Watershed Research and Education Program Directed Research Grant
Final Technical Report

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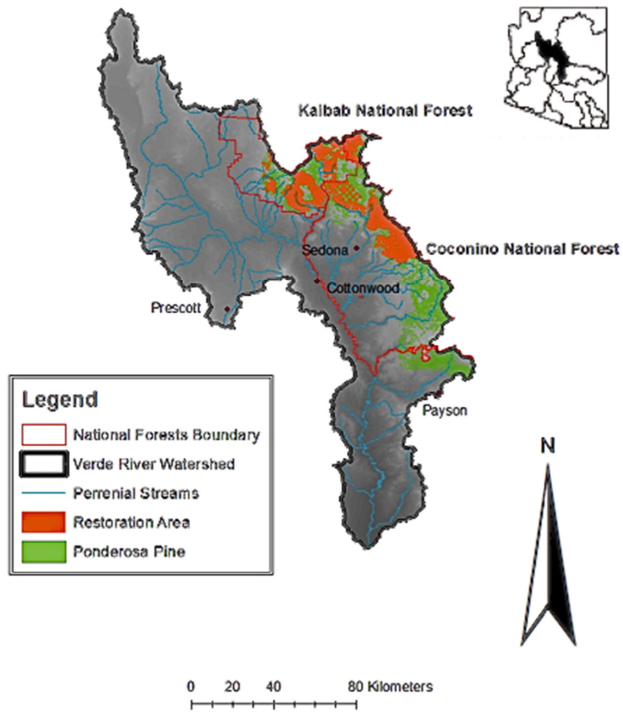
Background

In semi-arid Northern Arizona, where forested regions provide up to 90% of surface water, forest management practices provide unique opportunities for watershed improvement (Baker 2003). A century of misdirected forest management, mainly fire suppression, has resulted in unsustainable forest conditions that pose significant risks to water resources (Kimball and Brown, 2009). Overstocked forest conditions across Northern Arizona have prompted the Four Forests Restoration Initiative (4FRI), a landscape level restoration effort that intends to restore structure, function and composition to ponderosa pine (*Pinus ponderosa*) forests (Frederici 2003).



Of the 2.4 million acres of forest planned for restoration treatments through 4FRI, over 300,000 acres lie within the Verde River watershed (see figure at right). Planned ecological restoration treatments include a significant reduction in basal area, which has the potential to increase water yield from .25 acre-feet/acre/year to 0.33 acre-feet/acre/year (Brown 1974).

Restoration activities will also mitigate the imminent threat of catastrophic wildfire in the Verde River watershed, reducing the potential for sedimentation and deposition in downstream channels (Baker 2003). Considering that climate change predictions include a 14% reduction in regional stream-flow, restoration may serve as an important buffer to losses in water availability that would otherwise occur due to climate change (Christensen 2004). Maintenance restoration activities, such as prescribed burning, mimics historical disturbance regimes and is critical in sustaining water yields earned by mechanical thinning.

Optimization and protection of water resources is particularly important in the

Verde River watershed. Along its course from alpine tundra to Sonoran desert, the Verde River serves a number of important human and ecological communities (West et al. 2009). The Verde River is home to at least six sensitive, threatened or endangered fish species; all of which have recently experienced declines due to reduced water quantity and quality (Arizona Ecological Services 2011). Meanwhile, irrigation and population growth in the Verde Valley (projected to double by 2050) will place significant demands on the Verde River (West et al. 2009). These extensive demands have had significant impacts on the watershed, prompting the Verde River to be listed as the 10th most endangered river in 2006 by the American Rivers Association (American Rivers Association 2011).

Project Purpose

Although restoration is the only recognized solution for safeguarding the natural capital that resides in the Verde River watershed, restoration efforts are continually impeded by insufficient financial support (Holl and Howarth 2000, Wu et al. 2011). Funding for initial treatments will be supported by USFS funding and industrial sales, but funding remains uncertain for follow-up treatments. The benefits to watershed services following forest restoration, coupled with the need for new funding streams may create the opportunity for a Payment for Watershed Services (PWS) system. PWS systems have been employed internationally as well as in two western U.S municipal watersheds, with demonstrable success in generating funding for restoration and management practices (Greenwalt and McGrath 2009). *The overall goal of this study is to assess the feasibility of establishing a PWS system as a funding mechanism for continued forest restoration treatments in Verde River watershed of Northern Arizona.*

Research Approach and Expected Outcomes

In order for any viable PWS market to exist, there must be a supplier (an upstream landowner) who is willing and able to provide the good or service. Similarly, there must be buyers (downstream beneficiaries) who are willing and able to pay the costs required to produce the good or service (Wunder 2005). Thus, investigating how a PWS system can be applied in the Verde River watershed requires a two-pronged research approach.

Determine the extent to which the USFS is willing and able to serve as the provider in a Payment for Watershed Services system.

The United States Forest Service (USFS) is the predominant manager of the Verde River watershed's extensive ponderosa pine forests (see above figure). Although the USFS has both external and internal policy mandates to manage for water resources (Cech 2009), no policy mechanisms exist specifically for establishing a PWS system with the USFS as a provider. A mixed-method qualitative approach was employed to address this research objective. Preliminary interviews were conducted with forest, regional and national level USFS personnel engaged in water resource policy and management to discover the barriers and opportunities associated with PWS initiatives. Preliminary interview results guided the development of a focus group workshop that was held in the Fall 2011 that further developed knowledge of regional implementation of PWS programs. Interview and focus group audio-recordings were transcribed and coded to identify major themes in relation to the USFS and PWS systems (Morse and Richards 2002).

Interview and workshop results will be submitted for publication in a scholarly journal such as the *Journal of Forestry*. See the draft manuscript in Appendix A.

Determine the willingness-to-pay of water-users in the Verde Valley

Beneficiaries of watershed services include Verde Valley irrigators who use water diverted from the Verde River and/or its tributaries via irrigation ditch systems. To gauge their interest in engaging in a PWS system, we developed a contingent valuation survey after holding a focus group with key stakeholders of four ditch associations. An address list containing properties with water rights was obtained from the Yavapai County Assessors Office. The survey was sent to over 1200 water users and asked their willingness-to-pay for enhanced watershed services following forest restoration and what they view as the principal threats to their water supply. Following reception of surveys, survey results were entered into a database. Statistical analyses using STATA were conducted to arrive at a willingness-to-pay estimate that will inform future PWS program development in the region.

Results were distributed via regional media outlets and were submitted for publication in *Water Resources Research.* See the draft manuscript in Appendix B.

Broader Impacts

The broader impacts of this project mesh well with WREP's mission of promoting water resource research and education and facilitating storage and exchange of water resource information. Previous research suggests that water resources are greatly undervalued (Sedell 2000, Berry 2008). Accurate valuation of watershed services will inform future forest management and development in water limited regions. National Forest system lands are critical catchments for our water supply (Kimball and Brown 2009). Across the west, USFS lands provide over approximately 51% of total water used (Berry 2009). Understanding the policy mechanisms by which the USFS can serve as the provider in PWS systems will augment funding for watershed restoration and stewardship.

The support of the WREP Directed Research Grant provided funding for data collection and broad dissemination for my findings in multiple conferences and symposiums. For data collection, funds were used to support travel, lodging, food and room rental for hosting a collaborative workshop (n=25) that engaged regional and national partners interested in PWS. The findings from this study were presented at multiple conferences, including Arizona Hydrological Society Annual Symposium (n=30), The United States Forest Service National Office (n=15), the Arizona Governors Forest Health Council (n=18) and the National Council on Science and The Environment (open poster session).

