of total entitlement trading activity (Wheeler and Cheesman, 2013). However, some irrigators and state governments in Australia oppose the instream buyback program, and it was cut dramatically when the Labor Party fell from power in September 2013 (Bennett and Carroll, 2014).

However, water trades not explicitly intended for environmental purposes can create a host of adverse environmental impacts. They can, for example, change the timing, quantity, and quality of return flows, adversely affecting riparian and wetland habitats and the species that depend upon them. Some trades, such as from California's Owens Valley to Los Angeles, adversely affect public health by increasing the amount of dust emissions from exposed lakebed and fallowed land, generating significant externalities (LA DWP, 2013). Groundwater substitution, in which a user trades surface water and increases groundwater extraction, can lead to over-extraction, and sinking or caving in of land surfaces (subsidence), depleting springs and seeps, and robbing future generations (Brown *et al*., 2015).

Water trading can also diminish groundwater recharge rates, whether the water is generated via fallowing or increased efficiency. In the southern Indian state of Tamil Nadu, farmers irrigating with groundwater have increased extraction rates and sold the excess to water tanker trucks serving urban populations, an example of informal water trading. Yet this increased groundwater extraction lowered the water table, increasing pumping costs for other irrigators or drying up their wells entirely (Meinzen-Dick and Pradhan, 2005).

Efforts to mitigate the environmental impacts of water trading have had mixed success. In Spain, a proposal to add a small environmental mitigation fee to each unit of water traded was insufficient to overcome the strong opposition of environmental and social organizations (Albiac *et al.*, 2006). In California, state commitments to mitigate the environmental and public health impacts of the nation's largest agriculture-to-urban water trade have yet to result in any actual mitigation efforts, potentially jeopardizing several listed species and likely resulting in the loss of open water and wetland habitats that support several hundred species of birds (Cohen and Hyun, 2006).

Yet water trading occurs in regions of water scarcity, where water resources in particular have already undergone dramatic transformation. Dams, canals, and diversions have already altered the timing and magnitude of stream flows throughout many of the regions now turning to water trading (Worster, 1985). Determining the additional impacts of water trading upon this existing landscape would be difficult. An alternative basis for comparison could be the marginal or cumulative environmental impacts of water trading relative to the new impacts of additional water development. That is, water trading may prove to be less environmentally harmful than the construction of new dams and diversion projects, or even the construction of new desalination plants.

"...water trades not explicitly intended for environmental purposes can create... adverse environmental impacts."

SOCIAL PERFORMANCE

Water trading is usually characterized as a market-based mechanism that reduces economic inefficiencies by reallocating water from lower to higher value uses. Trading has been used to meet explicit environmental objectives, but, as described previously, it is rarely employed to address equity challenges. Indeed, water trading can exacerbate social and economic inequalities, worsening gender and geographic differences.

In regions with informal water rights and trading that are functional at the community level, such as rural Nepal, demands from outlying urban areas for larger scale trades can overwhelm local water management institutions. Trades from these rural areas might not reflect the true value of the many informal uses water has in the community (such as subsistence fishing or milling) or the full range of informal ownership and use rights within the community, meaning residents may be deprived of full compensation (Pant *el al.*, 2008). Even within the community, the complex web of informal water-use arrangements can complicate informal trading agreements and, in turn, generate a range of economic impacts on those using the water who had not been consulted or participated in the trading arrangements (Pant *et al.*, 2008).

Limarí Basin, Chile. Unequal access to water markets due to unequal access to information or credit can distort outcomes and reduce market efficiency. Chile's Limarí Basin has very high water trading activity, suggesting successful economic performance, but Romano and Leporati (2002) argued that it suffers from several market distortions arising from disparities between the resources available to those trading water. Peasants fare poorly in trading activity because their water rights often are not fully recognized, they are not as well-organized as those purchasing the water, and they lack access to information on pricing (Romano and Leporati, 2002). Dinar *et al.* (1997) noted that economic performance is affected by disparities in the value of water in different sectors and by the ability of those with limited means to participate in water trading.

Southern California. Water generated for trades by fallowing land can benefit water rights holders at the expense of farmworkers and equipment suppliers, potentially devastating rural communities. California's Owens Valley provides one of the early examples of the adverse impacts of trading water away from rural areas. In the early 1900s, agents secretly representing the City of Los Angeles (LA) covertly purchased land in the Owens Valley. In 1908, LA began a 5-year construction project of a 419-mile pipeline to divert water from Owens Valley farmland to LA. Although Owens Valley irrigators had willingly sold their water through market transactions, they had not contemplated the plight of the valley as a whole. Over the next several years, agitators from the valley dynamited the pipeline several times in a vain attempt to protect their water supplies (Hundley, 2001). In addition to the direct economic and social impacts on the Owens Valley, the water trade had desiccated Owens Lake by 1926, just 13 years after water first began flowing to LA, creating the single largest source of dust pollution in the United States. In the past decade, after years of litigation, LA has spent more than $1.4 billion on dust management efforts and has returned some of the water to Owens Lake.[17]

San Luis Valley, Colorado. As demonstrated by efforts to destroy the infrastructure moving water out of the Owens Valley, local opposition to trading water can be strong. In the late 1980s, the Canadian owner of the 97,000-acre Baca Ranch in southern Colorado's San Luis Valley began buying water rights from other farms in San Luis Valley, allegedly to irrigate new crops. Local residents, who soon discovered that the true purpose of the purchases was to sell the water to Denver suburbs, 100 miles to the northeast, feared that their valley would experience the devastation felt in Owens Valley. Thus, they formed Citizens for San Luis Valley Water to fight the water trade, working with the local irrigation district to support a special ballot measure to raise local taxes to fund litigation against the proposed water sale. The ballot measure prevailed with 92 percent of the vote. In 1991, the locals prevailed in court, stopping the proposed water trade. After Baca Ranch was subsequently sold, the new owner also attempted to sell the water out of the valley, sponsoring two statewide initiatives seen as efforts to support the water trade. In 1998, both initiatives failed, receiving less than 5 percent of the vote. With continued public pressure, the federal government purchased Baca Ranch in 2004 – more than a quarter century after the fight began – to prevent water from leaving the San Luis Valley. It then parceled the land to the newly designated Great Sand Dunes National Park, part to a nearby national forest, and 54,000 acres to the new Baca National Wildlife Refuge (Reimers, 2013).

Imperial Valley, California. On the other hand, water trading that promotes efficiency rather than fallowing of agricultural land can improve socio-economic outcomes for both the area of origin and the destination. For example, an ongoing water trade from the Imperial

[17] For information on the dust emissions at Owens Lake and the current dust management program, see the Great Basin Unified Air Pollution Control District website.

Valley that began in 1989 relies on efficiency-based measures rather than fallowing to generate water for trade, creating additional employment while keeping land in production.[18]

Water trading's social impacts vary based on several factors, including the relative economic health of the area of origin and the purchasing area, whether or not the water leaves the area of origin, the process used to trade the water, and the relative economic and political power of the parties (Meinzen-Dick and Pradhan, 2005), gender differences regarding access to and control of water (Zwarteveen, 1997), the amount of trading activity in the area (Howe, 2011), and the legitimacy of the water rights being traded (Meinzen-Dick and Pradhan, 2005). Impacts often vary within the same community, as those with water rights or allocations to trade receive compensation, while third parties – such as irrigation equipment suppliers or farmworkers – may suffer a loss of revenue or income as a result of trading (Meinzen-Dick and Pradhan, 2005).

Water trades within the same region typically have minimal or no adverse social or equity impacts. Howe (2011) noted the large number of small-volume, short-term water trades within an irrigation district as an example of positive economic and equity outcomes. Inter-sectoral trades, such as from agricultural to manufacturing or mining within the same region, may also generate positive economic and equity outcomes, as jobs shift from lower income farm employment to higher income industrial employment (Meinzen-Dick and Pradhan, 2005). However, Zwarteveen (1997) noted that even such intra-regional trades can generate differential impacts based on gender, requiring additional agricultural and domestic labor for women within households where men have left for new industrial jobs enabled by new water supplies. In places where rural agriculture, particularly at the household level, provides subsistence and food security, reduced access to water can impose significant adverse impacts (Farolfi and Perret, 2002).

Rural household access to water for domestic uses and for subsistence agriculture may have only informal community-level recognition that does not translate into tradable water rights. Water trading that does not recognize these informal or ad hoc water uses can adversely affect equity outcomes and prompt questions of legitimacy (Meinzen-Dick and Pradhan, 2005). Formal, state-recognized water rights typically require the means and ability to register and defend them, in turn conferring power on those with formal water rights. In South Asia and other parts of the developing world, informal water-use arrangements that permit and enable water use and trading can be disrupted by formal rights-based trades and command-and-control reallocations (Meinzen-Dick and Pradhan, 2005).

Zwarteveen (1997) noted that, as men in Ecuador, Nepal, and Peru have migrated in search of employment, women have assumed a disproportionately large number of agricultural roles, even as formal and informal water rights continue to be held by the absent men. These geographic and gender disparities can generate adverse outcomes as water is traded by absentee owners. Conversely, trading within households – even in the form of recognition of joint ownership – can encourage investment in water resource maintenance and productivity at the local level (Zwarteveen, 1997). Similarly, water organizations in the developing world, where decisions may be made about trading water out of the community, tend to have limited female participation, potentially neglecting compensation for impacts that would have been identified if there were stronger female roles and participation (Zwarteveen, 1997).

Water trading mechanisms can privilege certain populations and marginalize others, especially when cultural practices differ. For example, New Mexico's cooperative irrigation systems, known as *acequias*, usually enjoy

[18] The Imperial Irrigation District's *IID/MWD Water Conservation Program Final Construction Report* (2000) documented that 24 separate system water conservation projects and programs (as opposed to on-farm), such as lining irrigation canals and installing new headgates, had been implemented through 1999. The capital cost for these totaled $193 million (2014$), with an additional $8.3 million in annual operations and maintenance costs. These improvements yield 108,500 acre-feet of conserved water per year, at a cost of $254 per acre-foot. In addition to the jobs associated with the initial construction effort, the on-going water trade supports about 12–13 full-time positions for managing water deliveries, and for annual operations and maintenance.

very senior water rights. However, they have fared poorly when defending their rights or seeking compensation for third-party impacts in state proceedings, where language and cultural practices favor fluency in English and legal literacy (Meinzen-Dick and Pradhan, 2005). Romano and Leporati (2002) found similar circumstances in Chile, where less-educated rural peasants fared poorly in trading water rights to more powerful non-agricultural interests.

"Water trading mechanisms can privilege certain populations and marginalize others…"

Economic disparities also affect water-trading outcomes. As with the *acequias*, wealthy, powerful interests enjoy disproportionate advantages relative to many historic water rights holders. In South Africa in the late 1990s, mining interests sought to increase their production and activity in rural, water-scarce regions by purchasing water rights from small irrigators, at prices ten times higher than other irrigators were willing to offer. Although the mines offered employment and generated greater returns per unit of water, they threatened to dewater local subsistence farms and adversely affect a broad swath of rural economies beyond the irrigators voluntarily selling their water (Farolfi and Perret, 2002). A study of water trading in Chile's Limarí Valley found a similar impact, where increasing rural poverty was traced to water rights sales from peasants to non-agricultural interests and the general worsening of water-rights distribution (Romano and Leporati, 2002).

As noted in the examples of the Owens and San Luis Valleys, those in areas of origin can strongly, sometimes violently, oppose the sale of water to outside interests. A national study of water trading in Australia found that this opposition can extend to local interests that trade their water rights to external interests (Frontier Economics and Australia NWC, 2007). In addition to cultural and social bases for opposing such trades, trading can increase costs for those who do not sell, such as operations and maintenance costs associated with water storage and delivery structures. The economic and equity impacts of water traded from rural areas can accumulate with additional trading activity, reaching a tipping point where local demand for agricultural services falls below the level necessary to maintain operations, creating a cascading set of business failures and depressing the local tax base (Howe, 2011). Agricultural areas importing traded water may also suffer from third-party impacts, in the form of increased competition, extended wait-times for water deliveries via shared infrastructure, and rising water tables that may threaten plant roots or require additional drainage (Frontier Economics and Australia NWC, 2007).

The one key exception to water trading that exacerbates social and economic inequalities is in South Africa. Section 27(1) of South Africa's 1998 National Water Act states:

> "In issuing a general authorisation or licence a responsible authority must take into account all relevant factors, including…
> (b) the need to redress the results of past racial and gender discrimination;…
> (d) the socio-economic impact –
> (i) of the water use or uses if authorised; or
> (ii) of the failure to authorise the water use or uses."

While this act explicitly sought to use water trading to improve socio-economic conditions,[19] South Africa's Department of Water Affairs and Forestry (now known as the Department of Water and Sanitation) refused to permit more than 118 applications for water trades from 2005 through 2008, claiming that the trades failed to meet the Section 27(1) standards (Coleman, 2008). South Africa's Supreme Court found in 2012 that: i) one proposed trade would create new employment opportunities for both men and women in a region with high unemployment, meeting the standard established by

[19] The National Water Act is available at http://www.acts.co.za/national-water-act-1998/.

Section 27, and ii) the Department had acted improperly in failing to grant the requested license to trade the water.[20] According to a local source, however, the responsible authorities in South Africa continue to delay and deny licenses for water trades, meaning that South Africa's water market has been restricted for a decade (Backeberg, personal communication, 2015).

Necessary, enabling, and limiting conditions

Institutional arrangements determine the ultimate success or failure of water trading (Livingston, 1998). Successful water trading requires secure and flexible water rights that recognize and protect users and others from externalities. Such institutional arrangements also need to be flexible enough to adapt to changing physical conditions as well as changing social norms, such as the growing interest in meeting environmental needs and protecting water quality (Livingston, 1998). Recognizing and understanding these factors can help explain the varying successes and even the existence of water trading in different countries and regions within countries. Some factors, such as legal and transferable rights to use water, may be *necessary* for water trading to occur. Others, such as access to timely information about water available to trade, can *enable* water trading but may not be required for trading to occur. Still other factors, such as "no injury" regulations and "area of origin" protections, *limit* water trading or function as barriers or obstacles to trading. The following explains the details of the necessary, enabling and limiting conditions.

Necessary conditions include:

- legal, transferable rights to use water
- decoupling of water rights from land rights
- contract adjudication and enforcement
- means for buyers and sellers to communicate
- physical infrastructure to move water
- mechanisms to monitor and measure water flows and use.

Grafton *et al.* (2010) wrote that "Legal clarity over water rights, including what they can be used for and the rules of water trade, is a cornerstone of functioning water markets." Diversion or, better yet, consumptive use water rights with clear title and quantified allocations that can be leased or sold can be described as marketable property rights, a necessary condition for water trading (Grafton *et al.,* 2012). Culp *et al.* (2014) noted that water trading requires legally enforceable contracts that clearly and completely define the water right to be traded, an exclusive right to the water, and the recognized right to trade the water. Government plays a clear role in establishing these necessary conditions, documenting and, in some cases, allocating water rights themselves, establishing and maintaining the legal framework in which trading occurs and, in many cases, financing the physical infrastructure to store and convey water and allow water trading to occur (Dinar *et al.*, 1997). Strong and effective institutions that adjudicate and resolve disputes, enforce contracts, and monitor trading agreements are a necessary element in successful water markets (Zwarteveen, 1997).

Typically, infrastructure is also required to physically convey water from a seller to a buyer, or to store or otherwise manage water availability so that an agreed-upon volume can be conveyed to the buyer at the appropriate time. In some cases, creative agreements have enabled trades from unconnected or remote sources of water, creating what are known as "in-lieu" or "paper" trades.[21] While these trades can avoid requirements for connecting physical infrastructure, they do require sophisticated legal arrangements, management, and monitoring to ensure that the correct volumes of water move at the approved time.

[20] *Makhanya v Goede Wellington Boerdery (Pty) Ltd* (230/12) [2012] ZASCA 205 (30 November 2012).

[21] One example of an in-lieu water trade is the agreement between the Metropolitan Water District of Southern California and the Coachella Valley Water District and the Desert Water Agency. All three have contracts with California's State Water Project (SWP), but because a direct connection from SWP's California Aqueduct to Coachella Valley would have cost the equivalent of more than $1.8 billion, the latter two agencies agreed to an in-lieu exchange agreement with Metropolitan for a "bucket-for-bucket" exchange of SWP water for Colorado River water. That is, Metropolitan takes the other agencies' allotment of SWP water, in exchange for giving up an equivalent amount of Colorado River water. Source: cvwd.org/news/news178.php.

Water trading can and does occur when necessary conditions are satisfied, but markets are much more robust and active when additional enabling conditions are met.

Enabling conditions include:

- water rights equivalency (as opposed to prioritized rights)
- water banks and contracts
- clear, available information
- social cohesion
- competitive markets with multiple participants of roughly equivalent economic power.

One of the major factors contributing to Australia's successful adoption of water trading in the Murray-Darling Basin was the absence of prioritized water rights. This enabled water trading without concern for impacts on those holding less senior water rights (see Annex 1 for greater detail). By contrast, in the western United States and other regions with prioritized water rights (also known as prior appropriation or seniority), an entitlement holder with a senior water right (determined by the date the right was first exercised or "perfected") could only sell or lease water after ensuring that more junior rights holders receive compensation or do not otherwise protest the transaction. This distinction helps explain the frequency of trades within irrigation districts where district members share a common priority right – such as the Northern Colorado Water Conservancy District – and the much lower number of transactions between those with different priorities. That is, common priority rights or water rights with equivalent seniority can be traded more readily than rights with different priority dates.

Dinar and Saleth (2005) proposed a scale from zero to seven to describe a range of surface water rights conditions that could be used to evaluate the enabling conditions for water trading. It spans from a rating of zero for no water rights, to a rating of five for appropriative rights; six for proportional sharing systems (such as the Northern Colorado Water Conservancy District and Australia); and seven for water licenses and permits. Under this system, we could categorize no rights as precluding trading while the higher end of the scale can be seen as enabling trading.

Water banks can enable water trading by connecting buyers and sellers, posting information on availability and transaction history and, in some cases, by physically storing water to match availability and demands. The existence of technically skilled staff and monitoring equipment increases the efficacy of water banks and can help resolve disputes. Where water banks do not exist or have limited capacity, water contracting can enable spot trading (Brown *et al.*, 2015).

"Social cohesion can also enable water trading. Trading is more likely to occur where informal bonds exist..."

The availability of pertinent information can be considered both a necessary and an enabling condition, depending on the extent and type of information available. The availability of information on quantity, quality, location, and timing of water entitlements or allocations can enable trading by pairing sellers and buyers. Similarly, clear information about transaction costs enables trading. Additionally, greater information and certainty about future conditions, such as the security of a water right given climate changes, can also enable water trading (Brown *et al.*, 2015). Clear and timely information about prices also facilitates trading and decreases search costs (Levine *et al.*, 2007).

Social cohesion can also enable water trading. Trading is more likely to occur where informal bonds exist, such as between neighbors or within an irrigation district or even between irrigators, relative to trading between parties with no common history. In some cases, irrigators will accept a lower bid from another irrigator than a higher bid from a municipal agency, particularly one from outside the basin or region. Water rights holders may fear that indicating they have water to trade could be interpreted to mean that they do not need the water, jeopardizing the right or imposing political costs (Albiac *et al.*, 2006).

Levine *et al*. (2007) argued that successful water trading requires the participation of multiple buyers and sellers, with roughly equivalent power. They contended that, without these factors, market inefficiencies will result. In Australia's Murray-Darling Basin and within several United States irrigation districts, the satisfaction of these criteria has enabled active and successful water trading. In their absence, as seen in many agricultural-to-urban trades, a small number of economically powerful buyers have distorted markets and created significant externalities.

Limiting conditions, which hinder or reduce water trading, include:

- no injury rule
- anti-speculation doctrine
- beneficial use doctrine
- property rights/pre-conditions
- high transaction costs
- spatial and temporal differences in supply and demand.

In many arid and semi-arid regions, water scarcity and variability dictate that upstream "return flows" – water diverted but not consumed that subsequently returns to the stream – are used and claimed by downstream users. To protect the rights of these downstream users, courts or regulators typically require that the quantity and timing of these return flows be maintained when upstream water is traded. These and similar protections, known as "no injury" rules, place the burden of proof that the trade will not harm or adversely affect other water rights on those wishing to sell or lease water. The "no injury" rule is the prevailing law in most of the western United States, intended to presumptively protect junior water rights holders from harm that may occur due to changes in the volume or timing of return flows from senior appropriators. It dramatically increases transaction costs, requiring sellers to hire attorneys and hydrologists to prove no injury, or otherwise compensate all junior entitlement holders, and was a strong disincentive to water trading (Culp *et al*., 2014).

The anti-speculation doctrine requires buyers to describe the new location and use of the water, conditioning the trade on these terms and increasing transaction costs (Culp *et al*., 2014). The anti-speculation doctrine is intended to prevent hoarding and market distortion by those with the economic means to acquire large volumes of water (Grafton *et al*., 2010). In some areas, this doctrine is waived for municipal water agencies, enabling them to acquire water for unspecified future needs.

The beneficial use doctrine requires that water rights be exercised, encouraging inefficient or unproductive uses as rights holders must "use it or lose it." Some jurisdictions have amended beneficial use requirements to enable rights holders to sell or lease the water they conserve or save by implementing efficiency measures, water they would otherwise simply lose to junior rights holders. Without explicit protection for such conservation measures, the beneficial use doctrine precludes water efficiency and hinders trading. In some areas, laws prohibit users from selling or leasing water "salvaged" from conservation or efficiency measures (Culp *et al*., 2014).

Some kinds of water rights, such as non-consumptive, appurtenant water rights (common in wetter regions of the world) do not lend themselves to water trading.[22] Examples of such non-consumptive rights include rights to use or divert water to run mills or generate hydroelectric power.

Some markets limit participation to existing contractors or entitlement holders (Albiac *et al*., 2006). A related barrier is a limitation on the purpose or use to which a buyer may apply water. For example, several states only allow state agencies, and not private individuals or non-profit organizations, to purchase or lease water for environmental purposes.

22 An appurtenant water right is directly tied to the land itself, typically to lands adjacent to streams.

High transactions costs, driven by the various doctrines noted above as well as by the need to overcome information constraints and related factors, can hinder water trading. Similarly, the time required to complete a transaction may limit trading, particularly when buyers seek to meet a short-term demand such as an additional irrigation cycle or to offset a delivery disruption within an urban system; relatively fast trades will produce greater trading activity than prolonged approval processes.

"High transactions costs, driven by the various doctrines noted above as well as by the need to overcome information constraints and related factors, can hinder water trading."

Finally, geographic and temporal mismatches between supply and demand can impose additional barriers to water trading, especially in the absence of physical infrastructure to bridge these gaps. Where dams and conveyances do not exist, those wishing to sell water may lack the means to physically deliver the water to a potential buyer, or be unable to deliver the water at the right time (Bauer, 1997).

3.2 Payment for ecosystem services/payment for watershed services

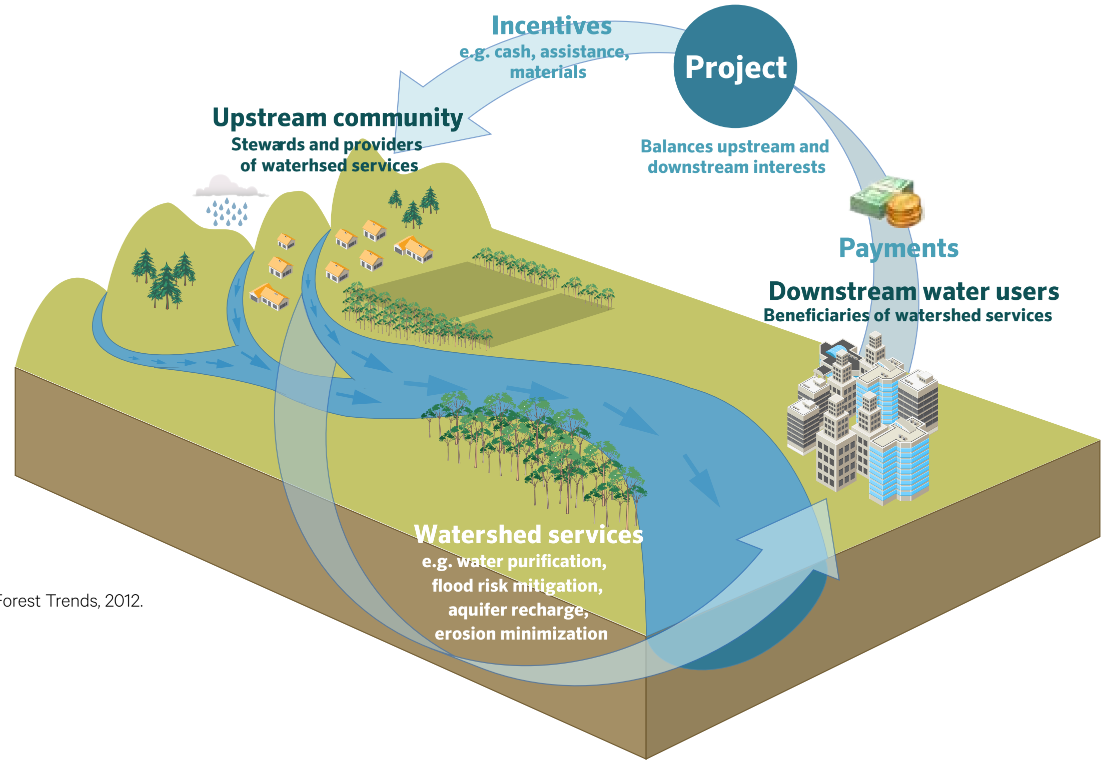
Description

Payment for ecosystem services (PES) is an incentive-based instrument that seeks to monetize the external, non-market values of environmental services, such as removal of pollutants and regulation of precipitation events, into financial incentives for local actors to provide such services. In practical terms, PES involves a series of payments to a land or resource manager in exchange for a guaranteed flow of environmental services (Figure 5). Payments are made to the environmental service provider by the beneficiary of those services, e.g. an individual, a community, a company, or a government. In essence, it is based on a beneficiary-pays principle, as opposed to a polluter-pays principle. Environmental services most often included in PES arrangements include carbon sequestration in biomass or soils; habitat provision for endangered species; protection of landscapes; and various hydrological functions related to the quality, quantity, or timing of freshwater flows from upstream areas to downstream users (Gómez-Baggethun *et al.,* 2010).

PES has no standardized definition. The definition most commonly used in the literature was developed by Wunder (2005) and is based on five criteria: i) a *voluntary* transaction where ii) a *well-defined* environmental service is iii) purchased by at least one environmental service *buyer* from iv) at least one environmental service *provider*, with v) payment *conditional* on the service provided. In reality, few projects actually meet all of these criteria. For example, money may come from donors rather than service providers, or participation in the program may be mandatory. Wunder (2005) argued, and several reviews confirm, that conditionality is the hardest criteria to meet because initiatives are often loosely monitored and payments are made up front or in good faith. Moreover, in some cases, participation is not voluntary (e.g. China), and the beneficiaries are broadly defined and are not directly contributing to the program. Wunder (2005) concluded that while there are a considerable number of PES-like arrangements, there are likely "very few 'true PES' conforming to the theoretical concept developed in the literature."

PES programs focused on watershed services are commonly referred to as payment for watershed services, or PWS. PWS arrangements, as with all PES arrangements, can take a variety of forms. They can be intended to prevent the degradation of a watershed or to restore a previously degraded watershed. They can be small, local schemes covering several hundred hectares or large, national schemes covering millions of

FIGURE 5. Schematic of a PES arrangement for watershed services



Source: Forest Trends, 2012.

hectares. PWS schemes can be financed directly from the beneficiary or from third parties acting on behalf of the beneficiary, e.g. governments or institutions, or some combination thereof. They can involve cash or in-kind payments and be paid all at once or periodically. In a comprehensive review of 50 ongoing PWS programs in developing countries, Porras *et al.* (2008) highlighted the following major trends.

- **Scale.** Most ongoing programs (82 percent) are local, operating at watershed level or smaller. The remaining 18 percent are national programs. Some of the local programs are linked to national programs or international projects.
- **Scope.** Local programs tend to target one or two watershed services (more commonly water *quality* than water *quantity*), while national programs tend to target multiple environmental services as a means of tapping into multiple funding sources.
- **Service providers.** For the vast majority of local and national programs, private landowners are the main watershed service providers, followed by communal landholders, private reserves, national parks and, in a very small number of local schemes, occupiers of public land.

"PWS schemes can be financed directly from the beneficiary or from third parties..."

- **Payment levels.** In national programs, payment levels are mostly determined administratively. In the local programs, negotiation through an intermediary is more common. Direct negotiations between supplier and buyer occur in very few cases. Funds and transfer of payments are in most cases managed by an intermediary, often in a specially set up trust fund.

- **Funding sources.** Funding sources are varied. National programs primarily receive government funding through the allocation of national budgets and donor funding, including loans from the World Bank. Funding for local programs is more varied but is primarily from: domestic and agricultural water fees; donors, including the Global Environment Facility (GEF), World Bank, and German Cooperation; the private sector, including downstream hydroelectric companies (in some cases, in the form of a donation); and local government budgets.
- **Conditionality.** Nearly all programs are unconditional, meaning service providers are paid on a per unit area basis for land-management practices "believed to have a high probability of resulting in provision of the environmental service." Only one payment scheme, Indonesia's Rewarding Upland Poor for Environmental Services (RUPES) initiative, is conditional on outcomes, such as the level of sediment reduction achieved.

Application

PWS arrangements are gaining prominence and have been applied in a wide range of settings. For example, the US Conservation Reserve Program (CRP), established in the 1950s in an effort to reduce erosion on agricultural lands, became more conservation oriented in the mid-1980s, making it among the oldest and longest running PES programs in the world. CRP today pays farmers to take land out of production in order to protect soil and water resources, as well as wildlife habitat (Karousakis and Brooke, 2010). In northeastern France, Vittel-Nestle Waters paid farmers and provided technical support (and some labor) to alter local dairy farming practices in order to reduce nitrate pollution of groundwater – the source of Vittel's bottled water (Perrot-Maitre 2006).

New York City provides another well-known example. In the late 1990s, New York City was faced with the prospect of building a $4–$6 billion filtration plant with an additional $250 million in annual operating costs to meet new federal Safe Drinking Water Act requirements – an approach that was "treating symptoms, not causes" (Appleton, 2010). An initial analysis suggested that preserving the upstream rural Catskill watershed would be far less expensive. However, New York City had a long-history of employing eminent domain to solve such issues. When farmers and rural landowners voiced immediate concern, the city and local farmers came together to develop a plan that could meet both groups' interests. A key element of the plan was the Whole Farm Program, a voluntary effort fully funded by New York City's Department of Environmental Protection whereby farmers would work with technical advisors to custom design point and nonpoint source pollution control measures to meet an environmental objective while also improving the viability of their farming business. By 2006, the city had spent or committed $1.4–$1.5 billion in watershed protection projects, averaging $167 million in expenditures per year (Kenny, 2006). Participation remains high, with 96 percent of large farms in the watershed participating in the program (Watershed Agricultural Council, 2011).

PWS arrangements have also been established in developing countries. In Ecuador, for example, the Socio Bosque Program (SBP), a national program established in 2008, provides financial incentives to individual and communal forest landowners to conserve native forest and Andean tundra ecosystems. The program, which includes environmental protection and poverty alleviation objectives, is largely state funded. Since 2012, however, additional support has been provided by the German Development Bank, NGOs, and General Motors Omnibus BB. Program participation is voluntary. Participants are provided a monetary incentive per hectare of land entered into the program, and in exchange, must agree to refrain from logging, changing existing land uses, burning, altering hydrological conditions or reducing carbon storage, and commercial or sport hunting and fishing for 20 years. By mid-2013, 1.1 million hectares had been conserved through 2,100 individual and 150 communal agreements (Raes and Mohebalian, 2013).

While PWS programs can be found in a wide range of settings and, in some cases, have been operating for decades, comprehensive data on their size or scope are not available. Ecosystem Marketplace (2013) estimated that the total transaction value of PWS programs and water funds in 2012 was $8.0 billion. Activity in 2013 was considerably higher, with an estimated $11.5 billion in transaction value for PWS programs in China alone. While these data suggest dramatic growth, Bennett (personal communication, 2015) noted that the difference can largely be explained by better reporting by a larger number of projects. Case studies of PWS programs in developing countries are maintained by the London-based International Institute for Environment and Development and at Watershed Connect, an online platform maintained by Forest Trends (2015a).

Environmental, economic, and social performance

Comprehensive studies on the performance of PWS programs are limited, although some studies have been conducted on various aspects of these programs. Below, we examine the available evidence looking at how PWS has performed environmentally, economically, and socially.

ENVIRONMENTAL PERFORMANCE

The environmental performance of PWS is not well understood due to a lack of scientific analysis. In an analysis of 47 PWS schemes in developing countries, Brouwer *et al.* (2011) found that "less than half of the schemes used quantifiable indicators and monitored the impact of the schemes on environmental performance." In most cases, the indicators were input-based, meaning that they, for example, looked at land area with forest cover, rather the actual impacts and outcomes of the program. In a review of Costa Rica's programs, Pagiola (2008) found it "unfortunately impossible to determine the extent to which the PSA[23] program has successfully generated environmental services. Although the PSA program has established a strong system to monitor land user compliance with payment contracts, the program remains weak in monitoring its effectiveness in generating the desired services."

There are several challenges to evaluating environmental performance:

- many programs lack baseline data or monitoring systems
- the connections between land-use practice and watershed services are not always clear, especially as they relate to water quantity, and are often site specific
- it can be difficult to attribute change to the program rather than to external factors (e.g. changing commodity prices)
- programs may not reach threshold levels for measureable impact, or that impact may occur over a relatively long time period.

As a result of these challenges, reliance on input-based indicators (sometimes referred to as behavioral change) has been borne out of necessity.

Porras (personal communication, 2015) argued that because of these challenges, monitoring should be based on input-based, rather than outcome-based, indicators, as outcome-based indicators shift too much risk to the ecosystem service provider and may raise equity concerns. She further noted the need to set meaningful expectations. For example, conservation projects may be implemented within a landslide-prone watershed to reduce the risk of landslides, with the understanding that, even with a successful program, a landslide would still likely occur, albeit with reduced frequency and intensity over the long term. Thus, an expectation of no landslides is unrealistic and could threaten the viability of the program.

"...PWS programs can be found in a wide range of settings..."

In the absence of data on project outcomes, Porras *et al.* (2008) found that reported impacts are often based on "perceptions of local populations and those operating the schemes and/or quick measurements of what the impacts should be, rather than in-depth scientific evidence drawing from site measurements and modelling of relationships." But even based on these sources, the available data suggest that environmental performance is mixed. In a review of previous studies

[23] *Pagos por servicios ambientales* (payment for environmental services)

and surveys of PWS scheme managers, Brouwer *et al*. (2011) found that "58 percent of the PWS schemes were classified as effective in reaching their environmental objectives, while 42 percent were not." Several factors, ranging from the number of intermediaries and mode of participation to the selection of service providers, level of community participation and type of monitoring, were found to improve environmental outcomes:

- schemes with fewer intermediaries were more effective in meeting environmental objectives
- mandatory participation increased environmental effectiveness compared with voluntary schemes
- selecting service providers based on a set of criteria, e.g. location, accessibility of land, or parcel size, tended to have a negative impact on environmental performance
- contracting with the community was more effective than contracting with a single ecosystem service provider
- programs that monitored progress toward achieving environmental objectives were more likely to reach those objectives.

The study also found that schemes for direct payments by downstream hydropower companies to upstream land owners to reduce sediment loads were generally identified as successful, while other factors – including the type of watershed service, age of the scheme, or scale of implementation – had no significant effect on the outcome. Recognizing this, Brouwer *et al*. (2011) called for international monitoring guidelines to compare programs, identify success factors, and support their future design.

Some have suggested that one way to improve environmental outcomes is through better selection of areas to include within the PWS program, a process that could be facilitated by the application of new technologies (e.g. satellite imagery) and modeling efforts. Porras *et al*. (2013) identified several criteria suggested in the literature for targeting efforts, including focusing on areas at high risk of deforestation, large blocks of land prone to landslides or other natural disasters, and biological corridors. In Costa Rica, for example, applicants for forest protection are prioritized based on the total number of points they receive, with more points awarded for forests in indigenous territories or those protecting water resources. Likewise, applicants for reforestation projects are awarded more points if they use native species or reforest degraded areas with high forestry potential (Porras *et al.,* 2013). The selection criteria can be tailored to reflect the environmental (and even social objectives) of the program and altered as priorities or needs change.

"...studies have suggested that untargeted, uniform payments reduce the cost effectiveness of PES schemes..."

ECONOMIC PERFORMANCE

Payment structures are generally uniform and untargeted, with flat rates per hectare for all sites (Porras *et al*., 2008; Karousakis and Brooke, 2010). Despite the prevalence of uniform, untargeted payments, program costs and benefits are spatially heterogeneous. Wunschler *et al.* (2006) found that ecosystem service provision varies spatially according to the ecosystem benefits, the threat of loss, and the cost of service provision. Several studies have suggested that untargeted, uniform payments reduce the cost effectiveness of PES schemes (Dillaha *et al.,* 2007; Ferraro, 2008), and given likely constraints on program budgets, reduces the project benefits and its long-term success (Karousakis and Brooke, 2010).

Reverse auctions (also referred to as procurement auctions) have been put forth as one option for improving the economic efficiency of PWS schemes (Karousakis and Brooke, 2010). In an ordinary auction, the buyers compete to obtain a good or service by offering increasingly higher prices. With reverse auctions, the sellers compete to obtain business from the buyer, and prices typically decrease as sellers undercut one another. The US Conservation Reserve Program, for example, combines reverse auctions with an environmental benefit index to select land for inclusion in the program. However, Ferraro (2008) acknowledged that auctions introduce their own set of challenges, especially in low- and middle-income countries. In these countries, PES schemes may have dual objectives, and reducing information asymmetries (and thus payments for the ecosystem service provider) may not be a priority. Additionally, administrators of these programs might be less likely to differentiate payment due to concerns about fairness, and it is unclear whether there would be institutional capacity to manage these programs. Moreover, auctions tend to increase transaction costs, which may already be relatively high in low- and middle-income countries where buyers of environmental services are likely to contract with many small, often semi-literate, landowners, who often have no legal titles and are in dispersed remote rural areas. Finally, differentiation of payment can make it difficult to identify corruption and ensure that differentiation is based on implementation of transparent rules. Alix-Garcia *et al.* (2009) suggested another option to reverse auctions would be "to conduct rigorous contingent valuation studies in areas targeted by the program."

While uniform payments are still common, there are several notable exceptions. Mexico's National Programme for Hydrological Environmental Services (PSAH) provides higher payments for lands that provide greater benefits. For example, primary forest owners receive 300 pesos per hectare per year (approximately $27). Cloud forest owners, by contrast, receive 400 pesos per hectare per year ($36) due to the perceived higher delivery of hydrological services associated with this type of forest which has a role in capturing water from fog and clouds during the dry season (Porras and Neves, 2006). Payments are made annually, at the end of the year, once the absence of land use change has been confirmed.

China's Sloping Land Conversion Program also provides targeted payments, although payments are differentiated according to the opportunity costs. China's program, which began as a pilot in 1999 and was fully implemented in 2002, requires farmers to set aside erosion-prone farmland within critical areas of the watersheds of the Yangtze and Yellow Rivers, the two largest rivers in China. Total investment is $4.3 million per year. Farmers in the Yangtze River Basin are paid yuan 417 per hectare per year ($50), while those in the Yellow River Basin are paid yuan 290 ($36) per hectare per year. In addition to the regular cash payments, farmers also receive a one-off cash payment and regular grain rations (Porras and Neves, 2006a). The program is designed to promote forestry and other economic endeavors on the land, rather than grain production.

Given that most programs are voluntary, some have argued that continued participation provides some indication that the programs are cost effective, i.e. that the benefits exceed the costs. The impact of PWS schemes on ecosystem service providers is generally estimated by looking at the payment as a fraction of household income. Using this metric, results are varied. Kosoy *et al.* (2007) found that the amount received from the PWS scheme was less than 2 percent of gross annual income for most providers in three cases in Costa Rica, Nicaragua, and Honduras; moreover, most watershed service providers did not think that the payment was fair. However, Wunder (2008) found that payments represented 10 to 16 percent of household income in schemes in Bolivia, Colombia, Ecuador, Venezuela, and Vietnam. Even these studies did not examine the transaction costs participants incurred in the program or the opportunity costs. In light of these findings, several studies have suggested that there are also important non-financial (or non-income) benefits (Kosoy *et al.*, 2007; Wunder, 2008). The most commonly cited non-financial benefits include increasing land-tenure security, increasing human and social capital through internal organization, and increasing the visibility of the community to donors and public entities (Wunder, 2008).

SOCIAL PERFORMANCE

Limited data are available on the social outcomes of PES programs, as studies have been more narrowly focused on "short- or mid-term outcomes such as increased income or capacity building since these are much easier to identify" than broader social impacts, such as changes in power dynamics (Richards, 2013). In one notable exception, a review of Mexico's PES program

(Alix-Garcia *et al.*, 2009) found that in most cases, there were no "obvious" changes in the social dynamics within a community. However, in two cases, they found a shift in the relative power of certain groups, whereby small, private forest holders who held land within or adjacent to communal lands threatened to cut down their forests if they did not receive some compensation.[24] In two other cases, the program improved environmental awareness and participation in conservation activities.

"PES schemes were ... to improve the efficiency of natural resource management, not as a mechanism to reduce poverty..."

Information on broader social outcomes is limited. However, there is information on the role of PES arrangements in alleviating poverty. It is important to recognize that PES schemes were conceptualized as a mechanism to improve the efficiency of natural resource management, not as a mechanism to reduce poverty (Pagiola *et al.*, 2005). While most programs prioritize areas critical for ecosystem services, some have been tailored to meet social objectives through a variety of mechanisms, including by targeting the programs to particular areas or populations, reducing transaction costs, and providing pro-poor premiums and subsidies (Wunder, 2005; Porras *et al.*, 2013). In Costa Rica, a social development index consisting of 11 health, participation, economics, and education indicators is one of the criteria that is then integrated with environmental criteria to select participants.[25] This particular social development index has been shown to be ineffective in targeting payments to low-income populations because it is biased toward large properties and is "too spatially coarse to represent the social impact of the programme at household level" (Porras *et al.*, 2013). However, it suggests that some sort of criterion – preferably tailored to individual characteristics rather than broad geographic regions – could be developed to improve social outcomes. While some have argued that the pursuit of poverty alleviation objectives is likely to result in environmental tradeoffs (see, e.g. Huang *et al.*, 2009), others suggest that this may not always be the case (Brouwer, personal communication, 2015).

South Africa's Working for Water (WfW) program is one of the few programs to have poverty alleviation as its primary objective. Between its launch in 1995 and 2009, WfW cleared more than 1 million hectares of invasive alien plants, which improved the timing and volume of surface water flows, provided erosion control, and increased biodiversity (Ferraro, 2009). The program, administered by the Department of Water Affairs and Forestry, employs 25,000 to 32,000 people annually, targeting low skilled, previously unemployed laborers, with a special focus on rural women, youth, and the disabled (Ferraro, 2009). Social development, an integral part of the program, includes "skills development, training, and awareness creation of communities in health issues, hygiene, environmental health, inoculation, sexually transmitted diseases, pregnancy and menopause" (Department of Environmental Affairs, 2015). The vast majority of the program budget is provided by the central government and the Department of Water Affairs and Forestry's general budget, with only very minor funding from foreign donors, municipalities, and the private sector. Ferraro (2009) argued that while the program is effectively the government paying for environmental services on government-controlled lands (and therefore not a true PES program), the program administrators are actively seeking voluntary payments from private and municipal actors to remove invasive plants from within their watersheds.

Several studies have examined the socio-economic status of participants in PES schemes, either as buyers or sellers. Porras *et al*. (2008) found mixed results in both national and local schemes, depending, to some extent, on land and forest tenure regimes and socio-economic conditions in the targeted area. In programs in Mexico and Nicaragua, for example, the poor were relatively well represented (Muñoz-Piña *et al.*, 2008; Pagiola *et al.*, 2005), whereas in Costa Rica, the poor

[24] In a somewhat unusual situation, this conflict was a result of the fact that only a small group had rights to the commons and only those with rights received payment.

[25] The index is used by Costa Rican government institutions to establish priority for social policy and budget allocations.

were not well represented (Zbinden and Lee, 2005). Wunder (2008) noted that one must typically own or hold land in order to be a seller, thereby excluding the "poorest of the poor." Some schemes have attempted to recognize informal access to resources (e.g. Indonesia's RUPES Program), although this has been difficult to replicate elsewhere (Porras *et al.*, 2008). A recent review of ten PWS schemes in developing countries by Bond and Mayers (2010) found only a small number of cases where livelihoods had been improved, concluding that "there are significant and positive indirect effects of PWS – particularly in building social capita in poor communities." They acknowledged that while improving education, health, and nutrition are better ways of reducing poverty than PWS, there is little evidence of these schemes actually doing any harm. Moreover, they suggested that targeting can make PWS programs more effective in alleviating poverty.

Additionally, while it is commonly assumed that upstream service providers are poorer than downstream users (Wunder, 2008), the reality may be more complicated. For example, George *et al.* (2009) found that downstream and upstream stakeholders were part of the same community in two watersheds in Thailand and Lao PDR with no clear distinction between upstream providers and downstream beneficiaries. In some cases, according to Porras *et al*. (2008), downstream users may, in fact, be poorer, raising concerns about their ability to pay as well as whether those payments are equitable. In cases where user fees were used to compensate ecosystem service providers, the authors found that the fees were generally found to be acceptable, with no detectable impact on water use or access to water. Additionally, some programs had taken steps to ensure that the poorest users were not impacted by these fees, e.g. by making payments voluntary or providing a lifeline supply of water.

Few studies have examined gender representation among program participants. In a literature review, Ravnborg *et al.* (2007) found that less than 5 percent of the references addressed gender-specific aspects of impacts of PES. In a more recent assessment, Richards (2013) concurred, finding that "Gender effects have not been monitored, and therefore there is no information about how women have been affected except some reference to their low levels of participation." Porras *et al.* (2008) cited two studies indicating low participation levels by women. However, these studies were more than a decade old and may not have reflected current conditions.

Necessary, enabling, and limiting conditions

Some factors, such as contract adjudication and enforcement, may be *necessary* for establishing a PWS program. Other factors, such as appropriate inventories and analyses and government support, can *enable* but may not be required for PES programs to be established. Still other factors, such as legal prohibitions, *limit* watershed PES or function as barriers or obstacles.

Necessary conditions include:

- a legal system recognizing that agreements must be kept
- a civil law providing contract parties with legal remedies to enforce contract rights in cases of non-compliance with contract obligations
- general respect for the rule of law.

"Few studies have examined … gender-specific aspects of impacts of PES."