Workshop Agenda

Payment for Watershed Services Workshop
October 6 &7, 2011
Northern Arizona University

Objectives

- Share information on existing PWS schemes and N. Arizona studies
- Identify potential partners/user groups and administrative instruments for PWS implementation
- Assess feasibility of PWS process and structure on USFS lands
- Identify key principles and guidance for PWS implementation on USFS lands

October 6, Large Pod Room, Applied Research and Development Building.

8:45-9:00. Sign-in and pick up materials

9:00-9:15. Welcome, introductions and objectives (Dr. Erik Nielsen and Wes Swaffar).

9:15-9:30. Presentation: *"Building an ecologically and economically sustainable restoration and monitoring plan for forested watersheds in Northern Arizona"* (Dr. Abe Springer)

9:30-10:30. Presentation: *Payment for Watershed Services (PWS): A tool for supporting western watershed stewardship?* (Wes Swaffar).

10:30-10:40. Break. Refreshments provided

10:40-11:00. Presentation: *Hydrologic responses in watershed services following forest restoration* (Abe Springer and/or Sharon Masek Lopez).

11:00-11:30. Presentation: Case Study, *Santa Fe Municipal Watershed Plan* (Sandy Hurlocker, USFS).

11:30-12:00. Lunch. *Roasted portobello on focaccia with provolone cheese.*

12:00-1:30. Video Conference: *USFS National Office Panel-- PWS, Partnerships and the USFS (*Joe Meade, Emily Weidner, Mark Nechodem , Andrea Bedell-Loucks, Willis Mitchell, Rainee Luciano)

1:30-1:45 Assessing concerns of PWS on USFS lands

1:45-2:45 Breakout groups: *What, where and with whom: establishing PWS across a variety of user groups.*

2:45-3:00. Break. Refreshments provided

3:00-3:30. Large Group discussion: *The role of facilitators for establishing PWS.*

3:30-4:00. Large Group Discussion: *Measuring effectiveness/monitoring and reporting*

5:00- Happy hour

October 7, Southwest Room, The du Bois Center

8:45-9:00. Arrive and assemble

9:00-9:15. *Debrief Day 1* (Erik Nielsen)

9:15-9:30 Presentation: *Key process steps to PWS implementation*. (Wes Swaffar)

9:30-10:15. Group discussion: *PWS challenges and Building Public Awareness and Support*.

10:15-10:30. Break. Pastries, bagels, fruit and refreshments.

10:30-11:45. Breakout groups and group discussion*: Building a feasible process model for PWS implementation.*

11:45-12:00. Group sharing.

12:00-12:45. Group Discussion*: Recommendations guiding future PWS schemes.*

12:45-1:00. Wrap-up and Evaluation

Workshop Participants

Name	Organization	Position	Location
Mark Sensibaugh	Ecological Restoration Institute, NAU		Flagstaff, AZ
Walter Dunn	USFS		Albequerque, NM
Roy Jemison	USFS		Albequerque, NM
Tim Skarupa	Salt River Project		Phoenix, AZ
Charlie Ester	Salt River Project		Phoenix, AZ
Gene Blankenbaker	USFS		Phoenix, AZ
Rory Steinke	USFS		Flagstaff, AZ
Chris Nelson	USFS		Springerville, AZ
Genevieve Johnson	USFS		Phoenix, AZ
Sandy Hurlocker	USFS		Santa Fe, NM
Marcus Selig	Grand Canyon Trust		Flagstaff, AZ
Jan Engert	RMRS, USFS		Fort Collins, CO
Henry Provencio	USFS		Flagstaff, AZ
Bill Possiel	National Forest Foundation		Missoula, MT
Brad Hill	City of Flagstaff		Flagstaff, AZ
Heidi Huber-Stearns	Colorado State University		Fort Collins, CO
Chuck Denton	USFS		Phoenix, AZ
Susan Brown	USFS		Williams, AZ
Claire Harper	USFS		Denver, CO
Erik Nielsen	Northern Arizona University		Flagstaff, AZ
Abe Springer	Northern Arizona University		Flagstaff, AZ
Wes Swaffar	Northern Arizona University		Flagstaff, AZ
Sharon Masek Lopez	Northern Arizona University		Flagstaff, AZ
Evan Reimondo	Northern Arizona University		Flagstaff, AZ
Spencer Plumb	Northern Arizona University		Flagstaff, AZ
Julie Mueller	Northern Arizona University		Flagstaff, AZ

Preliminary Workshop Findings

Governance/Institutions: Rights, policies, participation, and facilitator.

Key Findings:

- Existing, policies and authorities and instruments are sufficient for PWS type agreements
- USFS cannot give increased decision space to partners
- USFS must remain impartial
- Management to sustain watershed services is compatible with other resource mgmt. goals.
- USFS is legally bound at multiple levels to manage for water resources
- Nationally, the USFS is interested in PWS
- Roles include: convenor, engager, funding resources, broker, aggregator, decision support, monitoring framework, outreach, advocacy, conflict resolution, mitigating bias, build zone of agreement, incorporate science, valuation
- Necessary for impetus, administration and a range of other roles

Payment Mechanisms: Direct or trust or in kind, obligations, duration, on delivery, reporting

Key Findings:

- Santa Fe and Denver's water bill shows a line with where money has gone
- Must be eased in
- Different types of payment mechanisms:
- User Fees
    - Opt in/opt out
    - User fees through power companies

Suppliers/Land Managers: Targeted efficiency, payment sufficient to change land management, which level of the USFS

Key Findings:
- Multiple levels of the USFS should be engaged
- USFS is bound by governing legislation

Watershed Service/Provision: What services, and for whom

Key Findings:

- Wildfire is seen as the greatest threat to watershed services by USFS respondents, with drought and climate change perceived as second and third threats
- Watershed services for municipalities are quality, quantity, flow regulation
- Management for the protection of watershed services is generally compatible with other restoration objectives

Monitoring/Compliance/effectiveness

Key Findings:

- Not sufficient instrumentation across all forests to record additional watershed services
- Watershed Condition Framework and Forest to Faucet may be a framework for baseline conditions
- Metrics must demonstrate additional watershed services and this must be communicated
- A challenge may be metrics for a reduction of threats to watershed services

Buyers/Beneficiaries: What services, valuation, knowledge of linkage, types of buyers

Key Findings:

- Municipalities are likely buyers because of proximity more money, ease of payment mechanisms, and population
- Municipalities of different sizes will have different priorities
- Agriculture not the best target, a high use of water, but many disparate users
- Geographic scale may plan an important role in connecting users to upstream watersheds

Financing Mechanisms: Transactions costs, valuation, planning, monitoring, collaboration, contracting, reporting

Key Findings:

- USFS Grants and Agreement specialist should be involved for development
- MOU can be used to frame relationship and determine boundaries
- Collection agreement and Cost Share agreements are options
- Denver Water paid for watershed assessments, potential for user groups to pay for NEPA
- In Santa Fe, NM, New Mexico Water Trust Board put down $2 million to finance first five years. City is using grant money to conduct outreach, talk to taxpayers

- Voluntary contributions are better for one-time projects
- Third party fiduciary grant, cash, multi year agreements, in-kind

Press

Arizona Daily Sun
http://azdailysun.com/news/local/nau-research-targets-municipal-watershed-protection/article_90f17a72-10b1-11e1-b5d9-001cc4c03286.html

http://azdailysun.com/news/local/cities-water-supplies-at-risk/article_e94f76fa-e030-5519-a83e-1eb9e096bac6.html

Inside NAU spotlight
http://www4.nau.edu/insidenau/bumps/2011/10_24_11/spotlight.html

High Country News
http://www.hcn.org/issues/44.3/communities-help-pay-for-ecosystem-services-provided-by-forests

Presentations

- *Payment for Watyershed Services on Western National Forest Lands: Feasibility and Design Considerations.* Arizona Governors Forest Health Council, Phoenix, AZ, January 2012
- *Investigating Payment for Watershed Services in Northern Arizona*. Carpe Diem West's Healthy Headwaters Working Group Meeting, Phoenix, AZ, April 2012.
- *Payment for Watershed Services on National Forest Lands: Feasibility and Design Considerations*. National Council on Science and the Environment, Washington, D.C., January, 2012.
- *Payment for Watershed Services on National Forest Lands: Feasibility and Design Considerations*. United States Forest Service National Office, Washington, D.C., January, 2012.
- *Payment for Watershed Services: A tool for Supporting Southwestern Watershed Management?* Arizona Hydrological Society Annual Symposium, September, 2011, Flagstaff, AZ

Description of Attached Documents

WREP STATUS REPORT.pdf: A report compiled by SESES Administrative Associate, Mark Aasmundstad, that shows the status of the grant and funds used.

WREP DETAIL REPORT.pdf: A detailed report compiled by SESES Administrative Associate, Mark Aasumundstad, that shows a detailed breakdown of how funds were spent by month, by expense type, etc.

* Please note that there is a pending balance of $249.63 due to some charges that have not yet posted. The ending balance of the account should be, according to our calculations, should be **$2.66**.

Appendix A

FOREST TO FAUCET IN THE PINES: INSTITUTIONAL DESIGN CONSIDERATIONS FOR PAYMENT FOR WATERSHED SERVICES IN NORTHERN ARIZONA

WES SWAFFAR, ERIK NIELSEN

3.1 INTRODUCTION

Previous land management has altered the composition and structure of southwestern ponderosa pine *(Pinus ponderosa)* forests, contributing to widespread declines in forest health and increased risk of catastrophic wildfire. (Covington 2003, Kauffman 2004). To address this problem, the Four Forests Restoration Initiative (4FRI) has formed to restore 2.4 million acres of ponderosa pine forests across northern Arizona. Despite the need for restoration, insufficient congressional appropriations and high restoration costs may jeopardize sustained restoration efforts. The so-called "Forest to Faucet" approach employs an emerging conservation mechanism, Payment for Watershed Services (PWS), to leverage additional funds for forest restoration. To forward this effort, The United States Forest Service (USFS) has recently released the Forest-to-Faucet program, a decision support tool that highlights the connections between forests and downstream drinking water. Despite this recent release, the USFS has not taken an official position on PWS, inhibiting the development of PWS on National Forest System (NFS) lands. While institutional design criteria have been developed for guiding PWS internationally, PWS within the context of National Forest lands in the southwestern U.S. represents a unique institutional case study. This study seeks to develop institutional design criteria for guiding PWS development on southwestern National Forest lands to support the 4FRI.

Mega fires such as the Rodeo-Chediski Fire of 2002 and the Wallow fire of 2011 have become increasingly common, at significant public and environmental costs. Largely due to the increased prevalence of catastrophic wildfire, a broad consensus has emerged that restoration of southwestern ponderosa pine forests is necessary and urgent (Allen et al. 2002). Ecological restoration reduces the risk of catastrophic wildfire through mechanical thinning and prescribed burning, returning the ecosystem back to within its "natural range of variability" (Landres et al. 1999). Overstocked forest conditions and the associated threat of wildfire across Northern Arizona have prompted the Four Forests Restoration Initiative (4FRI), a collaborative landscape restoration effort that plans to restore structure, function and composition to ponderosa pine forests across 2.4 million acres of ponderosa pine forest across four national Forests (Apache-Sitegraves, Coconino, Kaibab, Tonto) at a rate of approximately 50,000 acres/year over a period of 20 years (USFS 2011).

As the largest restoration effort in the U.S., the 4FRI is attempting restoration at an unprecedented scale. Insufficient congressional appropriations, stressed forest management budgets and high restoration costs are significant barriers to initiating and sustaining landscape scale restoration efforts (Holl and Howarth 2000, Wu et al. 2011). Under the Collaborative Forest Landscape Restoration Program (CFLRP) program, 4FRI receives $4 million annually for use in implementation, administration and preparation of restoration treatments (USFS 2011). Stewardship contracts are expected to cover operational costs for mechanical thinning in most treatment areas. Funding for ancillary restoration activities-hand-thinning, prescribed burning, channel restoration, road de-commissioning and restoration monitoring-is insecure and may challenge the ability of forest management budgets to support these restoration tasks.

Despite high restoration costs and the scale of the challenge, numerous economic analyses confirm that it is more cost-effective to restore forests than to pay the costs associated with severe wildfire (Wu et al. 2011, Daugherty and Snider 2003, Berry 2010). The Rodeo-Chediski fire alone cost nearly $50 million in suppression efforts and over $129 million in home and property loss (Snider et al. 2003). Fire suppression costs will continue to increase, as poor forest conditions and changes in climate could lead to substantial increases in area burned per year (McKenzie et al. 2004).

In addition to the long-term avoided costs of reduced fire risk, forest restoration provides a suite of tangible, non-market benefits, including: watershed services, biodiversity, carbon sequestration, and enhanced recreational opportunities. “Watershed services” are the benefits that people obtain from ecosystems via watershed processes and include water quality, water quantity, flow regulation and aquatic productivity (Stanton et al. 2010). In northern Arizona, where approximately 90% of stream-flow is generated within forested lands, forest restoration can play a critical role in enhancing and protecting watershed services (Ffolliott 1975). However, the continued provisioning of these services is threatened by changing climate, wildfire and population growth. Changing climate conditions in the western U.S. are expected to increase the frequency and severity of drought conditions, decreasing stream flow and increasing rates of evaporative loss (Lueng 2004). Wildfire burns vegetation that would normally slow and uptake water, exacerbating erosion and sedimentation and impeding the hydrologic processes necessary to supply watershed services (Baker 2003). Lastly, human populations are expected to double within 50-100 years, dramatically increasing water demand across all sectors (Morello 2011)

If incorporated as part of a land management system, ecosystem service values can be used to create Payments for Ecosystem Services (PES) that would accelerate forest restoration. PES are voluntary transactions where a well-defined ecosystem service is being bought by a beneficiary from an ecosystem service provider (Wunder 2005). Payment for Watershed Services, (PWS), a sub-discipline of PES, are initiatives used to provide financial or in-kind incentives to land managers to adopt practices that can be linked to improvements of watershed services.

Successful PWS programs have been developed internationally that simultaneously achieve conservation goals and maintain valued watershed services (Wunder 2005, Porras et al. 2009). Domestically, there are over 30 active PWS initiatives, the most well documented case being New York City's PWS initiative that leverages municipal water fees to protect water quality through watershed protection in the city's upper watershed. Application of PWS for improving watershed conditions on NFS lands has been limited to several pilot watershed-based collaborative efforts that engage local USFS units and municipal water utilities, such as those in Santa Fe, NM and Denver, CO.

Forest ecosystems on NFS lands and the ecosystem services they supply represent a common pool resource for United States citizens (Brown and Harris 1992). As such, PWS may play an important role in sustaining National Forests as a common pool resource and address collective action failure. While NFS lands were originally established to provide institutional mechanisms for regulating the National Forest commons, governmental and market failures challenge the effective management of NFS lands (Brown and Harris 1991, Steelman and Burke 2007). In the case of the USFS, the current agency budgeting structures does not support landscape scale forest restoration and maintenance activities such as those planned in the 4FRI area (Wu et al. 2011). Furthermore, the market has failed to capture the positive externality of watershed services from National Forests, enabling downstream water users to benefit as "free-riders" without contributing to the maintenance of watershed services, resulting in imperiled or degraded watershed services (Vatn 2010). By leveraging additional public resources through accounting for watershed services and directing resources towards restoration and management, PWS can increase the management capacity of the USFS (Kline et al. 2009).