In general, PES schemes are flexible and the necessary conditions are relatively modest. However, Calvache *et al.* (2012) determined that they must be designed within the legal context of a particular area. Greiber (2009) provided additional detail on the legal framework for PWS implementation, noting that the framework will differ depending on the type of scheme implemented. For example, private schemes, defined as self-organized schemes between private entities, require the least government intervention and depend on only general legal requirements: e.g. a legal system recognizing that agreements must be kept, and civil law providing contract parties with legal remedies in case of non-compliance. However, if only these conditions are in place, Greiber (2009) asserted that these programs would "mostly develop at a small scale with the objective to solve a specific local water problem," and expanding these projects to address regional or national water problems would require a more developed policy and legal framework.

By contrast, public schemes are government-driven schemes that, by definition, require far greater government involvement, as local, regional, or national governments are involved as either watershed service providers or buyers, and payment may be done through user fees, taxes, or subsidies. However, many of these schemes have evolved on an ad hoc basis from initiatives of NGOs and overseas development corporations and, as a result, they typically lack comprehensive or coherent legislation. Greiber (2009) also noted that these conditions limit "the real potential of PES as an innovative instrument that might be applied more often, more efficiently, and at a larger scale to combat prevailing water problems." He argued that a specific legal and policy framework would stimulate PES development by creating greater legal certainty and helping to promote good governance practices.

While necessary conditions establish the minimum requirements for the implementation of a PES program, there is a set of enabling conditions that promotes the success and long-term viability of these programs. While some of the enabling conditions are technical in nature, others are legal, institutional, social, and political.

Technical enabling conditions include:

- an inventory of the value of hydrological services, including assessments of baseline conditions, and of how these values may change in response to land use alterations, infrastructure development, and climate
- an analysis of program costs, including implementation, opportunity, and transaction costs
- a registry of names, transactions, project data, credit issuance, or other information related to PES activities
- technical support from the government, civil society, or the private sector through trainings, information, or direct technical assistance
- methodologies for measuring, monitoring, reporting, and verifying progress toward achieving project outcomes.

Several studies have developed guides highlighting the technical requirements (Hawkins, 2011; Calvache *et al.*, 2012; Smith *et al.,* 2013). In addition to these requirements, methodologies for measuring, monitoring, reporting, and verifying progress toward achieving outcomes are also needed. Monitoring and evaluation are fundamental to the success of PES schemes because the information they provide gives assurance to the buyer that ecosystem services are delivered as promised and allows for adjustments to the program based on better information and changing conditions. Porras *et al.* (2013) made a distinction between monitoring for compliance and monitoring for environmental effectiveness. The former "seeks to ensure that the conditionality inherent in a PWS scheme is put into practice, and that the project is implemented effectively." The latter, by contrast, seeks to ensure that the scheme achieves its overall objectives and is needed to demonstrate additionality, i.e. that changes in watershed ecosystem services can be attributed to the program. While compliance and effectiveness monitoring are often linked, "a high degree of compliance does not necessarily ensure that a scheme is effective, as a poorly designed scheme may target the wrong land managers and land that is at least risk, meaning that the payments may not generate the desired hydro-ecological or conservation benefits."

Despite some of the challenges to monitoring (described in the application section of 3.2), Brouwer *et al.* (2011) pointed to the need for international monitoring guidelines to identify the relationship between the design of the program and its environmental effectiveness because understanding these relationships is "paramount to the future design of cost-effective PWS schemes." A recent *Science* article by a large team of scientists and practitioners in the PES field (Naeem *et al.,* 2015) noted that "many projects are based on weak scientific foundations, and effectiveness is rarely evaluated with the rigor necessary for scaling up and understanding the importance of these approaches as policy instruments and conservation tools." In an effort to advance the field,

TABLE 2. Natural-science principles and guidelines for PES programs

Principle: Dynamics **Objective:** Ensure project capacity to adapt to dynamic natural and anthropogenic processes.	**Principle:** Monitoring **Objective:** Track factors necessary for management, trade, forecasting, and assessment.
SCIENTIFIC GUIDELINES: **identify key services for each service type beyond target services** **identify spatiotemporal scales of targeted services** **identify data needs, resources, and gaps** **identify stressors and their spatiotemporal variability** **identify and forecast trends in endogenous and exogenous threats** identify services' production and functions and sensitivities determine trade-offs and synergies among services determine how functional diversity influences resilience.	SCIENTIFIC GUIDELINES: quantify deliverables associated with target services identify spatiotemporal scales in advance of implementation use established methods/protocols and best practices for monitoring estimate uncertainties **monitoring should inform decision-making** **monitoring should detect potential changes in baseline conditions** monitor non-target services that influence target services.
Principle: Baseline **Objective:** Document and initial conditions	**Principle:** Metrics **Objective:** Robust, efficient, and versatile methods for procuring data.
SCIENTIFIC GUIDELINES: **measure influences of interventions on services** **measure status and trends of non-target services** **ensure that measurements are feasible given resources** assess initial state of exogenous and endogenous threats to services measure factors important for forecasting service trends.	SCIENTIFIC GUIDELINES: must be relevant, reliable, and appropriate in scale should comply with voluntary standards, certification, and regulations should reflect spatiotemporal scales as identified in dynamics optimize balance between precision and simplicity assess progress (in conjunction with baseline and monitoring) should measure both absolute changes and changes in trends preferentially selected to allow comparisons across service types assess how services influence each other.
Principle: Multiple services **Objective:** Recognize trade-offs and synergies among services	**Principle:** Ecological sustainability **Objective:** Insure project durability and sustainability
SCIENTIFIC GUIDELINES: assess how intervention influences the other services avoid "double counting" assess impacts of intervention on non-target services.	SCIENTIFIC GUIDELINES: estimate short-term and long-term project or program performance.

Note: The scientific guidelines shown in **bold font** are intended to indicate "essential" guidelines that must be followed for a successful intervention. Guidelines shown in regular font are considered "desirable".

Source: Naeem *et al.,* 2015.

the authors put forth a set of natural science principles and guidelines for PES efforts that they felt were applicable to local-, regional-, and national-level programs in developed and developing countries (Table 2). A set of scientific guidelines for four of the principles – dynamics, monitoring, baseline, and metrics – were deemed "essential" for a successful intervention, whereas the remainder were deemed "desirable". While specific to PES arrangements, they argued that the principles and guidelines could be applicable to market-based conservation instruments more broadly. In a review of 118 active PES projects, however, the authors found that 60 percent did not adhere to the four essential principles, highlighting considerable room for improvement in the development and implementation of PES projects.

In addition to the more technical aspects of PES, there are a number of enabling legal, institutional, social, and political conditions that also improve the effectiveness of PES.

"Governments, for example, can pass laws or institute policies that enable the development of PES programs."

Enabling legal, institutional, social, and political conditions include:

- a policy and legal framework for PES
- incentives and/or requirements to participate in PES programs
- cultural and political acceptance of markets
- trust between ecosystem service providers and beneficiaries
- a supply and demand for ecosystem services.

Governments, for example, can pass laws or institute policies that enable the development of PES programs. In Costa Rica, participants of PES programs are exempt from paying property taxes (Porras *et al.*, 2013). Likewise, the Peruvian government unanimously passed a law providing a legal framework for voluntary PES programs between land stewards and beneficiaries of ecosystem services, while Colombia went even further by requiring departments and municipalities to invest at least 1 percent of annual revenues toward either PES to landowners or direct land acquisition in source water areas (Bennett *et al.*, 2014). Enabling legislation can occur at various levels (e.g. local, provincial, or national) and take a variety of forms. However, the appropriate level and form will depend on the prevailing governance system in a particular area.

A variety of social and political conditions increases the likelihood of the successful implementation of PES schemes. For example, cultural and political acceptance of markets in general, and of commercializing rights to land use and land management practices, creates an enabling environment. Dillaha *et al.* (2007) noted that PES activity is generally strong in Latin America, but that development tends to lag in areas with strong indigenous cultures (such as the Bolivian highlands) or closed economies (such as Venezuela). It is important to note that in areas where the natural environment has historically been used for free, "actually paying for environmental services in response to mounting resource scarcity represents a major change in attitude, which necessarily will take time" (Dillaha *et al.*, 2007).

Trust is also a key element for an effective PES program, as it helps to ensure that there are willing buyers and sellers, and reduces transaction costs. Dillaha *et al.* (2007) noted that service providers might fear that PES is a first-step toward appropriation of their resources, while service users "might suspect that they are or will be the victims of 'environmental blackmail'." Based on several cases in Asia, Neef and Thomas (2009) argued that "Lack of trust between potential buyers and providers of environmental services is probably one of the most constraining factors in setting up viable PES schemes." One way to facilitate the trust-building process is through stakeholder engagement, especially during the initial stages of the project. Likewise, transparency and access to information are also essential. Intermediaries, such as NGOs, can sometimes play a role in building and maintaining trust while also providing technical, legal, and financial support. As

Bond and Mayers (2010) acknowledged, trust "is hard to build and easy to lose."

Finally, there must be a supply of, and demand for, ecosystem services. On the supply side, payments must be big enough relative to other opportunities to create a real incentive for change. On the demand side, beneficiaries must have the ability to pay. For example, Huang *et al.* (2009) posited that by increasing incomes, rapid economic growth in Asia could increase demand for watershed services because there is greater willingness and ability to pay for amenities such as clean water and recreation. At the same time, rapid economic growth could increase demand for goods and services produced on the land, thereby increasing the opportunity cost of the land. In a regional review of PWS programs in sub-Saharan Africa, Ferraro (2009) suggested that demand for watershed services is relatively low, as there are relatively few formal water systems, and even those with formal systems may lack reliable access – which means there are few people who could be easily charged a water fee to pay for watershed services. Moreover, high poverty rates suggest that many would not be able to afford higher water costs.

There is also a set of conditions that can hinder or limit the development of PES schemes.

Limiting conditions can include:

- any legal provision prohibiting watershed PES contracts
- poorly defined property rights.

Greiber (2009) noted that "clearly defined property rights enable parties to enter into PES contracts and ensure the sustainability of PES schemes." Several challenges associated with property rights arise when implementing PES schemes. For example, ecosystem services are a relatively new concept and may not be recognized by the existing legal framework. In Peru, the state is the owner of natural resources and holds the property rights over ecosystem services. While the state can transfer certain property rights over natural resources to individuals, it has not yet been determined whether these rights also include "the right to receive income from the ecosystem services provided by the transferred natural resource." Likewise, in Asia, most forested and agricultural land is state-owned. Thus, individuals and communities have weak land rights, making it difficult for them to sign a contract and provide a legal guarantee of future land management practices (Huang *et al.*, 2009).

3.3 Water quality trading

Description

Water quality trading (WQT) is a market-based approach for reducing or controlling water pollution. It allows permitted dischargers in a watershed to *trade* water quality credits, or pollution allowances, in order to meet water quality standards. Markets in water quality differ from conventional markets in that they are not based on an actual physical commodity. Rather, they are based on trading a *license* or a *permit* to pollute. The primary goal of water quality trading is to reduce the costs of water pollution control, often following the imposition of a cap on pollutant emissions by regulators. Secondary goals are to reduce compliance costs and spur innovative solutions to pollution control.

"Water quality markets draw inspiration from the success of the Acid Rain Program in the US in the 1990s."

Water quality trading is an adjunct to regulation, and not an alternative to it. In fact, its success depends on the presence of a strong regulatory body to enforce water quality standards, and monitor and enforce discharge limits.

Water quality markets draw inspiration from the success of the Acid Rain Program (ARP) in the United States in the 1990s. At the time, most environmental groups and government agency staff favored a "command-and-control" approach to pollution control that would have required all power plants to install scrubbers on their smokestacks to remove sulfur dioxide (SO_2). Lawmakers instead opted for a bold policy experiment, setting a cap on total SO_2 emissions, and allowing polluters to buy and sell pollution allowances. Under this system, emissions from individual sources could rise or fall, as long as the total annual emissions stayed the same. The central idea was that allowing trading puts a price on pollution, and, in turn, encourages cost savings, efficiency, and innovation.

In most WQT markets, a cap is put on water pollutants. In the United States, the cap is usually set by state governments, which are responsible for regulating water quality in rivers, lakes, and estuaries. The cap should be based on a scientific analysis of how much pollutant a water body can assimilate without being excessively degraded, which is referred to as a total maximum daily load (TMDL). Government regulators issue pollution allowances, often referred to as “credits”, to existing polluters. For example, a credit may allow a facility to discharge one pound of phosphorus to a river. A facility manager may choose to install pollution-control technologies that limit emissions. If a facility’s emissions decrease to below its permitted level, this frees up additional credits that managers may then sell to other polluters. There typically may be two types of buyers that create a demand for credits: i) new entrants to the market, such as a new factory in the watershed, or ii) existing polluters that may wish to or need to increase their emissions, e.g. a factory that wishes to increase output, or a sewage plant serving a growing community. Trading allows the industry greater freedom to operate as it sees fit. A low-performing facility may continue to pollute more heavily, but it will be required to purchase credits, making the cost of doing business more expensive. High-performers that can reduce their pollution levels create valuable pollution credits that they can sell, and this creates an incentive to invest in pollution controls, at least according to theory.

To date, most water quality trading markets have been used to control pollution from nutrients that cause excessive algal growth and low dissolved oxygen levels in water bodies, a process referred to as “eutrophication”. Other water quality trading programs have been set up to control salinity, heavy metal, sediment, and temperature or thermal pollution (Morgan and Wolverton, 2005). These programs are typically based around specific watersheds or receiving waters, such as the Chesapeake Bay or Wisconsin’s Fox River. WQT markets are different from other emissions trading schemes, in that trading is used between sources in the same area of impact, e.g. a watershed that drains to a particular water body, such as a lake, estuary, or river. The geography of trading contrasts starkly with other well-known cap-and-trade-style environmental markets, such as national and international markets for carbon offsets, where emission reductions can take place even in remote parts of the world.

Trading within water quality markets can take several different forms. The most common arrangement in the United States is a bilateral market, where buyers negotiate trades directly with potential sellers, discussing their quantity and price. Often, a regulator will get involved by, for example, approving the terms of the agreement, or facilitating monitoring to ensure that actual discharge reductions take place. This arrangement makes transactions slow and costly, and has been partially blamed for the moribund trading activity in most US WQT markets (Woodward *et al*., 2002). In clearinghouse-style markets, a middleman such as a brokerage firm facilitates trades by connecting willing buyers and sellers, as has been done in the Tar-Pamlico River Basin Nutrient Trading Program in North Carolina. On the opposite extreme, exchanges are a form of trading where allowances are turned into standardized commodities and are freely traded. For example, in the United States, SO_2 allowances are traded on the Chicago Mercantile Exchange. The Hunter River Salinity Trading Scheme in Australia may also be considered an example of an exchange, although in this case, the government is responsible for trades (NSWDEC, 2003).

Water quality markets can be classified in a number of ways. One useful way to categorize markets is based on the regulatory system that drives the demand for trading and whether it includes a cap on total emissions (Anderson, 2004). This includes both cap-and-trade systems and credit systems.

Cap-and-trade systems put a limit on the total amount of allowed releases of pollution. They seek a specific environmental result (a cap), and trading allowances to release pollution are simply an option to minimize the cost of achieving the emission reductions specified in the regulatory cap. In the cap-and-trade approach, allowances for future emissions are sold or granted to existing sources.

Credit systems, on the other hand, do not establish any fixed ceiling on total emissions. Total emissions can increase if new sources of pollution enter the market, or if existing sources increase their outputs. In uncapped systems, tradable credits are earned for controlling pollution beyond what is specified in one's permit.

"WQT programs allow polluters to interact in the marketplace and decide among themselves how to allocate the right to discharge pollutants."

The literature is full of descriptions of the potential benefits of water quality trading compared with the more conventional "command-and-control" approach, where regulators allocate the right to pollute by imposing limits on individual polluters (Shortle and Horan, 2005). In particular, WQT markets are thought to be a less-costly, more-efficient alternative. When the total amount of pollutant emissions in a region is capped, the right to pollute becomes a scarce commodity and, as many economists assert, markets are the most efficient way of allocating a scarce commodity.[26] WQT programs allow polluters to interact in the marketplace and decide among themselves how to allocate the right to discharge pollutants. Markets are also thought to foster innovation – where "innovative, entrepreneurial companies can profit from low-cost reductions in emissions. Slower, less innovative firms can benefit as well by having the opportunity to purchase needed emission allowances for less than it would cost them to comply internally" (Anderson, 2004). Moreover, cap-and-trade programs may provide greater certainty in the outcome. With a fixed or declining cap, policy makers can be more certain of the environmental improvement that will be achieved, compared with alternative approaches such as best management practices or a pollution tax.

Application

A survey conducted by Bennett and Carroll (2014) for Forest Trends found that activity for WQT markets is still relatively small, although it has shown large increases in the past several years. In 2013, the trading value of WQT markets was about $22.2 million. Much of that activity was concentrated in the United States, where WQT markets had a trading value of $11.1 million in 2013, with a cumulative total of $95 million since 2000. While there are currently over 30 water quality markets in place in the United States, some have seen no trading or only a few trades, even two decades after their establishment. Among the reasons cited for the lack of trading activity are high transaction costs, lack of trust, uncertainty about the future of the market, or simply unfamiliarity and unwillingness to participate in the market (Shortle and Horan, 2008). While some of the longest-running markets are getting smaller, new programs in Oregon, Virginia, and Maryland have kept overall transaction values high. Indeed, in 2013, United States market activity was at its highest level ever recorded, although Bennet and Carroll (2014) posited that this likely represented recovery from the economic downturn rather than new growth. It is of note that New Zealand's Lake Taupo Trading Program, a relatively new program, has rapidly become the largest in the world, with at least $10.2 million in transactions in 2013. However, the future of that market is uncertain because "that market's biggest buyer, the Lake Taupo Protection Trust, announced in June 2013 it would

[26] While economic theory says that trading will lead to the most efficient allocation of a resource, it says little about distributional effects, i.e. who pays and who benefits, or other market "externalities".

withdraw from future trading, having made arrangements to achieve its remaining nitrogen reduction goals by purchasing and managing land in the catchment" (Bennett *et al.,* 2014).

"40 percent of America's surface water fails to meet its water quality goals."

The popularity of emissions trading for dealing with water pollution in the United States is largely a result of the Clean Water Act of 1972. The specifics of how the law was written and implemented have made it difficult for governments to handle pollution from farms. In particular, the law made it illegal for "point source" dischargers, such as factories or wastewater treatment plants, to release pollutants into waterways without a permit, but did *not* attempt to regulate pollution from "nonpoint sources", such as agriculture or urban runoff, since these were considered minor sources of pollution and believed to be difficult to regulate. In many watersheds, however, farms and feedlots are the largest source of pollutants. These nonpoint sources are exempt from most water pollution regulations, and there appears to be insufficient will to remedy this.

Forty years after passage of the landmark law, some 40 percent of America's surface water fails to meet its water quality goals (Faeth, 2000). Further, a set of studies in the 1990s showed that reducing nutrient pollution from agriculture could be 65 times more cost effective than imposing further controls on municipal or industrial sources. As a result, water quality regulators in the United States use WQT markets primarily as a tool to encourage point dischargers to fund nonpoint source pollution controls, largely because regulators lack the authority to deal with these sources of pollution.

One factor contributing to the popularity of emissions trading is its appeal to conservative politicians due to their invocation of the "power of the market" (Conniff, 2009). The original cap-and-trade programs were policy innovations developed by conservatives in the Reagan, George H.W. Bush, and George W. Bush administrations, "and were once strongly condemned by liberals and environmentalists" (Schmalensee and Stavins, 2012). The key element for overcoming conservative politicians' resistance to the policy was to replace regulation with a free market; the market would operate on its own with no intervention by the government, a step that would "radically disempower the regulators" (Conniff, 2009). However, this has not been the reality with most environmental markets, which have been designed with additional layers of government that oversee the market, monitor and enforce emissions limits, and facilitate and verify trades. By contrast, there are alternative pollution control policies that are simpler and require less government involvement, such as mandating the use of pollution-limiting technology or taxing pollution. There is some irony here, prompting one scholar to observe, "a putative form of rationalization or deregulation is in fact a case of 'reregulation'" (Mariola 2009).

As an example of how WQT markets work, consider the example of the Chesapeake Bay. To reduce nutrient discharge into the bay, regulators had the option of requiring wastewater plants to install expensive and technologically advanced treatment systems. Nitrogen removal costs for these systems are typically about \$200 per pound per year (Jones *et al.,* 2010). However, farms in the watershed are an even larger source of nitrogen, and removal costs are much lower, at \$1 to \$5 per pound per year. As a result, permitted dischargers have negotiated the ability to fulfill their permit requirements by funding pollution control projects on farms in the watershed, such as planting winter cover crops, planting vegetation around streams (called riparian buffers), or installing permeable filter strips around animal feedlots. These agricultural "best management practices" reduce soil erosion and sediment runoff from farms, reducing the amount of nutrients washed into local waterways. Because they use soil and vegetation to filter water and sediment, they are generally low-tech and relatively inexpensive to install and maintain. The Chesapeake Bay WQT program was set up specifically to encourage these kinds of exchanges.

Trading allows regulated polluters to meet their permitted discharge requirement at a much lower cost than with technology. Further, it helps to finance pollution reduction from the agricultural sector, which generates about 44 percent of the nutrients entering the bay. A recent assessment concluded that controlling discharges from agriculture is necessary to restore the bay (Steinzor *et al.,* 2012).

A second noteworthy example of a domestic WQT market is the relatively new Ohio River Basin Water Quality Trading Project developed by the Electric Power Research Institute, the research arm of the United States electric power industry. Coal-fired power plants in the Ohio River Basin are a major source of nitrogen pollution in rivers, due to their using water in scrubbers for air pollution control and to sluice the coal ash out of reactors (US EPA, 2009). The ash and water slurry most often goes into storage and treatment ponds that provide only a minimal level of treatment and where spills and illicit discharges have been common (Zucchino, 2015). Under the pilot program, power plants and other interested parties can pay for nonpoint source pollution reductions on farms, another major source of pollution in the watershed. Because on-farm improvements are much less expensive than installing wastewater treatment facilities, power plants stand to save $500,000 to $800,000 per year (EPRI, 2010).

The first projects are creating nutrient reduction credits through "activities like planting cover crops and creating treatment wetlands for animal wastes" (Ecosystem Marketplace, 2015). The program is notable for its thoroughness in documenting projects, posting a description and photos of every project on the Electric Power Research Institute (EPRI) website, and using a standard methodology for calculating the reduced pollution in farm runoff. The program is credited with reducing pollution by 100,000 pounds of nutrients between 2013 and 2015 (Barrett 2015). While commendable, this project is a small pilot, and pollutant reductions are small compared with the estimates of over 3 million pounds of nitrogen entering the watershed's rivers every day (Olszowa *et al.*, 1998). Further, on-farm nutrient controls will do little to control other toxins that are present in coal ash, such as arsenic, lead, mercury, and heavy metals. However, the program is notable as it is the first program in the United States that has allowed the purchase of pollution control credits across state lines (Fox, 2014).

In addition to the many markets in the United States, there are also examples of WQT markets in other regions, especially in Oceania:

- Lake Taupo Nitrogen Trading Program (New Zealand)
- South Creek Bubble Licensing Scheme (Australia)
- Murray-Darling Basin Salinity Credits Scheme (Australia)
- South Nation River Watershed Trading Program (Canada)
- Chao Lake Nutrient Trading Program (China, under consideration)

Several European countries have shown interest in WQT. A literature review by Wind (2012) summarized 14 studies of the concept within the European Union. Despite this interest, no markets have been created to date, and it appears that EU directives limit the ability of states to set up markets.

Perhaps the best example of a successful operating WQT market is on Australia's Hunter River, where coal mines and other sources are subject to discharge limits to protect water quality and drinking water sources in downstream cities. Saline soils are present throughout Australia, and during coal mining, salty water collects in mine pits and shafts and has to be pumped out to allow mining operations to continue (NSWDEC, 2003). The Hunter River Basin had a history of conflict among users, with mining activities making the water unsuitable for irrigation, and new mine proposals facing extremely high costs. The state government, following years of study and collaboration with stakeholders, set a cap on salinity levels in the river, and put a system of tradable discharge credits in place.

Under this system, no discharges of salty water are allowed when the river is in low flow. When the river is in high flow and its capacity to dilute salty inflows is greater, limited discharge is allowed, controlled by a system of salt credits. Permitted dischargers coordinate their activities so that the total salt concentration in the river never goes above a specified limit. Industries can buy and sell salt credits in real time via a trading website run by the state government. Several years after the program began, the trading program is popular among participants and functioning smoothly. The state government has set up real-time monitoring to make sure the river water quality meets standards, and to monitor for permit violations. Perhaps the biggest marker of the program's success is that new, potentially highly polluting mines have been established, but river water quality has met standards nearly 100 percent of the time.

"...there is a great deal of literature ... but few real-world evaluations of existing WQT markets."

Environmental, economic, and social performance

Despite the fact that water quality trading markets have existed for three decades in some areas, it is difficult to state whether they can be considered an overall success. In making such an evaluation, we must determine whether desired pollution reductions were achieved and water quality targets attained. We must also examine how the result compared with what would have occurred under another form of management: were the pollution reductions greater, did they occur more quickly, or at a lower cost?

Moreover, there is a great deal of literature about water quality trading and market-based solutions to water pollution but few real-world evaluations of existing WQT markets. Much of the literature about markets is theoretical and oriented toward "making the case" for WQT, e.g. describing how a market can or should be set up. Below, we examine the available evidence looking at how WQT markets have performed environmentally, economically, and socially.

ENVIRONMENTAL PERFORMANCE

While there are no comprehensive analyses of the environmental performance of WQT programs in general, there are several examples of successful programs. In the application section of 3.3, we cited Australia's Hunter River as one example. Indeed, since formation of the program, river water quality has met standards nearly 100 percent of the time, protecting water supplies to downstream irrigators and cities. This happened despite the establishment of new, potentially highly polluting mines in the watershed. The Alpine Cheese Company Nutrient Trading Program in Ohio is another notable success. As a part of this program, the company helped fund pollution reduction projects on local farms, paying 25 farmers to install 91 conservation measures that resulted in a 3,000-pound-per-year phosphorus reduction (US EPA, 2010).

A United States Environmental Protection Agency (US EPA) 2010 evaluation of the program found that it exceeded its nutrient reduction goals, and estimated that "conservation measures would reduce up to three times more nutrients than if equal funds were used for wastewater treatment upgrades." It is noteworthy that the project has also been praised by the local chapter of the Sierra Club, which has strongly opposed the creation of larger WQT schemes in other areas that could allow industry to continue implementing poor practices by purchasing offsets (Marida, 2010).

Likewise, the Connecticut Nitrogen Credit Exchange Program – currently the largest in the United States – was created in 2002 to reduce nitrogen pollution to Long Island Sound from the Connecticut River. Under the program, which covers 79 sewage treatment plants in the state of Connecticut, a plant can control pollution in excess of its permit requirement and sell excess nitrogen allowances to those plants that exceed their allowances. A 2012 review of the program suggested that the program had helped the state meet its environmental goals while lowering overall costs (Stacey *et al.*, 2012). The program helped reduce nitrogen loading by over 50 percent over 10 years, and was on track to meet water quality goals by 2014. As a result, the area of Long Island Sound suffering from hypoxia (low dissolved oxygen which is fatal to wildlife) had steadily declined.

Despite these examples, most water quality trading programs in the United States are either too small or have seen too little trading to make a meaningful difference on water quality. For example, a 2012 evaluation of Ohio's Great Miami Nutrient Trading Program called it "one of the most successful programs to date" (Newburn and Woodward, 2012). In 2009, the trading program attracted $1.3 million in trades and helped fund 100 projects that reduced nutrient pollution by 800,000 pounds per year. Proposed projects submitted by farmers in the watershed covered a variety of agricultural "best management practices" designed to prevent sediment and nutrients from entering waterways. Evaluators concluded that the program "has been successful in developing both supply and ensuring funding for agricultural pollution abatement projects compared to other WQT programs" (Newburn and Woodward, 2012). Despite this, they found that the program had not likely had a significant effect on regional water quality due to the "relatively minor role that the trading program has had on nutrient management in the watershed to date."

To date, the projects have simply been too small and too few to have a major impact. The Great Miami River watershed drains 748 square miles, the majority of which is cultivated, so a much larger investment would be needed to meaningfully improve water quality in the basin. This example highlights the caution needed when interpreting large numbers cited by market proponents. While 800,000 pounds sounds like a lot (and is indeed a worthwhile accomplishment), it pales in comparison with the estimated 1 trillion pounds of nitrogen entering the Ohio River watershed each year (Olszowa *et al.*, 1998). Like most WQT markets in the United States, the Greater Miami Basin program did not emerge from a cap on pollutants. Rather, it was created as a way to allow regulated point-source dischargers, such as factories and sewage plants, to lower their costs by paying for pollution controls on farms rather than installing expensive pollution control measures at their own facilities.

In an assessment of three mature WQT programs in the United States, one scholar concluded that there had been very little benefit as a direct result of trades. However, the programs had an unexpected benefit: they brought together watershed stakeholders and increased "the institutional capacity for watershed management" (Wallace, 2007). Stakeholders coming together around a common goal of improving water quality also helped lower resistance to new, more stringent water quality regulations. Wallace concluded that the markets themselves were not important mechanisms for reducing pollution. Rather, their presence contributed to "unintended contributions to increased pollution regulation and management on a watershed scale." So, on the one hand, these markets could be considered failures by some observers because many of them had seen no trading even decades after their creation.

The lack of trades can be explained by a number of factors: high transaction costs, lack of trust, uncertainty about the future of the market, or simply unfamiliarity and unwillingness to participate in the market. On the other hand, even where little or no trading occurred, water quality and governance had improved in the three watersheds evaluated by Wallace (2007). It is not always possible to disentangle how much of a role the market played in bringing about these improvements. On the one hand, financial transactions have not played a large role, tempting us to conclude that the markets were relatively unimportant. However, if discussion of the use of "market fundamentals" helped overcome resistance to environmental regulation and paved the way toward decreased pollution, then we may conclude that markets were a key feature in improving water quality, albeit indirectly.

ECONOMIC PERFORMANCE

It is difficult to assess the economic performance of WQT markets and how their economic performance compares with alternative forms of pollution control. To date, the size and impact of water quality markets is relatively small. There is some information in the literature on the number of trades that have occurred, and the prices paid for water quality credits. In the application section of 3.3, we cited a Forest Trends study that estimated the value of the United States water quality trading market as $11.1 million in 2013, in terms of the total value of payments. To put these numbers in perspective, state and local governments in the United States spent $70 billion on sanitation and sewerage in 2008 (US Census Bureau, 2012). Despite these investments, many argue that the United States should be spending much more to control water pollution. Researchers at Kansas State found that nutrient pollution from nitrogen and phosphorus cost the United States $2.2 billion in 2008, due to losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and increased treatment for drinking water (Dodds *et al.*, 2008).

"...advocates for WQT markets cite the lower overall cost of improving water quality as their main advantage..."

While limited data are available, advocates for WQT markets cite the lower overall cost of improving water quality as their main advantage, as compared with more conventional means of water pollution control. There is local evidence for this, especially in smaller markets. Take the case of the Alpine Cheese Company, in Ohio's Sugar Creek watershed. The plant was faced with expensive wastewater treatment upgrades to satisfy Clean Water Act permit requirements (US EPA, 2010). These upgrades would likely have cost over $1 million to install, plus ongoing costs for operation and maintenance. Instead, the company collaborated with others to reduce pollution through projects at farms in the watershed that have a much lower cost per pound of phosphorus prevented from entering streams, and which are expected to last 15 to 20 years (Moore, 2012). The company worked with universities, regulators, and local agricultural extension services, providing $800,000 over five years for planning, technical assistance, and outreach. In addition, these measures allowed the plant to expand, creating 12 new jobs. Further, the project provided funding to chronically cash-strapped local soil and water conservation districts and to the local agricultural economy. Local dairy farmers took pride in improving the environment and supporting the local economy, and also experienced other indirect benefits from the project, "by fencing cows out of streams, bacteria levels in milk were decreased, giving the farmers a premium price for milk and reducing costs for Alpine [Cheese Company]" (Marida, 2010).

As described previously, the Connecticut Nitrogen Credit Exchange Program is currently one of the largest WQT programs in operation. An evaluation of the program in 2012 suggested that the program has helped the state meet its environmental goal of reducing nitrogen loading to Long Island Sound while lowering overall costs. The state estimated that, in the first 10 years of the program, trading had lowered costs by $300 to $400 million below what individual facilities would have had to pay for equivalent pollution reductions (Stacey *et al.*, 2012).

SOCIAL PERFORMANCE

There is little research on the social impacts of WQT, and much of what we describe in this section is based on anecdotal evidence. Critics of environmental markets have raised questions about their fairness and justice. A specific concern relates to how regulators distribute pollution permits at the outset of market creation. Under a market system, pollution permits become valuable commodities to be bought and sold. In many cases, as in SO_2 trading in the United States, the government grants allowances to industries for free, based on their historic emissions. Critics point out that such "grandfathering" of permits rewards those polluters most responsible for environmental problems in the first place. It may also unfairly burden more recent market entrants, because they have no history of polluting and no "free" permits, yet would be required to purchase credits to offset 100 percent of their emissions. There are, however, different ways of issuing credits that help mitigate these concerns. For example, rather than giving away credits, they could be sold to polluters in an auction, as has been proposed in carbon markets.

Critics have also raised concerns about the fairness of water quality markets to potential sellers of water quality credits. Consider a farmer who installed pollution controls before a WQT program was established. Unlike his (polluting) neighbors, he would not be eligible for financing under the program. Thus, the program would reward "notorious polluters" rather than the good stewards, "because the good steward had already reduced pollution" (Ruppert, 2004). Despite these criticisms, there are several examples of WQT markets that have been considered successful, and earned support from industry, famers, regulators, and environmentalists.

As was discussed previously, the Alpine Cheese Company Trading Program in Ohio was a very small market that involved the purchase of credits from 25 farmers by a local cheese company. Many of the farmers already did business with Alpine Cheese, selling milk from their dairy herds, and have a strong interest in maintaining a strong agricultural economy. One observer wrote that, "socially, community has been built with the farmers taking pride in working together, their more sustainable farming practices and in seeing the success of the factory" (Marida, 2010). One sees a similar outcome in an evaluation of the Hunter River Salinity Trading Scheme in Australia. Where there was once "significant conflict between primary producers and mining operators," today, "agriculture, mining and electricity generation operate side by side, sharing the use of the river" (NSWDEC, 2003). Here, a history of conflict has been replaced by cooperation. This did not happen overnight, and required many years of painstaking consultation and negotiation.

In New Zealand, concerns have been raised about how the Lake Taupo Nutrient Trading Scheme affects different types of landowners, particularly indigenous Maori people. In this area, dairy farms and grazing were creating polluted runoff, negatively impacting a freshwater lake important for fishing and tourism. Regulators instituted a cap on nitrogen pollution seeking to maintain water quality at year 2000 levels. Larger corporate landowners were given more pollution credits based on their historical use of the land, while Maori landowners had not yet fully developed their lands (MOTU, 2009). There are historical and cultural reasons why Maoris have been slower to develop their lands: they did not own some lands until recently, and communal ownership makes it slower and more difficult to develop land. In a sense, those most responsible for past pollution have been rewarded with large (and valuable) pollution permits, while the Maori community will face higher costs to develop their lands economically. In response to these concerns, regulators altered the market design by relaxing the cap somewhat "to ease the restrictive nature of historical allocation on Tuwharetoa [Maori] and other forest owners" (Duhon *et al.*, 2011).

"Some critics have suggested that WQT programs could perpetuate or worsen environmental justice problems."

In the New Zealand case study, program managers realized the importance of dealing with issues of race and historical justice in order to make the program successful. In the United States, some program managers have also sought to address issues related to age and gender. For example, the Ohio River Basin Water Quality Trading Project directs money from the electric power industry to farmers to support on-farm improvements to reduce runoff and pollution. A concern was raised early on that the early adopters would be all younger, male farmers (Jessica Fox, EPRI, personal communication, 2015) because they would be more open to new ideas. Also, there are fewer woman-owned farms in the region compared with those owned by men. As a result, the managers of this program have made a particular effort to involve women farmers and older farmers.

Some critics have suggested that WQT programs could perpetuate or worsen environmental justice problems. The environmental justice movement in the United States has focused on the fact that pollution often occurs in areas where many poor and minority people live or work, and that disadvantaged communities bear an unfair burden of exposure to pollution. There is a possibility that trading could allow pollution "hot spots" to continue, with accompanying environmental justice concerns. For example, a polluter could purchase credits instead of making onsite pollution reductions.

This was the subject of a 2013 lawsuit by Food & Water Watch against the Chesapeake Bay Nutrient Trading Program, which was later dismissed by a federal judge (Hauter, 2013).

Trading programs are most effective when they cover pollutants with "far-field" impacts, meaning their effects are felt over a large area or over a long time period. Indeed, a thriving market under a cap could allow pollution hot spots to continue unchecked, and thus would be inappropriate for regulating pollutants which have acute local impacts. "This is the reason no one has seriously contemplated a market for toxics," according to Cy Jones, a World Resources Institute (WRI) senior fellow (personal communication, 2015). This issue is less important when trading operates within discrete basins. The larger the basin in which trading is allowed, the more chance there is to exacerbate hotspots. For this reason, some programs have rules restricting trading to smaller sub-watersheds, as has been done in the Ohio River program described above.

Necessary, enabling, and limiting conditions

In this section, we discuss the minimum conditions that are *necessary* for the creation and successful operation of a water quality market, followed by a discussion of conditions that can *enable* WQT markets. These enabling factors will increase the market's likelihood of succeeding but may not be required for it to be established. Finally, we discuss factors which may *limit* WQT markets by acting as barriers or obstacles.

Necessary conditions for a successful water quality trading program include the following three circumstances. The first is the presence of a regulator and its ability to set a cap on pollutants, monitor pollution, and verify the legitimacy of water quality credits that are created. Thus, the regulator must have the scientific and technical capacity to set water quality goals, and monitor water quality to ensure that those goals are being met. To do so first requires a set of "desired future conditions" for a particular waterbody. This may be set by law, custom, or local preferences. In the United States, the Clean Water Act established the concept of "designated use" for waterways (i.e. swimmable, boatable, or fishable), with water quality standards then developed based on the designated use. The process of developing a standard requires understanding the basic physical, environmental, and human elements of the watershed. Generally, scientists or engineers collect data and use computer models to determine the natural and human pollution sources (i.e. diffuse nonpoint sources and point discharges). They also use models to determine how much of a pollutant a water body can assimilate while restoring or maintaining beneficial uses.

"It is one thing to set up a water quality market; it is another for active trading to take place."

The second necessary condition is that polluters have the ability to create water quality improvements, or reduce pollutant discharge through technology or management. Further, the regulator must be able to verify that these pollution reductions are real and likely to last. Verification of credits can be cumbersome and time consuming, which can inhibit trading. Regulators may require field visits or photos to show that on-farm improvements have been properly installed and maintained. In the case of the Alpine Cheese Trading Program, soil conservation agents ensure that pollution control measures installed on farms meet "stringent engineering specifications" (Mariola, 2009). Implementation requires up to eight visits to a farm from project start to finish, and a full-time agent is required to coordinate a program involving one credit buyer and 25 farmers. In some cases, however, the role of verification falls to a trusted intermediary, as in the case of the South Nation River Program in Canada, where a conservation nonprofit hires local farmers to conduct field inspections (O'Grady, 2011). More often however, inspections and record-keeping are conducted by state or local governments. According to the US EPA, "mechanisms for determining and ensuring compliance may include a combination of record keeping, monitoring, reporting and inspections" (US EPA, 2003). There are other aspects of regulatory oversight necessary to ensure accountability on behalf of both buyers and sellers of credits. This oversight includes many aspects of a trading program:

- establishing trading eligibility
- tracking of trades
- verification of credit generation
- compliance and enforcement
- monitoring of results
- program assessment.

It is especially difficult and usually impractical to measure nonpoint source pollution reductions, for example, from projects designed to reduce polluted runoff from farms. The pollution source is usually spread out, and there is no obvious place to measure the discharge (as there would be at the outfall of a factory). Nonpoint source pollution also tends to be "episodic", occurring when rainfall flushes pollutants into waterways, further thwarting measurement efforts. Regulators have adopted several approaches to deal with these issues. Nonpoint source pollution reductions are most often estimated based on prior studies or modeling. To address the uncertainty associated with these estimates, regulators may place a higher burden for pollution reductions on nonpoint sources. Indeed, some markets have been designed with "trading ratios" where nonpoint source reductions trade against point sources at a ratio of 2:1 or 3:1.

The third necessary condition is an appropriate legal framework enabling trading. Some of the legal requirements for water quality trading are similar to those for other market-based instruments. Broadly, programs require a legal environment that will uphold the rights of buyers and sellers. Some basics, as outlined by Greiber (2009), include:

- a legal system that recognizes agreements must be kept
- a civil law providing contract parties with legal remedies to enforce contract rights in cases of non-compliance with contract obligations
- general respect for the rule of law.

Enabling conditions required for creation of a water quality trading program go beyond these basics. First, the government regulator must have the authority to set discharge limits to protect waterways. Second, the regulator needs the power to issue and enforce water pollution discharge permits. Enforcement, with the threat of meaningful fines or criminal penalties, is especially important. As Abraham Lincoln famously noted, "laws without enforcement are just good advice." Finally, there must be a legal framework by which trading can take place.

It is one thing to set up a water quality market; it is another for active trading to take place. As we have shown, many United States markets have been largely moribund. The following presents what we consider enabling conditions – meaning governments can set up a market without them, but there may be little or no trading. It would be tempting to classify an idle market as a failure, but as we have also seen, some United States markets have seen little trading, but they have been accompanied by an improvement in watershed stewardship and improvements to the environment.

There must be a demand for water quality credits. Demand is the first and foremost enabling condition for trades to take place. Generally, such demand is created by a strong regulatory or non-regulatory driver.[27] In the case of the Alpine Cheese Nutrient Trading Program described above, factory owners wished to expand production, but were unable to do so because of a restrictive discharge permit. Violating the permit could have resulted in fines or criminal charges. The factory owners faced otherwise undesirable options: they could

[27] An example of a non-regulatory driver could be where industrial emitters decide among themselves to voluntarily limit pollution to gain goodwill or in an attempt to pre-empt regulation. This is the case in the Ohio River study discussed above, where electric power companies have funded projects to reduce pollution from farms in their watersheds. These activities are not compulsory, so why would a for-profit corporation do it? Their motivation, as put forth by the program's manager in Congressional testimony is "to meet corporate sustainability goals and their voluntary participation may also be considered by the state permitting agencies when determining the need for flexible permit compliance options in the future" (Fox 2014). In other words, she was saying that companies hope that their activities today will buy them goodwill with regulators and that future regulation will be less burdensome as a result.

relocate the factory, install expensive onsite wastewater treatment, or stop production altogether. In Australia's Hunter River, salty discharge from mines was affecting the drinking water supplies for downstream cities, and an inflexible basin cap would have meant that existing mines could not expand and new industries could not develop. In other cases, industries are interested in mitigating their own pollution to create goodwill or to help lessen the burden of future regulation. This is the case for power companies in the Ohio River Basin. At present, large power companies such as Duke Energy, the largest electric power holding company in the United States with some 7.3 million customers, and American Electric Power, which has over 5 million customers, purchase credits "to meet corporate sustainability goals and their voluntary participation may also be considered by the state permitting agencies when determining the need for flexible permit compliance options in the future" (Fox, 2014).

In addition to demand, there must be willingness to engage in trade among buyers and sellers. One observer cited the most frequent roadblock to establishing a WQT program as the "simple absence of willing buyers and sellers" (O'Grady, 2011). In WQT markets, demand for the commodity (pollution credits) "is artificially created by regulatory decree and which cannot be seen or felt or even measured with precision" (Mariola, 2009). Because the market is entirely dependent on a regulatory driver, it can be fragile and susceptible to interference by politicians or the courts. For example, the United States Acid Rain Program (ARP), the nation's first national cap-and-trade program, suffered a series of legal challenges beginning in 2008, culminating in new rules in 2011 that severely limited trading between states. As a result, the market, which relied heavily on interstate trading, collapsed. In 2012, the market value of a credit to emit a ton of sulfur dioxide was less than $1. Previously, these same credits had sold for $100 to $200 for most of the last decade and peaked at $1,200 per ton in 2005 (Schmalensee and Stavins, 2013). The ARP's collapse is worth pausing to consider, as it was the model for all subsequent environmental markets. Schmalensee and Stavins (2013), economists from MIT and Harvard who studied the program, concluded that, by all accounts, it was a major success: following its launch in 1995, the market performed "exceptionally well along all relevant dimensions" and helped the United States reach emissions goals in 2006.

However, the market's collapse should be a cautionary tale: "When the government creates a market, it can also destroy it, possibly fostering a legacy of increased regulatory uncertainty and reduced investor confidence in future cap-and-trade regimes, and hence reduced credibility of pollution markets more broadly" (Schmalensee and Stavins, 2013).

"In addition to demand, there must be willingness to engage in trade among buyers and sellers."

Trust among market participants is a key element of any WQT program. In the United States, most water quality markets involve point sources purchasing pollution reduction credits from farms, or less frequently, from forests or other nonpoint sources. Controlling nonpoint source pollution from agriculture faces unique obstacles. Farmers often distrust regulators, and worry that participation in a trading program may open the door to future regulation. Some pilot programs in the United States have worked through local soil and water conservation districts, or made use of agricultural extension services, because the farmers know and trust these agents. In fact, Mariola (2009) found the most important factor for program success was "the use of a local, trusted, embedded intermediary as the link between programs and farmers emerges as the most important explanatory variable for program success."

Canadian WQT managers have come to similar conclusions. In the South Nation River watershed, wastewater dischargers face a cap on phosphorus discharge, and new wastewater systems are purchasing phosphorus credits from rural landowners, mainly farmers. Initially, the agricultural community had reservations about the program. One of the main concerns raised by farmers during the design of the South Nation program was their future liability.

"When trades can only take place within a single state or country, it reduces the potential for … water quality improvements."

Organizers confronted this concern during a series of public meetings and then added a key phrase to their final document that addressed the farmers' concerns and allowed trading to begin (O'Grady, 2011) – the phrase was: "Landowners are not bound, legally or otherwise, to attain the predicted phosphorus offset through the establishment of a BMP [best management practice, another term for an on-farm pollution control measure] on their property." Further, control of the program was granted to South Nation Conservation, a community-based watershed organization that was trusted by farmers. In addition, the program is run by a multi-stakeholder committee, "and all project field visits are done by farmers and not paid professionals." As a result, the program has been able to overcome much of the early resistance. An independent evaluation showed that most farmers had a high opinion of the program and have recommend the program to other farmers in their community (O'Grady, 2011).

The ability to trade water quality credits across regional borders may be an important enabling condition, depending on the geography of the watershed. Many important watersheds extend across multiple states, or across international boundaries. When trades can only take place within a single state or country, it reduces the potential for trading and for water quality improvements (Fisher-Vanden and Olmstead, 2013). In 2012, the pilot Ohio River Basin Trading Program became the first program in the United States to allow trading across state borders, with an agreement signed by the states of Ohio, Kentucky, and Indiana (Fox, 2014). Lessons learned from the Acid Rain Program suggest that legislation may be necessary for interstate programs: "the series of regulations, court rulings, and regulatory responses … affirmed that EPA cannot set up an interstate trading system under the Clean Air Act in the absence of specific legislation" (Schmalensee and Stavins, 2013).

Limiting conditions for water quality trading may be created by existing laws, policies, and institutions in some regions. Greiber (2009) described a number of possible concerns related to the legal and institutional frameworks for environmental markets. Unrelated laws may contradict the aims of a market by, for example, providing perverse incentives to polluting industries or restricting innovative ways of funding environmental projects. Land tenure is a key concern in some countries, as farmers without tenure may have little incentive to participate in programs if they do not own land and their futures are more uncertain.

Irrigation near Castroville, CA. Photograph by Gwendolyn Stansbury.

4

Role of the private sector

The private sector participates to some degree in all of the instruments described in the previous section. For example, in Michigan's Paw Paw River Watershed, Coca-Cola North America and other stakeholders recently developed and implemented a performance-based PWS program to compensate farmers for implementing practices that reduce soil loss and enhance groundwater recharge (Forest Trends, 2015b). The private sector also participates as a buyer or seller in water quality trading programs to comply with water quality regulations, or buys or sells water rights through water trading programs. In addition to these incentive-based instruments, the private sector may participate in a range of voluntary initiatives to, for example, restore or protect a watershed or provide water service to local communities. Moreover, they may employ incentives within their direct operations or supply chains to promote water stewardship. In this section, we describe some of the drivers for private sector engagement in water stewardship, provide examples of their participation in incentive-based programs, and provide an initial estimate of their investment in these programs.

"Companies ... understand their relationship to water in terms of their water footprint and their water-related business risk."

4.1 Corporate water stewardship

To produce goods and services, most companies rely on a consistent supply of adequate quality source water and permission to discharge wastewater. As population growth and economic development push the limits of renewable freshwater supplies and business-as-usual resource management strategies, and as rapid urbanization, water pollution, groundwater depletion, and climate change introduce new water-related risks, companies face increasing urgency to respond.

Companies typically come to understand their relationship to water in terms of their water footprint and their water-related business risk. A water footprint assessment – which estimates the volume of water consumed and polluted in the production of a material or a product, or in the operation of an entire business, industry, or nation – can help managers more fully understand the nature and extent of a company's dependence and impact on water resources. It is also appealing as a basis for setting targets to reduce water use related to, for example, manufacturing processes or production of agricultural raw materials. While a water footprint assessment can inform a risk assessment, a volumetric footprint measurement omits the local context necessary to characterize the risks related to water use, and obscures the difference in impact between using water from a source that's plentiful and using the same volume of water from a source that's overexploited or not readily replenished.[28]

Water-related business risks generally fall into three broad and interrelated categories:

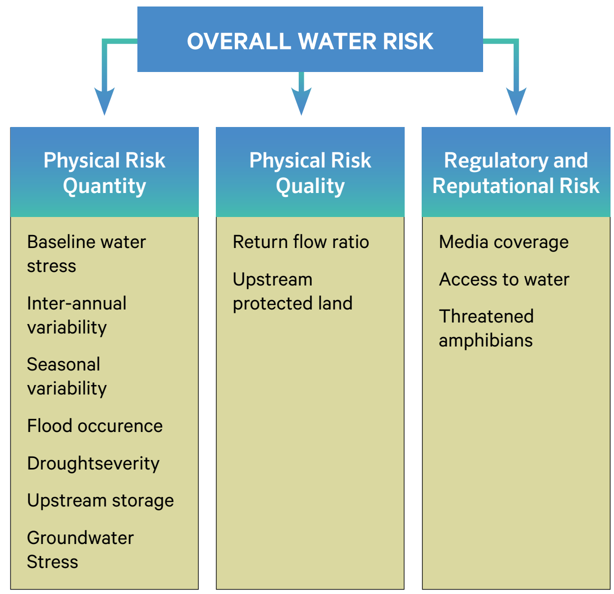
- *physical risks* include scarcity, degraded source water quality, and flooding
- *regulatory risks* relate to inconsistent, ineffective, or poorly enforced public policy, particularly when a change in regulation or enforcement could disrupt production or lead to an unexpected cost of compliance
- *reputational risks* are faced by companies that overexploit or are perceived to overexploit water resources – including inefficient use, water pollution, excessive withdrawal, competition with other users, or other negligent water-related activities.

All three categories of risk include financial impacts from increased operating costs, fines or unplanned capital expenditures, supply chain disruptions, damage to the value of a brand, or lost access to markets.

Increasingly, businesses are taking steps to identify, characterize, and mitigate these risks. For example, the Aqueduct Water Risk Atlas, a web-based tool produced by the World Resources Institute, identifies which and how many locations in a company's operations or supply chain face water-related risk in 12 dimensions, as shown in Figure 7. The Water Risk Filter, an online tool launched by the World Wide Fund for Nature (WWF) and the German Investment and Development Corporation (DEG), assigns each water-using location a score that incorporates both location-specific and company-specific risks, based on criteria such as the average water intensity or typical level of water pollution generated by suppliers to a particular industry sector (WWF and DEG, 2014).

[28] Water "neutrality" or "offsets" are related concepts, similar to carbon neutrality or carbon offsets. They imply that a company can compensate for the negative impacts of its water footprint. However, there is no standard for measuring negative impacts or defining which types and how much of any given activity is sufficient compensation (Hoekstra *et al.*, 2011).

FIGURE 7. Water risk indicators



Source: Gassert *et al.*, 2013.

Effective water resource management systems and regulatory frameworks, the performance of which can be enhanced by incentive-based instruments, benefit companies in a number of ways.

- As water users, companies benefit from a more reliable and higher quality supply of water.
- As polluters, businesses benefit from opportunities to manage the cost of compliance over time, and to seek innovative approaches to improve the quality and reduce the volume of wastewater.
- As ratepayers and taxpayers, companies benefit by avoiding the cost of adding new or expanding existing supply.

Efforts to reduce water-related business risks typically occur at three scales: within *direct operations*, in *supply chain* agricultural or manufacturing operations that are not within a company's direct control, or *outside the fenceline* of both owned and supply chain properties, where water-related risks are driven more by sociopolitical, hydrological, or ecological conditions than by the actions of the company or its suppliers.

- **Direct operations.** Companies that recognize water-related business risks often begin working voluntarily with direct operations – owned and operated offices, distribution or retail facilities, manufacturing facilities, farms or other means of production – to mitigate those risks. In direct operations, companies can plan and manage implementation internally and realize cost savings related to obtaining, pumping, heating, or treating smaller volumes of water when operational efficiencies are achieved.
- **Supply chains.** From agricultural raw materials to water- and chemical-intensive manufacturing processes, most companies face challenges managing water-related business risks in their supply chains, including those with advanced water stewardship practices in their direct operations. In many cases, complex business models and limited traceability are significant obstacles to quantifying corporate water footprints and identifying water-related business risks that exist in global supply chains.
- **Outside the fenceline.** Facilities that maintain industry average or better water efficiency and wastewater quality may not be immune to all water-related risks. The term "outside the fenceline" refers to conditions and activities outside the physical footprint of a production site. Water-related risk is said to originate outside the fenceline in regions where, for example, source water is scarce or polluted, projected demand exceeds renewable supply, regulations are inconsistent or nonexistent, or lack of access to water and sanitation damages public health. While internal process or policy changes are easier to implement, they would not necessarily mitigate these risks.

The private sector increasingly recognizes the need to evaluate site-level water use in the context of its local watershed characteristics, in order to inform and prioritize efficiency targets for different locations. For example, companies can manage risk more effectively by giving higher priority to efficiency improvements for water-intensive locations in drought-prone locations than for similar facilities where water resources are more plentiful.

Another recent development is the idea of engaging outside the fenceline. Leading companies understand that collective action with other stakeholders at the watershed scale may be required to address root causes of resource scarcity, accessibility, or source water quality, which can increase costs or disrupt operations. The Beverage Industry Environmental Roundtable (BIER), a coalition of business leaders in an industry that faces substantial water-related reputational risk, has acknowledged that in some locations, watershed-level interventions may in fact be more effective at mitigating water-related risk than facility-level water-use efficiency or other activities (BIER, 2015). To assist companies in prioritizing their efforts, BIER has proposed developing a decision support tool that could give more priority to intervention outside the fenceline than to internal efficiency or water quality improvements.

"Most private sector watershed investment activity ... took place in North America, Europe, and Africa."

4.2 Private sector engagement with incentive-based instruments

Private sector participation in incentive-based instruments, such as PWS and water quality trading, has been relatively modest but is growing. Bennett and Carroll (2014) found that in 2013, the private sector invested US$41 million in watershed services that supported "watershed restoration or protection that delivers benefits to society." While this represents more than twice the estimated private sector investment of $19 million to $26 million in 2011, it is still a very small portion of the overall $12.3 billion invested collectively in watersheds by governments, business, and individual donors in 2013. Most private sector watershed investment activity (about 95 percent) took place in North America, Europe, and Africa (Bennett and Carroll, 2014).

Incentives for private sector investments. Industry sectors with the highest levels of investment in watershed services (IWS) were energy utilities, water utilities, and the food and beverage industry, with investments of US$9.3 million, $8.9 million, and $8.8 million, respectively. The primary reported motivation for spending on watershed services was regulatory compliance, followed by water availability risks, water quality risks, corporate social responsibility and reputational risk, and biodiversity protection (Bennett and Carroll, 2014). The food and beverage sector, which accounted for nearly one-quarter of the total corporate investment in watersheds, is unlike other sectors in that it is driven primarily by water availability and water risks, rather than regulatory compliance. Bennett and Carroll (2014) found that 88 percent of buyers in the food and beverage industry acted voluntarily, compared with the private sector average of 31 percent.

For example, in 2012–2013, the Coca-Cola Company and its global bottling partners were involved in 20 projects around the world, buying at least $2.2 million in watershed services (Bennett and Carroll, 2014). Separately, the company publishes annual reports detailing its involvement in hundreds of other projects (LimnoTech, 2013). Indeed, the Coca-Cola Company is among a handful of private companies with a public commitment to "replenish" the water it uses.[29] However, as Coca-Cola acknowledges, the impacts of water use are specific and local, making it impossible for a multinational corporation to offset water use at the enterprise level. Rozza *et al.* (2013) described a detailed methodology for quantifying the value of Coca-Cola's replenish projects, including source water protection, water reuse for conservation or productive uses, and community-level sustainability projects. The company also requires its bottling plants to complete source water vulnerability assessments and to engage in the development of source water protection plans, which provide opportunities for projects within the corporate replenish initiative to directly mitigate risks in the global supply chain. Other projects' impacts, such as those related to access to water and sanitation or ones where Coca-Cola contributed to a collective action together with other companies, are estimated differently (Rozza *et al.*, 2013).

[29] Specifically, Coca-Cola is "Collaborating to replenish the water we use", pledging that by 2020, it will "safely return to communities and nature an amount of water equal to what we use in our finished beverages and their production."

Disincentives for private sector investments. There are also disincentives for private sector investments in public goods, including watershed services. The benefits must be shared with others that did not contribute to the investment, and the benefits could be exhausted by other actors that did not participate in the collective action or investment (Meißner, 2013). However, when the consequences of inaction are significant, there is a compelling case in favor of policy engagement, collective action, and investment in water-related initiatives outside the fenceline, including preservation of resources or delivery of ecosystem services via incentive-based instruments.

Among the barriers that prevent the private sector from participating more fully in watershed investments are three critical core competencies needed to achieve measureable outcomes with specific benefits for at-risk locations, which most companies do not possess:

- scientific and environmental engineering expertise to identify, design, and implement watershed-level solutions
- a nuanced understanding of the local environment and culture in the watershed where they seek to have a positive environmental outcome
- experience with partnerships involving diverse stakeholders outside the fenceline.

Therefore, in cases where companies identify risk and choose to take action at the watershed level, particularly if they choose to do so in more than one location across diverse global operations or an extended supply chain, it is helpful and sometimes necessary to involve an intermediary. Stanton *et al.* (2010) defined an intermediary as "any party other than the buyer or seller who

TABLE 3. Private sector activities, scale, drivers

ACTIVITIES, COMPLEXITY, INCLUSIVITY		
Operational efficiency Wastewater quality Owned facilities	Codes of conduct Social/environmental indices Voluntary sustainability standards Industry sector/association	Policy engagement Collective action Diverse stakeholders
SCALE		
Site-specific Small business	Supply chain Small to medium enterprise	Landscape Multinational
TIME/VALUE		
Near-term, return on investment	Medium-term, possible value capture	Long-term, sustainability
DRIVERS		
Financial self-interest Regulatory compliance	Externalities License to operate	Reputation Access to markets
EXTERNAL CONDITIONS		
Strong governance and enforcement	Inconsistent local regulation and enforcement	Weak governance Negative externalities of other actors

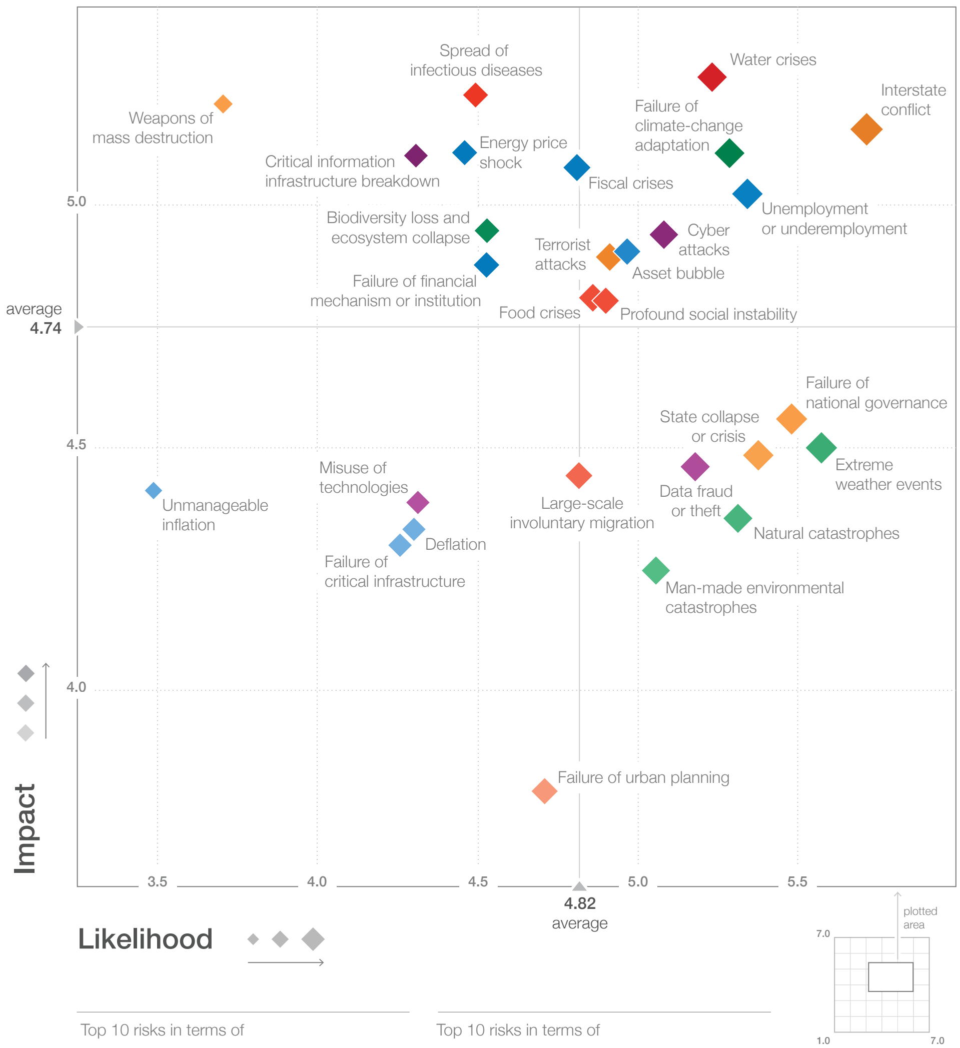
helps facilitate some aspect of the transaction or implementation of the overall program. This role is commonly played by NGOs, consultants, or academic institutions." Indeed, Coca-Cola has had to coordinate large-scale bilateral partnerships with more than one intermediary in order to achieve progress toward its global replenish objective, including The Nature Conservancy, WWF, and the United Nations Development Programme (UNDP). Table 3 illustrates increasing complexity and differences in motivation that companies face as they move from addressing efficiency in direct operations to engaging in collective action intended to create more sustainable operating conditions in watersheds where they do business.

Future investments by the private sector are uncertain. However, consumer preference for more sustainable products and investor concern about unmitigated risk are driving increased adoption of water risk assessment across the business community. For example, in its annual survey of leaders and decision makers about perceptions of global risks, the World Economic Forum (WEF, 2015) found that water crises have the greatest potential for impact and are the eighth most likely to occur, as shown in Figure 8. Moreover, WEF has considered water among the top three global risks since 2012 (WEF, 2012; 2013; 2014).

"...there is increasing awareness of water-specific issues and of best practices in corporate water stewardship..."

CDP, formerly known as the Carbon Disclosure Project, operates a water program that surveys companies

FIGURE 8: Global risks landscape, 2015



Top 10 risks in terms of
Likelihood

1. Interstate conflict
2. Extreme weather events
3. Failure of national governance
4. State collapse or crisis
5. Unemployment or underemployment
6. Natural catastrophes
7. Failure of climate-change adaptation
8. Water crises
9. Data fraud or theft
10. Cyber attacks

Top 10 risks in terms of
Impact

1. Water crises
2. Spread of infectious diseases
3. Weapons of mass destruction
4. Interstate conflict
5. Failure of climate-change adaptation
6. Energy price shock
7. Critical information infrastructure breakdown
8. Fiscal crises
9. Unemployment or underemployment
10. Biodiversity loss and ecosystem collapse

Categories

- Economic
- Environmental
- Geopolitical
- Societal
- Technological

Note: Taken from 2014 Global Risks Perception Survey. Survey respondents were asked to assess the likelihood and impact of the individual risks on a scale of 1 to 7, 1 representing a risk that is not likely to happen or have impact, and 7 a risk very likely to occur and with massive and devastating impacts. See Appendix B for more details. To ensure legibility, the names of the global risks are abbreviated. Also see Appendix A for the full name and description.

Source: World Economic Forum, 2015.

in order to reveal water-related risk in institutional investment portfolios. CDP's 2014 Global Water Report revealed that, of nearly 1,100 responding companies, 74 percent had evaluated how water quantity and quality could affect their growth strategy. However, of these, only 38 percent assessed water-related risk in both owned operations and their supply chain, and only 25 percent conducted detailed water risk assessments at the watershed level (CDP, 2014).

Concurrently, there is increasing awareness of water-specific issues and of best practices in corporate water stewardship, so there will likely be demand for mechanisms that can deliver quantifiable outcomes to benefit specific corporate assets or at-risk strategic supply chain locations. Increased understanding of water-related risks and opportunities could similarly drive an increase in private sector engagement in incentive-based instruments for watershed services.

Hunter River, Australia. Photograph by AussieLegend.

5

Summary and conclusions

Growing pressure on the availability and quality of water resources is having a major impact on our social, economic, and environmental well-being. These pressures are likely to worsen in response to continued population and economic growth, climate change, and other challenges. As water pollution exacerbates the challenges posed by water scarcity, and the world's water quality becomes increasingly degraded, new approaches and strategies are needed.

One key area of interest is the potential for incentive-based instruments to reduce pressure on water resources. To date, the primary environmental policy tool to address water challenges has been command-and-control regulations. Over the past several decades, however, the environmental policy "toolkit" has expanded to include a host of incentive-based instruments that use financial means, directly or indirectly, to motivate responsible parties to reduce the health and environmental risks posed by their facilities, processes, or products. While regulations and incentive-based instruments are often juxtaposed, "in reality the two often operate alongside each other" (UNEP, 2004). With water quality trading, for example, governments mandate caps on the allowable pollutant levels and issue tradable permits that allow those in the industry to allocate polluting activities among themselves, incentivized by market forces. Similarly, with water trading, governments may allocate water and then institute a framework by which water trading can occur. While incentive-based instruments may work in tandem, they must be integrated within a broader watershed management effort. In a recent review of PWS programs, Bond and Mayers (2010) cautioned that:

> *"PWS is a tool that will fail, or become irrelevant, if it is not integrated with wider regulatory approaches, broader watershed management efforts, and explicit attention to governance influences that shape what is possible. Policy makers need to consider the opportunities to ensure that future policy and legislation allow for a mix of both incentives and regulations to ensure the effective management of land and water resources."*

The choice of whether and which instrument to apply depends on the specific circumstances, conditions, and needs of a given area. It is important to avoid "the law of the instrument", i.e. the tendency to gravitate toward a particular tool and then look for applications of that tool. UNEP (2004) found that:

"Prior to designing and applying any policy instrument for environmental protection, the policy context must be understood, including the existing institutional, legal and economic conditions in which these tools are meant to function. Choosing an effective policy package that will both address the environmental problem policy makers are faced with and fit in with the institutional capabilities and existing policy framework remains one of the most difficult challenges."

This process should be open and transparent, with meaningful participation from all affected parties. This will enable crafting a solution that not only is appropriate for local conditions, it will help reduce opposition and promote buy-in from those who will be implementing and affected by the program. It is important to recognize that those with the least power may not have the resources to participate or be skeptical of the groups involved. In these cases, there will be a need for consistent and rigorous outreach and, potentially, a need for engaging a trusted intermediary.

Finally, monitoring and evaluation are essential to the success of any instrument. In particular, they help ensure outcomes are achieved and allow for adjustments in response to changing social, economic, or environmental conditions. Monitoring should evaluate the additionality of the program, i.e. whether the program has an effect when compared with baseline conditions. It should also examine any potential impacts on surrounding areas (e.g. leakage) and the permanence of the intervention. However, it is important to recognize that extensive monitoring requirements would increase transaction costs. Thus, the need for monitoring and evaluation must be balanced with practical considerations about the ability to maintain the viability of the program.

ANNEX 1

Demand management

A key way to reduce pressure on limited water supplies is through demand management, commonly referred to as water conservation and efficiency. In many cases, reducing demand is equivalent to augmenting or reallocating water supply. Demand management is typically less expensive and faster to implement than water supply augmentation, and often results in reduced energy demand and water and wastewater treatment costs. For example, a recent study in Westminster, Colorado, found that water conservation and efficiency since 1980 had reduced water use in the city, reducing tap fees by 80 percent and reducing customers' bills by 91 percent relative to what they would have been without these efforts (Feinglas, Gray, and Mayer 2013). In major cities, such as San Francisco and Los Angeles, total water use has *decreased* since the late 1970s despite population and economic growth. At a larger scale, a recent United States federal study found that water conservation and efficiency efforts have reduced annual demand for water from the Colorado River basin by more than 1.7 million acre-feet, a tremendous savings in an over-allocated basin (US Bureau of Reclamation 2015). In the United States, we have made considerable progress in managing the nation's water, with total water use less than it was in 1970, despite continued population and economic growth. Indeed, every sector, from agriculture to thermoelectric power generation, shows reductions in water use. Likewise, in Australia, a severe drought in the middle of the last decade prompted an intensive effort to reduce water demand. In response, total urban demand, including losses and non-residential consumption, fell from about 130 gallons per capita daily (gpcd) in 2005 to about 80 gpcd in 2010 (Queensland Water Commission, 2010).

There are many tools available to reduce water demand – some of which rely on an incentive-based approach, e.g. pricing and rebates, while others are based on a more traditional command-and-control approach. Numerous studies have shown that significant conservation and efficiency opportunities exist in urban and agricultural areas (see, e.g. Gleick *et al.*, 2003; Heberger, Cooley, and Gleick 2014). Below, we provide additional detail on the major demand management tools, including pricing, direct financial incentives, regulations, and education and outreach.

Water pricing. Well-designed tariff structures can meet multiple policy objectives, including supporting the financial stability of the utility, the affordability of water for low-income customers, the efficient allocation of water and other resources, and environmental sustainability. Most water utilities use some form of volumetric tariffs to achieve these objectives. There are several types of volumetric tariffs in use around the world:

- uniform tariffs in which the volumetric tariff ($/m3) is constant regardless of the quantity used;
- inclining block tariffs in which the volumetric tariff increases as the quantity used increases; and
- declining block tariffs in which the volumetric tariff decreases as the quantity used increases.

Uniform tariffs are the most common tariff structure in OECD and in developing countries (OECD 2009). Inclining block rates are becoming increasingly common (OECD 2009), as there is recognition that when designed properly, this approach can provide a strong financial incentive to conserve while ensuring that lower-income consumers are able to meet their basic water needs at a reduced cost. A 2003 survey of cities in the southwest United States found that per-capita water use is typically lower in cities with dramatically increasing block tariffs, such as Tucson and El Paso (WRA 2003).

Although less frequently employed, pricing has also been shown to be effective in reducing agricultural water use. For example, the Broadview Water District, a small district in California's San Joaquin Valley, implemented increasing block rates in 1988 to reduce the volume of contaminated drainage water flowing into the San Joaquin River. The rate was set at $16 per acre-foot ($0.013 per m3) for the first 90 percent of average water use during the 1986 to 1988 period and $40 per acre-foot ($0.032 per m3) for any additional water. By 1991, the district's average water use declined by 19 percent due to efficiency improvements and crop shifting (MacDougall *et al.,* 1992).

Direct financial incentives. Rebate programs are commonly used to encourage customers to make investments in water conservation and efficiency improvements. Residents and business owners purchase new devices as the old devices wear out. While most new standard devices use less water than older models, there are many new high-efficiency devices available that use even less water. While efficient devices are often cheaper over their lifetimes due to lower water, energy, and wastewater bills, users may be put off by the higher up-front costs. As a result, water utilities may provide their customers with a rebate to defray the additional cost of the more efficient device. There are several examples of water utilities partnering with local energy utilities to augment those rebates because of the energy savings (Cooley and Donnelly 2013). Additionally, utilities may partner with retailers to offer rebates at the point of sale, giving customers an immediate incentive to purchase the more efficient device.

Instead of providing rebates to cover a portion of the cost, some utilities have opted to institute direct-install programs that cover the entire cost of the device and the installation costs. In the mid-1990s, for example, the New York City Department of Environmental Protection launched a massive toilet rebate program to replace one-third of all water-wasting toilets in New York City with low-flow models. For this effort, property owners contracted directly with private licensed plumbers for the installation of the toilet, and after completion of the work, the City provided the property owner with a $240 rebate for the first toilet and $150 for the second toilet. Where possible, the plumber would also install low-flow showerheads and faucet aerators. The program was a huge success. Between 1994 and 1997, 1.3 million low-flow toilets were installed, saving 70 - 90 million gallons per day. Customers saw their water and wastewater bills drop 20 percent to 40 percent (EPA 2002). Additionally, the City was able to defer the need to develop new supply sources and expand wastewater treatment capacity, saving the community even more money.

Regulations. In addition to financial incentives, regulations are key demand management strategies. Regulations can take a variety of forms, ranging from a prescriptive approach focused on a particular appliance to a performance-based approach for outdoor water use. For example, the International Plumbing Code, which is widely used in the United States and forms the basis for plumbing codes in several other countries, specifies maximum flow rates for kitchen and lavatory faucets. Likewise, communities in the Las Vegas area have restricted lawn installation in new developments. California has also passed an ordinance to reduce outdoor water use, although the state opted for a performance-based approach. Landscape irrigation typically accounts for more than half of residential demand in the state, and in an effort to promote outdoor efficiency, the state adopted the Model Water Efficient Landscape Ordinance (MWELO). MWELO establishes a water budget for new construction and rehabilitated landscapes that are at least 2,500 square feet and require a building or landscaping permit (the size threshold is likely to be reduced to 500 square feet in response to the current drought). In addition, the ordinance requires mulching for most plantings; promotes the use of techniques to increase storm-water retention and infiltration; and requires new and refurbished landscapes to install irrigation systems run by weather, soil moisture, or other self-adjusting controllers. Also in California, Governor Schwarzenegger signed SBx7-7 in 2009, requiring urban water suppliers to reduce per-capita water use by 20 percent by 2020.

Education and outreach. Education and outreach programs can also be effective for promoting water conservation and efficiency. The US Environmental Protection Agency (EPA), for example, launched the WaterSense labeling program in 2006 to promote water-conserving devices that are 20 percent more efficient than standard products on the market and meet rigorous performance criteria. Social marketing has also gained prominence in recent years, with some programs tapping into new metering technologies and web-based platforms. For example, a recent study found that home water reports - which provide customers information on their current water use and comparisons to their past use, use by similar households, and efficient use - reduce water by 5 percent and were especially effective in reaching the highest water users (Mitchell and Chesnutt 2013).

ANNEX 2

Water trading in Australia:

Lessons from the Murray-Darling Basin

Australia's Murray-Darling Basin (MDB) figures prominently in discussions about water trading as an example of a thriving incentive-based system that successfully transitioned from a non-market system (Grafton *et al.*, 2012). The total value of water trading in Australia in fiscal year 2012-13 exceeded $1.4 billion (NWC 2013). Water trading in Australia includes both short-term trades, known as allocation trading, and long-term trades, known as entitlement trading. In fiscal year 2012-13, the most recent period for which comprehensive data are available, the total volume of short-term trading increased 44 percent from the previous year, from almost 3.5 million acre-feet to 5 million acre-feet, or roughly 50 percent of total surface water use in the MDB. This is an extremely active water market.

Background

The MDB covers some 390,000 square miles in southeastern Australia, comprising roughly 14 percent of that country's land area. Most of the basin is very arid, with 86 percent of the basin contributing little or no flow to rivers that drain the basin. The Murray-Darling Basin Authority (MDBA) estimates that total runoff within the basin is less than 26 million acre-feet annually, yielding an estimated long-term annual average 19 MAF of total river flow. As shown in Figure A-1, the system displays very high seasonal and annual variability. For example, flows in the southern Murray basin typically are much higher than in the northern Darling basin. Pre-development, an estimated 10 million acre-feet ran into the ocean; in 2009, during the historic Millennium drought, this had decreased to 4 million acre-feet.

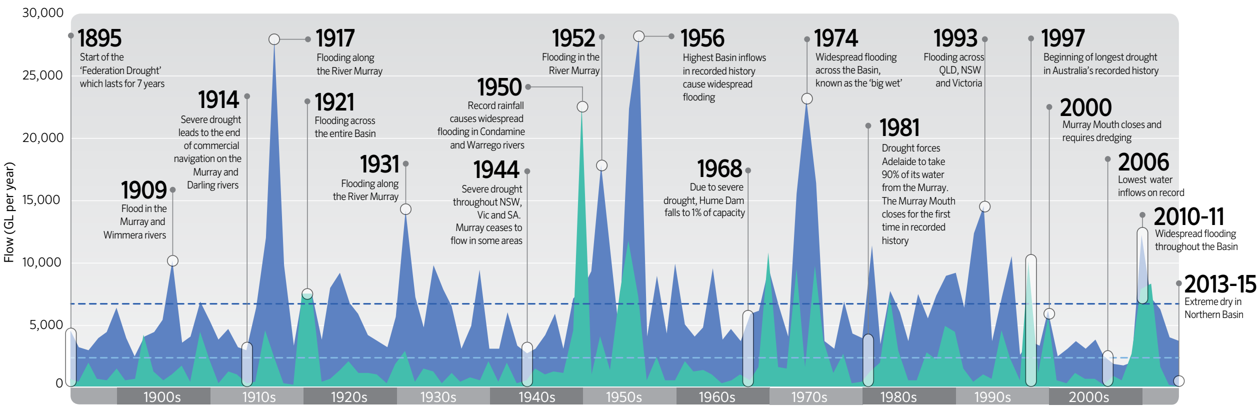
The MDB includes parts of four states (Queensland, New South Wales, Victoria, and South Australia) and the Australian Capital Territory. The MDB supplies water to about three million people, including the national capital (Canberra) and Adelaide, outside of the basin near the river's mouth. According to the MDBA, the basin contains some 70 percent of the nation's irrigated acreage, producing a third of the country's food supply. The MDBA reports the gross value of irrigated agriculture in the basin in 2012-13 at approximately $6.8 Billion. The MDB generates almost all of Australia's rice and cotton and 75 percent of its grapes, as well as roughly half of the nation's hay, fruit, livestock, and dairy production.

The construction of dams and canals and the diversion and depletion of MDB rivers has endangered the survival of at least 35 bird species and 16 mammal species within the basin. Many fish species, including the Murray cod, are also threatened. Wetlands have dried up or reached critically low levels, exacerbated by the Millennium drought, prompting public concern.

MDB and the Colorado River Basin

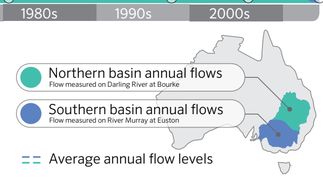
The MDB and the Colorado River Basin share many common traits: both are highly variable rivers in arid basins, where rapidly-growing urban populations have imposed new demands on limited, climate-stressed rivers. Basin size and runoff are similar. And, interestingly, the two basins share a common figure: Elwood Mead (namesake of Lake Mead), the Wyoming State

FIGURE A-1. Historical river flows within the Murray-Darling Basin



Note: Volumes in the figure shown in gigaliters, with 1000 GL = 0.8 million acre-feet.

Source: Australia's MDBA.



Irrigation Engineer from 1888-99, went on to serve as the Chairman of Victoria (Australia)'s State Rivers & Water Supply Commission (1907–15), prior to returning to the US and serving as the Commissioner of the Bureau of Reclamation from 1924-36 (McLeod 2014). However, Australia avoided Mead's legacy of prior appropriation and hierarchical water rights to embrace a very different system that promotes and facilitates water trading, as described in the following sections.

History

Australia has promoted and developed water trading over a period of more than 30 years (Grafton *et al.*, 2012), in a process that initially attempted to activate markets prior to recognizing that the water rights structure itself needed to be altered to encourage active trading and minimize transaction costs (Young, 2015). Table A-1 lists some of the major steps taken to create the current water trading structure. These changes have occurred over several decades and often reflect corrections to previous policies. Young (2010, 2015) asserts that Australia implemented water trading from the wrong direction, by first promoting trading and subsequently changing the water rights structure to facilitate trading and protect environmental resources.

In Australia, water rights typically refer to either entitlements or allocations.[30] The National Water Initiative of 2004 defines these as:

- **Water access entitlement** – *a perpetual or ongoing entitlement* to exclusive access to a share of water from a specified *consumptive pool* as defined in the relevant water plan.
- **Water allocation** – the specific volume of water allocated to water access entitlements *in a given season*, defined according to rules established in the relevant water plan. (Young, 2010).

Australian water rights are typically defined as the right to *divert* a specific volume, as opposed to a *consumptive use* right that is more typical with prior appropriation

[30] Additional water rights include: *Water use license* – a non-tradable use or condition linked to the place of use; and *Delivery right* – may be required to ensure that an allocation is delivered, typically associated with irrigation infrastructure, such as canals and headgates (Grafton and Horne 2014).

regimes (Connor and Kaczan, 2013). Diversions can be measured (and subsequently traded) more readily than consumptive use, which requires measurement of both diversions and surface and sub-surface return flows. Return flows often lag diversions, sometimes by weeks or months in the case of sub-surface returns, requiring more complicated measurements and estimates, challenging efforts to evaluate and quantify the full impacts (especially environmental impacts) of the trade, hindering transactions.

Initially, Australian water rights were linked to a specific land parcel. In many cases, the water right simply entitled the landowner to sufficient water to irrigate the land. Transforming these general land-based rights to discrete volumes then required determining historic usage patterns and water requirements for crops grown on that land. Several MDB states initially allowed water trading within individual irrigation districts, using shared infrastructure to trade water to different parcels within the district. These volumetric rights were subsequently "unbundled" from the land, enabling water to be traded between different irrigation districts. Despite these changes, restrictions on trading between different sub-basins often took years to revoke, due to concerns about adverse economic and equity impacts that trading could cause in areas of origin (Grafton and Horne 2014).

TABLE A-1. Policy and legislative milestones

YEAR	ACTION	DESCRIPTION
1960s	Volumetric water licenses	Start of conversion of land-based water entitlements to volumetric entitlements
1983	Water trading w/in districts	Allowed in New South Wales and South Australia
1987	1st MDB Agreement	Established the MDB Commission, to coordinate management
1991	Inter-district water trading	Allowed in New South Wales
1994	"Unbundling"	Council of Australian Governments agrees to separate statutory land rights from water rights, facilitating trading
1995	Diversion CAP implemented	Limits surface water diversions in the MDB; limits water rights
1995	National Competition Policy	Requires development of water markets and full-cost pricing
2000	Water Management Act	"Unbundles" diversion and use rights
2004	National Water Initiative	Promotes cohesive water planning and trading efforts
2004	Living Murray Initiative	Authorizes purchase and dedication of 0.4 MAF to the river
2007	Water Act	Promotes management of MDB
2008	Water Amendment Act	Establishes MDB Authority, replacing the Commission
2008	Water for the Future	Commits $3.1 billion to purchase water entitlements for the env.
2012	MD Basin Plan	Caps total MDB surface diversions at 8.8 MAF, coordinates basin management including water quality (esp. salinity)

Sources: MDBA, Young, 2010; Grafton and Horne, 2014.

Unlike the doctrine of prior appropriation in the western United States, water rights in Australia did not have priority dates or a seniority system for satisfying demands: all rights were considered equivalent. Additionally, Australian water rights did not have to be exercised on an annual or periodic basis to demonstrate possession (again, unlike the prior appropriation system); many rights holders maintained their rights for periodic or infrequent use (known as "dozer" rights) or never exercised their water rights (known as "sleepers"), perhaps in the expectation that they might be needed in the future.

The 1995 imposition of the diversion CAP limiting surface water diversions and rights within the MDBA explicitly recognized the continuing validity of dozer and sleeper rights and incorporated the volumes of these rights into the general calculation of the proportional shares of the new water rights regime. However, the result of recognizing dozer and sleeper rights within the context of water trading was to increase the financial value of these unexercised rights, leading to new diversions and greater strain on water supply, in turn reducing water reliability (Grafton and Horne 2014). Tony McLeod, General Manager for Water Planning at MDBA, explained that the recognition of these dozer and sleeper rights was intentional, to reduce resistance to the imposition of the CAP and smooth the transition to the new system of proportional sharing (McLeod, personal communication, 2014).

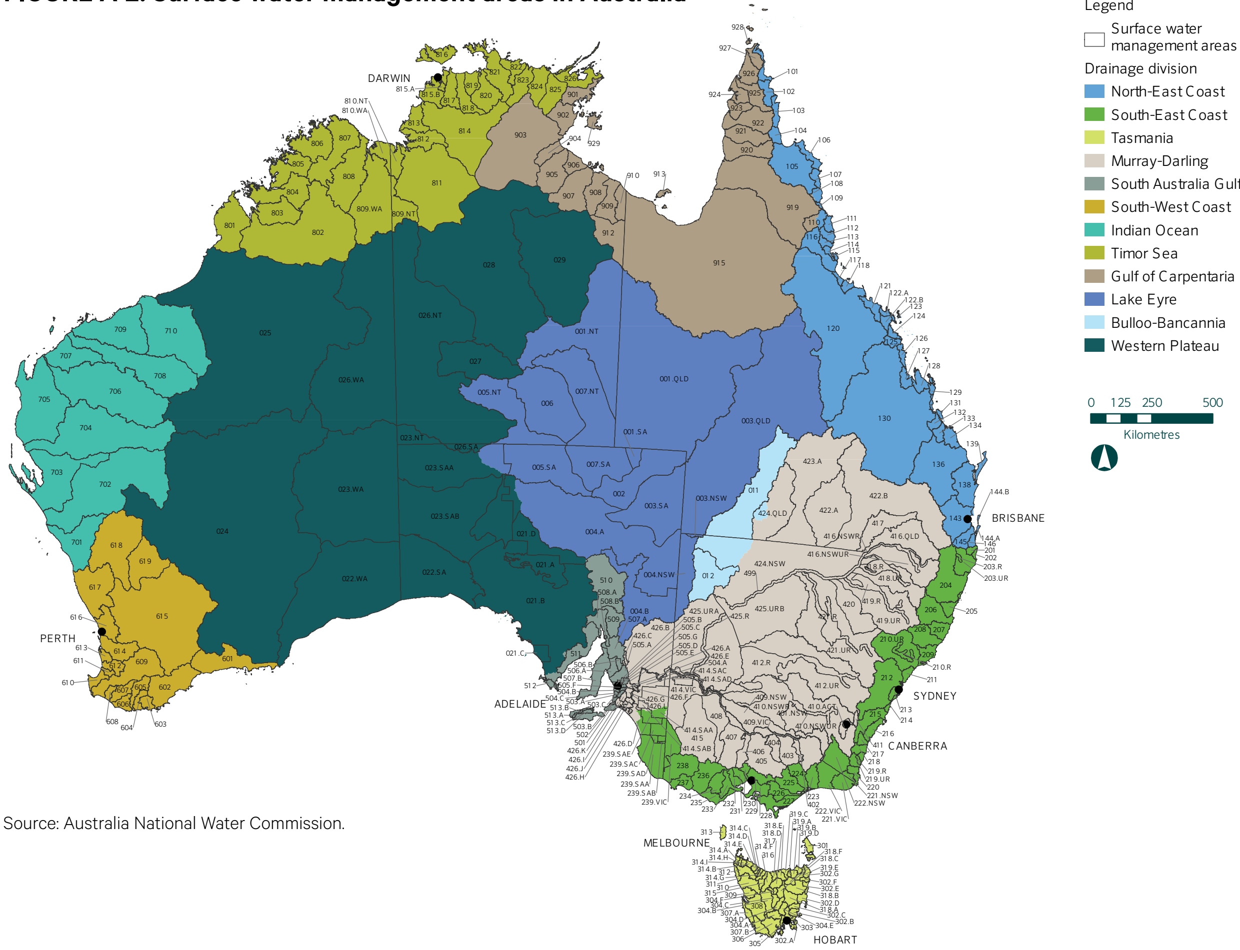
In response, the Australian government implemented several initiatives to purchase existing water entitlements and dedicate these to the environment, both to offset reservoir evaporation and other system losses (known as maintenance rights) and explicitly to ensure minimum instream flow volumes in designated reaches. The government has invested more than $3 Billion to date to purchase entitlements for environmental water. However, the relative priority of this environmental water remains contentious, with some states contending that such rights receive lower priority than human uses. New South Wales has attempted to limit federal purchases of water for the environment to no more than 3 percent of total entitlements, though this appears to contravene trading rules within the Basin Plan, which seek to minimize restrictions on trading (Grafton and Horne 2014).

State water plans allocate water entitlements into one or two "pools," known as a high security pool and a general or low security pool. The high security pool is allocated to those entitlement holders proportional to the size of their entitlement. For example, if a system only has two entitlement holders and one right is for nine units and the other is for one unit, the former would receive 90 percent of the pool's allocation and the latter would receive 10 percent. If additional water is available for the general pool, that volume is allocated to those entitlement holders. Every season, the state determines the total volume available for allocation for each pool. During drought, the general pool might not receive any water at all (Young, 2010).

Water trading activity

Australia's water trading activity is largely concentrated in the MDB, which represents as much as 94 percent of all such activity in Australia despite being only one of twelve surface water management areas (Figure A-2). Trading is very high as measured by the total volume of water traded (as much as 5 million acre-feet), the percentage of all diversions that are traded (as much as 50 percent), the number of farmers trading water (roughly half, in 2008-09), and the total number of trades (11,000, in 2011-12). The number of short-term (allocation) interstate trades also appears to be rising, reaching 20 percent of the total number of such trades in 2011/12 (Grafton and Horne 2014). Not surprisingly, the number of short-term (allocation) trades is much higher, in terms of numbers and volumes, than the number of entitlement trades. As the federal government has exercised its commitment to ensure minimum

FIGURE A-2. Surface water management areas in Australia



Source: Australia National Water Commission.

environmental flows by purchasing entitlements, such purchases have risen to 37 percent of the total number of entitlement trades in 2011/12. Only about 5 percent of farmers traded water entitlements, either to other farmers or to cities or to the government for augmenting environmental flows, in 2008/09, or about 10 percent of the number that reported trading allocations that year (Grafton and Horne 2014).

As expected, the number of allocation trades appears to be inversely correlated with precipitation and runoff, rising in drought years and falling when allocations are higher due to wetter conditions. Prices similarly vary in response to water availability, rising from the equivalent of about $22 per acre-foot in 2011/12 to the equivalent of about $54 per acre-foot in the drier 2012/13.[31] Similarly, trading in drier years tends to see water move from lower value uses, such as pasture and forage, to higher value wine and vegetable crops. Connor and Kaczan (2013) reported that many livestock operations irrigate pasture and forage crops in wet years but tend to trade away their allocations in drier years, when the price of water rises due to scarcity, using the profits to purchase feed from other areas. These trends also manifest regionally, as water tends to move across state lines from New South Wales into South Australia, which has more high-value

[31] These prices are about an order of magnitude lower than prices for short-term transfers in California in the 2014 drought year, but are comparable to prices paid for short-term rentals in the active Northern Colorado Water Conservancy district water market.

crops. In response, New South Wales and Victoria have imposed restrictions on the volume of water that may be exported from the state (Grafton and Horne 2014).

Enabling conditions

A large number of necessary and enabling conditions help explain Australia's water trading success. Key among these is the development of a proportional water sharing regime, in which the state, rather than administrative or water courts, determines total annual water availability, rather than granting rights holders an absolute or priority-based right to a fixed volume of water. The Australian experience also shows that water trading is more active when allocation pools encompass a large number of entitlement holders with a diverse range of uses (Young, 2010).

Grafton and Horne (2014) found that infrastructure, such as dams and canals, can facilitate water trading by storing water until needed and providing conveyances to deliver where needed. Similarly, access to accurate and timely information on water prices and availability facilitates water trading. In Australia, brokerage-type water banks are active in both the Murray-Darling Basin and in northern Victoria, where the banks post information about pricing and availability (O'Donnell and Colby 2010). Underpinning this information exchange is an extensive, credible, verifiable registry of entitlements and allocations and mechanism to quickly record, measure and monitor trades, as well as sufficient sanctions on those violating agreements (Connor and Kaczan 2013).

Lessons learned

Connor and Kaczan highlighted the classic dilemma facing those attempting to implement a water trading system: the tradeoff between protecting third parties with high transaction costs versus promoting trades with low transaction costs, with less concern for third parties. Australia has adopted the latter approach, choosing to minimize transaction costs and promote market activity while protecting environmental values by participating directly in the market, purchasing entitlements from willing sellers and dedicating this water to preserve threatened ecosystems and river reaches. This approach has come at great expense to the government (and taxpayers) but has been justified by the reported increase in economic activity and benefits arising from trading activity. In a robust assessment of water trading in Victoria's Murray Valley, Frontier Economics (2007) found strong local opposition to permanently trading water out of local areas, to the extent that some irrigators selling entitlements have been ostracized, but also found a combination of positive and negative socio-economic impacts from such trades. For example, the authors found that trading ameliorated the impacts of the Millennium Drought on dairy farmers in the region, who otherwise would have fared much worse. Additionally, water trading facilitated the expansion of the wine industry in the region.