Appropriate institutional designs can provide a pathway for avoiding Hardin's (1968) "tragedy of the commons" and resolve collective action and common pool resource problems (Ostrom 1999). Among international PWS case studies, there is considerable variation in the institutional designs governing PWS initiatives.

Variability in design may depend on: type of watershed service, watershed service provision, land ownership, how to limit access to benefits to paying beneficiaries, scale of relevant ecosystem processes that support it, and the geographical and historical context (Tognetti et al. 2005). While most programs involve national governments making payments to upstream landowners, others may involve individuals making payments to a private company for water provision. Almost all programs involving national governments include government agencies directing payments to private landowners for watershed improvement activities (Stanton et al. 2010) and not national government agencies as recipients of payments. While emerging design criteria exist from international PES and PWS case studies, no design criteria exist for this unique institutional arrangement wherein a ―public service government agency receives payments.

The Institutional Analysis and Development (IAD) framework developed by Ostrom (1990) offers a useful framework for analyzing and evaluating institutional arrangements for common pool resource governance. The IAD distinguishes three levels of action: operational rules, collective choice rules and constitutional choice rules. Operational rules include decisions about when, where and how to do something. Collective choice rules influence operational activities and outcomes by determining how operational rules can be changed and who can participate in these decisions. Constitutional choice rules influence operational rules and outcomes by determining who is eligible to participate and the rules to develop and change collective choice rules, which in turns effects the operational rules (Imperial 1999).

According to the IAD, three evaluative criteria are used to understand institutional performance: transaction costs (information costs, coordination costs and strategic costs), overall institutional performance (efficiency, equity, accountability and adaptability) and impacts (policy outcomes) (Imperial 1999). These evaluative criteria are also central concerns surrounding the robustness of PES and PWS identified in the international literature (Wunder 2005, Engel et al. 2008) and raise important questions. Are programs efficient in lowering transaction costs and costs associated with land management changes? Are land management activities effective in producing a demonstrable change in the provision of an ecosystem service? What are the equity implications of leveraging fees from a specific ecosystem service user group?

3.2 STUDY AREA

The project area encompasses four National Forests; the Apache-Sitegraves, Coconino, Kaibab and Tonto, all of which lie within USFS Region 3 (figure 1). While stewardship contracts and congressional appropriations will significantly offset most restoration costs, unfunded ancillary restoration activities (hand thinning, channel restoration, road decommissioning and monitoring) are also necessary to fully restore forest ecosystems. Furthermore, additional funding is needed to support long-term maintenance and ecological monitoring and oversight. Through the 4FRI, the USFS is attempting ecological restoration at an unprecedented scale, costing the USFS up to $16 million annually. Thus, the 4FRI project area provides an ideal case study for investigating the institutional design for incorporating ecosystem service payments into forest management and restoration. As the largest restoration initiative in the United States, the 4FRI area provides a unique and instructive opportunity to inform future PWS design with guidance for restoration efforts.

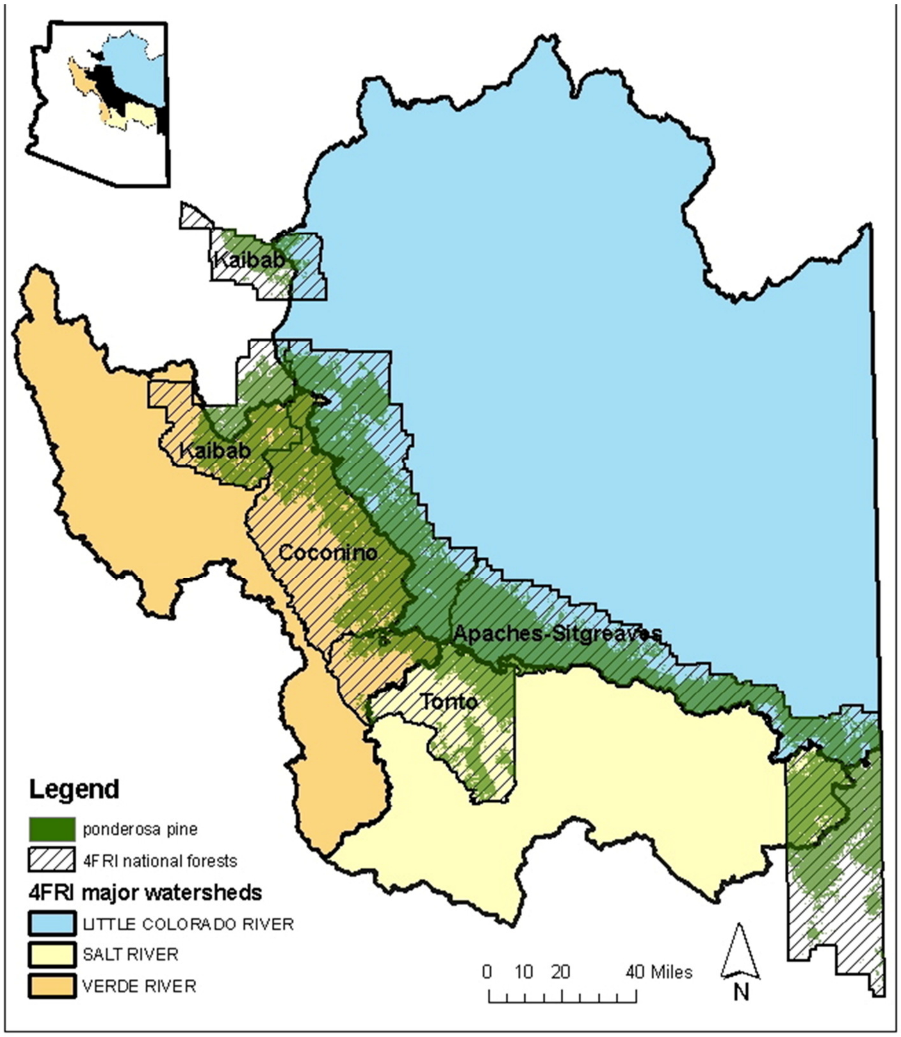


Figure 1: The 4FRI project area includes treatments on 2.4 million acres, spanning four National Forests and three major watersheds. The Salt and Verde River basins are the two major surface water sources in Arizona, servicing municipal and agricultural water needs in the Phoenix metro area.

3.3 STUDY PURPOSE

While emerging design criteria exist to guide PWS development internationally, designing PWS for Southwestern NFS lands provides a unique opportunity for an institutional design case study. The purpose of this study is to explore feasibility and institutional design criteria for PWS on NFS lands in USFS Region 3 through the perspectives of USFS staff and line officers and 4FRI stakeholders. These institutional design considerations can be used to guide potential development of PWS initiatives as a means of supporting forest restoration activities through the 4FRI.

3.4 STUDY METHODOLOGY

We employed an in-depth qualitative approach to develop institutional design criteria from the perspectives of key USFS personnel and affiliated stakeholders. The objective of this approach was to first identify the perspectives of USFS personnel in the region, then to use these perspectives to set the agenda for a collaborative workshop. This non-deterministic approach allowed salient themes to emerge, which together, provided the basis for formulating design criteria.