Several researchers have compiled extensive lists of lessons learned. Two of these are reproduced below. Young (2010) writes:

> **Lesson 1:** Unless carefully managed, the legacy of prior licensing decisions can result in markets causing over-allocation problems to emerge in a manner that erodes the health of rivers, aquifer and the water dependent ecosystems associated with them.
>
> **Lesson 2:** Transaction and administrative costs are lower when entitlements are defined using a unit share structure and not as an entitlement to a volume of water. *One of the simplest ways of preventing over-allocation problems from emerging is to assign the risks of adverse climate change and/or the emergence of long dry periods to entitlement holders and define entitlements as an entitlement to a share of the water defined as being available for use.*
>
> **Lesson 3:** Market efficiency is improved by using separate structures to define entitlements, manage allocations and control the use of water.

Lesson 4: Early attention to the development of accurate license registers is critical and a necessary precondition to the development of low-cost entitlement trading systems.

Lesson 5: Unless water market and allocation procedures allow unused water to be carried forward from year to year, trading may increase the severity of droughts.

Lesson 6: Early installation of meters and conversion from area based licenses to a volumetric management system is a necessary precursor to the development of low cost allocation trading systems. *Metering and conversion to a volumetric allocation system is a necessary precursor to the development of efficient water trading systems.* In order to facilitate the more efficient management of the available resource and trading, Australia has spent many years converting area-based licenses to volumetric licenses and installing meters. *Typically, conversion involves estimation of the amount of water used by crop type and the development of conversion factors.*

Lesson 7: It is difficult for communities to plan for an adverse climate shift and develop water sharing plans that deal adequately with a climatic shift to a drier regime. More robust planning and water entitlement systems are needed.

Lesson 8: The allocation regime for the provision of water necessary to maintain minimum flows, provide for conveyance and cover evaporative losses need to be more secure than that used to allocate water for environmental and other purposes.

Lesson 9: Unless all forms of water use are accounted for entitlement reliability will be eroded by expansion of un-metered uses like plantation forestry and farm dam development, increases in irrigation efficiency, etc. and place the integrity of the allocation system at risk.

Lesson 10: Unless connected ground and surface water systems are managed as a single integrated resource, groundwater development will reduce the amount of water available that can be allocated to surface water users.

Lesson 11: Water use and investment will be more efficient if all users are exposed to at least the full lower bound cost and preferably the upper bound cost of supplying water to them. One way of achieving this outcome is to transfer ownership of the supply system to these users.

Lesson 12: Manage environmental externalities using separate instruments so that the costs of avoiding them are reflected in the costs of production and use in a manner that encourages water users to avoid creating them.

Lesson 13: Removal of administrative impediments to inter-regional trade and inter-state trade is difficult but necessary for the development of efficient water markets. *Australia has taken the approach of appointing an independent agency to develop rules designed to remove unnecessary barriers to water trade.* Amongst other things, this has required the setting of guidelines that prevent water supply companies from setting charges and adopting practices that discriminate against people who wish to trade water out of a region.

Lesson 14: Markets will be more efficient and the volume of trade greater if entitlements are allocated to individual users rather than to irrigator controlled water supply companies and cooperatives. Whilst opposed by water supply companies and cooperatives, it is the Australian experience that *willingness to trade and market depth typically is much greater when entitlements are allocated to individuals rather than to water supply companies or associations as they are called in other countries.* The reason for this is that when allocations are issued to individuals they do not have to obtain the permission of the board of a water supply company or association to sell water out of a region.

Lesson 15: Equity and fairness principles require careful attention to and discipline in the way that allocation decisions and policy changes are announced.

Lesson 16: Water markets are more effective when information about the prices being paid and offered is made available to all participants in a timely manner.

Lesson 17: Develop brokering industry and avoid government involvement in the provision of water brokering services.

GRAFTON AND HORNE (2014) WRITE:

1. **Crises may facilitate reform** - As the focus on the crisis fades, so may do the reform zeal. This 'stop and go' reform process suggests that determination is required to make consistent progress, but that a crisis can facilitate reform.
2. **Water markets support regional resilience** - The geographical distribution of markets has meant these benefits have been concentrated in areas of greatest connectivity of the resource (the southern Murray-Darling Basin) where there is also the widest cross-section of users. An example is the significance of selling water by opportunistic commodity producers (such as rice growers) to perennial crop producers (such as citrus growers).
3. **Political and administrative leadership is critical** - This involves teams with a range of skills, much broader than the engineering-based specialists that have traditionally managed water resources.
4. **Capping extractions promotes effective use and sustainability** - any cap should be comprehensive and all water sources should be included to avoid substitution to uncontrolled or inadequately measured sources.
5. **Regulated water framework facilitates water trading** - entitlements delivered via regulated water storages account for about 90 percent of the water entitlements traded in the Southern MDB.
6. **Reliable, accessible and timely market information promotes effective decision-making** - the Australian government is investing over half a billion Australian dollars in improved water information and regulations.
7. **Statutory rights offer flexibility but carry risks** - can be modified without recourse to the courts. Developments to unbundle water rights have facilitated trade. A potential downside of statutory rights is sovereign risk, or the possibility that the value of existing water rights can be degraded by changes in regulation and discretionary behaviour by state governments.
8. **Markets can promote environmental outcomes** - Trading should always be subject to a public interest test. Where there are important public interests, such as flow volumes at key locations or the need to ensure minimum levels of water quality, trade may need to be constrained for environmental reasons. An example of this approach is the Basin Salinity Management Strategy that seeks to reduce salinity: actions that reduce salinity are treated as credits and actions that increase salinity as debits on state salinity registers.
9. **Acquiring water for the environment through buybacks has proved effective.**
10. **Prices contain information on scarcity and risk.**
11. **Basin-wide and local perspectives have roles to play** – local input can also prevent or undermine the emergence of strong water markets. ... Governments need to see through short-term and some-times parochial interests to facilitate optimal use in the longer term.
12. **Effective monitoring and control of extractions are critical for sustainability** – Farmers made substantial investments to increase their on-farm retention of water that might otherwise have flowed to the Basin's streams and rivers. Similarly, groundwater extractions increased by about half over the period 2000–2001 to 2007–2008 (from about 1 MAF to 1.4 MAF) as market users sought access to other cost effective water supplies.

Glossary

Aquifer – an underground layer of water-bearing materials, such as sandstone or gravel or other permeable material.

Command-and-control regulation – an environmental regulatory policy that is often contrasted with "incentive-based mechanisms" in the literature. A command and control (CAC) regulation can be defined as the direct regulation of an industry or activity that states what is permitted and what is illegal.

Economic Efficiency – generally, a state or condition with optimal resource use, allocation, or productivity. May or may not be consistent with equity considerations.

Equity – refers to fairness, justice, impartiality, such as in the allocation of resources or treatment of different classes of people. May or may not be consistent with economic efficiency considerations.

Eutrophication – excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen.

Incentive-based instrument – a broad set of tools that use financial means, directly or indirectly, to motivate responsible parties to reduce the health and environmental risks posed by their facilities, processes, or products.

Nonpoint source (NPS) pollution – water pollution from diffuse sources such as runoff from urbanized areas or farm fields.

Nutrients – nitrogen or phosphorus-containing water pollutants that can cause water quality problems. See eutrophication.

Paper water – the legal right to use a given volume of water, contrasted with "wet" or "real" water. In many basins, more paper water exists than wet water.

Payment for ecosystem services (PES) – an incentive-based instrument that seeks to translate external, non-market values of environment services into financial incentives for local actors to provide such services. In practical terms, PES involves a series of payments to a land or resource manager in exchange for a guaranteed flow of environmental services.

Payment for watershed services (PWS) – a type of PES arrangement that is focused on watershed services.

Water bank – may refer to the physical storage of water, typically in a reservoir or an aquifer, to an institution that facilitates or brokers a water transfer or serves as an information clearinghouse, or to any agency that holds water rights in trust for a specified purpose such as streamflow augmentation.

Water market – Often used interchangeably with **water transfer**, a water market can also refer to informal transactions involving the sale of water, e.g. from water tankers, that do not involve the lease or sale of water rights or concessions.

Water option – a type of conditional water transfer. Under **dry-year options** a buyer will pay the seller an annual fee to be able to exercise an option to purchase a pre-determined volume of water under a specific set of circumstances.

Water transfer – a change in the point of diversion, type of use, or location of water use. May refer to a temporary or permanent exchange of water rights (see **water market**), or to a non-market conveyance of water from one location to another.

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EVALUATION OFFICE

SYNTHESIS REVIEW

Incentive-Based Instruments for Water Management

December 2015

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Knowledge to build on.

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For more than 100 years, The Rockefeller Foundation's mission has been to promote the well-being of humanity throughout the world. Today, The Rockefeller Foundation pursues this mission through dual goals: advancing inclusive economies that expand opportunities for more broadly shared prosperity, and building resilience by helping people, communities, and institutions prepare for, withstand and emerge stronger from acute shocks and chronic stresses. Committed to supporting learning, accountability and performance improvements, the Evaluation Office of The Rockefeller Foundation works with staff, grantees, and partners to strengthen evaluation practice and to support innovative approaches to monitoring, evaluation, and learning.

For this synthesis review, The Rockefeller Foundation provided financial support, the Foundation Center and its IssueLab service were involved in project and technology development, and the Pacific Institute authored the report. Pacific Institute authors included Heather Cooley, Michael Cohen, Matthew Heberger, and Heather Rippman.

Cover: Hudson River, NY. Photograph by Daniel Case.

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Incentive-Based Instruments for Water Management

December 2015

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Chesapeake Bay, Maryland. Photograph by Bossi.

Table of Contents

Annexes

Acronyms

ARP	Acid Rain Program (US)
AWS	Alliance for Water Stewardship
BIER	Beverage Industry Environmental Roundtable
BMP	Best management practices
CAC	Command-and-control
CDP	Carbon Disclosure Project (former name)
CRP	Conservation Reserve Program (US)
DEG	German Investment and Development Corporation
EPA	Environmental Protection Agency (US)
EPRI	Electric Power Research Institute
GEF	The Global Environment Facility
GPCD	Gallons per capita daily
IID	Imperial Irrigation District (California, US)
IWS	Investment in watershed services
MAF	Million acre-feet
M&I	Municipal and industrial
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MWD	Metropolitan Water District of Southern California (California, US)
MWELO	Model Water Efficient Landscape Ordinance
NRC	National Research Council (US)
NSWDEC	New South Wales Department of Education and Communities (Australia)
NWC	National Water Commission (Australia)
PES	Payment for ecosystems services
PSAH	Programme for Hydrological Environmental Services (Mexico)
PSA	Pagos por servicios ambientales (payment for environmental services)
PWS	Payment for watershed services
RUPES	Rewarding Upland Poor for Environmental Services (Indonesia)
SBP	Socio Bosque Program (Ecuador)
SDCWA	San Diego County Water Authority
SO_2	Sulfur dioxide
SWP	State Water Project (California, US)
TMDL	Total maximum daily load
TWSTT	Transforming Water Scarcity through Trading

UCSB	University of California at Santa Barbara
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USBR	United States Bureau of Reclamation
WEF	World Economic Forum
WfW	Working for Water (South Africa)
WHO	World Health Organization
WQT	Water quality trading
WRI	World Resources Institute
WWF	World Wide Fund for Nature

Foreword

Human transformation of freshwater ecosystems is rapidly exceeding capacity required to sustain the conditions we need to survive and thrive. Water crises are already impacting people around the globe – from river basins in California and China, to the cities of São Palo and Bangkok. Under current population and growth trends, the 2030 Water Resources Group predicts global water demand will exceed available supply by 40 percent by 2030.

Humans have used, benefited from, and shaped the natural environment for the whole of human history. But what we have not done – especially in the course of industrialization and modernization – is find effective ways to integrate natural ecosystems into our economic and social systems. In response to these challenges, The Rockefeller Foundation's work focuses on incentive-based solutions that harness the importance of ecosystems as an asset for smart development, economic and social progress, and long-term resilience. In our work on agriculture and food security, climate change, energy, and fisheries, we seek new approaches to environmental care that will create incentives for the wise use of resources, and preserve their resilience. And in all of our work we place particular emphasis on the effects of these solutions on the poor or otherwise vulnerable members of society, who are most directly dependent on ecosystems to meet their basic needs and are mostly likely to bear the consequences of environmental degradation.

Freshwater crises are representative of the kind of misaligned incentives we seek to correct. Freshwater allocation and management systems often place little value on the benefits of functioning ecosystems. This, in turn, leads to a vicious cycle in which ecosystem degradation and overuse reduce future water supplies, making even more people vulnerable to water scarcity. As water crises continue to capture public attention – in January, the World Economic Forum's *Global Risk Report 2015* named water crises the number one economic risk in terms of impact – and decision makers worldwide scramble for answers, The Rockefeller Foundation is eager to help support the identification of sound solutions by synthesizing the knowledge and lessons from past and current water management interventions.

The synthesis report that follows examines several incentive-based instruments for improving freshwater management for all users, including poor and vulnerable populations and the freshwater ecosystems themselves. The report examines the economic, social, and environmental performance of three tools, which were selected because: there is growing interest in applying these instruments in a range of settings, they are clearly focused on voluntary transactions rather than sanctions or voluntary standards, they can be applied to improve water quality or quantity, and there is an existing body of literature about their implementation upon which we can build. However, one of the key findings is that these transactions are often not voluntary. The report highlights the importance of finding a fit between a community's water goals and the water management tool(s) it might choose and, perhaps most importantly, it characterizes the enabling conditions required for their effective implementation. We hope this synthesis review will serve as an entry point for those exploring opportunities to improve the management of freshwater, and will spark the development of more robust solutions to improve our management and maintenance of freshwater systems.

We hope that you will find this report useful and encourage you to explore the accompanying learning tool at freshwater.issuelab.org and to share it widely with colleagues.

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Learning from Experience – an ongoing collaboration between the Foundation Center and The Rockefeller Foundation

This synthesis review, *Incentive-based Instruments for Water Management*, is part of an ongoing collaboration between The Rockefeller Foundation and the Foundation Center, aimed at helping organizations build more effectively on each other's knowledge, lessons and experience. With financial support from The Rockefeller Foundation, the Foundation Center is engaging in synthesis reviews and the development of supportive technologies and practices that facilitate the collection, synthesis, and sharing of the sector's collective knowledge.

As part of our collaboration, we are committed to sharing all work products from these efforts as public goods. Too often, systematic and synthesis reviews result in a public report but leave future researchers having to duplicate search and selection efforts in order to further build on a synthesis. By collecting and sharing coded search results through an open repository and openly licensing all work products, we hope other researchers can more freely use and repurpose our findings.

Our goal is to contribute to better programmatic and funding strategies by enabling teams and organizations to start with a more inclusive and comprehensive understanding of what has worked, what hasn't, and why.

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Executive summary

Water is one of our most precious and valuable resources and is fundamental for maintaining human health, economic activity, and critical ecosystem functions. Yet, we can see clear signs of the overexploitation of available freshwater resources and the resultant inability to meet basic human and ecosystem needs. Already, some iconic rivers, such as the Colorado in the United States and the Yellow in China, no longer reach the sea. Groundwater withdrawals have tripled over the past 50 years, with groundwater extraction exceeding natural recharge in some areas, causing widespread depletion and declining groundwater levels. More than 660 million people lack access to an improved drinking water source, predominantly in sub-Saharan Africa and Oceania, and some 2.4 billion people lack access to basic sanitation.[1]

At the same time, the world's water quality is becoming increasingly degraded, with water pollution exacerbating the challenges posed by water scarcity. Pressure on water resources is intensifying in response to challenges such as economic and population growth, and, in turn, is having major impacts on our social, economic, and environmental well-being.

With traditional approaches to managing water having proven insufficient to address these challenges, new approaches and policies are needed. Policy makers and water managers are showing increasing interest in incentive-based instruments to reduce pressure on water resources.

In most regions, laws and regulations have been the primary policy tools employed to improve environmental outcomes. However, over the past several decades, the environmental policy "toolkit" has expanded to include incentive-based instruments that use financial means, directly or indirectly, to motivate responsible parties to reallocate water, or reduce the health and environmental risks posed by their facilities, processes, or products.

This report provides a synthesis review of a set of incentive-based instruments that have been employed to varying degrees around the world. It is part of an effort by The Rockefeller Foundation to improve understanding of both the potential of these instruments and their limitations. The report is divided into five sections. Section 1 provides an introduction to the synthesis review. Section 2 describes the research methodology. Section 3 provides background on policy instruments and detail on three incentive-based instruments – water trading, payment for ecosystem services, and water quality trading – describing the application of each, including their environmental, economic, and social performances, and the conditions needed for their implementation. Section 4 highlights the role of the private sector in implementing these instruments, and Section 5 provides a summary and conclusions.

Water trading

Water trading refers to the temporary or permanent transfer of the right to use water in exchange for some form of compensation. It is perhaps the best known and most widely used method of reallocating water. It has proven, in some cases, to be less expensive, more flexible, and less time-consuming than

[1] An "improved" drinking-water source is one that, by nature of its construction and when properly used, adequately protects the source from outside contamination, particularly fecal matter.

developing new water supplies through, for example, constructing new diversion structures or desalination plants. Similarly, water trading is generally a more accepted method of reallocating water than state appropriation or revoking of existing water rights. Today, examples of successful water trading in Australia and other locations – combined with classic economic theory which suggests that market mechanisms can optimize resource allocation – have heightened interest in this instrument in both academic literature and popular media.

Water trading occurs within sectors, from agriculture-to-agriculture and urban-to-urban, across sectors and, less frequently, from either of these to the environment. Water trading exists, to varying degrees, in countries around the world, though the most active water trading markets are in Australia and the western United States. In Australia, the total value of water trading in fiscal year 2012–13 exceeded $1.4 billion, with much of that activity concentrated within the Murray-Darling Basin. While the total volume of water traded via long-term trades within the Murray-Darling Basin decreased slightly in fiscal year 2012–2013, the volume of water traded via short-term trades increased by 44 percent from the previous year, from almost 3.5 to 5.0 million acre-feet (MAF), or about 50 percent of the total surface water use in the basin.[2] In the western United States, where the scale of water trading is considerably lower, there were more than 4,000 water trades between 1987 and 2008. In 2011, the most recent year for which data are available, more than 1.4 MAF of water were traded in California, representing about 4 percent of the total water use that year. Of that amount, 42 percent of the water traded went to municipal and industrial users, 37 percent to agricultural users, 17 percent was used for environmental purposes, and the remainder was for mixed uses.

The actual results of water trading worldwide have been decidedly mixed, due to two key challenges: externalities and transaction costs. In Australia's Murray-Darling Basin, the federal government overcame some of those challenges by investing more than $3 billion to purchase water for the environment, protecting ecological resources and directly addressing one of the major challenges to water trading. This has facilitated trading in the basin and reduced transaction costs by shifting them to national taxpayers. Over the last 30 years, the federal government also implemented significant institutional changes that facilitated trading and reduced transaction costs. Short-term water trading within irrigation districts in the United States, such as within the Northern Colorado Water Conservancy District, occurs smoothly and quickly because intra-district trades undergo very limited oversight, and because the third-party impacts of such trades tend to be small or negligible.

However, these examples of successful water trading regimes are countered by critical arguments and examples of less-successful trades from various parts of the world. Many authors challenge the applicability and efficacy of water trading, contending that externalities and the unique characteristics of water itself pose significant obstacles to trading water. Many of these externalities arise from the physical properties of water: it is heavy, unwieldy, and easily contaminated; varies seasonally and from year to year; and is readily lost through evaporation, seepage, or runoff. Further, externalities may be borne by disparate parties, such as the environment or future generations, challenging efforts to compensate those injured by trading. Questions of externalities, commodification, and the special nature of water

[2] An acre-foot, the conventional unit of water measurement in the western United States, is equivalent to 325,851 gallons or 1,233.48 m^3.

itself highlight the challenges faced when seeking to implement or expand water trading. Critics also highlight the many examples of "buy-and-dry" water trades, where water-rich agricultural areas sell their water rights, often to wealthier cities, only to find that rural communities as a whole suffer when agricultural production declines. Critics have pointed to examples around the world where wealthy communities or interests have purchased and withdrawn water from less powerful, poor rural areas.

The environmental performance of water trading has been highly variable, depending on the type of trade and site-specific conditions. Water trading has been used as a mechanism to obtain water for ecological purposes, to augment streamflow, and to address water quality concerns (such as temperature) in threatened reaches. The benefits of voluntary, incentive-based water acquisition include ease of transaction and greater community support, especially relative to regulatory takings,[3] though in most areas, such activity still represents a tiny fraction of total water use in any given area. In California, in the last three decades, environmental water purchases averaged 152,000 acre-feet per year, accounting for about 14 percent of trading activity and less than 0.5 percent of total water use in the state. Conversely, water trades for other purposes can inadvertently harm the environment. They can, for example, change the timing, quantity, and quality of return flows, adversely affecting riparian and wetland habitats and the species that depend upon them.

Water trading has rarely been employed to address equity challenges. Indeed, water trading can exacerbate social and economic inequalities, worsening gender and geographic differences. Unequal access to water markets due to unequal access to information or credit can distort outcomes and reduce market efficiency. On the other hand, water trading that promotes water-use efficiency rather than fallowing of agricultural land can improve socio-economic outcomes for both the area of origin and the destination. Water trading's social impacts vary based on several factors, including the relative economic health of the area of origin and the purchasing area, whether or not the water leaves the area of origin, the process used to trade the water, the relative economic and political power of the parties, gender differences regarding access to and control of water, the amount of trading activity in the area, and the legitimacy of the water rights being traded. Impacts often vary within the same community, as those with water rights or allocations to trade receive compensation, while third parties – such as irrigation equipment suppliers or farmworkers – may suffer a loss of revenue or income as a result of trading.

Institutional arrangements are among the most important factors that determine the ultimate success or failure of water trading. Successful water trading requires secure and flexible water rights that recognize and protect users and others from externalities. Such institutional arrangements also need to be flexible enough to adapt to changing physical conditions as well as changing social norms, such as the growing interest in meeting environmental needs and protecting water quality. Some factors, such as access to timely information about water available to trade, can enable water trading but may not be required. Other factors, such as legal and transferable rights to use water, may be necessary for water trading to occur. Still other factors, such as "no injury" regulations and "area of origin" protection, limit water trading or can function as barriers or obstacles to trading.

[3] A "regulatory taking" occurs when a government regulation limits or infringes upon a private property right to such an extent that it deprives the owner of some or all of the value of that property" (Fischel, 1995).

In a limited number of areas with the necessary legal and technical conditions and with sufficient public investment, water trading has offered a timely, relatively inexpensive, and flexible mechanism to reallocate water between users, or from water users back to the environment. Building a successful water market requires decades of determined effort to measure water flows and use, report transactions publicly, conduct regional water planning, and construct and maintain infrastructure to convey water. In Australia's case, it also required more than $3 billion of public funding to acquire water for environmental purposes, which also called for creating and, in turn, maintaining an environmental baseline above which trading activity could occur. Such significant institutional changes require broad public support and a considerable amount of time to implement. Although water trading can be used to reallocate water effectively, successful implementation requires a clear understanding of existing conditions and a determined, long-term effort to make the necessary changes and minimize externalities.

Payment for ecosystem services

Payment for ecosystem services is an incentive-based instrument that seeks to monetize the external, non-market values of environmental services – such as removal of pollutants and regulation of precipitation events – that can then be used as financial incentives for local actors to provide such services. In practical terms, they involve a series of payments to a land or resource manager in exchange for a guaranteed flow of environmental services. Payments are made to the environmental service provider by the beneficiary of those services, e.g. an individual, a community, a company, or a government. In essence, it is based on a beneficiary-pays principle, as opposed to a polluter-pays principle.

Payments for ecosystems services (PESs) that focus on watershed services, commonly referred to as "payments for watershed services" (PWSs), can take a variety of forms. They may be intended to prevent the degradation of a watershed or to restore a previously degraded one. They may be small, local schemes covering several hundred hectares or large, national schemes covering millions of hectares. Programs may be financed directly by the beneficiary or by third parties acting on behalf of the beneficiary, e.g. governments or institutions, or some combination thereof. They may involve cash or in-kind payments to be paid all at once or periodically.

New York City provides a well-known example. In the late 1990s, New York City was faced with the prospect of building a $4–$6 billion filtration plant with an additional $250 million in annual operating costs to meet new federal drinking water standards. An initial analysis suggested that preserving the upstream rural Catskill watershed would be far less expensive. The city and local farmers came together to develop a plan that could meet both groups' interests. A key element of the plan was the Whole Farm Program, a voluntary effort fully funded by New York City's Department of Environmental Protection whereby farmers would work with technical advisors to custom design pollution control measures to meet an environmental objective while also improving the viability of their farming businesses. By 2006, the city had spent or committed between $1.4 billion and $1.5 billion in watershed protection projects, averaging $167 million in expenditures per year – far less than building a water filtration plant. Participation remains high, with 96 percent of large farms in the watershed participating in the program.

Payments for watershed services are gaining prominence and have been applied in a wide range of settings. Some of the earliest programs were established in Central America but today, such programs can be found in countries around the world. The United States' Conservation Reserve Program pays farmers to take land out of production in order to protect soil and water resources and wildlife habitat. In northeastern France, Vittel-Nestle Waters paid farmers and provided technical support (and some labor) to alter local dairy farming practices in order to reduce nitrate pollution of groundwater – the source of Vittel's bottled water.

The largest PWS programs are in China. China's Sloping Land Conversion Programme, piloted in 1999 and fully implemented in 2002, requires farmers to set aside erosion-prone farmland within critical areas of the watershed of the Yangtze and Yellow Rivers – the two largest rivers in China. In exchange, farmers receive regular cash payments and grain rations. The program promotes forestry and other economic endeavors on the land rather than grain production, in order to prevent sediment from washing into rivers and clogging dams and shipping channels.

The environmental performance of PWS is not well understood. Evaluation of these programs is inherently difficult because the connections between land use practice and watershed services are not always clear, especially as they relate to water quantity, and they are often site-specific. It can also be difficult to attribute change to the program rather than to external factors (e.g. changing commodity prices), and programs may not reach threshold levels for measureable impact, or that impact may occur over a relatively long time period. In addition to these challenges, many programs lack baseline data or monitoring systems. In the absence of scientific information, performance is often based on perceptions of local populations and those operating the schemes. But even based on these sources, the available data suggest that environmental performance of PWS is mixed, with less than 60 percent of programs reaching their environmental objective. As the field has matured, it has increased emphasis on monitoring, which will inevitably help improve environmental outcomes.

Similarly, limited data are available on the social and economic impacts of payments for watershed services. Most studies have focused on increased income or capacity building rather than broader social impacts, such as changes in power dynamics. While participation in a PWS program can boost the income of small farmers, the payments they receive will typically boost their annual incomes only slightly. Several studies have also suggested that there are important non-financial (or non-income) benefits, such as increasing land-tenure security, creating human and social capital through internal organization, and improving the visibility of the community to donors and public entities. Some analysts have argued that because the programs are mostly voluntary, continued participation provides some indication that the programs are cost effective, i.e. that benefits exceed costs and participants are satisfied with the outcomes.

While information on broader social outcomes is limited, there is information on the role of these arrangements in alleviating poverty. However, it is important to recognize that payment for watershed services was conceptualized as a mechanism to improve the efficiency of natural resource management, not as a mechanism to reduce poverty. Several studies have examined the socio-economic status of participants, either as buyers or sellers, and have found mixed results, depending to some extent on land and forest tenure regimes and socio-economic conditions in the targeted areas. While most programs prioritize areas critical for ecosystem services, some have been tailored to meet social objectives through a variety of mechanisms, such as targeting the programs to particular areas or populations, reducing transaction costs, and providing pro-poor premiums and subsidies. While there are often more direct ways of reducing poverty than payments for watershed services (e.g. education or health programs), there is little evidence of these schemes actually doing any harm. Few studies have examined gender representation among program participants.

In general, payments for watershed services are flexible, and the necessary conditions are relatively modest. Small, self-organized schemes between private entities are based on general legal requirements: a legal system recognizing that agreements must be kept and that civil law must provide the contracting parties with legal remedies in case of non-compliance. Expanding these projects to address regional or national water problems would require a more developed policy and legal framework along with incentives or requirements to participate in PES programs, cultural and political acceptance of markets, trust between ecosystem service providers and beneficiaries, and a supply and demand for ecosystem services.

Water quality trading

Water quality trading (WQT) is an incentive-based approach for reducing or controlling water pollution. Under such a system, polluters are granted a permit to pollute, and these permits can be bought and sold among polluters. The central idea is that trading puts a price on pollution, encouraging cost savings, efficiency, and innovation. Water quality trading is an adjunct to regulation, not an alternative to it. In fact, its success depends on the presence of a strong regulatory body to enforce water quality standards, and monitor and enforce discharge limits.

Water quality markets have drawn inspiration from the success of the Acid Rain Program (ARP) established in the United States in the 1990s. The popularity of emissions trading for dealing with water pollution in the United States is largely a result of the Clean Water Act of 1972, which made it difficult for governments to handle pollution from farms. Water quality markets have been established in the United States, Canada, Australia, and New Zealand. There is also interest in China and Europe, although no programs are currently in place. To date, most water quality trading markets have been used to control pollution from nutrients that cause excessive algal growth and low dissolved oxygen levels in water bodies, a process referred to as "eutrophication". Other water quality trading programs have been set up to control salinity, heavy metal, sediment, and temperature or thermal pollution.

The largest WQT market in the United States in terms of transactions, the Connecticut Nitrogen Credit Exchange Program, was created in 2002 to reduce nitrogen pollution that came into Long Island Sound from the Connecticut River. Under the program, which covers 79 sewage treatment plants in the state of Connecticut, a plant can control pollution in excess of its permit requirement and sell excess nitrogen allowances to those plants that exceed their allowances. A 2012 review of the program found that in ten years, the program had helped reduce nitrogen pollution by over 50 percent while controlling costs.

One of the best examples of a successful water quality trading market is on Australia's Hunter River, where coal mines and other pollution sources are subject to discharge limits to protect water quality and drinking water sources in downstream cities. Under this system, limited discharge is allowed, but permitted dischargers must coordinate their activities so that the total salt concentration in the river never goes above a specified limit. Industries can buy and sell salt credits in real time via a trading website run by the state government. Several years after it began, the trading program remains popular among participants and functions smoothly. Perhaps the biggest marker of the program's success is that, even though new and potentially high-polluting mines have been established, river water quality has met standards nearly 100 percent of the time.

Despite the fact that water quality trading markets have existed for three decades in some areas, it is difficult to determine whether the approach can be considered an overall success. Many of the domestic WQT markets in the United States have not lived up to expectations, seeing few trades or no trades at all. This can be explained by a number of factors: high transaction costs, lack of trust, uncertainty about the future of the market, or simply unfamiliarity and unwillingness to participate. However, paradoxically, despite a lack of trading, the process of creating the market may have contributed to better watershed management. Bringing stakeholders together around a common goal of improving water quality has helped lower resistance to new, more stringent water quality regulations.

In other cases, discussion of the use of "market fundamentals" helped convince some political conservatives to implement a form of environmental regulation, paving the way for improved water quality. A common argument in favor of environmental markets is that they will be smaller, simpler, and lower cost, because they aim to replace regulation with a free market. However, water quality markets require a strong and capable regulatory ability to set a cap on pollutants, to monitor pollution, and to verify the legitimacy of water quality credits that are created. Ironically, this often results in the creation of additional layers of government to perform these functions.

WQT markets are valuable where large price asymmetries exist in water pollution control, and where certain polluters are beyond the reach of a regulatory agency. This is the case in the United States, where states are responsible for preserving water quality but have little authority over agriculture and some other nonpoint sources. On one hand, this has decreased the burden on municipal and industrial sources of pollution, allowing them to save on the cost of installing expensive treatment technologies. On the other hand, it has compelled them to fund projects on farms, often hundreds of miles away. We conclude that water quality trading is not a panacea for solving water pollution problems. However, it can be part of an effective regulatory approach under certain conditions.

Conclusions

In this report, we analyze the potential for incentive-based instruments to reduce pressure on water resources. To date, the primary environmental policy tools to address water challenges have been command-and-control regulations. However, over the past several decades, the environmental policy "toolkit" has expanded to include a host of incentive-based instruments that use financial means, directly or indirectly, to motivate responsible parties to reduce the health and environmental risks posed by their facilities, processes, or products.

While regulations and incentive-based instruments are frequently juxtaposed, they also frequently operate alongside one another. With water quality trading, for example, governments mandate caps on the allowable pollutant levels and issue tradable permits that allow industry groups to allocate polluting activities among themselves, governed by market forces. Similarly, with water trading, governments may allocate water and then institute a framework within which water trading can occur. While incentive-based instruments may work in tandem, they must be integrated within a broader watershed management effort.

Decisions about whether and how to apply a particular instrument depend on the specific objectives, circumstances, conditions, and needs of a given area. These decisions should be based on an open and transparent process, with meaningful participation from all affected parties. This approach will help in crafting a solution that is appropriate for local conditions, and ensure that it is fair and equitable. It will also help to reduce opposition and promote acceptance from those who will be implementing and affected by the program. It is important to recognize that those with the least power may not have the resources to participate, or they may be skeptical of the groups involved. In these cases, there is a need for consistent and rigorous outreach and, potentially, for engaging a trusted intermediary.

Finally, monitoring and evaluation are essential to the success of any instrument. In particular, monitoring and evaluation help ensure outcomes are achieved and allow for adjustments in response to changing social, economic, or environmental conditions. Monitoring should evaluate the "additionality" of the program, i.e. whether the program has an effect when compared with some baseline. It should also examine any potential impacts on surrounding areas (i.e. leakage) and the permanence of the intervention. However, extensive monitoring requirements would increase transaction costs, potentially threatening the viability of the program. Thus, the need for monitoring and evaluation must be balanced with practical considerations of the ability to maintain the viability of the program.

Limari River, Chile. Photograph by Eduardo Robles.

1

Introduction

Water is one of our most precious and valuable resources and is fundamental for maintaining human health, agricultural production, and economic activity as well as critical ecosystem functions. Even as the planet's endowment of water is expected to remain constant, human appropriation of fresh water, already at 50 percent by some measures (Postel *et al.,* 1996), is expected to increase further (Leflaive *et al.,* 2012). We can already see clear signs of the overexploitation of available freshwater resources. For example, some iconic rivers, including the Colorado River in the United States and the Yellow River in China, no longer reach the sea. Groundwater withdrawals have tripled over the past 50 years (UN, 2012), and in some areas, groundwater extraction exceeds natural recharge, causing widespread depletion and declining groundwater levels (Wada *et al.,* 2010; Famiglietti, 2014). Pressures on water resources are likely to worsen in response to continued economic and population growth, climate change, and other challenges. Water pollution exacerbates the challenges posed by water scarcity as the world's water quality is increasingly becoming degraded.

Growing pressures on the availability and quality of water resources have major impacts on our social, economic, and environmental well-being. The failure to provide safe drinking water and adequate sanitation services to all people is perhaps the greatest development failure of the twentieth century. Improving access to water and sanitation has been a key focus of the global development agenda since 2000. Water and sanitation were goals of the 2000–2015 Millennium Development Goals, and now, the Sustainable Development Goals launched in September 2015, also call for insuring access to water and sanitation for all.

"...more than 660 million people still lack access to an improved drinking water source..."

Yet, despite nearly two decades of international attention and tens of billions of dollars invested, more than 660 million people still lack access to improved drinking water, predominantly in sub-Saharan Africa and Oceania, and some 2.4 billion people lack access to basic sanitation (WHO and UNICEF, 2015).[4,5] In even the wealthiest countries, access to water and sanitation

4 Improved water sources include household connections, public standpipes, boreholes, protected dug wells, protected springs, and rainwater collections. Unimproved water sources are unprotected wells, unprotected springs, vendor-provided water, bottled water (unless water for other uses is available from an improved source), and tanker truck-provided water.

5 Improved sanitation includes connection to public sewers, connection to septic systems, pour-flush latrines, simple pit latrines, and ventilated improved pit latrines. Service or bucket latrines (where excreta is manually removed), public latrines and open latrines are not considered improved sanitation.

is not universal. A 2011 UN report (de Albuquerque, 2011) highlighted several areas of the United States, including California, where marginalized populations (e.g. those living in poverty, communities of color, and indigenous groups) lacked the basic rights to water and sanitation. Moreover, access to an improved water source does not necessarily mean that the water is affordable or safe to drink. For example, naturally occurring arsenic pollution in groundwater affects nearly 140 million people in 70 countries (United Nations, 2009).

Freshwater ecosystems are among the most extensively altered systems on earth. Rivers, streams, and lakes have been subjected to chemical, physical, and biological alteration as a result of large-scale water diversions, introduction of invasive species, overharvesting, pollution, and climate change (Carpenter *et al.,* 2011). As a result, an estimated 20 to 35 percent of freshwater fish are vulnerable or endangered (Cosgrove and Rijsberman, 2000). Likewise, about half of the world's wetlands have been lost since 1900, and much of the remaining wetlands are degraded (Zedler and Kercher, 2005). Freshwater ecosystem conditions are likely to continue to decline unless action is taken to address acute threats and better manage freshwater resources.

Traditional approaches to managing water supply and demand are not going to be effective in addressing these challenges. Throughout much of the twentieth century, the emphasis was on developing massive dams and pumping ever increasing amounts of groundwater to satisfy rising water demands. This approach, as noted by Sharma and Vairavamoorthy (2009), "has led to over-use of the resources, over-capitalisation, pollution and other problems of varying severity." The soft path for water has emerged as a promising alternative. The term "soft energy path", coined by Amory Lovins (1977) of the Rocky Mountain Institute, described an alternative path for energy development that emphasized energy efficiency and promoted smaller, decentralized energy systems fueled by renewable sources. The soft path for water, as described by Peter H. Gleick (2002, 2003), is based on integrating several key principles, including improving the overall productivity of water use, matching water quality to users' needs, prioritizing basic human and ecosystem water needs, and seeking meaningful local and community engagement in water management.

A key element of the soft path for water is shifting from a near exclusive supply-side orientation to one that seeks to manage water demand. Numerous studies have found significant opportunities to reduce water demand in all sectors using a variety of conservation and efficiency measures (e.g. Gleick *et al.,* 2003; Cohen *et al.*, 2013; Heberger *et al.*, 2014). These measures can be applied in countries at varying levels of economic development, although the types of measures employed and implementation strategies may differ (Sharma and Vairavamoorthy, 2009). Brooks (2006) argued that demand management is more than a set of techniques; rather, it is a governance approach linked to equity, environmental protection, and public engagement goals. Additional information on demand management can be found in Annex 1.

"...the environmental policy "toolkit" has expanded to include "incentive-based" instruments..."

New policy tools are also needed. In most places, regulations have been the primary tool employed to improve environmental outcomes. However, over the past several decades, the environmental policy "toolkit" has expanded to include "incentive-based" instruments. Incentive-based instruments use financial means, directly or indirectly, to motivate responsible parties to reallocate water or reduce the health and environmental risks posed by their facilities, processes, or products. These instruments have emerged for several reasons, but mainly because they are believed to be more cost effective than regulations, as they provide greater flexibility for the individual or firm to meet the environmental objective in the least costly manner. Incentive-based instruments are also thought to lower administrative costs and promote innovation by rewarding those who exceed their targets (Harrington and Morgenstern, 2004). Furthermore, Koplow (2004) suggests that these instruments can support self-enforcement by creating "groups of firms and individuals with vested interests in the proper use of resources and in emitting only as much pollution as allowed."

This report provides a synthesis review of a set of incentive-based instruments that have been employed in varying degrees around the world to reduce pressure on water resources. It is part of an effort to understand the full potential, and limitations, of these instruments in managing both the quantity and quality of freshwater. We have divided this review into five sections. This Section 1 introduces the synthesis review. Section 2 describes the research methodology. Section 3 provides background on policy instruments and detail on three incentive-based instruments that have been used in the United States and abroad – water trading, payment for ecosystem services, and water quality trading. For each instrument, we describe its application, its environmental, economic, and social performance, and the conditions needed for its implementation. Section 4 highlights the role of the private sector in implementing these instruments, and Section 5 provides a summary and conclusions.


Colorado River, Texas. Photograph by Leaflet.

2

Research methodology

The freshwater synthesis review is based on a five-step approach to making better use of existing evaluative knowledge. This approach, modeled by The Rockefeller Foundation to help inform its investment and programmatic decisions, has already been used in a review of success factors in small-scale coastal fisheries management in developing countries (The Rockefeller Foundation, 2013). Throughout the project, the project team held bi-weekly calls with The Rockefeller Foundation to review progress on the project, discuss key findings, and dive into specific case studies that could further support learning. The following steps were taken.

1. **Refine project scope.** The first step was to work with the Foundation Center and The Rockefeller Foundation to refine the scope of work and develop research questions.
2. **Undertake literature search and review.** The second step was to review the peer-reviewed literature and law reviews on the key topics for the research. We supplemented this formal literature search with a review of the gray literature, including government and other institutional reports, from organizations working to evaluate or implement these instruments. To identify the relevant literature, we used Web of Science (formerly Web of Knowledge) Internet-based search engines, and institutional website search engines. The literature on these incentive-based instruments is extensive. For example, a Google Scholar search of "water trading" returned nearly 1 million results. Given the need to review a large amount of information in a relatively short time, we prioritized articles published since 2000. We further refined our study by limiting our scope to articles and reports on the state of practice, rather than the state of theory. In total, we reviewed approximately 500 articles and reports.
3. **Conduct expert interviews.** The third step was to obtain the knowledge of experts working to address the study's key questions. It was designed to fill in any gaps in the literature. We developed the interview list based on the academic and grey literature search and from the research team's experience in the sector.
4. **Compile initial analysis and synthesis.** The fourth step included an initial analysis and synthesis of the knowledge gained from the first three steps, which was compiled into a detailed presentation and supporting materials, and formally presented to the Foundation Center and The Rockefeller Foundation Team in an interactive discussion in March 2015. The Rockefeller Foundation also reviewed the draft report in July 2015, providing additional input on the synthesis.
5. **Conduct further analysis and develop final knowledge product.** The fifth step was to conduct further analysis of the published and expert knowledge based on the discussions with the Foundation Center, The Rockefeller Foundation, and other parties. We worked closely with the Foundation Center to develop the final knowledge products, including this summary report and online components, such as a visualization of key findings and a public collection of cited research. All of the knowledge products are openly licensed and free to be used and repurposed.

Murray River, Australia. Photograph by Mattinbgn.

3

Environmental policy instruments

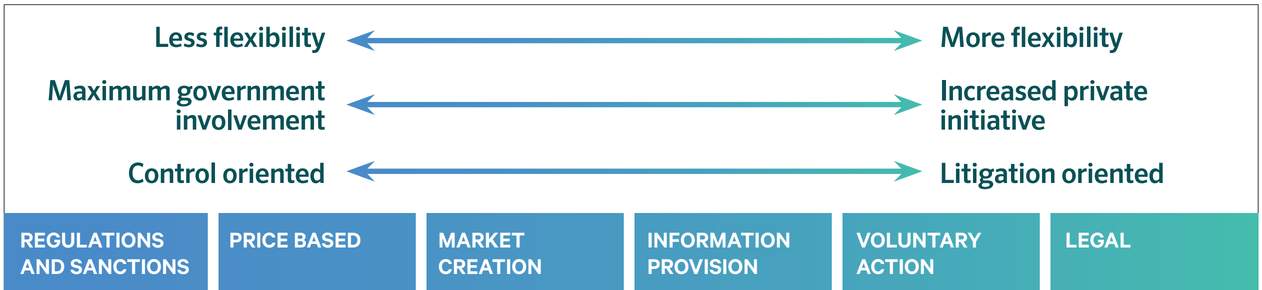
The objective of environmental policy is "to modify, slow, or stop resource extraction; to reduce or eliminate emissions of concern; and to shift consumption and production patterns towards greater sustainability" (Koplow, 2004). In most places, regulations have traditionally been the primary environmental policy instrument employed to achieve environmental outcomes. This approach, often referred to as command-and-control (CAC), relies on some governmental or similar body to establish a standard or target (the "command") that must then be complied with to avoid negative sanctions, such as fines or prosecution (the "control").

Over the past several decades, the environmental policy "toolkit" has expanded to include incentive-based instruments, also referred to as economic instruments or market-based instruments. While definitions vary, we use the term "incentive-based instruments" to refer to a set of tools that use financial means, directly or indirectly, to motivate responsible parties to reallocate water or reduce the health and environmental risks posed by their facilities, processes, or products. While CAC and incentive-based instruments are often juxtaposed with one another, a United Nations Environment Programme (UNEP) report (Koplow, 2004) noted that "in reality the two often operate alongside each other. Governments may, for example, mandate caps on allowable pollution for a region or country and use market-oriented approaches such as tradable permits to allocate the allowable emissions in an efficient manner."

Figure 1 provides a depiction of the range of environmental policy instruments currently applied around the world. These include the following.

- **Regulations and sanctions** – mechanisms that rely on guidelines, permits, or licenses, and often include a legal or financial penalty for non-compliance. Examples include pollution standards, water use quotes, and building standards.
- **Price-based instruments** – mechanisms that impose i) higher costs through fees, charges, or taxes on pollution or the use of a natural resource, making them more expensive and discouraging their production or consumption, or ii) lower costs through the use of subsidies for environmentally friendly activities or products. Examples include abstraction fees, pollution charges, grants, low-interest loans, and favorable tax treatment.
- **Market creation** – mechanisms that include i) tradable permits whereby user or polluter rights are assigned according to desirable use levels or historical practices, and compliance can be achieved by trade, or ii) deposit refund systems that create a market to buy back inefficient or polluting products. Examples include water trading and water quality trading.
- **Information provision** – mechanisms that use the provision and disclosure of information on environmental performance to incentivize producers to reduce their water use or emissions of pollutants,

FIGURE 1. Incentive-based policy instruments



WATER MANAGEMENT EXAMPLES:

Regulations and sanctions	Price based	Market creation	Information provision	Voluntary action	Legal
Pollution standards	Cost recovery tariffs	Water quality trading	Eco-labels	UN CEO Water Mandate	Criminal penalties
Water use quotas	Pollution taxes	Water trading	Corporate reporting	AWS International Water Stewardship Standard	Performance bonds
Building codes	Payment for watershed services		Environmental certification		Civil liability statutes

Source: adapted from Huber *et al.*, 1998; UNEP, 2009.

or to incentivize consumers to select products with superior performance. Examples include corporate reporting, product labeling (e.g. WaterSense),[6] and environmental certification schemes.

- **Voluntary action** – mechanisms that use voluntary agreements between the government and private firms and/or commitments made independent of government requirement. Examples include the UN CEO Water Mandate and the Alliance for Water Stewardship's International Water Stewardship Standard.
- **Legal instruments** – mechanisms for compensating victims when pollution causes human or environmental harm, and encouraging compliance with existing environmental regulations. Examples include criminal penalties, civil liability statutes, and performance bonds.

[6] WaterSense is an environmental program designed to encourage water efficiency in the US, through use of a special label on consumer products.