3.4.1 INTERVIEWS

In-depth semi-structured interviews were conducted with key USFS informants (n=8) at the forest and regional level in USFS Region 3. Personnel were selected using purposive, chain referral (snowball) sampling to select key informants that were particularly knowledgeable in the following areas: hydrology, watershed management, ecosystem services, restoration and administration (Henry 1990). The semi-structured interview instrument included an introductory explanation and 25 questions that addressed three pre-selected themes (water resource management, forest restoration, and PWS), but remained flexible enough for an in-depth exploration of these themes. Questions probed respondent's awareness of PWS, their thoughts on PWS feasibility, how PWS fits within the USFS management framework and their thoughts on certain aspects of PWS design. Interviews lasted between 25 minutes and 105 minutes. Interviews were transcribed.

3.4.2 WORKHSOP

Chain referral sampling from key informants in interviews was used to select USFS workshop participants at three administrative levels (forest, regional, national) (n=17). We also identified stakeholder groups of interest to the study area, which included 4FRI collaborative representatives, water utility representatives, non-profit groups, and academic institutions (n=10). The workshop was conducted on the Northern Arizona University campus and used video telephone conference technology to allow participation from four key staff members from the USFS National Headquarters in Washington, D.C. The objectives of the workshop were to share information on existing USFS PWS initiatives, identify potential partners for PWS in northern Arizona, assess the feasibility of PWS on NFS lands and identify key principles and guidance for PWS implementation on NFS lands. The workshop involved presentations, group ranking exercises and focused analysis sessions. Workshop results were recorded and transcribed.

3.4.3 DATA ANALYSIS

Qualitative analysis was conducted for interview responses using QSR NVIVO 9 qualitative analysis software. Word documents containing interview text were imported into NIVO 9 software to thematically code interviews and identify dominant themes. Coding organizes text into salient dimensions and patterns (Miles and Huberman (1994) by utilizing a structured, inductive process that organizes text into principal themes and sub-themes with graduated level of detail (Creswell 2002). Workshop results were transcribed into word processing software and coded into dominant themes and subthemes. Converging lines of evidence emerged from interview responses and workshop results and were used to confirm and augment interview analysis.

3.4.4 RESPONDENTS AND PARTICIPANTS

Interview respondents included 5 USFS personnel from the four National Forests involved in the 4FRI, 2 personnel from the USFS Region 3 office and one retired USFS employee. These personnel serve, or have served, in several different roles, with titles such as: watershed program manager, forest supervisor, social economist, grant program manager, and hydrologist. Workshop participants included 17 USFS personnel overall with four from the National Office, two from the USFS Region 3 office, and ten from the four National Forests involved in the 4FRI. Other stakeholders included two participants from a regional power and water utility, two non-profit representatives, a city water manager and several academic participants.

3.5 RESULTS

Our results first address two paradigmatic issues that emerged amongst USFS respondents. We then transition to practical institutional design considerations that were generated through coding. To underscore our findings, we provide verbatim quote from interview respondents.

3.5.1 PARADIGMATIC ISSUES

Results from interviews revealed an important paradigmatic issue regarding leveraging additional public funds through some kind of PWS for National Forest management and restoration. All interview respondents acknowledged that water resource management remains a fundamental management priority of the USFS, often citing the Organic Act of 1897 while also noting that congressional appropriations are unlikely to be sufficient for continued protection and provision of water resources.

> *"The water, the resources coming off national forest lands, I believe they're a national resource. At the same time, for watershed restoration, for vegetation restoration, we need to pay for it somehow"*

While interview respondents and workshop participants defined a need for additional funds for forest restoration and management, there was unease in leveraging additional fees from the public beyond taxes in order to fulfill an existing management mandate.

> *"I've had people argue that we already pay through taxes for management of the National Forest System including fire suppression, restoration treatments that we do and those types of things. So they're already paying as taxpayers to manage the National Forest System and wouldn't want to see an additional fee for that."*

> *"It seems to me that one of the purposes for establishing National Forests is to provide, uh, favorable conditions of flow, which, to my mind has always meant good watershed management. And, if that's one of our primary missions, I don't know that it's appropriate to charge downstream water users for that"*

These concerns stem from United States Department of Agriculture Ethics, which stipulates that agency personnel should not accept additional funds "*except pursuant* *to such reasonable exceptions as are provided by regulation*" (USDA 2012). These results raise important questions regarding the balance of agency responsibility, public contribution and sustainable management of publicly owned forest lands.

Another paradigmatic issue emerged amongst USFS regarded the commoditization of water resources from NFS lands. USFS personnel in interviews cited that participation in a *quid-pro-quo* marketplace was inappropriate with water resources. Rather, USFS personnel saw water as an ecosystem component not to be regarded as a market commodity.

> *"It would be basically treating it like a mined resource, and I really believe, again, water is a central part of ecosystems, so I'd rather see it managed as an ecosystem component rather than a commodity."*

Respondents noted that, since water resource management is part of the USFS mandate, the notion of "selling" water was inappropriate and not compatible with the agency's management objectives.

3.5.2 DESIGN CONSIDERATIONS

Design considerations for PWS initiatives emerged from the analysis across seven key components that illustrate the actors involved, the rules of engagement and how PWS might be designed. These components include: governance, intermediaries, watershed service provider, watershed service provided, monitoring and effectiveness, watershed service beneficiary, collection mechanism and financing mechanism (figure 2). Taken together, these key components provide a process diagram for PWS. Key findings are organized below according to each component of PWS scheme.

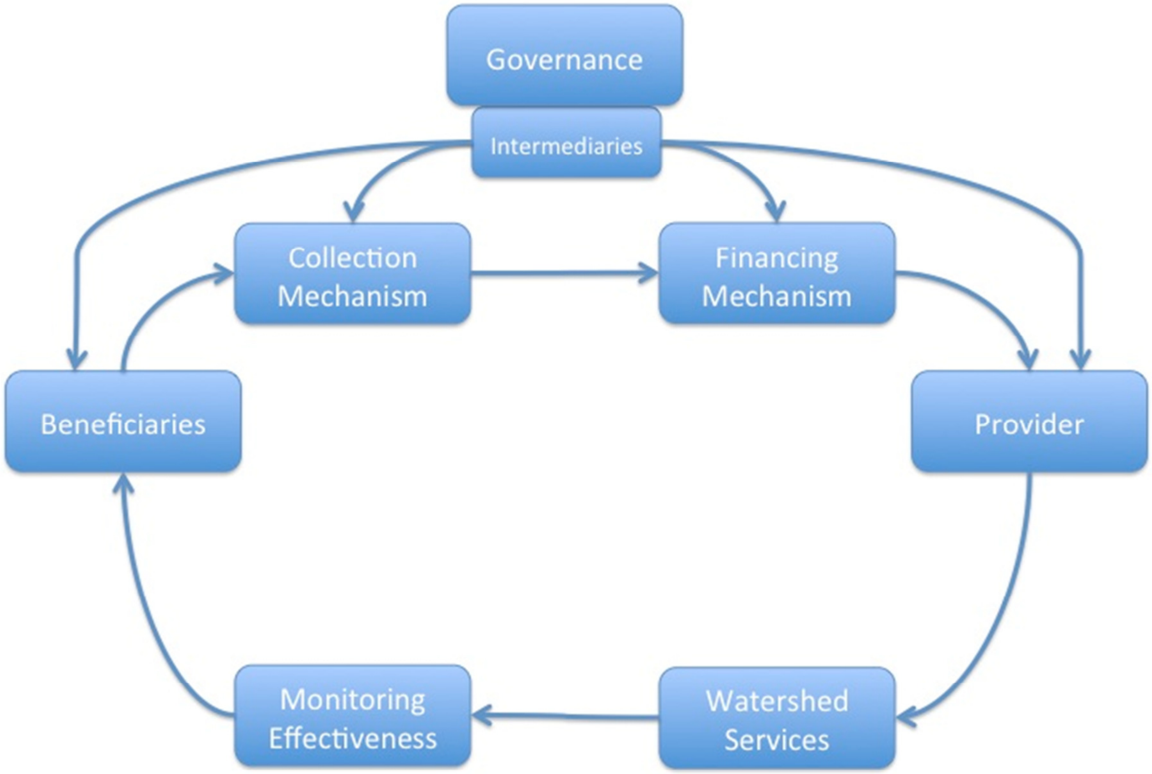


Figure 2: Key components of PWS identified in this study.