As shown in Figure 1, these instruments exist along a continuum, from "very strict command approaches to decentralized approaches that rely more on market or legal mechanisms" (Huber *et al.*, 1998). As noted, there are varying definitions of incentive-based instruments and the types of tools that would qualify. All definitions identify price-based instruments and market creation as incentive-based instruments. Some, however, use a broader definition that includes information provision, voluntary action, and liability instruments (see, e.g. Stavins, 2001; UNEP, 2001; Anderson, 2004). Product labeling schemes, such as the United States' "Energy Star" or Thailand's "Green Label", allow companies meeting environmental standards to place a recognized label on their product, boosting sales by making the product more appealing to consumers and providing a financial incentive to improve environmental performance (Stavins, 2001). These products may also be sold at a higher price than less environmentally-friendly models. Likewise, voluntary programs may reward meeting environmental outcomes with, e.g. public recognition which, in turn, increases sales.

The application and market activity of these instruments are not well understood. Several organizations track the application of some of these incentive-based instruments (IIED, 2015 and Forest Trends, 2015a).[7] However, there is no comprehensive list of the programs that have been implemented globally. Additionally, programs are sometimes poorly defined, fall into multiple categories, or change over time. Moreover, data on the activity of these instruments, including the number and value of transactions, are not collected or made available publicly. Despite these challenges, Forest Trends has been tracking the activity of five market and market-like instruments for watershed investments for several years.[8] It estimates that the market activity of watershed investments was $12.3 billion in 2013 (Table 1). The majority of this activity ($11.6 billion, or 94 percent) was associated with payment for watershed services, and 98 percent of that activity was in China. Collective action funds – which pool contributions from multiple investors to support coordinated interventions within a watershed – had the second highest transaction value at $563 million. We note, however, that the distinction between payment for watershed and collective action programs is sometimes unclear.[9] The market activity of instream buybacks – programs that purchase or lease water to augment instream flows – was considerably less ($97 million), followed by water quality trading ($22 million), and voluntary compensation ($320,000). It is of note that instream buybacks likely represent a modest fraction of the market activity of water trading programs, although comprehensive data on the latter are not readily available.[10] While the data suggest a rapid expansion in the application of these instruments since 2008, Ecosystem Marketplace's Genevieve Bennett (personal communication, 2015) noted that much of the increase is actually an outcome of better reporting.

7 See, for example, Watershed Markets (watershedmarkets.org), maintained by the London-based International Institute for Environment and Development, and Watershed Connect (watershedconnect.com), an online platform maintained by the Washington, D.C.-based Forest Trends.

8 Forest Trends is an international "non-profit organization with three principal roles: convening market players to advance market transformations, generating and disseminating critical information to market players, and facilitating deals between different critical links in the value chains of new forestry." See forest-trends.org.

9 Water funds are sometimes categorized as payment for watershed services and other times as collective action funds.

10 California, for example, has an active trading market but no centralized repository of data on the number and value of transactions.

TABLE 1. Transactions (in millions of US$) by type, 2008–2013

	2008	2009	2010	2011	2012	2013
Payment for watershed services/undefined	$ 7,950	$ 6,950	$ 7,470	$ 8,000	$ 9,600	$11,600
Collective action funds	n/a	n/a	n/a	n/a	$ 137	$ 563
Voluntary compensation	n/a	n/a	n/a	n/a	$ 0.230	$ 0.320
Water quality trading	$ 10.7	$ 8.30	$ 8.30	$ 7.70	$ 14.9	$ 22.2
Instream buybacks	n/a	$ 19	$ 390	$ 164	$ 144	$ 97.0
Total	$ 7,960	$ 6,980	$ 7,870	$ 8,170	$ 9,890	$ 12,300

Note: Numbers shown are nominal values. All values rounded to three significant figures. Numbers may not add up due to rounding. Based on data provided by Bennett (personal communication, 2015) and included in Bennett and Carroll (2014).

In this review, we evaluate three of the major incentive-based instruments that have been employed to improve water management: water trading, payment for ecosystem services, and water quality trading. These instruments are employed in developed and developing countries, and there is growing interest in expanding their application.

3.1 Water trading

Description

Water trading is perhaps the best known and most widely used method of reallocating water. In some cases, purchasing or leasing water from existing users has proven to be less expensive, more flexible, and less time-consuming than developing new water supplies, such as constructing new diversion structures or desalination plants. Similarly, water trading is generally a more accepted method for reallocating water than state appropriation or condemnation of existing water rights. Successful examples of water trading in Australia and other locations – combined with classic economic theory suggesting that market mechanisms can optimize resource allocation – have heightened interest in this instrument in both academic literature and popular media.

"...water trading provides a mechanism to improve the economic efficiency of water..."

As noted in Box 1, the peer-reviewed and gray literature employ several terms (e.g. water transfers, water markets, and water banks) to refer to a variety of sometimes overlapping instruments and methods for conveying and reallocating water. In this paper, we use the following terms:

- **water trading** – the temporary or permanent transfer of the right to use water in exchange for some form of compensation
- **informal water trading** – the sale of a specified volume of water for a limited period of time, which does not involve actual contracts or occurs outside of a recognized legal or administrative framework (e.g. the sale of groundwater to an adjacent irrigator)
- **water banks** – the institutions or agencies that i) broker or otherwise facilitate water trading (Culp *et al.*, 2014) or ii) are established for a specific objective, such as a trust created to obtain water rights for instream augmentation (Clifford, 2012). Water banks offer expertise and information for improving communication between buyers and sellers, and often provide a centralized repository or clearinghouse of information on current and historical transactions, including volumes, pricing, and locations.

There is an extensive body of literature suggesting that water trading provides a mechanism to improve the economic efficiency of water through its reallocation from lower to higher value uses (Glennon, 2005; Dellapenna, 2000; Bjornlund and McKay, 2002). The germinal study entitled *Water and Choice in the Colorado Basin* (NRC, 1968) recommended that water in the western United States be transferred from irrigation, which generates relatively low returns per unit of water, to high-value non-agricultural uses. More recent research has continued to emphasize the potential value created by water transfers. For example, models used to project California's economic costs under a dry climate change projection, (Medellín-Azuara *et al.*, 2008) found significantly increased benefits with market-based reallocations. Newlin *et al.* (2002) and Jenkins *et al.* (2004) asserted that water trading could dramatically reduce Southern California's water scarcity costs.

Water trading is attractive because it tends to minimize the impact on existing rights holders by providing compensation and, in many cases, additional security, for existing water rights, while providing opportunities to those with new or increasing demands (NRC, 1992).

A large number of experts challenge the applicability and efficacy of water trading. Freyfogle (1996) asserted that externalities, intrinsic to the very nature of water itself, pose such an insurmountable obstacle that water trading does not and cannot work. Many of these externalities arise from the physical properties of water: it is heavy, unwieldy, and easily contaminated; it sometimes has dramatic seasonal and year-to-year variability; and it can be easily lost through evaporation, seepage, or runoff (Salzman, 2006). Further, these externalities may be borne by disparate parties, such as the environment or future generations, challenging efforts to compensate those injured by trading (Freyfogle, 1996). Moreover, Salzman (2006) argued that custom, history, and religion in many parts of the world treat drinking water as a common property resource, rather than a tradeable commodity. Similarly, Zellmer and Harder (2007) asserted, "Water is a uniquely essential resource with uniquely public attributes," unlike other resources typically treated as property. Questions of externalities, commodification, and the special nature of water itself highlight the challenges faced by implementing or expanding water trading.

In some cases, water trading is effectively zero-sum, simply shifting water use and economic productivity from one area or sector to another. In other cases, it can

BOX 1

A note on terminology

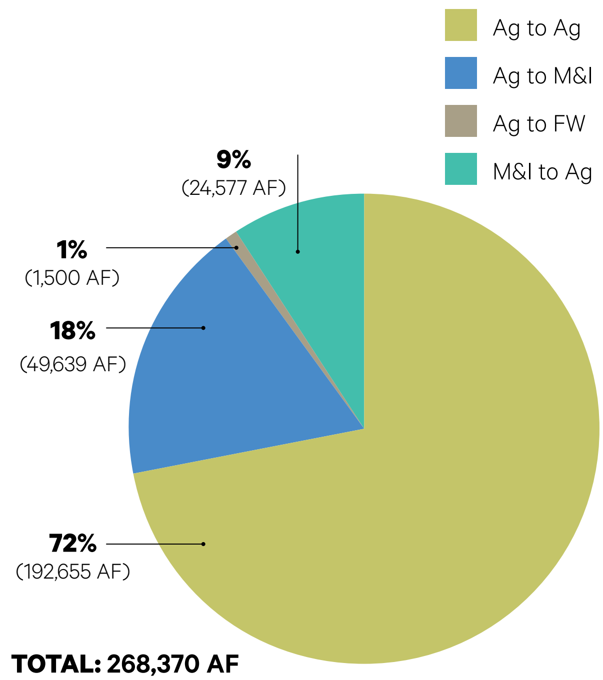
Water transfers. The National Research Council (NRC) of the United States National Academies defines water transfers as changes in the point of diversion, type of use, or location of water use (NRC *et al*., 1992). The term "water transfers" encompasses a broad range of market-based and non-market water reallocation mechanisms of varying periods, geographic scales, and arrangements. Water transfers can range from short-term leases or conditional arrangements to the permanent transfer (i.e. sale) of a water right. They can range in scale from i) change in type of use on an existing parcel of land, such as when a water right shifts from irrigation to municipal use when agricultural land is purchased and converted to housing, to ii) inter-basin transfers, such as when a city purchases or leases water from a different watershed.

Water bank. A water bank is a mechanism for changing the time or location of water use. Water banking, as with water transfers, can refer to market-based or non-market activities. The term "water bank" can refer to an actual institution or to the physical storage of water. Water banks as institutions may function as i) brokers that connect buyers and sellers of water rights or leases, providing an important communication function; ii) clearinghouses that directly purchase or lease water from willing sellers and aggregate supplies for subsequent sale to other buyers; iii) facilitators that expedite water transfers using existing storage or conveyance facilities (Culp *et al*., 2014); or iv) trusts that hold or otherwise manage water rights or entitlements for a specific purpose, such as streamflow augmentation (O'Donnell and Colby, 2010). When serving as facilitators, water banks may perform various administrative and technical functions, including the confirmation of water rights and screening of potential buyers (Clifford, 2012). Water banks may also refer to physical storage, either in surface reservoirs or in aquifers, which, in turn, may be a component of a larger water transfer or simply a mechanism enabling an entitlement holder to store water for its own future use, but we do not use this definition in this review.

Water market. The term water market refers to a range of different market-based practices, typically referring to water trading. According to Brown (2006), the term water market lacks a precise definition, "but once a few voluntary trades of water of relatively common physical and legal characteristics occur, it is said that a water market exists." A water market may also refer to informal transactions involving the direct sale of water that does not involve the lease or sale of water rights. Informal water transactions can include purchasing bottled water or water from a tanker truck, a common practice in many parts of the developing world that lack a reliable, piped water supply. While a "water contract" can refer to a one-time voluntary water exchange between two actors, a water market is where many actors come together and make trades; a market also includes some formalization of the transactions (Brown *et al*., 2015).

increase system-wide water efficiency, by providing the area of origin with funds for investing in improved efficiency, maintaining local productivity with lower water use, and then transferring the conserved water. Water can be made available for trading from a variety of activities, including fallowing fields, crop shifting, and in some cases, a shift from surface water diversions to groundwater pumping. Water trades can also be linked to water conservation and efficiency efforts, including increasing irrigation efficiency and decreasing system losses that generate surplus water by, e.g. lining canals or constructing operating reservoirs. However, increasing demand for greater efficiencies in irrigation can challenge the flexibility of existing institutions (Hundley, 2001), such as irrigation districts and water courts, which often do not recognize a legal property right to this "new" water created by conservation or efficiency. Additionally, existing institutions often impose significant costs on those attempting to dedicate water to non-traditional uses such as instream flows (Getches, 1985). These changes have tested the resilience of water institutions, which have shown some flexibility in adapting to new values and goals but often impose high transaction costs (Colby *et al.*, 1991).

FIGURE 2. Non-project water transfers within the Sacramento-San Joaquin watersheds in 2013



Note: Ag – agriculture; FW – fish and wildlife; M&I – municipal and industrial; AF – acre-foot.

Source: California Department of Water Resources.

"The most active water trading markets occur in Australia and the western United States."

Water trading can occur within sectors, from agriculture-to-agriculture and urban-to-urban, across these sectors, and, less frequently, from either of these to the environment (Brewer *et al.*, 2007). Figure 2, from the California Department of Water Resources, shows the relative proportions of water trading within and between different sectors. Although water trading is often considered a means to move water from agriculture to urban uses, nearly three-quarters of the 270,000 acre-feet of water traded in California in 2013 occurred between agricultural users. Interestingly, nearly 25,000 acre-feet of water were traded from municipal and industrial (M&I) uses *to* agriculture, which was nearly half of the volume of water traded from agriculture to M&I uses.

Application

Water trading exists, to varying degrees, in countries around the world. When Grafton *et al.* (2010) assessed water trading in two wealthy countries (Australia and the United States), two low- to middle-income countries (Chile and South Africa), and one poor, rapidly developing country (China), they found that differing levels of information availability, legal rights structures, institutional constraints, and management goals had resulted in very different levels of activity and performance.

The most active water trading markets occur in Australia and the western United States. Within Australia, water trading includes both short-term trades (referred to as allocation trading) and long-term trades (referred to as entitlement trading). The total value of water trading in Australia in fiscal year 2012–13 exceeded $1.4 billion

(NWC, 2013). Trading within the Murray-Darling Basin, which has an active and well-documented water market first established more than 30 years ago (Grafton *et al.,* 2012), accounts for 98 percent of all allocation trades and 78 percent of all entitlement trades within Australia, by volume. Indeed, the Murray-Darling Basin figures prominently in discussions about water trading, as an example of a thriving incentive-based system that successfully transitioned from a non-market system (Grafton *et al.,* 2012). In fiscal year 2012–13, the total volume of short-term (allocation) trading within the Murray-Darling Basin increased 44 percent from the previous year, from almost 3.5 million acre-feet (MAF) to 5 MAF, or about 50 percent of total surface water use in the basin. The total volume of long-term trades, however, decreased by about 14 percent over that period, to about 0.85 MAF. A national study found that these permanent entitlement trades often offset the temporary allocation trades, as irrigators planting perennial crops, such as grapes or almonds, purchased entitlements to meet expected future demand, but then sold a portion of the temporary allocations associated with these entitlements to generate revenue (Frontier Economics and Australia National Water Commission, 2007). For more information on Australia's water market, see Annex 2.

In the western United States, the scale of water trading is considerably lower. A database compiled by the University of California Santa Barbara (UCSB) Bren School shows notifications for more than 4,000 water trades in 12 states in the western United States from the years 1987–2008.[11] Brewer *et al.* (2007) documented the large variability in the volume, price, and duration of water trades in the western United States, both within and between sectors. In 2009, the most recent year for which data are available, the database reports almost 640,000 acre-feet of water traded in California, through 36 trades with a total value of about $234 million (all values adjusted to 2014$). More than 80 percent of the water was leased rather than sold. According to the database, 15 of these trades, accounting for about 88,000 acre-feet of total volume, occurred within one agricultural district. However, the Bren School database only records the initial year a water trade is reported, and thus does not reflect the volume of multiyear trading agreements. That means that a review of 2009 trading activity does not reflect previous multi-year trades that may still have been active in 2009, so the values reported above understate trading activity in 2009.

A comprehensive review of water trading in California reports about 1.5 MAF of water were traded in 2009, a dry year (Hanak and Stryjewski, 2012). Volumes reported for 2011, a wet year and the most recent year for which data are available, were about 5 percent lower, at 1.4 MAF. In 2011, 42 percent of the water traded went to municipal and industrial users, 37 percent to agricultural users, 17 percent for environmental purposes, and the remainder to mixed uses. Because of limited data, the study does not include trading activity within irrigation districts or similar users associations, although some estimates suggest that such intra-district activity accounted for several hundred thousand acre-feet of water, a third of total water supplies within some of the larger irrigation districts. Hanak and Stryjewski (2012) did not provide total dollar values associated with the California water market, though they noted that prices of temporary water transfers had increased from an average of $30–$40 per acre-foot in one region in the mid-1990s to $180 per acre-foot in 2011, while average prices in another basin rose to an average of $400 per acre-foot. The authors noted the shifting trend from short-term to longer-term leases and permanent trades, pumping restrictions in the Bay-Delta, and rising transaction costs that had slowed market activity in the past decade.

California is also home to the largest United States water trade to date. The San Diego County Water Authority (SDCWA) entered into a 45-year contract

[11] The database summary notes that "The data are drawn from water transactions reported in the monthly trade journal the Water Strategist and its predecessor the Water Intelligence Monthly from 1987 through February 2010." These data reflect published reports that in some cases do not reflect final transfer agreements. For example, the database reports that the Imperial Irrigation District-San Diego County Water Authority water transfer began in 1997, although the final transfer agreement was not actually signed and the transfer did not begin (at different volumes than the database reports) until October 2003. The Bren School water transfer database is available at bren.ucsb.edu/news/water_transfers.htm.

in 2003, with an option for a 30-year extension, with the Imperial Irrigation District (IID), one of the largest irrigation districts in the country.[12] Under the terms of the agreement, the SDCWA pays the IID to reduce its diversion of Colorado River water, while the Authority diverts a like amount farther upstream. After a 15-year period intended to create time to address ecological and public health impacts resulting from the trade, the IID will shift to efficiency-based methods (such as lining canals and constructing regulating reservoirs) to generate the water to be conserved. In essence, the Authority is paying the District to improve the efficiency of its operations and receiving the water conserved. The trade is ramping up to a maximum volume of 200,000 acre-feet per year by 2021, representing about 25 percent of the region's total water supply. In 2014, the price for the water was $594 per acre-foot, plus an additional $445 per acre-foot to a different agency to convey the water through its facilities. This total, which does not include additional payments to offset the environmental impacts of the trade, is about half what the Authority has contracted to pay for water generated by a new desalination plant on the coast.

In Central and South America, Chile and Mexico have active water trading markets. Chile's Limarí Basin enjoys water rights trading and water transfers, enabled by three large state-built reservoirs and robust local water organizations. The actual number of water trades in Chile's Limarí Basin has averaged about 33 each year (Romano and Leporati, 2002), although water trading has been more limited in the rest of the country (Bauer, 1997). Mexico's National Water Law of 1992 established a formal water market with tradable concessions that formed the basis for active markets in several parts of the country (Thobani, 1997), with nearly 3,700 registered water transfer requests in 2006 alone (CONAGUA, 2012).

Water markets have also been established in parts of Europe, Asia, and Africa. In Spain, informal trades, sales, and short-term exchanges of water are common, while formal transfers of long-term water rights are generally limited to groundwater (Albiac *et al.,* 2006). In Spain's Alicante basin, several irrigation districts auction their annual water allocations to district farmers (Albiac *et al.,* 2006), creating a strong incentive to improve water-use efficiency and shift toward higher value crops. England has encouraged water trading for more than a decade, although only about 60 trades have occurred to date (TWSTT, 2014).

"Water banks are generally less widespread than water trading..."

South Africa has more extensive water markets that continue to be plagued by conflict and inadequate institutional support (Grafton *et al.,* 2010). South Africa's Water Act of 1998 has provided a framework for water trading. Historically, agricultural irrigators traded water rights within their sector, mediated by the national Department of Water Affairs and Forestry (Farolfi and Perret, 2002). In 2001, mining companies seeking to expand operations in northern South Africa successfully negotiated a temporary trade of some 10,000 acre-feet of water (13 million m^3) from neighboring farmers – representing more than 70 percent of their annual allocation – in exchange for the current equivalent of about $1 million. These funds, used to help rehabilitate the local irrigation infrastructure, represented less than 0.1 percent of the mines' development costs, reflecting a significant economic disparity between the two interests (Farolfi and Perret, 2002).

In Asia, India and Pakistan have informal water trading, in which well-owners may sell some of the water they extract to neighboring farms or residents (Easter *et al.*, 1999). In a report published by the Nepal Water Conservation Foundation and the Institute for Social

12 With the exception of "water conservancy districts", to the best of our knowledge there is no strict naming convention for water agencies. The ability to create conservancy districts is established by statute, enabling state district courts or other authorities to establish conservancy districts with the power to impose property taxes to support district functions (Howe, 2011). Water authorities tend to serve municipal areas, and irrigation districts primarily serve agricultural users. However, the San Diego County Water Authority has agricultural customers (fewer than before, as they have phased out subsidies for irrigation water), while the Imperial Irrigation District sells water to all of the cities within its service area, serving more than 170,000 people. Similarly, water conservancy districts usually serve agriculture, although some districts may also serve municipal customers.

and Environmental Transition, Moench *et al*. (2003) described an active but largely unregulated water trading system in Chennai, India, where private companies meet as much as 35 percent of urban water demand by delivering raw or purified well water purchased from farmers in surrounding areas or extracted from the companies' wells. This private sector engagement helps meet a demand for water that the intermittent municipal water supply cannot meet, though the price is much higher. Moench *et al*. (2003) reported that the price of water for urban customers can be 1,000 times higher than the price paid to the peri-urban farmers supplying the water. Also in Asia, in a rare international water trade, the Bishkek Treaty of 1998 committed Kyrgyzstan to deliver water via the Syr Darya to Uzbekistan and Kazakhstan in exchange for compensation (Ambec *et al.,* 2013). China reportedly has small, local water markets (Grafton *et al.,* 2010). In Oman, the local *falaj* irrigation systems purchase short-term allocations of water based on units of time rather than volume (e.g. a certain duration of water delivery) in a village-based auction (Al-Marshudi, 2007).

Water banks are generally less widespread than water trading because they require additional expertise, funding, and governance structures. Water banks appear to be most prevalent in the western United States, although there are examples in several other countries. The presence of three reservoirs in Chile's Limarí Basin facilitates the large number of water trades in the region (Bauer, 1997), meaning that, in this case, the physical storage rather than an institutional bank facilitates the water trades. In Australia, brokerage-type water banks are active in both the Murray-Darling Basin and in northern Victoria, where the banks post information about pricing and availability (O'Donnell and Colby, 2010). Mexico's National Water Commission reported that the 13 state-based water banks in the country broker thousands of water trades annually (CONAGUA, 2012). In three basins in Spain, water banks operated by local water agencies, known as "exchange centers", have successfully brokered water trades that have lessened groundwater overdraft (Garrido and Llamas, 2009).

In 2003, nine states in the western United States had functioning state-operated water banks, although their level of activity varied dramatically and several are no longer active. From 1995–2003, for example, Texas' water bank only reported one transaction (Clifford, 2012). California's Drought Water Bank functioned for a limited period in the early 1990s, providing a mechanism to facilitate and expedite water trading between agriculture and cities during a multi-year drought, while also ensuring minimum instream flows and providing limited groundwater recharge. The Drought Water Bank purchased, held, and sold water, primarily from northern agricultural users to southern municipal and industrial users, though about half of the more than 800,000 acre-feet purchased in 1991 was dedicated to instream flows (20 percent) and to recharge aquifers (32 percent) (Dinar *et al*., 1997). Idaho operates water banks to manage storage in reservoirs, and in Oregon, river conservancies operate as water trusts to purchase or lease water rights to supplement instream flows (Clifford, 2012). The Northern Colorado Water Conservancy District maintains a webpage that functions as an online bulletin board connecting those seeking to acquire water with those who have water to rent, an example of a brokerage-type water bank. The very active water trading within the Conservancy District is attributable to the equal volume and priority of each share available for trade, the absence of any requirement to preserve return flows or protect downstream or junior priority users, and the fact that trading only requires the approval of the district itself, not a water court, as is the case for most other trades within Colorado (Howe and Goemans, 2003).

The Colorado River basin, shown in Figure 3, boasts a large number of creative approaches to water banking. In 1998, the federal government adopted a new rule permitting interstate banking agreements within the basin. To date, Arizona has diverted and stored more than 600,000 acre-feet of Colorado River water for southern Nevada, and a southern California water agency has diverted and stored more than 161,000 acre-feet for southern Nevada, representing creative methods of skirting state prohibitions of interstate water trading. In 2007, the seven basin states adopted a new set of rules for managing the river that, among other key developments, permitted entitlement holders in Arizona, California, and Nevada to invest in various water efficiency projects within their own states and store a percentage of the conserved water in Lake Mead for later use. To date, more than 1.1 million acre-feet have been stored in Lake Mead under this new program. More recently, four large municipal water agencies in the basin, in cooperation with the federal Bureau of Reclamation, agreed to invest $11 million in fallowing and efficiency improvements, and to dedicate the conserved water to the Colorado River Basin system as a whole, rather than claiming it for themselves. In this instance, the Bureau of Reclamation acts as a water bank by obtaining water through a reverse auction process, augmenting system storage for the benefit of the system as a whole.

Environmental, economic, and social performance

The primary goal of water trading is usually to promote economic efficiency by reallocating water from lower to higher value uses. However, in some cases,

FIGURE 3. The Colorado River Basin

Source: Cohen *et al.*, 2013.

water trading has been used for environmental or recreational purposes, reflecting the increasing societal value ascribed to instream flows. In this section, we evaluate the environmental, social, and economic performance of water trading. While much of the literature on water trading tends toward theoretical assessments or recommendations about trading (Newlin *et al.*, 2002) or specific elements of trading, such as property rights regimes or institutional capacity (Culp *et al.*, 2014), we examine the literature on actual impacts to evaluate the state of practice.

"...the number of detailed economic assessments of existing water trades is surprisingly limited."

ECONOMIC PERFORMANCE

Although there are a large number of articles and studies modeling the potential economic benefits of water trading, the number of detailed economic assessments of existing water trades is surprisingly limited. Some studies on local impacts suggest positive net economic performance, but these studies typically do not describe changes in the distribution of impacts, and they rarely describe broader economic impacts. Assessing the economic performance of water trading is frequently as simple as documenting trading activity and quantifying the number, volume, and value of reported water trades. A more comprehensive analysis would require surveys to estimate the number and volume of additional water trades that users would like to make, as a means to assess the disparity between availability and demand. An even more robust analysis would compare the ability of different instruments – such as water trading, demand-side management, and supply augmentation – to meet specific water demands, and the cost of those instruments. While water agencies seeking to improve their water supply reliability may perform such analyses within their service area, these assessments are often not publicly available.

The large number of trades and the significant volumes traded, especially in Australia, indicate that water trading can be an effective means of reallocating water, where the appropriate conditions exist. The application section of 3.1 of this report describes the range of countries where water trading occurs in general terms. In most of these regions, limited data precludes detailed assessment of the number or volume of water trading activities. In several locations, such as the Murray-Darling Basin and the Northern Colorado Water Conservancy District, water trades occur frequently, often for small volumes, suggesting a robust and active market with low transaction costs (Howe and Goemans, 2003). In other areas, there tend to be fewer but larger transactions, suggesting higher barriers to trading.

The largest agriculture-to-urban water trade in the United States has been successful for San Diego County, which currently receives about 25 percent of its water supply from the rural Imperial Valley,[13] at a unit cost of water that is less than half the contracted price of water from a desalination plant that will soon be operational on the San Diego coastline. The long-term water trade appears to be cost effective from San Diego's perspective but, due to significant externalities, may not be from the broader society's perspective. Total transaction costs for this water trade have exceeded $175 million in attorney fees, plus an additional $171 million in mitigation fees to offset public health and environmental impacts. In addition, the State of California agreed to cover all direct mitigation costs in excess of a pre-determined financial cap for the water trade parties. The magnitude of these additional mitigation costs – primarily for managing dust emissions – will not be known for many years but are expected to run into the hundreds of millions of dollars (Cohen, 2014). As suggested by the Imperial Valley-San Diego example, a narrow focus on direct economic performance may ignore trading's broader economic impacts.

Although there are thousands of peer-reviewed articles on the economic potential of water trading, robust economic analyses of specific water trades do

[13] Roughly 15 percent of San Diego County's current water supply comes from the water trade with the Imperial Valley, while an additional 10 percent comes from water conserved via the lining of the All-American Canal, a project funded primarily by the state of California.

not appear to exist. For example, despite its size and importance, there do not appear to be any economic analyses of the Imperial Valley-San Diego County water trade that assess revenues, agricultural production lost due to fallowing, value of transfer payments, relative value of the water in San Diego, or employment impacts. There are, however, general regional or district-level assessments of water trading, as well as an extensive body of literature on macro-economic trends, and expected or modeled benefits of water trading. Yet, assessments of "net" economic benefit at the state or regional level, expressed in terms of net increase in employment or revenue, can mask disparities between areas of origin and importing areas, and even within the areas of origin themselves.

"In Australia, water trading has enabled the expansion of the wine industry and other high value crops, such as almonds."

In one study, the income and employment gains found in regions in California that imported water via trades exceeded the net losses (total compensation often failed to cover foregone crop revenue) in exporting areas (Howitt, 1998). In 1991, trading activity generated an average net income loss in water-exporting areas equivalent to about 5 percent of net agricultural activity, though this varied within different parts of the state. However, agricultural areas importing water saw total gains greater than the losses in exporting areas: net agricultural water trading activity was positive, as water moved from lower-value crops to higher-value crops (Howitt, 1998). In another example, an agricultural community in California exporting water to urban areas saw a 26 percent decrease in the number of farms overall, but this masked a 70 percent loss in the number of small farms and the loss of almost half of the number of produce firms in the area (Meinzen-Dick and Pradhan, 2005).

The Northern Colorado Water Conservancy District, introduced in Section 3.1, has a very active water market in part because of low transaction costs. Much of the trading activity in the district is short term and low volume, especially in comparison with trading activity in the same water basin but outside of the district. Municipal and industrial (M&I) users buy district water rights to meet expected future demand and then lease some of this water back to district irrigators. This rising M&I demand has increased the price of imported water rights (known as allotments) within the district (Howe, 2011). Within the relatively prosperous district, this has improved economic performance. However, in other regions, particularly in economically depressed rural areas, selling water out of the area has exacerbated economic decline, causing property values to fall and the local tax base to shrink (Howe, 2011).

In Australia, water trading has enabled the expansion of the wine industry and other high value crops, such as almonds. Over time, the dairy industry in one part of the Murray-Darling Basin transitioned from a small purchaser of water entitlements to a net seller of entitlements, primarily to the expanding wine and nut producers in other parts of the basin. These expanding industries have also exhibited a shift from the former model of shared irrigation infrastructure (such as common canals) to direct extraction from the river by individual irrigators – in other words, from a communal to a more flexible individual approach to irrigation (Frontier Economics and Australia NWC, 2007).

Water trading within the Murray-Darling Basin grew and matured within the context of the devastating drought that afflicted the region from 2006 through 2010. The national water trading assessment noted the challenge of disentangling the economic impacts of the drought from those of water trading itself, generally concluding that trading offered irrigators an additional revenue stream, plus additional flexibility and resilience within the face of a severely limited water supply. Without water trading, some sectors, such as the dairy industry, would have seen even greater losses. Trading also offered a mechanism to adjust for historic water apportionments, facilitating the voluntary sale of water from less productive to more productive lands and uses (Frontier Economics and Australia NWC, 2007).

The active participation of the Australian government in water trading increased prices and participation but may also have increased total water use within the basin. A large survey (n=520) of those selling entitlements or allocations to the Australian environmental water program found that sellers believed they received a higher price from the government than they would have from other private agents, or that the government was the only purchaser in the market. The survey also found that sellers reportedly used 69 to 77 percent of their water allocations prior to trading it to the government (Wheeler and Cheesman, 2013). That is, survey respondents reported selling portions of their allocations that they would not have used otherwise. Selling unused water allocations is not a reallocation so much as an expansion of total water use.

"Water trading can also generate large environmental externalities, adversely affecting either natural habitats or downstream users, or both"

Water trading occurs in a variety of forms. Howe (2011) noted that, in practice, many water trades reflect a change in type of use rather than a change in location. For example, in the Northern Colorado Water Conservancy District, developers have purchased farmland and its water rights and then converted the land and water to residential or commercial use, often generating a significant increase in revenue per unit of water while limiting some of the social and environmental externalities that would occur if the water were physically moved to a different location.

ENVIRONMENTAL PERFORMANCE

Water trading has been used as a mechanism to obtain water for ecological purposes, to augment streamflows, and to address water quality concerns (such as temperature) in threatened reaches. The environmental performance of water trading is highly variable, depending on the type of trade and site-specific conditions. The benefits of voluntary, incentive-based water acquisition include ease of transaction and greater community support, especially relative to regulatory takings. However, water trading can also generate large environmental externalities, adversely affecting either natural habitats or downstream users, or both (NRC, 1992). For example, when water for trading is generated by efficiency or by fallowing land, the trade may reduce the amount of runoff supporting local habitat and may diminish instream flows.[14] On the other hand, some water trades may improve local instream flows by decreasing diversions and contaminant loadings. Where water is traded to downstream users using the existing stream as a conveyance, trading could offer measurable environmental benefits. Where water is traded out of the basin or alters the timing and magnitude of flows, adverse impacts are likely to occur. Unfortunately, there do not appear to be published assessments of the relative impacts of water trading on streamflow.[15] In the following, we discuss the environmental performance of several examples of water trading.

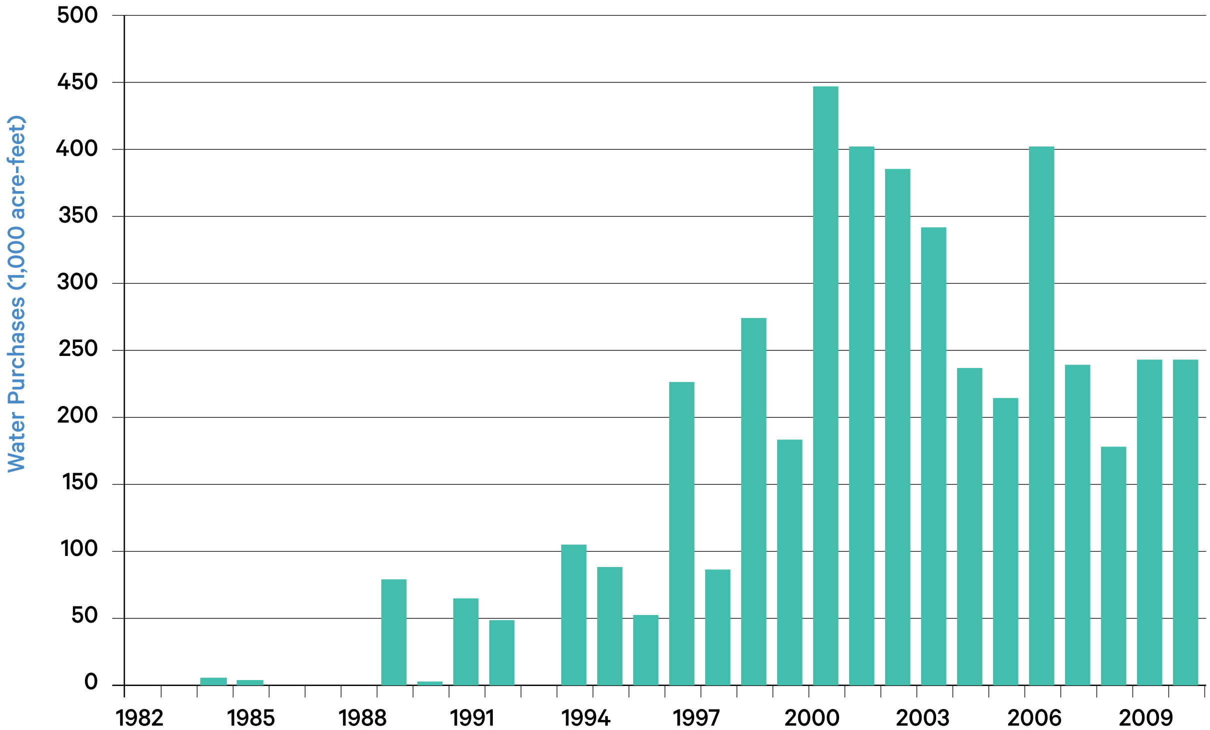
Water trading is now used in some areas to return water to river channels, in order to support listed species or threatened habitats, and for general ecosystem restoration (Tarlock, 2014). However in most areas, such activity still represents only a tiny fraction of total water use in any given area.[16] For example, the Colorado Water Trust (CWT) brokered a lease agreement between two state

[14] In efficiency-based agricultural water trades, the buyer typically pays the irrigator to install more efficient irrigation equipment or methods, such as hiring additional irrigation management staff, installing pump-back systems, lining canals, or constructing new regulatory reservoirs. The water conserved by these new practices would then be available for transfer to the buyer/investor. Efficiency-based trades keep agricultural land in production and can increase total employment in the area of origin, but they require additional monitoring and measurement to document or calculate the volume of water conserved. In fallowing-based trades, also known as "buy-and-dry", the buyer simply pays the irrigator not to irrigate and, in exchange, receives the volume of water historically used by the parcel. This requires less effort and less time to implement, but takes land out of production and typically generates significant adverse impacts on rural communities.

[15] For example, the various water trading agreements between Imperial Valley and urban Southern California will have the direct effect of reducing the volume of water flowing down the lower Colorado River between Parker Dam – the new diversion point – and Imperial Dam, about 150 river miles downstream, by more than 300,000 acre-feet per year, equivalent to roughly 5 percent of the historic average annual flow between these two diversion points.

[16] Such instream flows typically require additional legal conditions, such as explicit recognition of instream flow rights, improved monitoring and measurement, and the acceptance of local entitlement holders.

FIGURE 4. Water purchases for the environment in California, 1982–2011



Source: Hanak and Stryjewski, 2012.

agencies, increasing low-season flows in the White River by 3,000 acre-feet of water three times over a 10-year period to lower the temperature of river flows and, in turn, benefit fish (CWT, 2015). Similarly, the Columbia Basin Water Transactions Program, active for more than a decade, works with partner organizations in four western states to acquire and dedicate water for instream flows within the basin. In 2013, 45 transactions led to the acquisition of more than 48,000 acre-feet of water, costing about $13.9 million and benefiting some 276 miles of streams, the fish and wildlife, and the communities that depend on them (National Fish and Wildlife Foundation, 2014). Bonneville Power Administration, in cooperation with the Northwest Power and Conservation Council, provides some of the funding for the program due, in part, to concerns about endangered species. In California, environmental water purchases averaged 152,000 acre-feet, accounting for about 14 percent of trading activity between 1982 and 2011, but less than 0.5 percent of total water use in the state (Figure 4).

In Australia, the federal government has invested more than $3 billion to date to purchase entitlements and allocations for environmental water, protecting ecological resources to enable and expedite water trading between non-governmental users. In 2008–2009, for example, the government purchased nearly 880,000 acre-feet of long-term water entitlements and 1.4 million acre-feet of short-term allocations, at a total cost of about $2 billion (adjusted to 2014$). The price for this water ranged from about $269 to $377 per acre-foot. Local interest in this environmental water buyback program, known as "Restoring the Balance", has been strong, with the Australian government receiving nearly 7,600 applications to sell water from 2007 to early 2012. Water entitlement sales for the environment account for roughly 25 percent of total entitlement trading activity (Wheeler and Cheesman, 2013). However, some irrigators and state governments in Australia oppose the instream buyback program, and it was cut dramatically when the Labor Party fell from power in September 2013 (Bennett and Carroll, 2014).

However, water trades not explicitly intended for environmental purposes can create a host of adverse environmental impacts. They can, for example, change the timing, quantity, and quality of return flows, adversely affecting riparian and wetland habitats and the species that depend upon them. Some trades, such as from California's Owens Valley to Los Angeles, adversely affect public health by increasing the amount of dust emissions from exposed lakebed and fallowed land, generating significant externalities (LA DWP, 2013). Groundwater substitution, in which a user trades surface water and increases groundwater extraction, can lead to over-extraction, and sinking or caving in of land surfaces (subsidence), depleting springs and seeps, and robbing future generations (Brown *et al*., 2015).

Water trading can also diminish groundwater recharge rates, whether the water is generated via fallowing or increased efficiency. In the southern Indian state of Tamil Nadu, farmers irrigating with groundwater have increased extraction rates and sold the excess to water tanker trucks serving urban populations, an example of informal water trading. Yet this increased groundwater extraction lowered the water table, increasing pumping costs for other irrigators or drying up their wells entirely (Meinzen-Dick and Pradhan, 2005).

Efforts to mitigate the environmental impacts of water trading have had mixed success. In Spain, a proposal to add a small environmental mitigation fee to each unit of water traded was insufficient to overcome the strong opposition of environmental and social organizations (Albiac *et al.*, 2006). In California, state commitments to mitigate the environmental and public health impacts of the nation's largest agriculture-to-urban water trade have yet to result in any actual mitigation efforts, potentially jeopardizing several listed species and likely resulting in the loss of open water and wetland habitats that support several hundred species of birds (Cohen and Hyun, 2006).

Yet water trading occurs in regions of water scarcity, where water resources in particular have already undergone dramatic transformation. Dams, canals, and diversions have already altered the timing and magnitude of stream flows throughout many of the regions now turning to water trading (Worster, 1985). Determining the additional impacts of water trading upon this existing landscape would be difficult. An alternative basis for comparison could be the marginal or cumulative environmental impacts of water trading relative to the new impacts of additional water development. That is, water trading may prove to be less environmentally harmful than the construction of new dams and diversion projects, or even the construction of new desalination plants.

"...water trades not explicitly intended for environmental purposes can create... adverse environmental impacts."

SOCIAL PERFORMANCE

Water trading is usually characterized as a market-based mechanism that reduces economic inefficiencies by reallocating water from lower to higher value uses. Trading has been used to meet explicit environmental objectives, but, as described previously, it is rarely employed to address equity challenges. Indeed, water trading can exacerbate social and economic inequalities, worsening gender and geographic differences.

In regions with informal water rights and trading that are functional at the community level, such as rural Nepal, demands from outlying urban areas for larger scale trades can overwhelm local water management institutions. Trades from these rural areas might not reflect the true value of the many informal uses water has in the community (such as subsistence fishing or milling) or the full range of informal ownership and use rights within the community, meaning residents may be deprived of full compensation (Pant *el al.*, 2008). Even within the community, the complex web of informal water-use arrangements can complicate informal trading agreements and, in turn, generate a range of economic impacts on those using the water who had not been consulted or participated in the trading arrangements (Pant *et al.*, 2008).

Limarí Basin, Chile. Unequal access to water markets due to unequal access to information or credit can distort outcomes and reduce market efficiency. Chile's Limarí Basin has very high water trading activity, suggesting successful economic performance, but Romano and Leporati (2002) argued that it suffers from several market distortions arising from disparities between the resources available to those trading water. Peasants fare poorly in trading activity because their water rights often are not fully recognized, they are not as well-organized as those purchasing the water, and they lack access to information on pricing (Romano and Leporati, 2002). Dinar *et al.* (1997) noted that economic performance is affected by disparities in the value of water in different sectors and by the ability of those with limited means to participate in water trading.

Southern California. Water generated for trades by fallowing land can benefit water rights holders at the expense of farmworkers and equipment suppliers, potentially devastating rural communities. California's Owens Valley provides one of the early examples of the adverse impacts of trading water away from rural areas. In the early 1900s, agents secretly representing the City of Los Angeles (LA) covertly purchased land in the Owens Valley. In 1908, LA began a 5-year construction project of a 419-mile pipeline to divert water from Owens Valley farmland to LA. Although Owens Valley irrigators had willingly sold their water through market transactions, they had not contemplated the plight of the valley as a whole. Over the next several years, agitators from the valley dynamited the pipeline several times in a vain attempt to protect their water supplies (Hundley, 2001). In addition to the direct economic and social impacts on the Owens Valley, the water trade had desiccated Owens Lake by 1926, just 13 years after water first began flowing to LA, creating the single largest source of dust pollution in the United States. In the past decade, after years of litigation, LA has spent more than $1.4 billion on dust management efforts and has returned some of the water to Owens Lake.[17]

San Luis Valley, Colorado. As demonstrated by efforts to destroy the infrastructure moving water out of the Owens Valley, local opposition to trading water can be strong. In the late 1980s, the Canadian owner of the 97,000-acre Baca Ranch in southern Colorado's San Luis Valley began buying water rights from other farms in San Luis Valley, allegedly to irrigate new crops. Local residents, who soon discovered that the true purpose of the purchases was to sell the water to Denver suburbs, 100 miles to the northeast, feared that their valley would experience the devastation felt in Owens Valley. Thus, they formed Citizens for San Luis Valley Water to fight the water trade, working with the local irrigation district to support a special ballot measure to raise local taxes to fund litigation against the proposed water sale. The ballot measure prevailed with 92 percent of the vote. In 1991, the locals prevailed in court, stopping the proposed water trade. After Baca Ranch was subsequently sold, the new owner also attempted to sell the water out of the valley, sponsoring two statewide initiatives seen as efforts to support the water trade. In 1998, both initiatives failed, receiving less than 5 percent of the vote. With continued public pressure, the federal government purchased Baca Ranch in 2004 – more than a quarter century after the fight began – to prevent water from leaving the San Luis Valley. It then parceled the land to the newly designated Great Sand Dunes National Park, part to a nearby national forest, and 54,000 acres to the new Baca National Wildlife Refuge (Reimers, 2013).

Imperial Valley, California. On the other hand, water trading that promotes efficiency rather than fallowing of agricultural land can improve socio-economic outcomes for both the area of origin and the destination. For example, an ongoing water trade from the Imperial

[17] For information on the dust emissions at Owens Lake and the current dust management program, see the Great Basin Unified Air Pollution Control District website.

Valley that began in 1989 relies on efficiency-based measures rather than fallowing to generate water for trade, creating additional employment while keeping land in production.[18]

Water trading's social impacts vary based on several factors, including the relative economic health of the area of origin and the purchasing area, whether or not the water leaves the area of origin, the process used to trade the water, and the relative economic and political power of the parties (Meinzen-Dick and Pradhan, 2005), gender differences regarding access to and control of water (Zwarteveen, 1997), the amount of trading activity in the area (Howe, 2011), and the legitimacy of the water rights being traded (Meinzen-Dick and Pradhan, 2005). Impacts often vary within the same community, as those with water rights or allocations to trade receive compensation, while third parties – such as irrigation equipment suppliers or farmworkers – may suffer a loss of revenue or income as a result of trading (Meinzen-Dick and Pradhan, 2005).

Water trades within the same region typically have minimal or no adverse social or equity impacts. Howe (2011) noted the large number of small-volume, short-term water trades within an irrigation district as an example of positive economic and equity outcomes. Inter-sectoral trades, such as from agricultural to manufacturing or mining within the same region, may also generate positive economic and equity outcomes, as jobs shift from lower income farm employment to higher income industrial employment (Meinzen-Dick and Pradhan, 2005). However, Zwarteveen (1997) noted that even such intra-regional trades can generate differential impacts based on gender, requiring additional agricultural and domestic labor for women within households where men have left for new industrial jobs enabled by new water supplies. In places where rural agriculture, particularly at the household level, provides subsistence and food security, reduced access to water can impose significant adverse impacts (Farolfi and Perret, 2002).

Rural household access to water for domestic uses and for subsistence agriculture may have only informal community-level recognition that does not translate into tradable water rights. Water trading that does not recognize these informal or ad hoc water uses can adversely affect equity outcomes and prompt questions of legitimacy (Meinzen-Dick and Pradhan, 2005). Formal, state-recognized water rights typically require the means and ability to register and defend them, in turn conferring power on those with formal water rights. In South Asia and other parts of the developing world, informal water-use arrangements that permit and enable water use and trading can be disrupted by formal rights-based trades and command-and-control reallocations (Meinzen-Dick and Pradhan, 2005).