GOVERNANCE

In reference to the policy necessary for developing and implementing PWS on National Forests, almost all respondents were unable to identify policies that could enable the establishment of PWS. All participants agreed that PWS falls within the scope of the USFS directive, FSM 2522.12d-*Funding Water Yield Enhancement Projects,* which authorizes multi-financing from partnering groups or agencies for projects related to water yield enhancement. During the workshop discussion of authorities most respondents recognized that existing USFS policies are sufficient for establishing and governing PWS if based on a partnership model. Key policies mentioned included the Cooperative Funds Act of 1914 and the Granger-Thyne Act of 1950. Workshop results confirmed that, in entering into funding based partnerships, it is important for the USFS to retain their decision authority regarding management decisions on NFS lands, even while working cooperatively with partners.

One key concern regarding governance of PWS partnerships was the need for USFS impartiality and avoiding advocacy or an active organizing role. When approaching funding-based partnerships, the USFS cannot actively solicit additional funds from the public and cannot advocate for PWS-type partnerships, pursuant to USDA ethics legislation.

INTERMEDIARIES

Partnerships and collaboration emerged as a dominant theme pertaining to the governance of PWS programs. Interview and workshop participants noted an inherent reliance on external organizations for catalyzing and administering PWS initiatives. Because of a need to remain impartial, intermediary organizations were perceived to be critical for the development and governance of PWS initiatives in coordination with the USFS.

> *"Very often it's an intermediary that takes the lead in trying to broadcast, announce, inform and engage the external public into a specific project."*

Participants identified several roles for intermediaries, including: development, education and outreach, management, financing, brokering. Because of the need to remain impartial as the watershed service provider, the agency must rely on intermediaries to serve these roles. Intermediary groups identified in the workshop included national non-profit groups, regional non-profit groups, and academic institutions.

BENEFICIARIES

Workshop participants ranked several water user groups or beneficiaries that could be potential targets for PWS partnerships within the 4FRI area, including (listed from highest to lowest priority): municipal water utilities, agriculture, industry, recreation and hydropower. Municipal water utilities were identified as the most likely target for PWS initiatives because of the following criteria: population density, available monetary resources, proximity to watersheds, and ease of utilizing existing payment mechanism. The municipal and regional water utilities workshop participants expressed interest in PWS as a means of protecting and enhancing their water supply. Interview responses and workshop results revealed that user groups that are closer to a forested watershed are more likely to engage in a PWS initiative because they more aware of their reliance on forested watersheds.

> *"In places where people really perceive risk, like Santa Fe, they understand that if there's a big forest fire in their municipal watershed, they're screwed."*

Understanding public values of watershed services was identified by respondents as a necessary prerequisite because results of willingness-to-pay or public opinion surveys may be an indicator of social and political will and can concurrently play an important role in education and outreach**.** Interview and workshop results indicated that disaster such as catastrophic wildfire and visible degradation of watershed services may be a necessary or important catalyst for engaging beneficiaries.

COLLECTION MECHANISM

Collection mechanisms are instruments by which funds are collected and aggregated from individual water users. Workshop participants asserted that watershed service payments should be sufficient to significantly offset or cover the stated restoration objectives and activities. Participants suggested that payment amounts could be negotiated based on the costs of restoration treatments and the benefits received by beneficiaries.

> *"If the planning was done correctly, if the communities could say 'we feel we're receiving these types of benefits from the forest, and then some negotiated payment could be provided'….and it could be designated that the monies that are paid are for what types of treatments."*

Workshop participants indicated that understanding beneficiaries willingness-to-pay and estimates of restoration costs are crucial for the development of an effective and efficient collection mechanism. Workshop participants suggested that collection mechanisms should be designed in as an augmented existing user fee administered by the partnering agency or group, such as a water utility, to minimize transaction costs. Interview respondents and workshop participants also thought that user fees administered by partnering groups or agencies should consider an "opt-out" fees, allowing individual beneficiaries the chance to not pay the fee increase. Opt-out fees were preferred because they are likely more palatable to the public and might garner more political support than mandated fee increases.

FINANCING MECHANISM

Financing mechanisms are the mechanisms by which money is transferred from a collection entity to the USFS. All USFS respondents were strongly opposed to market-based approaches to PWS. Reasons cited included commoditization of a public good, marginalization of multiple use management objectives and inflexible contractual obligations.

> *"We are managing multiple resources and actually treating water as a commodity in a situation like this, would be basically treating it like a mined resource. And I really believe, again, water is a central part of ecosystems".*

Respondents preferred a fund-based approach because it would provide a mechanism for the flexible transfer of funds. Workshop participants indicated that when entering into PWS-type partnerships on NFS lands, USFS grants and agreement specialists should be involved early and often for selecting the appropriate instrument(s) and assuring that arrangements are authorized by the existing legislative framework. Participants identified three principle instruments useful for structuring and funding PWS initiatives. These included Memorandums of Understanding (MOU) for defining roles and responsibilities in the partnership agreement while Cost Share agreements (Granger-Thyne Act of 1950) and Collections Agreements (Cooperative Funds Act of 1914) would allow for the transfer of monies to a specific USFS unit. Additionally, these contractual instruments include provisions for termination and/or re-negotation if the terms of the contract are not met by either party.

ROLE OF USFS AS WATERSHED SERVICE PROVIDER

USFS interview participants at three administrative levels (forest, regional, national) expressed significant interest and opportunity for agency involvement in

PWS in the following areas: education, partnerships and communication, community benefits, augmented funding, and maintenance of ecological integrity. Engagement at multiple levels was indicated as a necessary institutional precondition for enabling PWS-type partnerships on NFS lands. Interview respondents acknowledged that as the legal bound stewards of water resources from NFS lands, they must be guided by existing USFS water resource management directives outlined in the Forest Service Manuals (FSM 2500). Concern emerged that PWS initiatives must not displace other management responsibilities and fit within the USFS multiple use framework. That is, acceptance of additional funds from a partnering group or agency for must not influence or alter existing restoration, desired conditions or forest management objectives.

> *"I mean, we're a multiple use agency, and so, being a multiple use agency, the resource [NFS lands] is used to produce timber, it's used to produce water, it's for watersheds and so, if you were just looking to produce water, you may do certain things differently than if you were trying to provide for all the different multiple uses."*

WATERSHED SERVICES

Interview respondents indicated that the USFS could not guarantee any specific watershed services (such as water yield, water quality, aquatic productivity), particularly in the face of environmental services. Rather, risk reduction and protection of watershed services through restoration of forested watersheds should be the primary goal of the PWS.

> *"I can't control water quantity in a drought, or flow regulation. I can't control water quality if I have a catastrophic fire. So, if it says to be guaranteed, that sounds so absolute, and our world doesn't work that way. We can implement projects with best*

> *management practices, try to create resilient forests, so that would be a means to buffer impacts."*

Interview respondents rated several threats to watershed services on southwestern NFS lands. In order of severity: wildfire, drought and climate change, and development were identified as the principal threats to watershed services. Interview respondents expressed confidence that management for the protection of watershed services (versus production of water yield) is compatible with other resource management objectives, such as timber, wildlife, and grazing. Similarly, utility representatives at the workshop expressed interest in risk reduction to and enhancement of their water supplies.