Zwarteveen (1997) noted that, as men in Ecuador, Nepal, and Peru have migrated in search of employment, women have assumed a disproportionately large number of agricultural roles, even as formal and informal water rights continue to be held by the absent men. These geographic and gender disparities can generate adverse outcomes as water is traded by absentee owners. Conversely, trading within households – even in the form of recognition of joint ownership – can encourage investment in water resource maintenance and productivity at the local level (Zwarteveen, 1997). Similarly, water organizations in the developing world, where decisions may be made about trading water out of the community, tend to have limited female participation, potentially neglecting compensation for impacts that would have been identified if there were stronger female roles and participation (Zwarteveen, 1997).

Water trading mechanisms can privilege certain populations and marginalize others, especially when cultural practices differ. For example, New Mexico's cooperative irrigation systems, known as *acequias*, usually enjoy

[18] The Imperial Irrigation District's *IID/MWD Water Conservation Program Final Construction Report* (2000) documented that 24 separate system water conservation projects and programs (as opposed to on-farm), such as lining irrigation canals and installing new headgates, had been implemented through 1999. The capital cost for these totaled $193 million (2014$), with an additional $8.3 million in annual operations and maintenance costs. These improvements yield 108,500 acre-feet of conserved water per year, at a cost of $254 per acre-foot. In addition to the jobs associated with the initial construction effort, the on-going water trade supports about 12–13 full-time positions for managing water deliveries, and for annual operations and maintenance.

very senior water rights. However, they have fared poorly when defending their rights or seeking compensation for third-party impacts in state proceedings, where language and cultural practices favor fluency in English and legal literacy (Meinzen-Dick and Pradhan, 2005). Romano and Leporati (2002) found similar circumstances in Chile, where less-educated rural peasants fared poorly in trading water rights to more powerful non-agricultural interests.

"Water trading mechanisms can privilege certain populations and marginalize others..."

Economic disparities also affect water-trading outcomes. As with the *acequias*, wealthy, powerful interests enjoy disproportionate advantages relative to many historic water rights holders. In South Africa in the late 1990s, mining interests sought to increase their production and activity in rural, water-scarce regions by purchasing water rights from small irrigators, at prices ten times higher than other irrigators were willing to offer. Although the mines offered employment and generated greater returns per unit of water, they threatened to dewater local subsistence farms and adversely affect a broad swath of rural economies beyond the irrigators voluntarily selling their water (Farolfi and Perret, 2002). A study of water trading in Chile's Limarí Valley found a similar impact, where increasing rural poverty was traced to water rights sales from peasants to non-agricultural interests and the general worsening of water-rights distribution (Romano and Leporati, 2002).

As noted in the examples of the Owens and San Luis Valleys, those in areas of origin can strongly, sometimes violently, oppose the sale of water to outside interests. A national study of water trading in Australia found that this opposition can extend to local interests that trade their water rights to external interests (Frontier Economics and Australia NWC, 2007). In addition to cultural and social bases for opposing such trades, trading can increase costs for those who do not sell, such as operations and maintenance costs associated with water storage and delivery structures. The economic and equity impacts of water traded from rural areas can accumulate with additional trading activity, reaching a tipping point where local demand for agricultural services falls below the level necessary to maintain operations, creating a cascading set of business failures and depressing the local tax base (Howe, 2011). Agricultural areas importing traded water may also suffer from third-party impacts, in the form of increased competition, extended wait-times for water deliveries via shared infrastructure, and rising water tables that may threaten plant roots or require additional drainage (Frontier Economics and Australia NWC, 2007).

The one key exception to water trading that exacerbates social and economic inequalities is in South Africa. Section 27(1) of South Africa's 1998 National Water Act states:

> "In issuing a general authorisation or licence a responsible authority must take into account all relevant factors, including...
> (b) the need to redress the results of past racial and gender discrimination;...
> (d) the socio-economic impact –
> (i) of the water use or uses if authorised; or
> (ii) of the failure to authorise the water use or uses."

While this act explicitly sought to use water trading to improve socio-economic conditions,[19] South Africa's Department of Water Affairs and Forestry (now known as the Department of Water and Sanitation) refused to permit more than 118 applications for water trades from 2005 through 2008, claiming that the trades failed to meet the Section 27(1) standards (Coleman, 2008). South Africa's Supreme Court found in 2012 that: i) one proposed trade would create new employment opportunities for both men and women in a region with high unemployment, meeting the standard established by

[19] The National Water Act is available at http://www.acts.co.za/national-water-act-1998/.

Section 27, and ii) the Department had acted improperly in failing to grant the requested license to trade the water.[20] According to a local source, however, the responsible authorities in South Africa continue to delay and deny licenses for water trades, meaning that South Africa's water market has been restricted for a decade (Backeberg, personal communication, 2015).

Necessary, enabling, and limiting conditions

Institutional arrangements determine the ultimate success or failure of water trading (Livingston, 1998). Successful water trading requires secure and flexible water rights that recognize and protect users and others from externalities. Such institutional arrangements also need to be flexible enough to adapt to changing physical conditions as well as changing social norms, such as the growing interest in meeting environmental needs and protecting water quality (Livingston, 1998). Recognizing and understanding these factors can help explain the varying successes and even the existence of water trading in different countries and regions within countries. Some factors, such as legal and transferable rights to use water, may be *necessary* for water trading to occur. Others, such as access to timely information about water available to trade, can *enable* water trading but may not be required for trading to occur. Still other factors, such as "no injury" regulations and "area of origin" protections, *limit* water trading or function as barriers or obstacles to trading. The following explains the details of the necessary, enabling and limiting conditions.

Necessary conditions include:

- legal, transferable rights to use water
- decoupling of water rights from land rights
- contract adjudication and enforcement
- means for buyers and sellers to communicate
- physical infrastructure to move water
- mechanisms to monitor and measure water flows and use.

[20] *Makhanya v Goede Wellington Boerdery (Pty) Ltd* (230/12) [2012] ZASCA 205 (30 November 2012).

Grafton *et al.* (2010) wrote that "Legal clarity over water rights, including what they can be used for and the rules of water trade, is a cornerstone of functioning water markets." Diversion or, better yet, consumptive use water rights with clear title and quantified allocations that can be leased or sold can be described as marketable property rights, a necessary condition for water trading (Grafton *et al.,* 2012). Culp *et al.* (2014) noted that water trading requires legally enforceable contracts that clearly and completely define the water right to be traded, an exclusive right to the water, and the recognized right to trade the water. Government plays a clear role in establishing these necessary conditions, documenting and, in some cases, allocating water rights themselves, establishing and maintaining the legal framework in which trading occurs and, in many cases, financing the physical infrastructure to store and convey water and allow water trading to occur (Dinar *et al.*, 1997). Strong and effective institutions that adjudicate and resolve disputes, enforce contracts, and monitor trading agreements are a necessary element in successful water markets (Zwarteveen, 1997).

Typically, infrastructure is also required to physically convey water from a seller to a buyer, or to store or otherwise manage water availability so that an agreed-upon volume can be conveyed to the buyer at the appropriate time. In some cases, creative agreements have enabled trades from unconnected or remote sources of water, creating what are known as "in-lieu" or "paper" trades.[21] While these trades can avoid requirements for connecting physical infrastructure, they do require sophisticated legal arrangements, management, and monitoring to ensure that the correct volumes of water move at the approved time.

[21] One example of an in-lieu water trade is the agreement between the Metropolitan Water District of Southern California and the Coachella Valley Water District and the Desert Water Agency. All three have contracts with California's State Water Project (SWP), but because a direct connection from SWP's California Aqueduct to Coachella Valley would have cost the equivalent of more than $1.8 billion, the latter two agencies agreed to an in-lieu exchange agreement with Metropolitan for a "bucket-for-bucket" exchange of SWP water for Colorado River water. That is, Metropolitan takes the other agencies' allotment of SWP water, in exchange for giving up an equivalent amount of Colorado River water. Source: cvwd.org/news/news178.php.

Water trading can and does occur when necessary conditions are satisfied, but markets are much more robust and active when additional enabling conditions are met.

Enabling conditions include:

- water rights equivalency (as opposed to prioritized rights)
- water banks and contracts
- clear, available information
- social cohesion
- competitive markets with multiple participants of roughly equivalent economic power.

One of the major factors contributing to Australia's successful adoption of water trading in the Murray-Darling Basin was the absence of prioritized water rights. This enabled water trading without concern for impacts on those holding less senior water rights (see Annex 1 for greater detail). By contrast, in the western United States and other regions with prioritized water rights (also known as prior appropriation or seniority), an entitlement holder with a senior water right (determined by the date the right was first exercised or "perfected") could only sell or lease water after ensuring that more junior rights holders receive compensation or do not otherwise protest the transaction. This distinction helps explain the frequency of trades within irrigation districts where district members share a common priority right – such as the Northern Colorado Water Conservancy District – and the much lower number of transactions between those with different priorities. That is, common priority rights or water rights with equivalent seniority can be traded more readily than rights with different priority dates.

Dinar and Saleth (2005) proposed a scale from zero to seven to describe a range of surface water rights conditions that could be used to evaluate the enabling conditions for water trading. It spans from a rating of zero for no water rights, to a rating of five for appropriative rights; six for proportional sharing systems (such as the Northern Colorado Water Conservancy District and Australia); and seven for water licenses and permits. Under this system, we could categorize no rights as precluding trading while the higher end of the scale can be seen as enabling trading.

Water banks can enable water trading by connecting buyers and sellers, posting information on availability and transaction history and, in some cases, by physically storing water to match availability and demands. The existence of technically skilled staff and monitoring equipment increases the efficacy of water banks and can help resolve disputes. Where water banks do not exist or have limited capacity, water contracting can enable spot trading (Brown *et al.*, 2015).

"Social cohesion can also enable water trading. Trading is more likely to occur where informal bonds exist..."

The availability of pertinent information can be considered both a necessary and an enabling condition, depending on the extent and type of information available. The availability of information on quantity, quality, location, and timing of water entitlements or allocations can enable trading by pairing sellers and buyers. Similarly, clear information about transaction costs enables trading. Additionally, greater information and certainty about future conditions, such as the security of a water right given climate changes, can also enable water trading (Brown *et al.*, 2015). Clear and timely information about prices also facilitates trading and decreases search costs (Levine *et al.*, 2007).

Social cohesion can also enable water trading. Trading is more likely to occur where informal bonds exist, such as between neighbors or within an irrigation district or even between irrigators, relative to trading between parties with no common history. In some cases, irrigators will accept a lower bid from another irrigator than a higher bid from a municipal agency, particularly one from outside the basin or region. Water rights holders may fear that indicating they have water to trade could be interpreted to mean that they do not need the water, jeopardizing the right or imposing political costs (Albiac *et al.*, 2006).

Levine *et al*. (2007) argued that successful water trading requires the participation of multiple buyers and sellers, with roughly equivalent power. They contended that, without these factors, market inefficiencies will result. In Australia's Murray-Darling Basin and within several United States irrigation districts, the satisfaction of these criteria has enabled active and successful water trading. In their absence, as seen in many agricultural-to-urban trades, a small number of economically powerful buyers have distorted markets and created significant externalities.

Limiting conditions, which hinder or reduce water trading, include:

- no injury rule
- anti-speculation doctrine
- beneficial use doctrine
- property rights/pre-conditions
- high transaction costs
- spatial and temporal differences in supply and demand.

In many arid and semi-arid regions, water scarcity and variability dictate that upstream "return flows" – water diverted but not consumed that subsequently returns to the stream – are used and claimed by downstream users. To protect the rights of these downstream users, courts or regulators typically require that the quantity and timing of these return flows be maintained when upstream water is traded. These and similar protections, known as "no injury" rules, place the burden of proof that the trade will not harm or adversely affect other water rights on those wishing to sell or lease water. The "no injury" rule is the prevailing law in most of the western United States, intended to presumptively protect junior water rights holders from harm that may occur due to changes in the volume or timing of return flows from senior appropriators. It dramatically increases transaction costs, requiring sellers to hire attorneys and hydrologists to prove no injury, or otherwise compensate all junior entitlement holders, and was a strong disincentive to water trading (Culp *et al*., 2014).

The anti-speculation doctrine requires buyers to describe the new location and use of the water, conditioning the trade on these terms and increasing transaction costs (Culp *et al*., 2014). The anti-speculation doctrine is intended to prevent hoarding and market distortion by those with the economic means to acquire large volumes of water (Grafton *et al*., 2010). In some areas, this doctrine is waived for municipal water agencies, enabling them to acquire water for unspecified future needs.

The beneficial use doctrine requires that water rights be exercised, encouraging inefficient or unproductive uses as rights holders must "use it or lose it." Some jurisdictions have amended beneficial use requirements to enable rights holders to sell or lease the water they conserve or save by implementing efficiency measures, water they would otherwise simply lose to junior rights holders. Without explicit protection for such conservation measures, the beneficial use doctrine precludes water efficiency and hinders trading. In some areas, laws prohibit users from selling or leasing water "salvaged" from conservation or efficiency measures (Culp *et al*., 2014).

Some kinds of water rights, such as non-consumptive, appurtenant water rights (common in wetter regions of the world) do not lend themselves to water trading.[22] Examples of such non-consumptive rights include rights to use or divert water to run mills or generate hydroelectric power.

Some markets limit participation to existing contractors or entitlement holders (Albiac *et al*., 2006). A related barrier is a limitation on the purpose or use to which a buyer may apply water. For example, several states only allow state agencies, and not private individuals or non-profit organizations, to purchase or lease water for environmental purposes.

[22] An appurtenant water right is directly tied to the land itself, typically to lands adjacent to streams.

High transactions costs, driven by the various doctrines noted above as well as by the need to overcome information constraints and related factors, can hinder water trading. Similarly, the time required to complete a transaction may limit trading, particularly when buyers seek to meet a short-term demand such as an additional irrigation cycle or to offset a delivery disruption within an urban system; relatively fast trades will produce greater trading activity than prolonged approval processes.

"High transactions costs, driven by the various doctrines noted above as well as by the need to overcome information constraints and related factors, can hinder water trading."

Finally, geographic and temporal mismatches between supply and demand can impose additional barriers to water trading, especially in the absence of physical infrastructure to bridge these gaps. Where dams and conveyances do not exist, those wishing to sell water may lack the means to physically deliver the water to a potential buyer, or be unable to deliver the water at the right time (Bauer, 1997).

3.2 Payment for ecosystem services/payment for watershed services

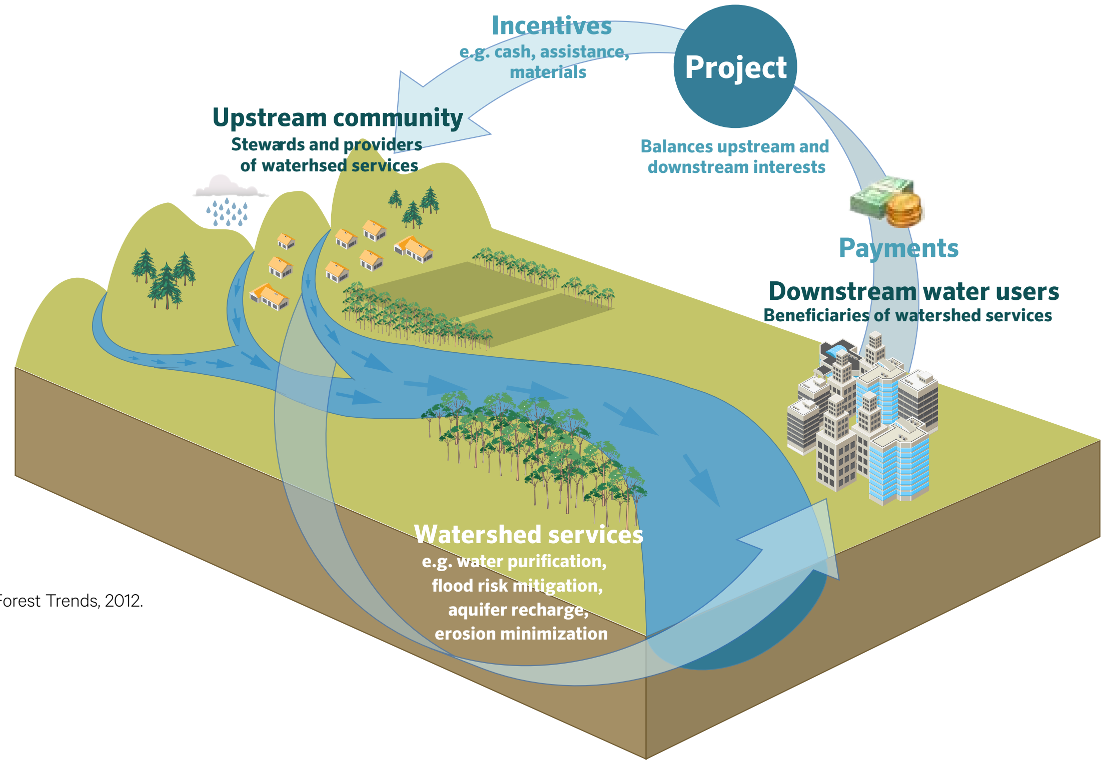
Description

Payment for ecosystem services (PES) is an incentive-based instrument that seeks to monetize the external, non-market values of environmental services, such as removal of pollutants and regulation of precipitation events, into financial incentives for local actors to provide such services. In practical terms, PES involves a series of payments to a land or resource manager in exchange for a guaranteed flow of environmental services (Figure 5). Payments are made to the environmental service provider by the beneficiary of those services, e.g. an individual, a community, a company, or a government. In essence, it is based on a beneficiary-pays principle, as opposed to a polluter-pays principle. Environmental services most often included in PES arrangements include carbon sequestration in biomass or soils; habitat provision for endangered species; protection of landscapes; and various hydrological functions related to the quality, quantity, or timing of freshwater flows from upstream areas to downstream users (Gómez-Baggethun *et al.,* 2010).

PES has no standardized definition. The definition most commonly used in the literature was developed by Wunder (2005) and is based on five criteria: i) a *voluntary* transaction where ii) a *well-defined* environmental service is iii) purchased by at least one environmental service *buyer* from iv) at least one environmental service *provider*, with v) payment *conditional* on the service provided. In reality, few projects actually meet all of these criteria. For example, money may come from donors rather than service providers, or participation in the program may be mandatory. Wunder (2005) argued, and several reviews confirm, that conditionality is the hardest criteria to meet because initiatives are often loosely monitored and payments are made up front or in good faith. Moreover, in some cases, participation is not voluntary (e.g. China), and the beneficiaries are broadly defined and are not directly contributing to the program. Wunder (2005) concluded that while there are a considerable number of PES-like arrangements, there are likely "very few 'true PES' conforming to the theoretical concept developed in the literature."

PES programs focused on watershed services are commonly referred to as payment for watershed services, or PWS. PWS arrangements, as with all PES arrangements, can take a variety of forms. They can be intended to prevent the degradation of a watershed or to restore a previously degraded watershed. They can be small, local schemes covering several hundred hectares or large, national schemes covering millions of

FIGURE 5. Schematic of a PES arrangement for watershed services



Source: Forest Trends, 2012.

hectares. PWS schemes can be financed directly from the beneficiary or from third parties acting on behalf of the beneficiary, e.g. governments or institutions, or some combination thereof. They can involve cash or in-kind payments and be paid all at once or periodically. In a comprehensive review of 50 ongoing PWS programs in developing countries, Porras *et al.* (2008) highlighted the following major trends.

- **Scale.** Most ongoing programs (82 percent) are local, operating at watershed level or smaller. The remaining 18 percent are national programs. Some of the local programs are linked to national programs or international projects.
- **Scope.** Local programs tend to target one or two watershed services (more commonly water *quality* than water *quantity*), while national programs tend to target multiple environmental services as a means of tapping into multiple funding sources.
- **Service providers.** For the vast majority of local and national programs, private landowners are the main watershed service providers, followed by communal landholders, private reserves, national parks and, in a very small number of local schemes, occupiers of public land.

"PWS schemes can be financed directly from the beneficiary or from third parties..."

- **Payment levels.** In national programs, payment levels are mostly determined administratively. In the local programs, negotiation through an intermediary is more common. Direct negotiations between supplier and buyer occur in very few cases. Funds and transfer of payments are in most cases managed by an intermediary, often in a specially set up trust fund.

- **Funding sources.** Funding sources are varied. National programs primarily receive government funding through the allocation of national budgets and donor funding, including loans from the World Bank. Funding for local programs is more varied but is primarily from: domestic and agricultural water fees; donors, including the Global Environment Facility (GEF), World Bank, and German Cooperation; the private sector, including downstream hydroelectric companies (in some cases, in the form of a donation); and local government budgets.
- **Conditionality.** Nearly all programs are unconditional, meaning service providers are paid on a per unit area basis for land-management practices "believed to have a high probability of resulting in provision of the environmental service." Only one payment scheme, Indonesia's Rewarding Upland Poor for Environmental Services (RUPES) initiative, is conditional on outcomes, such as the level of sediment reduction achieved.

Application

PWS arrangements are gaining prominence and have been applied in a wide range of settings. For example, the US Conservation Reserve Program (CRP), established in the 1950s in an effort to reduce erosion on agricultural lands, became more conservation oriented in the mid-1980s, making it among the oldest and longest running PES programs in the world. CRP today pays farmers to take land out of production in order to protect soil and water resources, as well as wildlife habitat (Karousakis and Brooke, 2010). In northeastern France, Vittel-Nestle Waters paid farmers and provided technical support (and some labor) to alter local dairy farming practices in order to reduce nitrate pollution of groundwater – the source of Vittel's bottled water (Perrot-Maitre 2006).

New York City provides another well-known example. In the late 1990s, New York City was faced with the prospect of building a $4–$6 billion filtration plant with an additional $250 million in annual operating costs to meet new federal Safe Drinking Water Act requirements – an approach that was "treating symptoms, not causes" (Appleton, 2010). An initial analysis suggested that preserving the upstream rural Catskill watershed would be far less expensive. However, New York City had a long-history of employing eminent domain to solve such issues. When farmers and rural landowners voiced immediate concern, the city and local farmers came together to develop a plan that could meet both groups' interests. A key element of the plan was the Whole Farm Program, a voluntary effort fully funded by New York City's Department of Environmental Protection whereby farmers would work with technical advisors to custom design point and nonpoint source pollution control measures to meet an environmental objective while also improving the viability of their farming business. By 2006, the city had spent or committed $1.4–$1.5 billion in watershed protection projects, averaging $167 million in expenditures per year (Kenny, 2006). Participation remains high, with 96 percent of large farms in the watershed participating in the program (Watershed Agricultural Council, 2011).

PWS arrangements have also been established in developing countries. In Ecuador, for example, the Socio Bosque Program (SBP), a national program established in 2008, provides financial incentives to individual and communal forest landowners to conserve native forest and Andean tundra ecosystems. The program, which includes environmental protection and poverty alleviation objectives, is largely state funded. Since 2012, however, additional support has been provided by the German Development Bank, NGOs, and General Motors Omnibus BB. Program participation is voluntary. Participants are provided a monetary incentive per hectare of land entered into the program, and in exchange, must agree to refrain from logging, changing existing land uses, burning, altering hydrological conditions or reducing carbon storage, and commercial or sport hunting and fishing for 20 years. By mid-2013, 1.1 million hectares had been conserved through 2,100 individual and 150 communal agreements (Raes and Mohebalian, 2013).

While PWS programs can be found in a wide range of settings and, in some cases, have been operating for decades, comprehensive data on their size or scope are not available. Ecosystem Marketplace (2013) estimated that the total transaction value of PWS programs and water funds in 2012 was $8.0 billion. Activity in 2013 was considerably higher, with an estimated $11.5 billion in transaction value for PWS programs in China alone. While these data suggest dramatic growth, Bennett (personal communication, 2015) noted that the difference can largely be explained by better reporting by a larger number of projects. Case studies of PWS programs in developing countries are maintained by the London-based International Institute for Environment and Development and at Watershed Connect, an online platform maintained by Forest Trends (2015a).

Environmental, economic, and social performance

Comprehensive studies on the performance of PWS programs are limited, although some studies have been conducted on various aspects of these programs. Below, we examine the available evidence looking at how PWS has performed environmentally, economically, and socially.

ENVIRONMENTAL PERFORMANCE

The environmental performance of PWS is not well understood due to a lack of scientific analysis. In an analysis of 47 PWS schemes in developing countries, Brouwer *et al.* (2011) found that "less than half of the schemes used quantifiable indicators and monitored the impact of the schemes on environmental performance." In most cases, the indicators were input-based, meaning that they, for example, looked at land area with forest cover, rather the actual impacts and outcomes of the program. In a review of Costa Rica's programs, Pagiola (2008) found it "unfortunately impossible to determine the extent to which the PSA[23] program has successfully generated environmental services. Although the PSA program has established a strong system to monitor land user compliance with payment contracts, the program remains weak in monitoring its effectiveness in generating the desired services."

There are several challenges to evaluating environmental performance:

- many programs lack baseline data or monitoring systems
- the connections between land-use practice and watershed services are not always clear, especially as they relate to water quantity, and are often site specific
- it can be difficult to attribute change to the program rather than to external factors (e.g. changing commodity prices)
- programs may not reach threshold levels for measureable impact, or that impact may occur over a relatively long time period.

As a result of these challenges, reliance on input-based indicators (sometimes referred to as behavioral change) has been borne out of necessity.

Porras (personal communication, 2015) argued that because of these challenges, monitoring should be based on input-based, rather than outcome-based, indicators, as outcome-based indicators shift too much risk to the ecosystem service provider and may raise equity concerns. She further noted the need to set meaningful expectations. For example, conservation projects may be implemented within a landslide-prone watershed to reduce the risk of landslides, with the understanding that, even with a successful program, a landslide would still likely occur, albeit with reduced frequency and intensity over the long term. Thus, an expectation of no landslides is unrealistic and could threaten the viability of the program.

"…PWS programs can be found in a wide range of settings…"

In the absence of data on project outcomes, Porras *et al.* (2008) found that reported impacts are often based on "perceptions of local populations and those operating the schemes and/or quick measurements of what the impacts should be, rather than in-depth scientific evidence drawing from site measurements and modelling of relationships." But even based on these sources, the available data suggest that environmental performance is mixed. In a review of previous studies

[23] *Pagos por servicios ambientales* (payment for environmental services)

and surveys of PWS scheme managers, Brouwer *et al*. (2011) found that "58 percent of the PWS schemes were classified as effective in reaching their environmental objectives, while 42 percent were not." Several factors, ranging from the number of intermediaries and mode of participation to the selection of service providers, level of community participation and type of monitoring, were found to improve environmental outcomes:

- schemes with fewer intermediaries were more effective in meeting environmental objectives
- mandatory participation increased environmental effectiveness compared with voluntary schemes
- selecting service providers based on a set of criteria, e.g. location, accessibility of land, or parcel size, tended to have a negative impact on environmental performance
- contracting with the community was more effective than contracting with a single ecosystem service provider
- programs that monitored progress toward achieving environmental objectives were more likely to reach those objectives.

The study also found that schemes for direct payments by downstream hydropower companies to upstream land owners to reduce sediment loads were generally identified as successful, while other factors – including the type of watershed service, age of the scheme, or scale of implementation – had no significant effect on the outcome. Recognizing this, Brouwer *et al*. (2011) called for international monitoring guidelines to compare programs, identify success factors, and support their future design.

Some have suggested that one way to improve environmental outcomes is through better selection of areas to include within the PWS program, a process that could be facilitated by the application of new technologies (e.g. satellite imagery) and modeling efforts. Porras *et al*. (2013) identified several criteria suggested in the literature for targeting efforts, including focusing on areas at high risk of deforestation, large blocks of land prone to landslides or other natural disasters, and biological corridors. In Costa Rica, for example, applicants for forest protection are prioritized based on the total number of points they receive, with more points awarded for forests in indigenous territories or those protecting water resources. Likewise, applicants for reforestation projects are awarded more points if they use native species or reforest degraded areas with high forestry potential (Porras *et al.,* 2013). The selection criteria can be tailored to reflect the environmental (and even social objectives) of the program and altered as priorities or needs change.

"...studies have suggested that untargeted, uniform payments reduce the cost effectiveness of PES schemes..."

ECONOMIC PERFORMANCE

Payment structures are generally uniform and untargeted, with flat rates per hectare for all sites (Porras *et al*., 2008; Karousakis and Brooke, 2010). Despite the prevalence of uniform, untargeted payments, program costs and benefits are spatially heterogeneous. Wunschler *et al.* (2006) found that ecosystem service provision varies spatially according to the ecosystem benefits, the threat of loss, and the cost of service provision. Several studies have suggested that untargeted, uniform payments reduce the cost effectiveness of PES schemes (Dillaha *et al.,* 2007; Ferraro, 2008), and given likely constraints on program budgets, reduces the project benefits and its long-term success (Karousakis and Brooke, 2010).

Reverse auctions (also referred to as procurement auctions) have been put forth as one option for improving the economic efficiency of PWS schemes (Karousakis and Brooke, 2010). In an ordinary auction, the buyers compete to obtain a good or service by offering increasingly higher prices. With reverse auctions, the sellers compete to obtain business from the buyer, and prices typically decrease as sellers undercut one another. The US Conservation Reserve Program, for example, combines reverse auctions with an environmental benefit index to select land for inclusion in the program. However, Ferraro (2008) acknowledged that auctions introduce their own set of challenges, especially in low- and middle-income countries. In these countries, PES schemes may have dual objectives, and reducing information asymmetries (and thus payments for the ecosystem service provider) may not be a priority. Additionally, administrators of these programs might be less likely to differentiate payment due to concerns about fairness, and it is unclear whether there would be institutional capacity to manage these programs. Moreover, auctions tend to increase transaction costs, which may already be relatively high in low- and middle-income countries where buyers of environmental services are likely to contract with many small, often semi-literate, landowners, who often have no legal titles and are in dispersed remote rural areas. Finally, differentiation of payment can make it difficult to identify corruption and ensure that differentiation is based on implementation of transparent rules. Alix-Garcia *et al.* (2009) suggested another option to reverse auctions would be "to conduct rigorous contingent valuation studies in areas targeted by the program."

While uniform payments are still common, there are several notable exceptions. Mexico's National Programme for Hydrological Environmental Services (PSAH) provides higher payments for lands that provide greater benefits. For example, primary forest owners receive 300 pesos per hectare per year (approximately $27). Cloud forest owners, by contrast, receive 400 pesos per hectare per year ($36) due to the perceived higher delivery of hydrological services associated with this type of forest which has a role in capturing water from fog and clouds during the dry season (Porras and Neves, 2006). Payments are made annually, at the end of the year, once the absence of land use change has been confirmed.

China's Sloping Land Conversion Program also provides targeted payments, although payments are differentiated according to the opportunity costs. China's program, which began as a pilot in 1999 and was fully implemented in 2002, requires farmers to set aside erosion-prone farmland within critical areas of the watersheds of the Yangtze and Yellow Rivers, the two largest rivers in China. Total investment is $4.3 million per year. Farmers in the Yangtze River Basin are paid yuan 417 per hectare per year ($50), while those in the Yellow River Basin are paid yuan 290 ($36) per hectare per year. In addition to the regular cash payments, farmers also receive a one-off cash payment and regular grain rations (Porras and Neves, 2006a). The program is designed to promote forestry and other economic endeavors on the land, rather than grain production.

Given that most programs are voluntary, some have argued that continued participation provides some indication that the programs are cost effective, i.e. that the benefits exceed the costs. The impact of PWS schemes on ecosystem service providers is generally estimated by looking at the payment as a fraction of household income. Using this metric, results are varied. Kosoy *et al.* (2007) found that the amount received from the PWS scheme was less than 2 percent of gross annual income for most providers in three cases in Costa Rica, Nicaragua, and Honduras; moreover, most watershed service providers did not think that the payment was fair. However, Wunder (2008) found that payments represented 10 to 16 percent of household income in schemes in Bolivia, Colombia, Ecuador, Venezuela, and Vietnam. Even these studies did not examine the transaction costs participants incurred in the program or the opportunity costs. In light of these findings, several studies have suggested that there are also important non-financial (or non-income) benefits (Kosoy *et al.*, 2007; Wunder, 2008). The most commonly cited non-financial benefits include increasing land-tenure security, increasing human and social capital through internal organization, and increasing the visibility of the community to donors and public entities (Wunder, 2008).

SOCIAL PERFORMANCE

Limited data are available on the social outcomes of PES programs, as studies have been more narrowly focused on "short- or mid-term outcomes such as increased income or capacity building since these are much easier to identify" than broader social impacts, such as changes in power dynamics (Richards, 2013). In one notable exception, a review of Mexico's PES program

(Alix-Garcia *et al.,* 2009) found that in most cases, there were no "obvious" changes in the social dynamics within a community. However, in two cases, they found a shift in the relative power of certain groups, whereby small, private forest holders who held land within or adjacent to communal lands threatened to cut down their forests if they did not receive some compensation.[24] In two other cases, the program improved environmental awareness and participation in conservation activities.

"PES schemes were ... to improve the efficiency of natural resource management, not as a mechanism to reduce poverty..."

Information on broader social outcomes is limited. However, there is information on the role of PES arrangements in alleviating poverty. It is important to recognize that PES schemes were conceptualized as a mechanism to improve the efficiency of natural resource management, not as a mechanism to reduce poverty (Pagiola *et al.,* 2005). While most programs prioritize areas critical for ecosystem services, some have been tailored to meet social objectives through a variety of mechanisms, including by targeting the programs to particular areas or populations, reducing transaction costs, and providing pro-poor premiums and subsidies (Wunder, 2005; Porras *et al.,* 2013). In Costa Rica, a social development index consisting of 11 health, participation, economics, and education indicators is one of the criteria that is then integrated with environmental criteria to select participants.[25] This particular social development index has been shown to be ineffective in targeting payments to low-income populations because it is biased toward large properties and is "too spatially coarse to represent the social impact of the programme at household level" (Porras *et al.,* 2013). However, it suggests that some sort of criterion – preferably tailored to individual characteristics rather than broad geographic regions – could be developed to improve social outcomes. While some have argued that the pursuit of poverty alleviation objectives is likely to result in environmental tradeoffs (see, e.g. Huang *et al.,* 2009), others suggest that this may not always be the case (Brouwer, personal communication, 2015).

South Africa's Working for Water (WfW) program is one of the few programs to have poverty alleviation as its primary objective. Between its launch in 1995 and 2009, WfW cleared more than 1 million hectares of invasive alien plants, which improved the timing and volume of surface water flows, provided erosion control, and increased biodiversity (Ferraro, 2009). The program, administered by the Department of Water Affairs and Forestry, employs 25,000 to 32,000 people annually, targeting low skilled, previously unemployed laborers, with a special focus on rural women, youth, and the disabled (Ferraro, 2009). Social development, an integral part of the program, includes "skills development, training, and awareness creation of communities in health issues, hygiene, environmental health, inoculation, sexually transmitted diseases, pregnancy and menopause" (Department of Environmental Affairs, 2015). The vast majority of the program budget is provided by the central government and the Department of Water Affairs and Forestry's general budget, with only very minor funding from foreign donors, municipalities, and the private sector. Ferraro (2009) argued that while the program is effectively the government paying for environmental services on government-controlled lands (and therefore not a true PES program), the program administrators are actively seeking voluntary payments from private and municipal actors to remove invasive plants from within their watersheds.

Several studies have examined the socio-economic status of participants in PES schemes, either as buyers or sellers. Porras *et al*. (2008) found mixed results in both national and local schemes, depending, to some extent, on land and forest tenure regimes and socio-economic conditions in the targeted area. In programs in Mexico and Nicaragua, for example, the poor were relatively well represented (Muñoz-Piña *et al.,* 2008; Pagiola *et al.,* 2005), whereas in Costa Rica, the poor

[24] In a somewhat unusual situation, this conflict was a result of the fact that only a small group had rights to the commons and only those with rights received payment.

[25] The index is used by Costa Rican government institutions to establish priority for social policy and budget allocations.

were not well represented (Zbinden and Lee, 2005). Wunder (2008) noted that one must typically own or hold land in order to be a seller, thereby excluding the "poorest of the poor." Some schemes have attempted to recognize informal access to resources (e.g. Indonesia's RUPES Program), although this has been difficult to replicate elsewhere (Porras *et al.*, 2008). A recent review of ten PWS schemes in developing countries by Bond and Mayers (2010) found only a small number of cases where livelihoods had been improved, concluding that "there are significant and positive indirect effects of PWS – particularly in building social capita in poor communities." They acknowledged that while improving education, health, and nutrition are better ways of reducing poverty than PWS, there is little evidence of these schemes actually doing any harm. Moreover, they suggested that targeting can make PWS programs more effective in alleviating poverty.

Additionally, while it is commonly assumed that upstream service providers are poorer than downstream users (Wunder, 2008), the reality may be more complicated. For example, George *et al.* (2009) found that downstream and upstream stakeholders were part of the same community in two watersheds in Thailand and Lao PDR with no clear distinction between upstream providers and downstream beneficiaries. In some cases, according to Porras *et al*. (2008), downstream users may, in fact, be poorer, raising concerns about their ability to pay as well as whether those payments are equitable. In cases where user fees were used to compensate ecosystem service providers, the authors found that the fees were generally found to be acceptable, with no detectable impact on water use or access to water. Additionally, some programs had taken steps to ensure that the poorest users were not impacted by these fees, e.g. by making payments voluntary or providing a lifeline supply of water.

Few studies have examined gender representation among program participants. In a literature review, Ravnborg *et al.* (2007) found that less than 5 percent of the references addressed gender-specific aspects of impacts of PES. In a more recent assessment, Richards (2013) concurred, finding that "Gender effects have not been monitored, and therefore there is no information about how women have been affected except some reference to their low levels of participation." Porras *et al.* (2008) cited two studies indicating low participation levels by women. However, these studies were more than a decade old and may not have reflected current conditions.

Necessary, enabling, and limiting conditions

Some factors, such as contract adjudication and enforcement, may be *necessary* for establishing a PWS program. Other factors, such as appropriate inventories and analyses and government support, can *enable* but may not be required for PES programs to be established. Still other factors, such as legal prohibitions, *limit* watershed PES or function as barriers or obstacles.

Necessary conditions include:

- a legal system recognizing that agreements must be kept
- a civil law providing contract parties with legal remedies to enforce contract rights in cases of non-compliance with contract obligations
- general respect for the rule of law.

"Few studies have examined ... gender-specific aspects of impacts of PES."

In general, PES schemes are flexible and the necessary conditions are relatively modest. However, Calvache *et al.* (2012) determined that they must be designed within the legal context of a particular area. Greiber (2009) provided additional detail on the legal framework for PWS implementation, noting that the framework will differ depending on the type of scheme implemented. For example, private schemes, defined as self-organized schemes between private entities, require the least government intervention and depend on only general legal requirements: e.g. a legal system recognizing that agreements must be kept, and civil law providing contract parties with legal remedies in case of non-compliance. However, if only these conditions are in place, Greiber (2009) asserted that these programs would "mostly develop at a small scale with the objective to solve a specific local water problem," and expanding these projects to address regional or national water problems would require a more developed policy and legal framework.

By contrast, public schemes are government-driven schemes that, by definition, require far greater government involvement, as local, regional, or national governments are involved as either watershed service providers or buyers, and payment may be done through user fees, taxes, or subsidies. However, many of these schemes have evolved on an ad hoc basis from initiatives of NGOs and overseas development corporations and, as a result, they typically lack comprehensive or coherent legislation. Greiber (2009) also noted that these conditions limit "the real potential of PES as an innovative instrument that might be applied more often, more efficiently, and at a larger scale to combat prevailing water problems." He argued that a specific legal and policy framework would stimulate PES development by creating greater legal certainty and helping to promote good governance practices.

While necessary conditions establish the minimum requirements for the implementation of a PES program, there is a set of enabling conditions that promotes the success and long-term viability of these programs. While some of the enabling conditions are technical in nature, others are legal, institutional, social, and political.

Technical enabling conditions include:

- an inventory of the value of hydrological services, including assessments of baseline conditions, and of how these values may change in response to land use alterations, infrastructure development, and climate
- an analysis of program costs, including implementation, opportunity, and transaction costs
- a registry of names, transactions, project data, credit issuance, or other information related to PES activities
- technical support from the government, civil society, or the private sector through trainings, information, or direct technical assistance
- methodologies for measuring, monitoring, reporting, and verifying progress toward achieving project outcomes.

Several studies have developed guides highlighting the technical requirements (Hawkins, 2011; Calvache *et al.*, 2012; Smith *et al.*, 2013). In addition to these requirements, methodologies for measuring, monitoring, reporting, and verifying progress toward achieving outcomes are also needed. Monitoring and evaluation are fundamental to the success of PES schemes because the information they provide gives assurance to the buyer that ecosystem services are delivered as promised and allows for adjustments to the program based on better information and changing conditions. Porras *et al.* (2013) made a distinction between monitoring for compliance and monitoring for environmental effectiveness. The former "seeks to ensure that the conditionality inherent in a PWS scheme is put into practice, and that the project is implemented effectively." The latter, by contrast, seeks to ensure that the scheme achieves its overall objectives and is needed to demonstrate additionality, i.e. that changes in watershed ecosystem services can be attributed to the program. While compliance and effectiveness monitoring are often linked, "a high degree of compliance does not necessarily ensure that a scheme is effective, as a poorly designed scheme may target the wrong land managers and land that is at least risk, meaning that the payments may not generate the desired hydro-ecological or conservation benefits."

Despite some of the challenges to monitoring (described in the application section of 3.2), Brouwer *et al.* (2011) pointed to the need for international monitoring guidelines to identify the relationship between the design of the program and its environmental effectiveness because understanding these relationships is "paramount to the future design of cost-effective PWS schemes." A recent *Science* article by a large team of scientists and practitioners in the PES field (Naeem *et al.*, 2015) noted that "many projects are based on weak scientific foundations, and effectiveness is rarely evaluated with the rigor necessary for scaling up and understanding the importance of these approaches as policy instruments and conservation tools." In an effort to advance the field,

TABLE 2. Natural-science principles and guidelines for PES programs

Principle: Dynamics **Objective:** Ensure project capacity to adapt to dynamic natural and anthropogenic processes.	**Principle:** Monitoring **Objective:** Track factors necessary for management, trade, forecasting, and assessment.
SCIENTIFIC GUIDELINES: **identify key services for each service type beyond target services** **identify spatiotemporal scales of targeted services** **identify data needs, resources, and gaps** **identify stressors and their spatiotemporal variability** **identify and forecast trends in endogenous and exogenous threats** identify services' production and functions and sensitivities determine trade-offs and synergies among services determine how functional diversity influences resilience.	SCIENTIFIC GUIDELINES: quantify deliverables associated with target services identify spatiotemporal scales in advance of implementation use established methods/protocols and best practices for monitoring estimate uncertainties **monitoring should inform decision-making** **monitoring should detect potential changes in baseline conditions** monitor non-target services that influence target services.
Principle: Baseline **Objective:** Document and initial conditions	**Principle:** Metrics **Objective:** Robust, efficient, and versatile methods for procuring data.
SCIENTIFIC GUIDELINES: **measure influences of interventions on services** **measure status and trends of non-target services** **ensure that measurements are feasible given resources** assess initial state of exogenous and endogenous threats to services measure factors important for forecasting service trends.	SCIENTIFIC GUIDELINES: must be relevant, reliable, and appropriate in scale should comply with voluntary standards, certification, and regulations should reflect spatiotemporal scales as identified in dynamics optimize balance between precision and simplicity assess progress (in conjunction with baseline and monitoring) should measure both absolute changes and changes in trends preferentially selected to allow comparisons across service types assess how services influence each other.
Principle: Multiple services **Objective:** Recognize trade-offs and synergies among services	**Principle:** Ecological sustainability **Objective:** Insure project durability and sustainability
SCIENTIFIC GUIDELINES: assess how intervention influences the other services avoid "double counting" assess impacts of intervention on non-target services.	SCIENTIFIC GUIDELINES: estimate short-term and long-term project or program performance.

Note: The scientific guidelines shown in **bold font** are intended to indicate "essential" guidelines that must be followed for a successful intervention. Guidelines shown in regular font are considered "desirable".

Source: Naeem *et al.,* 2015.

the authors put forth a set of natural science principles and guidelines for PES efforts that they felt were applicable to local-, regional-, and national-level programs in developed and developing countries (Table 2). A set of scientific guidelines for four of the principles – dynamics, monitoring, baseline, and metrics – were deemed "essential" for a successful intervention, whereas the remainder were deemed "desirable". While specific to PES arrangements, they argued that the principles and guidelines could be applicable to market-based conservation instruments more broadly. In a review of 118 active PES projects, however, the authors found that 60 percent did not adhere to the four essential principles, highlighting considerable room for improvement in the development and implementation of PES projects.

In addition to the more technical aspects of PES, there are a number of enabling legal, institutional, social, and political conditions that also improve the effectiveness of PES.

"Governments, for example, can pass laws or institute policies that enable the development of PES programs."

Enabling legal, institutional, social, and political conditions include:

- a policy and legal framework for PES
- incentives and/or requirements to participate in PES programs
- cultural and political acceptance of markets
- trust between ecosystem service providers and beneficiaries
- a supply and demand for ecosystem services.

Governments, for example, can pass laws or institute policies that enable the development of PES programs. In Costa Rica, participants of PES programs are exempt from paying property taxes (Porras *et al.*, 2013). Likewise, the Peruvian government unanimously passed a law providing a legal framework for voluntary PES programs between land stewards and beneficiaries of ecosystem services, while Colombia went even further by requiring departments and municipalities to invest at least 1 percent of annual revenues toward either PES to landowners or direct land acquisition in source water areas (Bennett *et al.*, 2014). Enabling legislation can occur at various levels (e.g. local, provincial, or national) and take a variety of forms. However, the appropriate level and form will depend on the prevailing governance system in a particular area.

A variety of social and political conditions increases the likelihood of the successful implementation of PES schemes. For example, cultural and political acceptance of markets in general, and of commercializing rights to land use and land management practices, creates an enabling environment. Dillaha *et al.* (2007) noted that PES activity is generally strong in Latin America, but that development tends to lag in areas with strong indigenous cultures (such as the Bolivian highlands) or closed economies (such as Venezuela). It is important to note that in areas where the natural environment has historically been used for free, "actually paying for environmental services in response to mounting resource scarcity represents a major change in attitude, which necessarily will take time" (Dillaha *et al.*, 2007).

Trust is also a key element for an effective PES program, as it helps to ensure that there are willing buyers and sellers, and reduces transaction costs. Dillaha *et al.* (2007) noted that service providers might fear that PES is a first-step toward appropriation of their resources, while service users "might suspect that they are or will be the victims of 'environmental blackmail'." Based on several cases in Asia, Neef and Thomas (2009) argued that "Lack of trust between potential buyers and providers of environmental services is probably one of the most constraining factors in setting up viable PES schemes." One way to facilitate the trust-building process is through stakeholder engagement, especially during the initial stages of the project. Likewise, transparency and access to information are also essential. Intermediaries, such as NGOs, can sometimes play a role in building and maintaining trust while also providing technical, legal, and financial support. As

Bond and Mayers (2010) acknowledged, trust "is hard to build and easy to lose."