MONITORING EFFECTIVENESS

Most interview respondents suggested, that, while instrumentation (such as stream gauges) may exist on some units of southwestern NFS lands, instrumentation is not universally existent across the 4FRI area. Workshop participants suggested that it may not be necessary to measure "additional" watershed services because the USFS can only guarantee risk reduction to, and protection of existing watershed services.

> *"In terms of the level of monitoring to be absolutely clear about water quality monitoring or water quantity, I don't know we have any metrics specifically for that. You know, we do not have every watershed gauged for water quality and quantity. So we rely on best management for those protections."*

The USFS has developed programs such as the *Watershed Condition Framework* and the *Forest to Faucet Program*, which categorize watershed condition and determine the importance of sub-basins to drinking water supply. Interview respondents noted that these programs could be used for obtaining knowledge about watershed condition and monitoring. Interview respondents indicated that metrics are necessary for communicating additional watershed services back to partnering groups or agencies to encourage transparency and build trust. Interview responses and workshop participants suggest that, although no metric exists for the protection of watershed services, this could be a useful tool for communicating risk reduction and restoration progress to beneficiaries.

3.5.3 INSTITUTIONAL CHALLENGES

Throughout our analysis, we identified several challenges to PWS that emerged from interviews and workshop data. First, we found that there was a significant lack of awareness of design and implementations of PWS schemes and enabling policies amongst USFS personnel and partners. Second, we found that amongst USFS personnel, there was a general unease regarding leveraging additional funds from the public. Third, our workshop participants identified that the lack of institutional arrangements to engage high water use sectors, such as more geographically distant agricultural and hydropower beneficiaries as a significant challenge for the widespread application of PWS in the study area.

3.6 DISCUSSION

From an institutional design framework, the design considerations generated by this study support key principles elucidated by Ostrom (1999) to overcome common pool resource management problems based in existing market and government failures. The design considerations in this study define operational rules for PWS participants, including how funds are collected and transferred, where funds are transferred and when payments are negotiated and collected. Collective choice rules are defined in our study with the identified contractual mechanisms (MOU, Cost Share Agreement, and Collection Agreements) defining specific operational activities and outcomes. Constitutional choice rules in this model involve deciding which beneficiaries and/or intermediaries should participate and defining their operational rules.

Our findings suggest the potential for PWS on National Forest lands as a robust institution based on the evaluative criteria established by Ostrom (1990). Our findings specify fewer partners and use of existing collection and financing mechanism as a means of lowering overall transactions costs. In terms of institutional performance, our findings echo the considerations generated by previous research on international PWS initiatives (Stanton et al. 2010, Wunder 2008). Agreements are accountable to the collection and financing mechanisms, and may be renegotiated or terminated if treatments are ineffective through the collaborative planning process. By providing the options for voluntary contributions, these design criteria address concerns of equity, but may raise questions about program effectiveness (Brouwer et al. 2011). Moreover, because these design criteria involve the USFS, they are adaptable beyond this particular geographic area. Lastly, our findings meet Ostrom's evaluative criteria by potentially generating policy outcomes due to the conditionality of payments for enhancement of watershed services. If implemented, PWS has the potential to result in accelerated rate of forest restoration that is independent from congressional appropriations or forest management budgets.

Our results demonstrate significant unease amongst agency personnel in acquiring additional fees from the public for watershed service provision. These findings echo previous studies concerning the implementation of recreation fees by the USFS. Controversy over "double-taxing" through recreation access fees has been expressed from the perspectives of both public land managers and the publics they serve (Crompton 1981, McCormick 1995). In their study of the USFS recreation fee program, Winter and Palucki (1999) conclude that trust and communication of how fees will be used are important components in building public support for fee increases. These findings highlight the importance of a carefully framed education and outreach campaign for engaging with potential beneficiaries (Kline et al. 2009). While there are similarities, it is important to note that PWS is different from the recreation fee program in that it functions on voluntary contributions and engagement with local/regional partners rather than a mandatory fee increase at a national scale.

While a number of international PWS initiatives employ a market based approach-payments made for gains in specific quantities of watershed services - most initiatives involve payments made for land use practices that protect or enhance watershed services (Majanen et al. 2011). Our results are consistent with these findings- as the purveyor of a public good, the USFS is unable to enter into agreements that guarantee the delivery of any specific watershed services. Rather, payments are made for effective implementation of restoration activities that protect and enhance existing watershed services. Future PWS development on NFS lands should employ a fund-based approach using existing partnership instruments rather than implementing market-based mechanisms.

The key role of intermediaries identified by interview respondents and workshop participants support previous findings regarding the role of intermediaries in the governance of international PWS initiatives. Intermediaries play an instrumental role in developing PWS by mediating relations between upstream landowners and downstream beneficiaries (Majanen et al. 2011). Wunder (2008) notes that because participants in PES initiatives may have conflicting interests, an intermediary "broker" may be required for PWS administration.

While there is considerable variation in the actors involved in international PES/PWS initiatives, most domestic PES/PWS programs involve government agencies making payments to private landowners, as in the Conservation Reserve Program (Stanton et al. 2010). PWS initiatives on NFS lands involve the USFS, a government agency, acting as the service provider and the public acting as the beneficiary-an entirely unique institutional structure of most PWS initiatives. There is an increasing interest amongst potential public sector buyers, such as water utilities, in investing in watershed protection as a means of reducing future costs (Majanen et al. 2011). This suggests that municipal water utilities may be ideal partners for PWS partnerships in the region.

Our results speak to the increasing presence of collaboration and partnership development in public lands planning. Because the USFS must remain impartial and not advocate for PWS on NFS lands, the USFS must rely on partnerships and collaborative planning and management. As Cheng (2001) acknowledges, in the face of declining budgets, public land management agencies such as the USFS will rely increasingly on collaboration for many reasons, including the pooling of financial resources. The expected increase in PWS activity in the U.S. (Majanen et al. 2011) provides an opportunity for increasing collaboration and partnerships between the USFS and downstream water users, strengthening place-based governance at the watershed scale.

3.7 CONCLUSIONS AND RECOMMENDATIONS

Declining forest health in northern Arizona's ponderosa pine forests have engaged a broad base of stakeholders to accomplish forest restoration at the landscape scale. Insufficient congressional appropriations, stressed forest management budgets and high restoration costs may jeopardize the future of restoration activities-as well as the ability of NFS lands to provide reliable water supplies for downstream use. PWS may offer a funding stream by accounting for the positive externality of increased watershed services following forest restoration. Our study identifies design criteria for seven key components of PWS initiatives. Our results suggest that, with these design criteria in mind, PWS initiatives are one feasible component that can be used to augment USFS resources for watershed stewardship and forest management. While our study area was entirely within USFS Region 3, these institutional design criteria can be used to guide PWS development in other USFS regions and various watershed management scenarios.

Our research has identified a significant lack of awareness of PWS initiatives and existing policy amongst USFS personnel and partners and yet a keen interest in exploring institutional arrangements to expand participation in watershed management and enhance resources for effective implementation. With this in mind, we recommend a concerted effort by the USFS to build capacity at all levels of the USFS and amongst partnering groups and agencies. Dissemination of early PWS pilot project successes and failures would be a valuable means of building capacity and awareness while also providing useful insight for designing PWS partnerships. Education and outreach with the public and potential PWS beneficiaries may be critical for building trust and absolving the paradigmatic issue of "double-taxing".

We also recommend that research is conducted to identify variations in institutional arrangements for engaging a broader array of beneficiary groups. While municipal water utilities can provide meaningful contributions for funding restoration activities in the 4FRI project area, higher water use sectors-such as agriculture, industry and hydropower- may be able to leverage additional financial support for restoration activities.