Finally, there must be a supply of, and demand for, ecosystem services. On the supply side, payments must be big enough relative to other opportunities to create a real incentive for change. On the demand side, beneficiaries must have the ability to pay. For example, Huang *et al.* (2009) posited that by increasing incomes, rapid economic growth in Asia could increase demand for watershed services because there is greater willingness and ability to pay for amenities such as clean water and recreation. At the same time, rapid economic growth could increase demand for goods and services produced on the land, thereby increasing the opportunity cost of the land. In a regional review of PWS programs in sub-Saharan Africa, Ferraro (2009) suggested that demand for watershed services is relatively low, as there are relatively few formal water systems, and even those with formal systems may lack reliable access – which means there are few people who could be easily charged a water fee to pay for watershed services. Moreover, high poverty rates suggest that many would not be able to afford higher water costs.

There is also a set of conditions that can hinder or limit the development of PES schemes.

Limiting conditions can include:

- any legal provision prohibiting watershed PES contracts
- poorly defined property rights.

Greiber (2009) noted that "clearly defined property rights enable parties to enter into PES contracts and ensure the sustainability of PES schemes." Several challenges associated with property rights arise when implementing PES schemes. For example, ecosystem services are a relatively new concept and may not be recognized by the existing legal framework. In Peru, the state is the owner of natural resources and holds the property rights over ecosystem services. While the state can transfer certain property rights over natural resources to individuals, it has not yet been determined whether these rights also include "the right to receive income from the ecosystem services provided by the transferred natural resource." Likewise, in Asia, most forested and agricultural land is state-owned. Thus, individuals and communities have weak land rights, making it difficult for them to sign a contract and provide a legal guarantee of future land management practices (Huang *et al.,* 2009).

3.3 Water quality trading

Description

Water quality trading (WQT) is a market-based approach for reducing or controlling water pollution. It allows permitted dischargers in a watershed to *trade* water quality credits, or pollution allowances, in order to meet water quality standards. Markets in water quality differ from conventional markets in that they are not based on an actual physical commodity. Rather, they are based on trading a *license* or a *permit* to pollute. The primary goal of water quality trading is to reduce the costs of water pollution control, often following the imposition of a cap on pollutant emissions by regulators. Secondary goals are to reduce compliance costs and spur innovative solutions to pollution control.

"Water quality markets draw inspiration from the success of the Acid Rain Program in the US in the 1990s."

Water quality trading is an adjunct to regulation, and not an alternative to it. In fact, its success depends on the presence of a strong regulatory body to enforce water quality standards, and monitor and enforce discharge limits.

Water quality markets draw inspiration from the success of the Acid Rain Program (ARP) in the United States in the 1990s. At the time, most environmental groups and government agency staff favored a "command-and-control" approach to pollution control that would have required all power plants to install scrubbers on their smokestacks to remove sulfur dioxide (SO_2). Lawmakers instead opted for a bold policy experiment, setting a cap on total SO_2 emissions, and allowing polluters to buy and sell pollution allowances. Under this system, emissions from individual sources could rise or fall, as long as the total annual emissions stayed the same. The central idea was that allowing trading puts a price on pollution, and, in turn, encourages cost savings, efficiency, and innovation.

In most WQT markets, a cap is put on water pollutants. In the United States, the cap is usually set by state governments, which are responsible for regulating water quality in rivers, lakes, and estuaries. The cap should be based on a scientific analysis of how much pollutant a water body can assimilate without being excessively degraded, which is referred to as a total maximum daily load (TMDL). Government regulators issue pollution allowances, often referred to as "credits", to existing polluters. For example, a credit may allow a facility to discharge one pound of phosphorus to a river. A facility manager may choose to install pollution-control technologies that limit emissions. If a facility's emissions decrease to below its permitted level, this frees up additional credits that managers may then sell to other polluters. There typically may be two types of buyers that create a demand for credits: i) new entrants to the market, such as a new factory in the watershed, or ii) existing polluters that may wish to or need to increase their emissions, e.g. a factory that wishes to increase output, or a sewage plant serving a growing community. Trading allows the industry greater freedom to operate as it sees fit. A low-performing facility may continue to pollute more heavily, but it will be required to purchase credits, making the cost of doing business more expensive. High-performers that can reduce their pollution levels create valuable pollution credits that they can sell, and this creates an incentive to invest in pollution controls, at least according to theory.

To date, most water quality trading markets have been used to control pollution from nutrients that cause excessive algal growth and low dissolved oxygen levels in water bodies, a process referred to as "eutrophication". Other water quality trading programs have been set up to control salinity, heavy metal, sediment, and temperature or thermal pollution (Morgan and Wolverton, 2005). These programs are typically based around specific watersheds or receiving waters, such as the Chesapeake Bay or Wisconsin's Fox River. WQT markets are different from other emissions trading schemes, in that trading is used between sources in the same area of impact, e.g. a watershed that drains to a particular water body, such as a lake, estuary, or river. The geography of trading contrasts starkly with other well-known cap-and-trade-style environmental markets, such as national and international markets for carbon offsets, where emission reductions can take place even in remote parts of the world.

Trading within water quality markets can take several different forms. The most common arrangement in the United States is a bilateral market, where buyers negotiate trades directly with potential sellers, discussing their quantity and price. Often, a regulator will get involved by, for example, approving the terms of the agreement, or facilitating monitoring to ensure that actual discharge reductions take place. This arrangement makes transactions slow and costly, and has been partially blamed for the moribund trading activity in most US WQT markets (Woodward *et al*., 2002). In clearinghouse-style markets, a middleman such as a brokerage firm facilitates trades by connecting willing buyers and sellers, as has been done in the Tar-Pamlico River Basin Nutrient Trading Program in North Carolina. On the opposite extreme, exchanges are a form of trading where allowances are turned into standardized commodities and are freely traded. For example, in the United States, SO_2 allowances are traded on the Chicago Mercantile Exchange. The Hunter River Salinity Trading Scheme in Australia may also be considered an example of an exchange, although in this case, the government is responsible for trades (NSWDEC, 2003).

Water quality markets can be classified in a number of ways. One useful way to categorize markets is based on the regulatory system that drives the demand for trading and whether it includes a cap on total emissions (Anderson, 2004). This includes both cap-and-trade systems and credit systems.

Cap-and-trade systems put a limit on the total amount of allowed releases of pollution. They seek a specific environmental result (a cap), and trading allowances to release pollution are simply an option to minimize the cost of achieving the emission reductions specified in the regulatory cap. In the cap-and-trade approach, allowances for future emissions are sold or granted to existing sources.

Credit systems, on the other hand, do not establish any fixed ceiling on total emissions. Total emissions can increase if new sources of pollution enter the market, or if existing sources increase their outputs. In uncapped systems, tradable credits are earned for controlling pollution beyond what is specified in one's permit.

> **"WQT programs allow polluters to interact in the marketplace and decide among themselves how to allocate the right to discharge pollutants."**

The literature is full of descriptions of the potential benefits of water quality trading compared with the more conventional "command-and-control" approach, where regulators allocate the right to pollute by imposing limits on individual polluters (Shortle and Horan, 2005). In particular, WQT markets are thought to be a less-costly, more-efficient alternative. When the total amount of pollutant emissions in a region is capped, the right to pollute becomes a scarce commodity and, as many economists assert, markets are the most efficient way of allocating a scarce commodity.[26] WQT programs allow polluters to interact in the marketplace and decide among themselves how to allocate the right to discharge pollutants. Markets are also thought to foster innovation – where "innovative, entrepreneurial companies can profit from low-cost reductions in emissions. Slower, less innovative firms can benefit as well by having the opportunity to purchase needed emission allowances for less than it would cost them to comply internally" (Anderson, 2004). Moreover, cap-and-trade programs may provide greater certainty in the outcome. With a fixed or declining cap, policy makers can be more certain of the environmental improvement that will be achieved, compared with alternative approaches such as best management practices or a pollution tax.

Application

A survey conducted by Bennett and Carroll (2014) for Forest Trends found that activity for WQT markets is still relatively small, although it has shown large increases in the past several years. In 2013, the trading value of WQT markets was about \$22.2 million. Much of that activity was concentrated in the United States, where WQT markets had a trading value of \$11.1 million in 2013, with a cumulative total of \$95 million since 2000. While there are currently over 30 water quality markets in place in the United States, some have seen no trading or only a few trades, even two decades after their establishment. Among the reasons cited for the lack of trading activity are high transaction costs, lack of trust, uncertainty about the future of the market, or simply unfamiliarity and unwillingness to participate in the market (Shortle and Horan, 2008). While some of the longest-running markets are getting smaller, new programs in Oregon, Virginia, and Maryland have kept overall transaction values high. Indeed, in 2013, United States market activity was at its highest level ever recorded, although Bennet and Carroll (2014) posited that this likely represented recovery from the economic downturn rather than new growth. It is of note that New Zealand's Lake Taupo Trading Program, a relatively new program, has rapidly become the largest in the world, with at least \$10.2 million in transactions in 2013. However, the future of that market is uncertain because "that market's biggest buyer, the Lake Taupo Protection Trust, announced in June 2013 it would

[26] While economic theory says that trading will lead to the most efficient allocation of a resource, it says little about distributional effects, i.e. who pays and who benefits, or other market "externalities".

withdraw from future trading, having made arrangements to achieve its remaining nitrogen reduction goals by purchasing and managing land in the catchment" (Bennett *et al.,* 2014).

"40 percent of America's surface water fails to meet its water quality goals."

The popularity of emissions trading for dealing with water pollution in the United States is largely a result of the Clean Water Act of 1972. The specifics of how the law was written and implemented have made it difficult for governments to handle pollution from farms. In particular, the law made it illegal for "point source" dischargers, such as factories or wastewater treatment plants, to release pollutants into waterways without a permit, but did *not* attempt to regulate pollution from "nonpoint sources", such as agriculture or urban runoff, since these were considered minor sources of pollution and believed to be difficult to regulate. In many watersheds, however, farms and feedlots are the largest source of pollutants. These nonpoint sources are exempt from most water pollution regulations, and there appears to be insufficient will to remedy this.

Forty years after passage of the landmark law, some 40 percent of America's surface water fails to meet its water quality goals (Faeth, 2000). Further, a set of studies in the 1990s showed that reducing nutrient pollution from agriculture could be 65 times more cost effective than imposing further controls on municipal or industrial sources. As a result, water quality regulators in the United States use WQT markets primarily as a tool to encourage point dischargers to fund nonpoint source pollution controls, largely because regulators lack the authority to deal with these sources of pollution.

One factor contributing to the popularity of emissions trading is its appeal to conservative politicians due to their invocation of the "power of the market" (Conniff, 2009). The original cap-and-trade programs were policy innovations developed by conservatives in the Reagan, George H.W. Bush, and George W. Bush administrations, "and were once strongly condemned by liberals and environmentalists" (Schmalensee and Stavins, 2012). The key element for overcoming conservative politicians' resistance to the policy was to replace regulation with a free market; the market would operate on its own with no intervention by the government, a step that would "radically disempower the regulators" (Conniff, 2009). However, this has not been the reality with most environmental markets, which have been designed with additional layers of government that oversee the market, monitor and enforce emissions limits, and facilitate and verify trades. By contrast, there are alternative pollution control policies that are simpler and require less government involvement, such as mandating the use of pollution-limiting technology or taxing pollution. There is some irony here, prompting one scholar to observe, "a putative form of rationalization or deregulation is in fact a case of 'reregulation'" (Mariola 2009).

As an example of how WQT markets work, consider the example of the Chesapeake Bay. To reduce nutrient discharge into the bay, regulators had the option of requiring wastewater plants to install expensive and technologically advanced treatment systems. Nitrogen removal costs for these systems are typically about $200 per pound per year (Jones *et al.,* 2010). However, farms in the watershed are an even larger source of nitrogen, and removal costs are much lower, at $1 to $5 per pound per year. As a result, permitted dischargers have negotiated the ability to fulfill their permit requirements by funding pollution control projects on farms in the watershed, such as planting winter cover crops, planting vegetation around streams (called riparian buffers), or installing permeable filter strips around animal feedlots. These agricultural "best management practices" reduce soil erosion and sediment runoff from farms, reducing the amount of nutrients washed into local waterways. Because they use soil and vegetation to filter water and sediment, they are generally low-tech and relatively inexpensive to install and maintain. The Chesapeake Bay WQT program was set up specifically to encourage these kinds of exchanges.

Trading allows regulated polluters to meet their permitted discharge requirement at a much lower cost than with technology. Further, it helps to finance pollution reduction from the agricultural sector, which generates about 44 percent of the nutrients entering the bay. A recent assessment concluded that controlling discharges from agriculture is necessary to restore the bay (Steinzor *et al.,* 2012).

A second noteworthy example of a domestic WQT market is the relatively new Ohio River Basin Water Quality Trading Project developed by the Electric Power Research Institute, the research arm of the United States electric power industry. Coal-fired power plants in the Ohio River Basin are a major source of nitrogen pollution in rivers, due to their using water in scrubbers for air pollution control and to sluice the coal ash out of reactors (US EPA, 2009). The ash and water slurry most often goes into storage and treatment ponds that provide only a minimal level of treatment and where spills and illicit discharges have been common (Zucchino, 2015). Under the pilot program, power plants and other interested parties can pay for nonpoint source pollution reductions on farms, another major source of pollution in the watershed. Because on-farm improvements are much less expensive than installing wastewater treatment facilities, power plants stand to save $500,000 to $800,000 per year (EPRI, 2010).

The first projects are creating nutrient reduction credits through "activities like planting cover crops and creating treatment wetlands for animal wastes" (Ecosystem Marketplace, 2015). The program is notable for its thoroughness in documenting projects, posting a description and photos of every project on the Electric Power Research Institute (EPRI) website, and using a standard methodology for calculating the reduced pollution in farm runoff. The program is credited with reducing pollution by 100,000 pounds of nutrients between 2013 and 2015 (Barrett 2015). While commendable, this project is a small pilot, and pollutant reductions are small compared with the estimates of over 3 million pounds of nitrogen entering the watershed's rivers every day (Olszowa *et al.,* 1998). Further, on-farm nutrient controls will do little to control other toxins that are present in coal ash, such as arsenic, lead, mercury, and heavy metals. However, the program is notable as it is the first program in the United States that has allowed the purchase of pollution control credits across state lines (Fox, 2014).

In addition to the many markets in the United States, there are also examples of WQT markets in other regions, especially in Oceania:

- Lake Taupo Nitrogen Trading Program (New Zealand)
- South Creek Bubble Licensing Scheme (Australia)
- Murray-Darling Basin Salinity Credits Scheme (Australia)
- South Nation River Watershed Trading Program (Canada)
- Chao Lake Nutrient Trading Program (China, under consideration)

Several European countries have shown interest in WQT. A literature review by Wind (2012) summarized 14 studies of the concept within the European Union. Despite this interest, no markets have been created to date, and it appears that EU directives limit the ability of states to set up markets.

Perhaps the best example of a successful operating WQT market is on Australia's Hunter River, where coal mines and other sources are subject to discharge limits to protect water quality and drinking water sources in downstream cities. Saline soils are present throughout Australia, and during coal mining, salty water collects in mine pits and shafts and has to be pumped out to allow mining operations to continue (NSWDEC, 2003). The Hunter River Basin had a history of conflict among users, with mining activities making the water unsuitable for irrigation, and new mine proposals facing extremely high costs. The state government, following years of study and collaboration with stakeholders, set a cap on salinity levels in the river, and put a system of tradable discharge credits in place.

Under this system, no discharges of salty water are allowed when the river is in low flow. When the river is in high flow and its capacity to dilute salty inflows is greater, limited discharge is allowed, controlled by a system of salt credits. Permitted dischargers coordinate their activities so that the total salt concentration in the river never goes above a specified limit. Industries can buy and sell salt credits in real time via a trading website run by the state government. Several years after the program began, the trading program is popular among participants and functioning smoothly. The state government has set up real-time monitoring to make sure the river water quality meets standards, and to monitor for permit violations. Perhaps the biggest marker of the program's success is that new, potentially highly polluting mines have been established, but river water quality has met standards nearly 100 percent of the time.

"...there is a great deal of literature ... but few real-world evaluations of existing WQT markets."

Environmental, economic, and social performance

Despite the fact that water quality trading markets have existed for three decades in some areas, it is difficult to state whether they can be considered an overall success. In making such an evaluation, we must determine whether desired pollution reductions were achieved and water quality targets attained. We must also examine how the result compared with what would have occurred under another form of management: were the pollution reductions greater, did they occur more quickly, or at a lower cost?

Moreover, there is a great deal of literature about water quality trading and market-based solutions to water pollution but few real-world evaluations of existing WQT markets. Much of the literature about markets is theoretical and oriented toward "making the case" for WQT, e.g. describing how a market can or should be set up. Below, we examine the available evidence looking at how WQT markets have performed environmentally, economically, and socially.

ENVIRONMENTAL PERFORMANCE

While there are no comprehensive analyses of the environmental performance of WQT programs in general, there are several examples of successful programs. In the application section of 3.3, we cited Australia's Hunter River as one example. Indeed, since formation of the program, river water quality has met standards nearly 100 percent of the time, protecting water supplies to downstream irrigators and cities. This happened despite the establishment of new, potentially highly polluting mines in the watershed. The Alpine Cheese Company Nutrient Trading Program in Ohio is another notable success. As a part of this program, the company helped fund pollution reduction projects on local farms, paying 25 farmers to install 91 conservation measures that resulted in a 3,000-pound-per-year phosphorus reduction (US EPA, 2010).

A United States Environmental Protection Agency (US EPA) 2010 evaluation of the program found that it exceeded its nutrient reduction goals, and estimated that "conservation measures would reduce up to three times more nutrients than if equal funds were used for wastewater treatment upgrades." It is noteworthy that the project has also been praised by the local chapter of the Sierra Club, which has strongly opposed the creation of larger WQT schemes in other areas that could allow industry to continue implementing poor practices by purchasing offsets (Marida, 2010).

Likewise, the Connecticut Nitrogen Credit Exchange Program – currently the largest in the United States – was created in 2002 to reduce nitrogen pollution to Long Island Sound from the Connecticut River. Under the program, which covers 79 sewage treatment plants in the state of Connecticut, a plant can control pollution in excess of its permit requirement and sell excess nitrogen allowances to those plants that exceed their allowances. A 2012 review of the program suggested that the program had helped the state meet its environmental goals while lowering overall costs (Stacey *et al.*, 2012). The program helped reduce nitrogen loading by over 50 percent over 10 years, and was on track to meet water quality goals by 2014. As a result, the area of Long Island Sound suffering from hypoxia (low dissolved oxygen which is fatal to wildlife) had steadily declined.

Despite these examples, most water quality trading programs in the United States are either too small or have seen too little trading to make a meaningful difference on water quality. For example, a 2012 evaluation of Ohio's Great Miami Nutrient Trading Program called it "one of the most successful programs to date" (Newburn and Woodward, 2012). In 2009, the trading program attracted $1.3 million in trades and helped fund 100 projects that reduced nutrient pollution by 800,000 pounds per year. Proposed projects submitted by farmers in the watershed covered a variety of agricultural "best management practices" designed to prevent sediment and nutrients from entering waterways. Evaluators concluded that the program "has been successful in developing both supply and ensuring funding for agricultural pollution abatement projects compared to other WQT programs" (Newburn and Woodward, 2012). Despite this, they found that the program had not likely had a significant effect on regional water quality due to the "relatively minor role that the trading program has had on nutrient management in the watershed to date."

To date, the projects have simply been too small and too few to have a major impact. The Great Miami River watershed drains 748 square miles, the majority of which is cultivated, so a much larger investment would be needed to meaningfully improve water quality in the basin. This example highlights the caution needed when interpreting large numbers cited by market proponents. While 800,000 pounds sounds like a lot (and is indeed a worthwhile accomplishment), it pales in comparison with the estimated 1 trillion pounds of nitrogen entering the Ohio River watershed each year (Olszowa *et al.*, 1998). Like most WQT markets in the United States, the Greater Miami Basin program did not emerge from a cap on pollutants. Rather, it was created as a way to allow regulated point-source dischargers, such as factories and sewage plants, to lower their costs by paying for pollution controls on farms rather than installing expensive pollution control measures at their own facilities.

In an assessment of three mature WQT programs in the United States, one scholar concluded that there had been very little benefit as a direct result of trades. However, the programs had an unexpected benefit: they brought together watershed stakeholders and increased "the institutional capacity for watershed management" (Wallace, 2007). Stakeholders coming together around a common goal of improving water quality also helped lower resistance to new, more stringent water quality regulations. Wallace concluded that the markets themselves were not important mechanisms for reducing pollution. Rather, their presence contributed to "unintended contributions to increased pollution regulation and management on a watershed scale." So, on the one hand, these markets could be considered failures by some observers because many of them had seen no trading even decades after their creation.

The lack of trades can be explained by a number of factors: high transaction costs, lack of trust, uncertainty about the future of the market, or simply unfamiliarity and unwillingness to participate in the market. On the other hand, even where little or no trading occurred, water quality and governance had improved in the three watersheds evaluated by Wallace (2007). It is not always possible to disentangle how much of a role the market played in bringing about these improvements. On the one hand, financial transactions have not played a large role, tempting us to conclude that the markets were relatively unimportant. However, if discussion of the use of "market fundamentals" helped overcome resistance to environmental regulation and paved the way toward decreased pollution, then we may conclude that markets were a key feature in improving water quality, albeit indirectly.

ECONOMIC PERFORMANCE

It is difficult to assess the economic performance of WQT markets and how their economic performance compares with alternative forms of pollution control. To date, the size and impact of water quality markets is relatively small. There is some information in the literature on the number of trades that have occurred, and the prices paid for water quality credits. In the application section of 3.3, we cited a Forest Trends study that estimated the value of the United States water quality trading market as $11.1 million in 2013, in terms of the total value of payments. To put these numbers in perspective, state and local governments in the United States spent $70 billion on sanitation and sewerage in 2008 (US Census Bureau, 2012). Despite these investments, many argue that the United States should be spending much more to control water pollution. Researchers at Kansas State found that nutrient pollution from nitrogen and phosphorus cost the United States $2.2 billion in 2008, due to losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and increased treatment for drinking water (Dodds *et al.*, 2008).

"…advocates for WQT markets cite the lower overall cost of improving water quality as their main advantage…"

While limited data are available, advocates for WQT markets cite the lower overall cost of improving water quality as their main advantage, as compared with more conventional means of water pollution control. There is local evidence for this, especially in smaller markets. Take the case of the Alpine Cheese Company, in Ohio's Sugar Creek watershed. The plant was faced with expensive wastewater treatment upgrades to satisfy Clean Water Act permit requirements (US EPA, 2010). These upgrades would likely have cost over $1 million to install, plus ongoing costs for operation and maintenance. Instead, the company collaborated with others to reduce pollution through projects at farms in the watershed that have a much lower cost per pound of phosphorus prevented from entering streams, and which are expected to last 15 to 20 years (Moore, 2012). The company worked with universities, regulators, and local agricultural extension services, providing $800,000 over five years for planning, technical assistance, and outreach. In addition, these measures allowed the plant to expand, creating 12 new jobs. Further, the project provided funding to chronically cash-strapped local soil and water conservation districts and to the local agricultural economy. Local dairy farmers took pride in improving the environment and supporting the local economy, and also experienced other indirect benefits from the project, "by fencing cows out of streams, bacteria levels in milk were decreased, giving the farmers a premium price for milk and reducing costs for Alpine [Cheese Company]" (Marida, 2010).

As described previously, the Connecticut Nitrogen Credit Exchange Program is currently one of the largest WQT programs in operation. An evaluation of the program in 2012 suggested that the program has helped the state meet its environmental goal of reducing nitrogen loading to Long Island Sound while lowering overall costs. The state estimated that, in the first 10 years of the program, trading had lowered costs by $300 to $400 million below what individual facilities would have had to pay for equivalent pollution reductions (Stacey *et al.*, 2012).

SOCIAL PERFORMANCE

There is little research on the social impacts of WQT, and much of what we describe in this section is based on anecdotal evidence. Critics of environmental markets have raised questions about their fairness and justice. A specific concern relates to how regulators distribute pollution permits at the outset of market creation. Under a market system, pollution permits become valuable commodities to be bought and sold. In many cases, as in SO_2 trading in the United States, the government grants allowances to industries for free, based on their historic emissions. Critics point out that such "grandfathering" of permits rewards those polluters most responsible for environmental problems in the first place. It may also unfairly burden more recent market entrants, because they have no history of polluting and no "free" permits, yet would be required to purchase credits to offset 100 percent of their emissions. There are, however, different ways of issuing credits that help mitigate these concerns. For example, rather than giving away credits, they could be sold to polluters in an auction, as has been proposed in carbon markets.

Critics have also raised concerns about the fairness of water quality markets to potential sellers of water quality credits. Consider a farmer who installed pollution controls before a WQT program was established. Unlike his (polluting) neighbors, he would not be eligible for financing under the program. Thus, the program would reward "notorious polluters" rather than the good stewards, "because the good steward had already reduced pollution" (Ruppert, 2004). Despite these criticisms, there are several examples of WQT markets that have been considered successful, and earned support from industry, famers, regulators, and environmentalists.

As was discussed previously, the Alpine Cheese Company Trading Program in Ohio was a very small market that involved the purchase of credits from 25 farmers by a local cheese company. Many of the farmers already did business with Alpine Cheese, selling milk from their dairy herds, and have a strong interest in maintaining a strong agricultural economy. One observer wrote that, "socially, community has been built with the farmers taking pride in working together, their more sustainable farming practices and in seeing the success of the factory" (Marida, 2010). One sees a similar outcome in an evaluation of the Hunter River Salinity Trading Scheme in Australia. Where there was once "significant conflict between primary producers and mining operators," today, "agriculture, mining and electricity generation operate side by side, sharing the use of the river" (NSWDEC, 2003). Here, a history of conflict has been replaced by cooperation. This did not happen overnight, and required many years of painstaking consultation and negotiation.

In New Zealand, concerns have been raised about how the Lake Taupo Nutrient Trading Scheme affects different types of landowners, particularly indigenous Maori people. In this area, dairy farms and grazing were creating polluted runoff, negatively impacting a freshwater lake important for fishing and tourism. Regulators instituted a cap on nitrogen pollution seeking to maintain water quality at year 2000 levels. Larger corporate landowners were given more pollution credits based on their historical use of the land, while Maori landowners had not yet fully developed their lands (MOTU, 2009). There are historical and cultural reasons why Maoris have been slower to develop their lands: they did not own some lands until recently, and communal ownership makes it slower and more difficult to develop land. In a sense, those most responsible for past pollution have been rewarded with large (and valuable) pollution permits, while the Maori community will face higher costs to develop their lands economically. In response to these concerns, regulators altered the market design by relaxing the cap somewhat "to ease the restrictive nature of historical allocation on Tuwharetoa [Maori] and other forest owners" (Duhon *et al.*, 2011).

"Some critics have suggested that WQT programs could perpetuate or worsen environmental justice problems."

In the New Zealand case study, program managers realized the importance of dealing with issues of race and historical justice in order to make the program successful. In the United States, some program managers have also sought to address issues related to age and gender. For example, the Ohio River Basin Water Quality Trading Project directs money from the electric power industry to farmers to support on-farm improvements to reduce runoff and pollution. A concern was raised early on that the early adopters would be all younger, male farmers (Jessica Fox, EPRI, personal communication, 2015) because they would be more open to new ideas. Also, there are fewer woman-owned farms in the region compared with those owned by men. As a result, the managers of this program have made a particular effort to involve women farmers and older farmers.

Some critics have suggested that WQT programs could perpetuate or worsen environmental justice problems. The environmental justice movement in the United States has focused on the fact that pollution often occurs in areas where many poor and minority people live or work, and that disadvantaged communities bear an unfair burden of exposure to pollution. There is a possibility that trading could allow pollution "hot spots" to continue, with accompanying environmental justice concerns. For example, a polluter could purchase credits instead of making onsite pollution reductions.

This was the subject of a 2013 lawsuit by Food & Water Watch against the Chesapeake Bay Nutrient Trading Program, which was later dismissed by a federal judge (Hauter, 2013).

Trading programs are most effective when they cover pollutants with "far-field" impacts, meaning their effects are felt over a large area or over a long time period. Indeed, a thriving market under a cap could allow pollution hot spots to continue unchecked, and thus would be inappropriate for regulating pollutants which have acute local impacts. "This is the reason no one has seriously contemplated a market for toxics," according to Cy Jones, a World Resources Institute (WRI) senior fellow (personal communication, 2015). This issue is less important when trading operates within discrete basins. The larger the basin in which trading is allowed, the more chance there is to exacerbate hotspots. For this reason, some programs have rules restricting trading to smaller sub-watersheds, as has been done in the Ohio River program described above.

Necessary, enabling, and limiting conditions

In this section, we discuss the minimum conditions that are *necessary* for the creation and successful operation of a water quality market, followed by a discussion of conditions that can *enable* WQT markets. These enabling factors will increase the market's likelihood of succeeding but may not be required for it to be established. Finally, we discuss factors which may *limit* WQT markets by acting as barriers or obstacles.

Necessary conditions for a successful water quality trading program include the following three circumstances. The first is the presence of a regulator and its ability to set a cap on pollutants, monitor pollution, and verify the legitimacy of water quality credits that are created. Thus, the regulator must have the scientific and technical capacity to set water quality goals, and monitor water quality to ensure that those goals are being met. To do so first requires a set of "desired future conditions" for a particular waterbody. This may be set by law, custom, or local preferences. In the United States, the Clean Water Act established the concept of "designated use" for waterways (i.e. swimmable, boatable, or fishable), with water quality standards then developed based on the designated use. The process of developing a standard requires understanding the basic physical, environmental, and human elements of the watershed. Generally, scientists or engineers collect data and use computer models to determine the natural and human pollution sources (i.e. diffuse nonpoint sources and point discharges). They also use models to determine how much of a pollutant a water body can assimilate while restoring or maintaining beneficial uses.

"It is one thing to set up a water quality market; it is another for active trading to take place."

The second necessary condition is that polluters have the ability to create water quality improvements, or reduce pollutant discharge through technology or management. Further, the regulator must be able to verify that these pollution reductions are real and likely to last. Verification of credits can be cumbersome and time consuming, which can inhibit trading. Regulators may require field visits or photos to show that on-farm improvements have been properly installed and maintained. In the case of the Alpine Cheese Trading Program, soil conservation agents ensure that pollution control measures installed on farms meet "stringent engineering specifications" (Mariola, 2009). Implementation requires up to eight visits to a farm from project start to finish, and a full-time agent is required to coordinate a program involving one credit buyer and 25 farmers. In some cases, however, the role of verification falls to a trusted intermediary, as in the case of the South Nation River Program in Canada, where a conservation nonprofit hires local farmers to conduct field inspections (O'Grady, 2011). More often however, inspections and record-keeping are conducted by state or local governments. According to the US EPA, "mechanisms for determining and ensuring compliance may include a combination of record keeping, monitoring, reporting and inspections" (US EPA, 2003). There are other aspects of regulatory oversight necessary to ensure accountability on behalf of both buyers and sellers of credits. This oversight includes many aspects of a trading program:

- establishing trading eligibility
- tracking of trades
- verification of credit generation
- compliance and enforcement
- monitoring of results
- program assessment.

It is especially difficult and usually impractical to measure nonpoint source pollution reductions, for example, from projects designed to reduce polluted runoff from farms. The pollution source is usually spread out, and there is no obvious place to measure the discharge (as there would be at the outfall of a factory). Nonpoint source pollution also tends to be "episodic", occurring when rainfall flushes pollutants into waterways, further thwarting measurement efforts. Regulators have adopted several approaches to deal with these issues. Nonpoint source pollution reductions are most often estimated based on prior studies or modeling. To address the uncertainty associated with these estimates, regulators may place a higher burden for pollution reductions on nonpoint sources. Indeed, some markets have been designed with "trading ratios" where nonpoint source reductions trade against point sources at a ratio of 2:1 or 3:1.

The third necessary condition is an appropriate legal framework enabling trading. Some of the legal requirements for water quality trading are similar to those for other market-based instruments. Broadly, programs require a legal environment that will uphold the rights of buyers and sellers. Some basics, as outlined by Greiber (2009), include:

- a legal system that recognizes agreements must be kept
- a civil law providing contract parties with legal remedies to enforce contract rights in cases of non-compliance with contract obligations
- general respect for the rule of law.

Enabling conditions required for creation of a water quality trading program go beyond these basics. First, the government regulator must have the authority to set discharge limits to protect waterways. Second, the regulator needs the power to issue and enforce water pollution discharge permits. Enforcement, with the threat of meaningful fines or criminal penalties, is especially important. As Abraham Lincoln famously noted, "laws without enforcement are just good advice." Finally, there must be a legal framework by which trading can take place.

It is one thing to set up a water quality market; it is another for active trading to take place. As we have shown, many United States markets have been largely moribund. The following presents what we consider enabling conditions – meaning governments can set up a market without them, but there may be little or no trading. It would be tempting to classify an idle market as a failure, but as we have also seen, some United States markets have seen little trading, but they have been accompanied by an improvement in watershed stewardship and improvements to the environment.

There must be a demand for water quality credits. Demand is the first and foremost enabling condition for trades to take place. Generally, such demand is created by a strong regulatory or non-regulatory driver.[27] In the case of the Alpine Cheese Nutrient Trading Program described above, factory owners wished to expand production, but were unable to do so because of a restrictive discharge permit. Violating the permit could have resulted in fines or criminal charges. The factory owners faced otherwise undesirable options: they could

[27] An example of a non-regulatory driver could be where industrial emitters decide among themselves to voluntarily limit pollution to gain goodwill or in an attempt to pre-empt regulation. This is the case in the Ohio River study discussed above, where electric power companies have funded projects to reduce pollution from farms in their watersheds. These activities are not compulsory, so why would a for-profit corporation do it? Their motivation, as put forth by the program's manager in Congressional testimony is "to meet corporate sustainability goals and their voluntary participation may also be considered by the state permitting agencies when determining the need for flexible permit compliance options in the future" (Fox 2014). In other words, she was saying that companies hope that their activities today will buy them goodwill with regulators and that future regulation will be less burdensome as a result.

relocate the factory, install expensive onsite wastewater treatment, or stop production altogether. In Australia's Hunter River, salty discharge from mines was affecting the drinking water supplies for downstream cities, and an inflexible basin cap would have meant that existing mines could not expand and new industries could not develop. In other cases, industries are interested in mitigating their own pollution to create goodwill or to help lessen the burden of future regulation. This is the case for power companies in the Ohio River Basin. At present, large power companies such as Duke Energy, the largest electric power holding company in the United States with some 7.3 million customers, and American Electric Power, which has over 5 million customers, purchase credits "to meet corporate sustainability goals and their voluntary participation may also be considered by the state permitting agencies when determining the need for flexible permit compliance options in the future" (Fox, 2014).

In addition to demand, there must be willingness to engage in trade among buyers and sellers. One observer cited the most frequent roadblock to establishing a WQT program as the "simple absence of willing buyers and sellers" (O'Grady, 2011). In WQT markets, demand for the commodity (pollution credits) "is artificially created by regulatory decree and which cannot be seen or felt or even measured with precision" (Mariola, 2009). Because the market is entirely dependent on a regulatory driver, it can be fragile and susceptible to interference by politicians or the courts. For example, the United States Acid Rain Program (ARP), the nation's first national cap-and-trade program, suffered a series of legal challenges beginning in 2008, culminating in new rules in 2011 that severely limited trading between states. As a result, the market, which relied heavily on interstate trading, collapsed. In 2012, the market value of a credit to emit a ton of sulfur dioxide was less than $1. Previously, these same credits had sold for $100 to $200 for most of the last decade and peaked at $1,200 per ton in 2005 (Schmalensee and Stavins, 2013). The ARP's collapse is worth pausing to consider, as it was the model for all subsequent environmental markets. Schmalensee and Stavins (2013), economists from MIT and Harvard who studied the program, concluded that, by all accounts, it was a major success: following its launch in 1995, the market performed "exceptionally well along all relevant dimensions" and helped the United States reach emissions goals in 2006.

However, the market's collapse should be a cautionary tale: "When the government creates a market, it can also destroy it, possibly fostering a legacy of increased regulatory uncertainty and reduced investor confidence in future cap-and-trade regimes, and hence reduced credibility of pollution markets more broadly" (Schmalensee and Stavins, 2013).

"In addition to demand, there must be willingness to engage in trade among buyers and sellers."

Trust among market participants is a key element of any WQT program. In the United States, most water quality markets involve point sources purchasing pollution reduction credits from farms, or less frequently, from forests or other nonpoint sources. Controlling nonpoint source pollution from agriculture faces unique obstacles. Farmers often distrust regulators, and worry that participation in a trading program may open the door to future regulation. Some pilot programs in the United States have worked through local soil and water conservation districts, or made use of agricultural extension services, because the farmers know and trust these agents. In fact, Mariola (2009) found the most important factor for program success was "the use of a local, trusted, embedded intermediary as the link between programs and farmers emerges as the most important explanatory variable for program success."

Canadian WQT managers have come to similar conclusions. In the South Nation River watershed, wastewater dischargers face a cap on phosphorus discharge, and new wastewater systems are purchasing phosphorus credits from rural landowners, mainly farmers. Initially, the agricultural community had reservations about the program. One of the main concerns raised by farmers during the design of the South Nation program was their future liability.

"When trades can only take place within a single state or country, it reduces the potential for … water quality improvements."

Organizers confronted this concern during a series of public meetings and then added a key phrase to their final document that addressed the farmers' concerns and allowed trading to begin (O'Grady, 2011) – the phrase was: "Landowners are not bound, legally or otherwise, to attain the predicted phosphorus offset through the establishment of a BMP [best management practice, another term for an on-farm pollution control measure] on their property." Further, control of the program was granted to South Nation Conservation, a community-based watershed organization that was trusted by farmers. In addition, the program is run by a multi-stakeholder committee, "and all project field visits are done by farmers and not paid professionals." As a result, the program has been able to overcome much of the early resistance. An independent evaluation showed that most farmers had a high opinion of the program and have recommend the program to other farmers in their community (O'Grady, 2011).

The ability to trade water quality credits across regional borders may be an important enabling condition, depending on the geography of the watershed. Many important watersheds extend across multiple states, or across international boundaries. When trades can only take place within a single state or country, it reduces the potential for trading and for water quality improvements (Fisher-Vanden and Olmstead, 2013). In 2012, the pilot Ohio River Basin Trading Program became the first program in the United States to allow trading across state borders, with an agreement signed by the states of Ohio, Kentucky, and Indiana (Fox, 2014). Lessons learned from the Acid Rain Program suggest that legislation may be necessary for interstate programs: "the series of regulations, court rulings, and regulatory responses … affirmed that EPA cannot set up an interstate trading system under the Clean Air Act in the absence of specific legislation" (Schmalensee and Stavins, 2013).

Limiting conditions for water quality trading may be created by existing laws, policies, and institutions in some regions. Greiber (2009) described a number of possible concerns related to the legal and institutional frameworks for environmental markets. Unrelated laws may contradict the aims of a market by, for example, providing perverse incentives to polluting industries or restricting innovative ways of funding environmental projects. Land tenure is a key concern in some countries, as farmers without tenure may have little incentive to participate in programs if they do not own land and their futures are more uncertain.

Irrigation near Castroville, CA. Photograph by Gwendolyn Stansbury.

4

Role of the private sector

The private sector participates to some degree in all of the instruments described in the previous section. For example, in Michigan's Paw Paw River Watershed, Coca-Cola North America and other stakeholders recently developed and implemented a performance-based PWS program to compensate farmers for implementing practices that reduce soil loss and enhance groundwater recharge (Forest Trends, 2015b). The private sector also participates as a buyer or seller in water quality trading programs to comply with water quality regulations, or buys or sells water rights through water trading programs. In addition to these incentive-based instruments, the private sector may participate in a range of voluntary initiatives to, for example, restore or protect a watershed or provide water service to local communities. Moreover, they may employ incentives within their direct operations or supply chains to promote water stewardship. In this section, we describe some of the drivers for private sector engagement in water stewardship, provide examples of their participation in incentive-based programs, and provide an initial estimate of their investment in these programs.

"Companies ... understand their relationship to water in terms of their water footprint and their water-related business risk."

4.1 Corporate water stewardship

To produce goods and services, most companies rely on a consistent supply of adequate quality source water and permission to discharge wastewater. As population growth and economic development push the limits of renewable freshwater supplies and business-as-usual resource management strategies, and as rapid urbanization, water pollution, groundwater depletion, and climate change introduce new water-related risks, companies face increasing urgency to respond.

Companies typically come to understand their relationship to water in terms of their water footprint and their water-related business risk. A water footprint assessment – which estimates the volume of water consumed and polluted in the production of a material or a product, or in the operation of an entire business, industry, or nation – can help managers more fully understand the nature and extent of a company's dependence and impact on water resources. It is also appealing as a basis for setting targets to reduce water use related to, for example, manufacturing processes or production of agricultural raw materials. While a water footprint assessment can inform a risk assessment, a volumetric footprint measurement omits the local context necessary to characterize the risks related to water use, and obscures the difference in impact between using water from a source that's plentiful and using the same volume of water from a source that's overexploited or not readily replenished.[28]

Water-related business risks generally fall into three broad and interrelated categories:

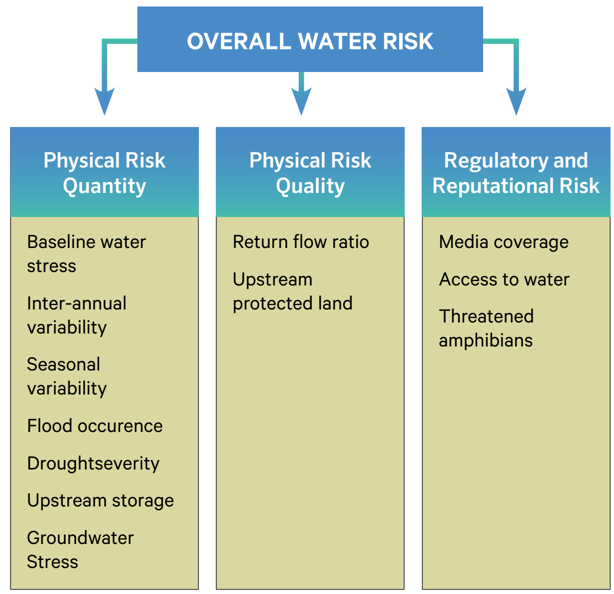
- *physical risks* include scarcity, degraded source water quality, and flooding
- *regulatory risks* relate to inconsistent, ineffective, or poorly enforced public policy, particularly when a change in regulation or enforcement could disrupt production or lead to an unexpected cost of compliance
- *reputational risks* are faced by companies that overexploit or are perceived to overexploit water resources – including inefficient use, water pollution, excessive withdrawal, competition with other users, or other negligent water-related activities.

All three categories of risk include financial impacts from increased operating costs, fines or unplanned capital expenditures, supply chain disruptions, damage to the value of a brand, or lost access to markets.

Increasingly, businesses are taking steps to identify, characterize, and mitigate these risks. For example, the Aqueduct Water Risk Atlas, a web-based tool produced by the World Resources Institute, identifies which and how many locations in a company's operations or supply chain face water-related risk in 12 dimensions, as shown in Figure 7. The Water Risk Filter, an online tool launched by the World Wide Fund for Nature (WWF) and the German Investment and Development Corporation (DEG), assigns each water-using location a score that incorporates both location-specific and company-specific risks, based on criteria such as the average water intensity or typical level of water pollution generated by suppliers to a particular industry sector (WWF and DEG, 2014).

[28] Water "neutrality" or "offsets" are related concepts, similar to carbon neutrality or carbon offsets. They imply that a company can compensate for the negative impacts of its water footprint. However, there is no standard for measuring negative impacts or defining which types and how much of any given activity is sufficient compensation (Hoekstra *et al.*, 2011).

FIGURE 7. Water risk indicators



Source: Gassert *et al.*, 2013.

Effective water resource management systems and regulatory frameworks, the performance of which can be enhanced by incentive-based instruments, benefit companies in a number of ways.

- As water users, companies benefit from a more reliable and higher quality supply of water.
- As polluters, businesses benefit from opportunities to manage the cost of compliance over time, and to seek innovative approaches to improve the quality and reduce the volume of wastewater.
- As ratepayers and taxpayers, companies benefit by avoiding the cost of adding new or expanding existing supply.

Efforts to reduce water-related business risks typically occur at three scales: within *direct operations*, in *supply chain* agricultural or manufacturing operations that are not within a company's direct control, or *outside the fenceline* of both owned and supply chain properties, where water-related risks are driven more by sociopolitical, hydrological, or ecological conditions than by the actions of the company or its suppliers.

- **Direct operations.** Companies that recognize water-related business risks often begin working voluntarily with direct operations – owned and operated offices, distribution or retail facilities, manufacturing facilities, farms or other means of production – to mitigate those risks. In direct operations, companies can plan and manage implementation internally and realize cost savings related to obtaining, pumping, heating, or treating smaller volumes of water when operational efficiencies are achieved.
- **Supply chains.** From agricultural raw materials to water- and chemical-intensive manufacturing processes, most companies face challenges managing water-related business risks in their supply chains, including those with advanced water stewardship practices in their direct operations. In many cases, complex business models and limited traceability are significant obstacles to quantifying corporate water footprints and identifying water-related business risks that exist in global supply chains.
- **Outside the fenceline.** Facilities that maintain industry average or better water efficiency and wastewater quality may not be immune to all water-related risks. The term "outside the fenceline" refers to conditions and activities outside the physical footprint of a production site. Water-related risk is said to originate outside the fenceline in regions where, for example, source water is scarce or polluted, projected demand exceeds renewable supply, regulations are inconsistent or nonexistent, or lack of access to water and sanitation damages public health. While internal process or policy changes are easier to implement, they would not necessarily mitigate these risks.

The private sector increasingly recognizes the need to evaluate site-level water use in the context of its local watershed characteristics, in order to inform and prioritize efficiency targets for different locations. For example, companies can manage risk more effectively by giving higher priority to efficiency improvements for water-intensive locations in drought-prone locations than for similar facilities where water resources are more plentiful.

Another recent development is the idea of engaging outside the fenceline. Leading companies understand that collective action with other stakeholders at the watershed scale may be required to address root causes of resource scarcity, accessibility, or source water quality, which can increase costs or disrupt operations. The Beverage Industry Environmental Roundtable (BIER), a coalition of business leaders in an industry that faces substantial water-related reputational risk, has acknowledged that in some locations, watershed-level interventions may in fact be more effective at mitigating water-related risk than facility-level water-use efficiency or other activities (BIER, 2015). To assist companies in prioritizing their efforts, BIER has proposed developing a decision support tool that could give more priority to intervention outside the fenceline than to internal efficiency or water quality improvements.

"Most private sector watershed investment activity ... took place in North America, Europe, and Africa."

4.2 Private sector engagement with incentive-based instruments

Private sector participation in incentive-based instruments, such as PWS and water quality trading, has been relatively modest but is growing. Bennett and Carroll (2014) found that in 2013, the private sector invested US$41 million in watershed services that supported "watershed restoration or protection that delivers benefits to society." While this represents more than twice the estimated private sector investment of $19 million to $26 million in 2011, it is still a very small portion of the overall $12.3 billion invested collectively in watersheds by governments, business, and individual donors in 2013. Most private sector watershed investment activity (about 95 percent) took place in North America, Europe, and Africa (Bennett and Carroll, 2014).

Incentives for private sector investments. Industry sectors with the highest levels of investment in watershed services (IWS) were energy utilities, water utilities, and the food and beverage industry, with investments of US$9.3 million, $8.9 million, and $8.8 million, respectively. The primary reported motivation for spending on watershed services was regulatory compliance, followed by water availability risks, water quality risks, corporate social responsibility and reputational risk, and biodiversity protection (Bennett and Carroll, 2014). The food and beverage sector, which accounted for nearly one-quarter of the total corporate investment in watersheds, is unlike other sectors in that it is driven primarily by water availability and water risks, rather than regulatory compliance. Bennett and Carroll (2014) found that 88 percent of buyers in the food and beverage industry acted voluntarily, compared with the private sector average of 31 percent.

For example, in 2012–2013, the Coca-Cola Company and its global bottling partners were involved in 20 projects around the world, buying at least $2.2 million in watershed services (Bennett and Carroll, 2014). Separately, the company publishes annual reports detailing its involvement in hundreds of other projects (LimnoTech, 2013). Indeed, the Coca-Cola Company is among a handful of private companies with a public commitment to "replenish" the water it uses.[29] However, as Coca-Cola acknowledges, the impacts of water use are specific and local, making it impossible for a multinational corporation to offset water use at the enterprise level. Rozza *et al*. (2013) described a detailed methodology for quantifying the value of Coca-Cola's replenish projects, including source water protection, water reuse for conservation or productive uses, and community-level sustainability projects. The company also requires its bottling plants to complete source water vulnerability assessments and to engage in the development of source water protection plans, which provide opportunities for projects within the corporate replenish initiative to directly mitigate risks in the global supply chain. Other projects' impacts, such as those related to access to water and sanitation or ones where Coca-Cola contributed to a collective action together with other companies, are estimated differently (Rozza *et al*., 2013).

[29] Specifically, Coca-Cola is "Collaborating to replenish the water we use", pledging that by 2020, it will "safely return to communities and nature an amount of water equal to what we use in our finished beverages and their production."

Disincentives for private sector investments. There are also disincentives for private sector investments in public goods, including watershed services. The benefits must be shared with others that did not contribute to the investment, and the benefits could be exhausted by other actors that did not participate in the collective action or investment (Meißner, 2013). However, when the consequences of inaction are significant, there is a compelling case in favor of policy engagement, collective action, and investment in water-related initiatives outside the fenceline, including preservation of resources or delivery of ecosystem services via incentive-based instruments.

Among the barriers that prevent the private sector from participating more fully in watershed investments are three critical core competencies needed to achieve measureable outcomes with specific benefits for at-risk locations, which most companies do not possess:

- scientific and environmental engineering expertise to identify, design, and implement watershed-level solutions
- a nuanced understanding of the local environment and culture in the watershed where they seek to have a positive environmental outcome
- experience with partnerships involving diverse stakeholders outside the fenceline.

Therefore, in cases where companies identify risk and choose to take action at the watershed level, particularly if they choose to do so in more than one location across diverse global operations or an extended supply chain, it is helpful and sometimes necessary to involve an intermediary. Stanton *et al*. (2010) defined an intermediary as "any party other than the buyer or seller who

TABLE 3. Private sector activities, scale, drivers

ACTIVITIES, COMPLEXITY, INCLUSIVITY		
Operational efficiency Wastewater quality Owned facilities	Codes of conduct Social/environmental indices Voluntary sustainability standards Industry sector/association	Policy engagement Collective action Diverse stakeholders
SCALE		
Site-specific Small business	Supply chain Small to medium enterprise	Landscape Multinational
TIME/VALUE		
Near-term, return on investment	Medium-term, possible value capture	Long-term, sustainability
DRIVERS		
Financial self-interest Regulatory compliance	Externalities License to operate	Reputation Access to markets
EXTERNAL CONDITIONS		
Strong governance and enforcement	Inconsistent local regulation and enforcement	Weak governance Negative externalities of other actors

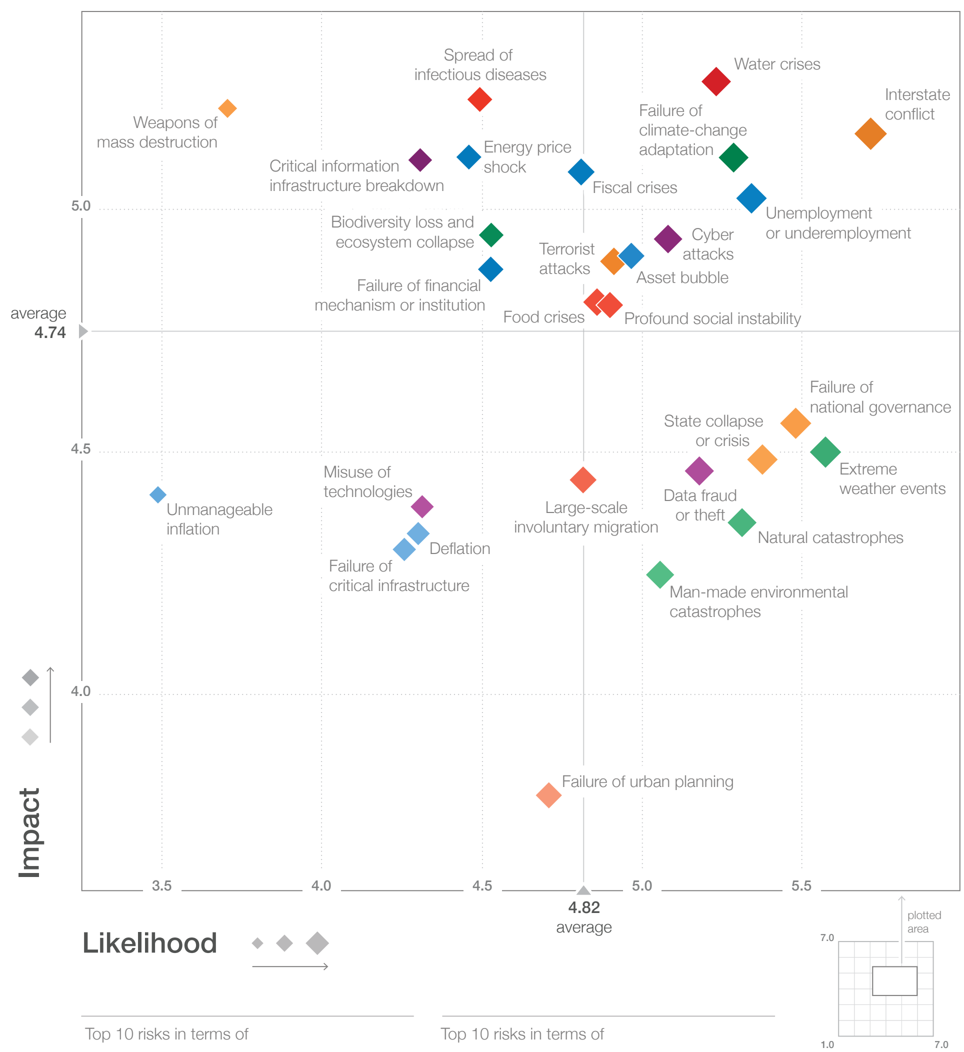
helps facilitate some aspect of the transaction or implementation of the overall program. This role is commonly played by NGOs, consultants, or academic institutions." Indeed, Coca-Cola has had to coordinate large-scale bilateral partnerships with more than one intermediary in order to achieve progress toward its global replenish objective, including The Nature Conservancy, WWF, and the United Nations Development Programme (UNDP). Table 3 illustrates increasing complexity and differences in motivation that companies face as they move from addressing efficiency in direct operations to engaging in collective action intended to create more sustainable operating conditions in watersheds where they do business.

Future investments by the private sector are uncertain. However, consumer preference for more sustainable products and investor concern about unmitigated risk are driving increased adoption of water risk assessment across the business community. For example, in its annual survey of leaders and decision makers about perceptions of global risks, the World Economic Forum (WEF, 2015) found that water crises have the greatest potential for impact and are the eighth most likely to occur, as shown in Figure 8. Moreover, WEF has considered water among the top three global risks since 2012 (WEF, 2012; 2013; 2014).

"…there is increasing awareness of water-specific issues and of best practices in corporate water stewardship…"

CDP, formerly known as the Carbon Disclosure Project, operates a water program that surveys companies

FIGURE 8: Global risks landscape, 2015



Top 10 risks in terms of **Likelihood**	Top 10 risks in terms of **Impact**
1 Interstate conflict	1 Water crises
2 Extreme weather events	2 Spread of infectious diseases
3 Failure of national governance	3 Weapons of mass destruction
4 State collapse or crisis	4 Interstate conflict
5 Unemployment or underemployment	5 Failure of climate-change adaptation
6 Natural catastrophes	6 Energy price shock
7 Failure of climate-change adaptation	7 Critical information infrastructure breakdown
8 Water crises	8 Fiscal crises
9 Data fraud or theft	9 Unemployment or underemployment
10 Cyber attacks	10 Biodiversity loss and ecosystem collapse

Categories

- Economic
- Environmental
- Geopolitical
- Societal
- Technological

Note: Taken from 2014 Global Risks Perception Survey. Survey respondents were asked to assess the likelihood and impact of the individual risks on a scale of 1 to 7, 1 representing a risk that is not likely to happen or have impact, and 7 a risk very likely to occur and with massive and devastating impacts. See Appendix B for more details. To ensure legibility, the names of the global risks are abbreviated. Also see Appendix A for the full name and description.

Source: World Economic Forum, 2015.

in order to reveal water-related risk in institutional investment portfolios. CDP's 2014 Global Water Report revealed that, of nearly 1,100 responding companies, 74 percent had evaluated how water quantity and quality could affect their growth strategy. However, of these, only 38 percent assessed water-related risk in both owned operations and their supply chain, and only 25 percent conducted detailed water risk assessments at the watershed level (CDP, 2014).

Concurrently, there is increasing awareness of water-specific issues and of best practices in corporate water stewardship, so there will likely be demand for mechanisms that can deliver quantifiable outcomes to benefit specific corporate assets or at-risk strategic supply chain locations. Increased understanding of water-related risks and opportunities could similarly drive an increase in private sector engagement in incentive-based instruments for watershed services.

Hunter River, Australia. Photograph by AussieLegend.

5

Summary and conclusions

Growing pressure on the availability and quality of water resources is having a major impact on our social, economic, and environmental well-being. These pressures are likely to worsen in response to continued population and economic growth, climate change, and other challenges. As water pollution exacerbates the challenges posed by water scarcity, and the world's water quality becomes increasingly degraded, new approaches and strategies are needed.

One key area of interest is the potential for incentive-based instruments to reduce pressure on water resources. To date, the primary environmental policy tool to address water challenges has been command-and-control regulations. Over the past several decades, however, the environmental policy "toolkit" has expanded to include a host of incentive-based instruments that use financial means, directly or indirectly, to motivate responsible parties to reduce the health and environmental risks posed by their facilities, processes, or products. While regulations and incentive-based instruments are often juxtaposed, "in reality the two often operate alongside each other" (UNEP, 2004). With water quality trading, for example, governments mandate caps on the allowable pollutant levels and issue tradable permits that allow those in the industry to allocate polluting activities among themselves, incentivized by market forces. Similarly, with water trading, governments may allocate water and then institute a framework by which water trading can occur. While incentive-based instruments may work in tandem, they must be integrated within a broader watershed management effort. In a recent review of PWS programs, Bond and Mayers (2010) cautioned that:

> *"PWS is a tool that will fail, or become irrelevant, if it is not integrated with wider regulatory approaches, broader watershed management efforts, and explicit attention to governance influences that shape what is possible. Policy makers need to consider the opportunities to ensure that future policy and legislation allow for a mix of both incentives and regulations to ensure the effective management of land and water resources."*

The choice of whether and which instrument to apply depends on the specific circumstances, conditions, and needs of a given area. It is important to avoid "the law of the instrument", i.e. the tendency to gravitate toward a particular tool and then look for applications of that tool. UNEP (2004) found that:

"Prior to designing and applying any policy instrument for environmental protection, the policy context must be understood, including the existing institutional, legal and economic conditions in which these tools are meant to function. Choosing an effective policy package that will both address the environmental problem policy makers are faced with and fit in with the institutional capabilities and existing policy framework remains one of the most difficult challenges."

This process should be open and transparent, with meaningful participation from all affected parties. This will enable crafting a solution that not only is appropriate for local conditions, it will help reduce opposition and promote buy-in from those who will be implementing and affected by the program. It is important to recognize that those with the least power may not have the resources to participate or be skeptical of the groups involved. In these cases, there will be a need for consistent and rigorous outreach and, potentially, a need for engaging a trusted intermediary.

Finally, monitoring and evaluation are essential to the success of any instrument. In particular, they help ensure outcomes are achieved and allow for adjustments in response to changing social, economic, or environmental conditions. Monitoring should evaluate the additionality of the program, i.e. whether the program has an effect when compared with baseline conditions. It should also examine any potential impacts on surrounding areas (e.g. leakage) and the permanence of the intervention. However, it is important to recognize that extensive monitoring requirements would increase transaction costs. Thus, the need for monitoring and evaluation must be balanced with practical considerations about the ability to maintain the viability of the program.

ANNEX 1

Demand management

A key way to reduce pressure on limited water supplies is through demand management, commonly referred to as water conservation and efficiency. In many cases, reducing demand is equivalent to augmenting or reallocating water supply. Demand management is typically less expensive and faster to implement than water supply augmentation, and often results in reduced energy demand and water and wastewater treatment costs. For example, a recent study in Westminster, Colorado, found that water conservation and efficiency since 1980 had reduced water use in the city, reducing tap fees by 80 percent and reducing customers' bills by 91 percent relative to what they would have been without these efforts (Feinglas, Gray, and Mayer 2013). In major cities, such as San Francisco and Los Angeles, total water use has *decreased* since the late 1970s despite population and economic growth. At a larger scale, a recent United States federal study found that water conservation and efficiency efforts have reduced annual demand for water from the Colorado River basin by more than 1.7 million acre-feet, a tremendous savings in an over-allocated basin (US Bureau of Reclamation 2015). In the United States, we have made considerable progress in managing the nation's water, with total water use less than it was in 1970, despite continued population and economic growth. Indeed, every sector, from agriculture to thermoelectric power generation, shows reductions in water use. Likewise, in Australia, a severe drought in the middle of the last decade prompted an intensive effort to reduce water demand. In response, total urban demand, including losses and non-residential consumption, fell from about 130 gallons per capita daily (gpcd) in 2005 to about 80 gpcd in 2010 (Queensland Water Commission, 2010).

There are many tools available to reduce water demand – some of which rely on an incentive-based approach, e.g. pricing and rebates, while others are based on a more traditional command-and-control approach. Numerous studies have shown that significant conservation and efficiency opportunities exist in urban and agricultural areas (see, e.g. Gleick *et al.*, 2003; Heberger, Cooley, and Gleick 2014). Below, we provide additional detail on the major demand management tools, including pricing, direct financial incentives, regulations, and education and outreach.

Water pricing. Well-designed tariff structures can meet multiple policy objectives, including supporting the financial stability of the utility, the affordability of water for low-income customers, the efficient allocation of water and other resources, and environmental sustainability. Most water utilities use some form of volumetric tariffs to achieve these objectives. There are several types of volumetric tariffs in use around the world:

- uniform tariffs in which the volumetric tariff ($/m3) is constant regardless of the quantity used;
- inclining block tariffs in which the volumetric tariff increases as the quantity used increases; and
- declining block tariffs in which the volumetric tariff decreases as the quantity used increases.

Uniform tariffs are the most common tariff structure in OECD and in developing countries (OECD 2009). Inclining block rates are becoming increasingly common (OECD 2009), as there is recognition that when designed properly, this approach can provide a strong financial incentive to conserve while ensuring that lower-income consumers are able to meet their basic water needs at a reduced cost. A 2003 survey of cities in the southwest United States found that per-capita water use is typically lower in cities with dramatically increasing block tariffs, such as Tucson and El Paso (WRA 2003).

Although less frequently employed, pricing has also been shown to be effective in reducing agricultural water use. For example, the Broadview Water District, a small district in California's San Joaquin Valley, implemented increasing block rates in 1988 to reduce the volume of contaminated drainage water flowing into the San Joaquin River. The rate was set at $16 per acre-foot ($0.013 per m3) for the first 90 percent of average water use during the 1986 to 1988 period and $40 per acre-foot ($0.032 per m3) for any additional water. By 1991, the district's average water use declined by 19 percent due to efficiency improvements and crop shifting (MacDougall *et al.,* 1992).

Direct financial incentives. Rebate programs are commonly used to encourage customers to make investments in water conservation and efficiency improvements. Residents and business owners purchase new devices as the old devices wear out. While most new standard devices use less water than older models, there are many new high-efficiency devices available that use even less water. While efficient devices are often cheaper over their lifetimes due to lower water, energy, and wastewater bills, users may be put off by the higher up-front costs. As a result, water utilities may provide their customers with a rebate to defray the additional cost of the more efficient device. There are several examples of water utilities partnering with local energy utilities to augment those rebates because of the energy savings (Cooley and Donnelly 2013). Additionally, utilities may partner with retailers to offer rebates at the point of sale, giving customers an immediate incentive to purchase the more efficient device.

Instead of providing rebates to cover a portion of the cost, some utilities have opted to institute direct-install programs that cover the entire cost of the device and the installation costs. In the mid-1990s, for example, the New York City Department of Environmental Protection launched a massive toilet rebate program to replace one-third of all water-wasting toilets in New York City with low-flow models. For this effort, property owners contracted directly with private licensed plumbers for the installation of the toilet, and after completion of the work, the City provided the property owner with a $240 rebate for the first toilet and $150 for the second toilet. Where possible, the plumber would also install low-flow showerheads and faucet aerators. The program was a huge success. Between 1994 and 1997, 1.3 million low-flow toilets were installed, saving 70 - 90 million gallons per day. Customers saw their water and wastewater bills drop 20 percent to 40 percent (EPA 2002). Additionally, the City was able to defer the need to develop new supply sources and expand wastewater treatment capacity, saving the community even more money.

Regulations. In addition to financial incentives, regulations are key demand management strategies. Regulations can take a variety of forms, ranging from a prescriptive approach focused on a particular appliance to a performance-based approach for outdoor water use. For example, the International Plumbing Code, which is widely used in the United States and forms the basis for plumbing codes in several other countries, specifies maximum flow rates for kitchen and lavatory faucets. Likewise, communities in the Las Vegas area have restricted lawn installation in new developments. California has also passed an ordinance to reduce outdoor water use, although the state opted for a performance-based approach. Landscape irrigation typically accounts for more than half of residential demand in the state, and in an effort to promote outdoor efficiency, the state adopted the Model Water Efficient Landscape Ordinance (MWELO). MWELO establishes a water budget for new construction and rehabilitated landscapes that are at least 2,500 square feet and require a building or landscaping permit (the size threshold is likely to be reduced to 500 square feet in response to the current drought). In addition, the ordinance requires mulching for most plantings; promotes the use of techniques to increase stormwater retention and infiltration; and requires new and refurbished landscapes to install irrigation systems run by weather, soil moisture, or other self-adjusting controllers. Also in California, Governor Schwarzenegger signed SBx7-7 in 2009, requiring urban water suppliers to reduce per-capita water use by 20 percent by 2020.

Education and outreach. Education and outreach programs can also be effective for promoting water conservation and efficiency. The US Environmental Protection Agency (EPA), for example, launched the WaterSense labeling program in 2006 to promote water-conserving devices that are 20 percent more efficient than standard products on the market and meet rigorous performance criteria. Social marketing has also gained prominence in recent years, with some programs tapping into new metering technologies and web-based platforms. For example, a recent study found that home water reports - which provide customers information on their current water use and comparisons to their past use, use by similar households, and efficient use - reduce water by 5 percent and were especially effective in reaching the highest water users (Mitchell and Chesnutt 2013).

ANNEX 2

Water trading in Australia:

Lessons from the Murray-Darling Basin

Australia's Murray-Darling Basin (MDB) figures prominently in discussions about water trading as an example of a thriving incentive-based system that successfully transitioned from a non-market system (Grafton *et al.*, 2012). The total value of water trading in Australia in fiscal year 2012-13 exceeded $1.4 billion (NWC 2013). Water trading in Australia includes both short-term trades, known as allocation trading, and long-term trades, known as entitlement trading. In fiscal year 2012-13, the most recent period for which comprehensive data are available, the total volume of short-term trading increased 44 percent from the previous year, from almost 3.5 million acre-feet to 5 million acre-feet, or roughly 50 percent of total surface water use in the MDB. This is an extremely active water market.

Background

The MDB covers some 390,000 square miles in southeastern Australia, comprising roughly 14 percent of that country's land area. Most of the basin is very arid, with 86 percent of the basin contributing little or no flow to rivers that drain the basin. The Murray-Darling Basin Authority (MDBA) estimates that total runoff within the basin is less than 26 million acre-feet annually, yielding an estimated long-term annual average 19 MAF of total river flow. As shown in Figure A-1, the system displays very high seasonal and annual variability. For example, flows in the southern Murray basin typically are much higher than in the northern Darling basin. Pre-development, an estimated 10 million acre-feet ran into the ocean; in 2009, during the historic Millennium drought, this had decreased to 4 million acre-feet.

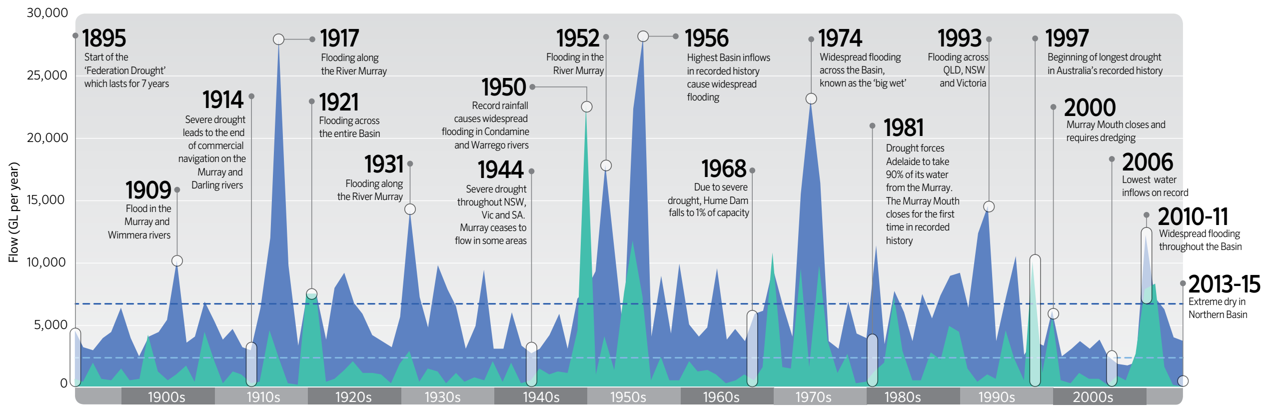
The MDB includes parts of four states (Queensland, New South Wales, Victoria, and South Australia) and the Australian Capital Territory. The MDB supplies water to about three million people, including the national capital (Canberra) and Adelaide, outside of the basin near the river's mouth. According to the MDBA, the basin contains some 70 percent of the nation's irrigated acreage, producing a third of the country's food supply. The MDBA reports the gross value of irrigated agriculture in the basin in 2012-13 at approximately $6.8 Billion. The MDB generates almost all of Australia's rice and cotton and 75 percent of its grapes, as well as roughly half of the nation's hay, fruit, livestock, and dairy production.

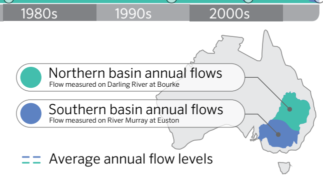
The construction of dams and canals and the diversion and depletion of MDB rivers has endangered the survival of at least 35 bird species and 16 mammal species within the basin. Many fish species, including the Murray cod, are also threatened. Wetlands have dried up or reached critically low levels, exacerbated by the Millennium drought, prompting public concern.

MDB and the Colorado River Basin

The MDB and the Colorado River Basin share many common traits: both are highly variable rivers in arid basins, where rapidly-growing urban populations have imposed new demands on limited, climate-stressed rivers. Basin size and runoff are similar. And, interestingly, the two basins share a common figure: Elwood Mead (namesake of Lake Mead), the Wyoming State

FIGURE A-1. Historical river flows within the Murray-Darling Basin





Note: Volumes in the figure shown in gigaliters, with 1000 GL = 0.8 million acre-feet.

Source: Australia's MDBA.

Irrigation Engineer from 1888-99, went on to serve as the Chairman of Victoria (Australia)'s State Rivers & Water Supply Commission (1907–15), prior to returning to the US and serving as the Commissioner of the Bureau of Reclamation from 1924-36 (McLeod 2014). However, Australia avoided Mead's legacy of prior appropriation and hierarchical water rights to embrace a very different system that promotes and facilitates water trading, as described in the following sections.

History

Australia has promoted and developed water trading over a period of more than 30 years (Grafton *et al.*, 2012), in a process that initially attempted to activate markets prior to recognizing that the water rights structure itself needed to be altered to encourage active trading and minimize transaction costs (Young, 2015). Table A-1 lists some of the major steps taken to create the current water trading structure. These changes have occurred over several decades and often reflect corrections to previous policies. Young (2010, 2015) asserts that Australia implemented water trading from the wrong direction, by first promoting trading and subsequently changing the water rights structure to facilitate trading and protect environmental resources.

In Australia, water rights typically refer to either entitlements or allocations.[30] The National Water Initiative of 2004 defines these as:

- **Water access entitlement** – *a perpetual or ongoing entitlement* to exclusive access to a share of water from a specified *consumptive pool* as defined in the relevant water plan.
- **Water allocation** – the specific volume of water allocated to water access entitlements *in a given season*, defined according to rules established in the relevant water plan. (Young, 2010).

Australian water rights are typically defined as the right to *divert* a specific volume, as opposed to a *consumptive use* right that is more typical with prior appropriation

[30] Additional water rights include: *Water use license* – a non-tradable use or condition linked to the place of use; and *Delivery right* – may be required to ensure that an allocation is delivered, typically associated with irrigation infrastructure, such as canals and headgates (Grafton and Horne 2014).

regimes (Connor and Kaczan, 2013). Diversions can be measured (and subsequently traded) more readily than consumptive use, which requires measurement of both diversions and surface and sub-surface return flows. Return flows often lag diversions, sometimes by weeks or months in the case of sub-surface returns, requiring more complicated measurements and estimates, challenging efforts to evaluate and quantify the full impacts (especially environmental impacts) of the trade, hindering transactions.

Initially, Australian water rights were linked to a specific land parcel. In many cases, the water right simply entitled the landowner to sufficient water to irrigate the land. Transforming these general land-based rights to discrete volumes then required determining historic usage patterns and water requirements for crops grown on that land. Several MDB states initially allowed water trading within individual irrigation districts, using shared infrastructure to trade water to different parcels within the district. These volumetric rights were subsequently "unbundled" from the land, enabling water to be traded between different irrigation districts. Despite these changes, restrictions on trading between different sub-basins often took years to revoke, due to concerns about adverse economic and equity impacts that trading could cause in areas of origin (Grafton and Horne 2014).

TABLE A-1. **Policy and legislative milestones**

YEAR	ACTION	DESCRIPTION
1960s	Volumetric water licenses	Start of conversion of land-based water entitlements to volumetric entitlements
1983	Water trading w/in districts	Allowed in New South Wales and South Australia
1987	1st MDB Agreement	Established the MDB Commission, to coordinate management
1991	Inter-district water trading	Allowed in New South Wales
1994	"Unbundling"	Council of Australian Governments agrees to separate statutory land rights from water rights, facilitating trading
1995	Diversion CAP implemented	Limits surface water diversions in the MDB; limits water rights
1995	National Competition Policy	Requires development of water markets and full-cost pricing
2000	Water Management Act	"Unbundles" diversion and use rights
2004	National Water Initiative	Promotes cohesive water planning and trading efforts
2004	Living Murray Initiative	Authorizes purchase and dedication of 0.4 MAF to the river
2007	Water Act	Promotes management of MDB
2008	Water Amendment Act	Establishes MDB Authority, replacing the Commission
2008	Water for the Future	Commits $3.1 billion to purchase water entitlements for the env.
2012	MD Basin Plan	Caps total MDB surface diversions at 8.8 MAF, coordinates basin management including water quality (esp. salinity)

Sources: MDBA, Young, 2010; Grafton and Horne, 2014.

Unlike the doctrine of prior appropriation in the western United States, water rights in Australia did not have priority dates or a seniority system for satisfying demands: all rights were considered equivalent. Additionally, Australian water rights did not have to be exercised on an annual or periodic basis to demonstrate possession (again, unlike the prior appropriation system); many rights holders maintained their rights for periodic or infrequent use (known as "dozer" rights) or never exercised their water rights (known as "sleepers"), perhaps in the expectation that they might be needed in the future.

The 1995 imposition of the diversion CAP limiting surface water diversions and rights within the MDBA explicitly recognized the continuing validity of dozer and sleeper rights and incorporated the volumes of these rights into the general calculation of the proportional shares of the new water rights regime. However, the result of recognizing dozer and sleeper rights within the context of water trading was to increase the financial value of these unexercised rights, leading to new diversions and greater strain on water supply, in turn reducing water reliability (Grafton and Horne 2014). Tony McLeod, General Manager for Water Planning at MDBA, explained that the recognition of these dozer and sleeper rights was intentional, to reduce resistance to the imposition of the CAP and smooth the transition to the new system of proportional sharing (McLeod, personal communication, 2014).

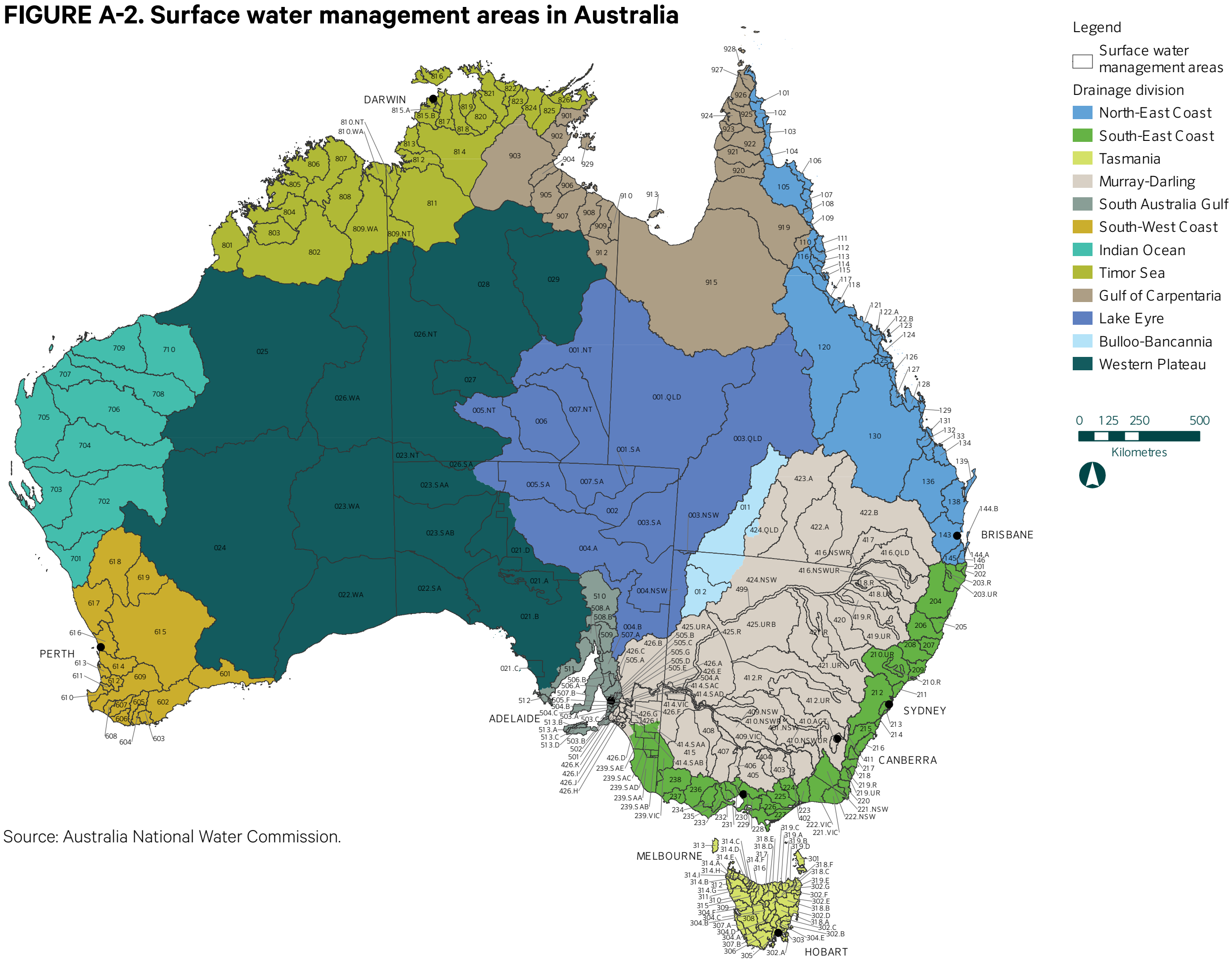
In response, the Australian government implemented several initiatives to purchase existing water entitlements and dedicate these to the environment, both to offset reservoir evaporation and other system losses (known as maintenance rights) and explicitly to ensure minimum instream flow volumes in designated reaches. The government has invested more than $3 Billion to date to purchase entitlements for environmental water. However, the relative priority of this environmental water remains contentious, with some states contending that such rights receive lower priority than human uses. New South Wales has attempted to limit federal purchases of water for the environment to no more than 3 percent of total entitlements, though this appears to contravene trading rules within the Basin Plan, which seek to minimize restrictions on trading (Grafton and Horne 2014).

State water plans allocate water entitlements into one or two "pools," known as a high security pool and a general or low security pool. The high security pool is allocated to those entitlement holders proportional to the size of their entitlement. For example, if a system only has two entitlement holders and one right is for nine units and the other is for one unit, the former would receive 90 percent of the pool's allocation and the latter would receive 10 percent. If additional water is available for the general pool, that volume is allocated to those entitlement holders. Every season, the state determines the total volume available for allocation for each pool. During drought, the general pool might not receive any water at all (Young, 2010).

Water trading activity

Australia's water trading activity is largely concentrated in the MDB, which represents as much as 94 percent of all such activity in Australia despite being only one of twelve surface water management areas (Figure A-2). Trading is very high as measured by the total volume of water traded (as much as 5 million acre-feet), the percentage of all diversions that are traded (as much as 50 percent), the number of farmers trading water (roughly half, in 2008-09), and the total number of trades (11,000, in 2011-12). The number of short-term (allocation) interstate trades also appears to be rising, reaching 20 percent of the total number of such trades in 2011/12 (Grafton and Horne 2014). Not surprisingly, the number of short-term (allocation) trades is much higher, in terms of numbers and volumes, than the number of entitlement trades. As the federal government has exercised its commitment to ensure minimum

FIGURE A-2. Surface water management areas in Australia



Source: Australia National Water Commission.

environmental flows by purchasing entitlements, such purchases have risen to 37 percent of the total number of entitlement trades in 2011/12. Only about 5 percent of farmers traded water entitlements, either to other farmers or to cities or to the government for augmenting environmental flows, in 2008/09, or about 10 percent of the number that reported trading allocations that year (Grafton and Horne 2014).

As expected, the number of allocation trades appears to be inversely correlated with precipitation and runoff, rising in drought years and falling when allocations are higher due to wetter conditions. Prices similarly vary in response to water availability, rising from the equivalent of about \$22 per acre-foot in 2011/12 to the equivalent of about \$54 per acre-foot in the drier 2012/13.[31] Similarly, trading in drier years tends to see water move from lower value uses, such as pasture and forage, to higher value wine and vegetable crops. Connor and Kaczan (2013) reported that many livestock operations irrigate pasture and forage crops in wet years but tend to trade away their allocations in drier years, when the price of water rises due to scarcity, using the profits to purchase feed from other areas. These trends also manifest regionally, as water tends to move across state lines from New South Wales into South Australia, which has more high-value

[31] These prices are about an order of magnitude lower than prices for short-term transfers in California in the 2014 drought year, but are comparable to prices paid for short-term rentals in the active Northern Colorado Water Conservancy district water market.

crops. In response, New South Wales and Victoria have imposed restrictions on the volume of water that may be exported from the state (Grafton and Horne 2014).

Enabling conditions

A large number of necessary and enabling conditions help explain Australia's water trading success. Key among these is the development of a proportional water sharing regime, in which the state, rather than administrative or water courts, determines total annual water availability, rather than granting rights holders an absolute or priority-based right to a fixed volume of water. The Australian experience also shows that water trading is more active when allocation pools encompass a large number of entitlement holders with a diverse range of uses (Young, 2010).

Grafton and Horne (2014) found that infrastructure, such as dams and canals, can facilitate water trading by storing water until needed and providing conveyances to deliver where needed. Similarly, access to accurate and timely information on water prices and availability facilitates water trading. In Australia, brokerage-type water banks are active in both the Murray-Darling Basin and in northern Victoria, where the banks post information about pricing and availability (O'Donnell and Colby 2010). Underpinning this information exchange is an extensive, credible, verifiable registry of entitlements and allocations and mechanism to quickly record, measure and monitor trades, as well as sufficient sanctions on those violating agreements (Connor and Kaczan 2013).

Lessons learned

Connor and Kaczan highlighted the classic dilemma facing those attempting to implement a water trading system: the tradeoff between protecting third parties with high transaction costs versus promoting trades with low transaction costs, with less concern for third parties. Australia has adopted the latter approach, choosing to minimize transaction costs and promote market activity while protecting environmental values by participating directly in the market, purchasing entitlements from willing sellers and dedicating this water to preserve threatened ecosystems and river reaches. This approach has come at great expense to the government (and taxpayers) but has been justified by the reported increase in economic activity and benefits arising from trading activity. In a robust assessment of water trading in Victoria's Murray Valley, Frontier Economics (2007) found strong local opposition to permanently trading water out of local areas, to the extent that some irrigators selling entitlements have been ostracized, but also found a combination of positive and negative socio-economic impacts from such trades. For example, the authors found that trading ameliorated the impacts of the Millennium Drought on dairy farmers in the region, who otherwise would have fared much worse. Additionally, water trading facilitated the expansion of the wine industry in the region.

Several researchers have compiled extensive lists of lessons learned. Two of these are reproduced below. Young (2010) writes:

> **Lesson 1:** Unless carefully managed, the legacy of prior licensing decisions can result in markets causing over-allocation problems to emerge in a manner that erodes the health of rivers, aquifer and the water dependent ecosystems associated with them.
>
> **Lesson 2:** Transaction and administrative costs are lower when entitlements are defined using a unit share structure and not as an entitlement to a volume of water. *One of the simplest ways of preventing over-allocation problems from emerging is to assign the risks of adverse climate change and/or the emergence of long dry periods to entitlement holders and define entitlements as an entitlement to a share of the water defined as being available for use.*
>
> **Lesson 3:** Market efficiency is improved by using separate structures to define entitlements, manage allocations and control the use of water.

Lesson 4: Early attention to the development of accurate license registers is critical and a necessary precondition to the development of low-cost entitlement trading systems.

Lesson 5: Unless water market and allocation procedures allow unused water to be carried forward from year to year, trading may increase the severity of droughts.

Lesson 6: Early installation of meters and conversion from area based licenses to a volumetric management system is a necessary precursor to the development of low cost allocation trading systems. *Metering and conversion to a volumetric allocation system is a necessary precursor to the development of efficient water trading systems*. In order to facilitate the more efficient management of the available resource and trading, Australia has spent many years converting area-based licenses to volumetric licenses and installing meters. *Typically, conversion involves estimation of the amount of water used by crop type and the development of conversion factors.*

Lesson 7: It is difficult for communities to plan for an adverse climate shift and develop water sharing plans that deal adequately with a climatic shift to a drier regime. More robust planning and water entitlement systems are needed.

Lesson 8: The allocation regime for the provision of water necessary to maintain minimum flows, provide for conveyance and cover evaporative losses need to be more secure than that used to allocate water for environmental and other purposes.

Lesson 9: Unless all forms of water use are accounted for entitlement reliability will be eroded by expansion of un-metered uses like plantation forestry and farm dam development, increases in irrigation efficiency, etc. and place the integrity of the allocation system at risk.

Lesson 10: Unless connected ground and surface water systems are managed as a single integrated resource, groundwater development will reduce the amount of water available that can be allocated to surface water users.

Lesson 11: Water use and investment will be more efficient if all users are exposed to at least the full lower bound cost and preferably the upper bound cost of supplying water to them. One way of achieving this outcome is to transfer ownership of the supply system to these users.

Lesson 12: Manage environmental externalities using separate instruments so that the costs of avoiding them are reflected in the costs of production and use in a manner that encourages water users to avoid creating them.

Lesson 13: Removal of administrative impediments to inter-regional trade and inter-state trade is difficult but necessary for the development of efficient water markets. *Australia has taken the approach of appointing an independent agency to develop rules designed to remove unnecessary barriers to water trade.* Amongst other things, this has required the setting of guidelines that prevent water supply companies from setting charges and adopting practices that discriminate against people who wish to trade water out of a region.

Lesson 14: Markets will be more efficient and the volume of trade greater if entitlements are allocated to individual users rather than to irrigator controlled water supply companies and cooperatives. Whilst opposed by water supply companies and cooperatives, it is the Australian experience that *willingness to trade and market depth typically is much greater when entitlements are allocated to individuals rather than to water supply companies or associations as they are called in other countries.* The reason for this is that when allocations are issued to individuals they do not have to obtain the permission of the board of a water supply company or association to sell water out of a region.

Lesson 15: Equity and fairness principles require careful attention to and discipline in the way that allocation decisions and policy changes are announced.

Lesson 16: Water markets are more effective when information about the prices being paid and offered is made available to all participants in a timely manner.

Lesson 17: Develop brokering industry and avoid government involvement in the provision of water brokering services.

GRAFTON AND HORNE (2014) WRITE:

1. **Crises may facilitate reform** - As the focus on the crisis fades, so may do the reform zeal. This 'stop and go' reform process suggests that determination is required to make consistent progress, but that a crisis can facilitate reform.
2. **Water markets support regional resilience** - The geographical distribution of markets has meant these benefits have been concentrated in areas of greatest connectivity of the resource (the southern Murray-Darling Basin) where there is also the widest cross-section of users. An example is the significance of selling water by opportunistic commodity producers (such as rice growers) to perennial crop producers (such as citrus growers).
3. **Political and administrative leadership is critical** - This involves teams with a range of skills, much broader than the engineering-based specialists that have traditionally managed water resources.
4. **Capping extractions promotes effective use and sustainability** - any cap should be comprehensive and all water sources should be included to avoid substitution to uncontrolled or inadequately measured sources.
5. **Regulated water framework facilitates water trading** - entitlements delivered via regulated water storages account for about 90 percent of the water entitlements traded in the Southern MDB.
6. **Reliable, accessible and timely market information promotes effective decision-making** - the Australian government is investing over half a billion Australian dollars in improved water information and regulations.
7. **Statutory rights offer flexibility but carry risks** - can be modified without recourse to the courts. Developments to unbundle water rights have facilitated trade. A potential downside of statutory rights is sovereign risk, or the possibility that the value of existing water rights can be degraded by changes in regulation and discretionary behaviour by state governments.
8. **Markets can promote environmental outcomes** - Trading should always be subject to a public interest test. Where there are important public interests, such as flow volumes at key locations or the need to ensure minimum levels of water quality, trade may need to be constrained for environmental reasons. An example of this approach is the Basin Salinity Management Strategy that seeks to reduce salinity: actions that reduce salinity are treated as credits and actions that increase salinity as debits on state salinity registers.
9. **Acquiring water for the environment through buybacks has proved effective.**
10. **Prices contain information on scarcity and risk.**
11. **Basin-wide and local perspectives have roles to play** – local input can also prevent or undermine the emergence of strong water markets. … Governments need to see through short-term and some-times parochial interests to facilitate optimal use in the longer term.
12. **Effective monitoring and control of extractions are critical for sustainability** – Farmers made substantial investments to increase their on-farm retention of water that might otherwise have flowed to the Basin's streams and rivers. Similarly, groundwater extractions increased by about half over the period 2000–2001 to 2007–2008 (from about 1 MAF to 1.4 MAF) as market users sought access to other cost effective water supplies.

Glossary

Aquifer – an underground layer of water-bearing materials, such as sandstone or gravel or other permeable material.

Command-and-control regulation – an environmental regulatory policy that is often contrasted with "incentive-based mechanisms" in the literature. A command and control (CAC) regulation can be defined as the direct regulation of an industry or activity that states what is permitted and what is illegal.

Economic Efficiency – generally, a state or condition with optimal resource use, allocation, or productivity. May or may not be consistent with equity considerations.

Equity – refers to fairness, justice, impartiality, such as in the allocation of resources or treatment of different classes of people. May or may not be consistent with economic efficiency considerations.

Eutrophication – excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen.

Incentive-based instrument – a broad set of tools that use financial means, directly or indirectly, to motivate responsible parties to reduce the health and environmental risks posed by their facilities, processes, or products.

Nonpoint source (NPS) pollution – water pollution from diffuse sources such as runoff from urbanized areas or farm fields.

Nutrients – nitrogen or phosphorus-containing water pollutants that can cause water quality problems. See eutrophication.

Paper water – the legal right to use a given volume of water, contrasted with "wet" or "real" water. In many basins, more paper water exists than wet water.

Payment for ecosystem services (PES) – an incentive-based instrument that seeks to translate external, non-market values of environment services into financial incentives for local actors to provide such services. In practical terms, PES involves a series of payments to a land or resource manager in exchange for a guaranteed flow of environmental services.

Payment for watershed services (PWS) – a type of PES arrangement that is focused on watershed services.

Water bank – may refer to the physical storage of water, typically in a reservoir or an aquifer, to an institution that facilitates or brokers a water transfer or serves as an information clearinghouse, or to any agency that holds water rights in trust for a specified purpose such as streamflow augmentation.

Water market – Often used interchangeably with **water transfer**, a water market can also refer to informal transactions involving the sale of water, e.g. from water tankers, that do not involve the lease or sale of water rights or concessions.

Water option – a type of conditional water transfer. Under **dry-year options** a buyer will pay the seller an annual fee to be able to exercise an option to purchase a pre-determined volume of water under a specific set of circumstances.

Water transfer – a change in the point of diversion, type of use, or location of water use. May refer to a temporary or permanent exchange of water rights (see **water market**), or to a non-market conveyance of water from one location to another.

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