Appendix B

ESTIMATING THE VALUE OF WATERSHED SERVICES FOLLOWING FOREST RESTORATION

WES SWAFFAR, JULIE MUELLER, ABE SPRINGER, ERIK NIELSEN, SHARON MASEK LOPEZ

2.1 INTRODUCTION

In his early observations of “the Arid Lands” of the western United States, John Wesley Powell [1879] observed that sustainable human development would require careful management of its scarce water resources. Water management in the arid western U.S., which generally receives less than 50.8 cm. of precipitation annually, would require a recognition of the importance of forested headwaters for effective water resource management. As increasing population demands and climate change threaten the sustainability of water supplies in the arid West, forest restoration plays an important role in buffering the mounting threats to water resources. Despite the need for forest restoration, funding shortfalls remain a significant barrier to implementation of restoration plans.

Across the United States, National Forest lands cover an area in excess of 78,104,329 hectares and play a critical role in capturing precipitation, enhancing groundwater recharge and supplying high quality water for downstream uses [Kimball and Brown 2003]. National Forests contribute the largest source of drinking water for the contiguous United States [Furniss et al. 2010] totaling over 329 billion cubic meters annually [Brown and Froemke 2009]. National Forest lands are particularly important in the arid western U.S., providing 51% of water supplies in the 11 contiguous Western states [Brown et al. 2005].

The quantity and quality of water resources from National Forests is highly dependent upon forest conditions and land management. Previous land management practices, particularly fire suppression and exclusion, have altered the composition and structure of western forests, contributing to declines in forest health [Kaufman 2004]. Consequently, an estimated 4,875,519 hectares are classified as unnaturally dense conditions with excessive woody fuels [Snider et al. 2003]. Unnaturally dense forest conditions restrict water availability by increasing rates of evaporative loss [Baker 2003]. Water resources are further threatened by the environmental phenomena associated with impaired forest health, such as wildfire and insect outbreak. Additionally, seasonal drought and climate change have significant impacts on the quality and quantity of water from National Forests [Berry 2010]

Global climate change will have a profound impact on southwestern water resources, including reduced stream flow due to higher evapotranspiration rates and increase in the frequency and severity of drought conditions. Climate projections for western North America indicate temperature increases of 2-5 °C by 2040 [IPCC 2007] and precipitation decreases of up to 15% for the same period [Rousteenoja et al. 2003]. Lueng [2004] suggests that climate change will significantly affect water resources in the western U.S. by the mid twenty-first century, with a 1°C temperature increase expected to decrease stream flows in the southwestern U.S. by approximately 14% [Christensen 2004]. Climate projections also forecast an increase in the variability of extreme weather events, including drought. Not surprisingly, Arizona has experienced varying levels of drought since 1996, with some of the worst since the late nineteenth century [Sheppard et al. 2002].

Increased incidences of drought and consequent declines in water availability will have significant impacts on high water-use sectors. Irrigation accounts for the largest use of surface water nationally, and claims over 70% of total water use in Arizona [Colby 2007]. Climate change could cause a reduction of the number of farmed acres in Arizona by 4 to 20 percent [Owens 2009]. Improving the condition of the forested watersheds that supply surface water for irrigated agriculture may enhance water supplies and buffer the projected losses caused by climate change.

Previous forest management practices have caused widespread declines in forest health, predisposing them to uncharacteristically severe wildfires [Kauffman 2004]. Severe wildfire can negatively impact water resources by burning vegetation that would normally slow and uptake water along its downhill course, exacerbating erosion and sedimentation. Erosion and sedimentation result in decreased water quality and significant potential damage to water-delivery infrastructure [Stanton et al. 2010]. For example, sediment and silt removal costs following wildfire in one of the Denver, Colorado's municipal watersheds amounted to $40 million [Stanton and Zwick 2010].

Trends indicate an increase in the severity and frequency of large wildfires in the western U.S. since the 1980's [Westerling et al. 2006], particularly in southwestern Ponderosa pine (*Pinus ponderosa*) forests. An average of 179,397 hectares burned annually between the years of 1993 and 2001 in Arizona and New Mexico [Snider et al. 2003]. Since then, mega fires such as the Rodeo-Chediski fire of 2002 and the Wallow fire of 2011 have consumed increasing acreage, with over 419,632 hectares burned in 2011 alone (National Interagency Fire Center 2011). The economic costs of increasing wildfire trends to society are significant, with suppression costs consuming nearly two-thirds of total United States Forest Service [USFS] congressional appropriations. The Rodeo-Chediski fire alone cost nearly $50 million in suppression efforts and over $129 million in home and property loss [Snider et al. 2003]. These cost estimations do not include the loss of important ecosystem services, such watershed function, biodiversity and air quality. Costs of fire suppression will continue to increase, as experts estimate that poor forest conditions and changes in climate could lead to substantial increases in area burned per year [McKenzie et al. 2004].

Ecological restoration can play a pivotal role in restoring ecosystem health and mitigating catastrophic wildfire potential [Allen et al. 2002]. An effort to restore southwestern Ponderosa pine (*Pinus ponderosa)* forests, the Four Forest Restoration Initiative [4FRI], seeks to restore over 970,000 hectares of ponderosa pine forests across four National Forests in Arizona. Ecological restoration generally involves a combination of mechanical thinning and prescribed burning to restore forests to within their “historic range of variability” [Mast 2003, Wu et al. 2011]. Restored forests maintain a structure that encourages natural surface fire regimes, discourages seedling recruitment, overstocking and the consequent threat of stand-replacing wildfire [Mast 2003]. After treatment areas are initially thinned, maintaining this forest condition requires follow-up treatments in the form of frequent burning and restoration monitoring.

Without large-scale intervention, fire suppression and rehabilitation costs will continue to grow, impeding the ability to maintain and restore forest conditions into the future [Covington 2000, Daugherty and Snider 2003]. Restoration costs, however, remain a significant barrier to restoration. Including overhead, average restoration costs are $2000/hectare, totaling billions of dollars at the landscape scale [Holl and Howarth 2000, Wu et al. 2011]. If viable markets for small diameter timber can be established, restoration efforts may be paid for by the resulting timber products [Daugherty and Snider 2003]. Although commercial utilization of restoration by-products may offset initial restoration costs, funding remains uncertain for maintenance restoration activities and restoration monitoring. Despite high restoration costs and the scale of the challenge, numerous economic analyses confirm that it is more cost-effective to restore forests than to pay the costs associated with severe wildfire [Wu et al. 2011, Daugherty and Snider 2003, Berry 2010]

2.2 BENEFITS

Forest restoration through the 4FRI will include treatments in three major watersheds: the Salt, Verde, and Little Colorado River watersheds (Figure 1). Hydrologic responses including enhanced water yield, enhanced snowpack retention and reduced risk of catastrophic wildfire are expected within the 4FRI watersheds following restoration treatments.

Extensive research has shown that alterations in forest vegetation can have demonstrable changes in stream flow quantity and quality [Baker 1986, Baker 2003, Brown et al. 1974]. In a study conducted by Baker [1986], water yield was found to increase for a period of 6 years following vegetation manipulation experiments in the Beaver Creek watershed, a sub-basin of the Verde River. A 33% reduction in forest over-story generated a 35% peak increase in water yield the first year following treatments, with yield increases incrementally decreasing toward pre-treatment levels for a period of six years [Baker 1986]. Increased water yields are primarily attributed to decreased canopy interception and subsequent evapotranspiration. The decreases in water loss to interception and transpiration occur as increased overland flow, and ultimately stream-flow [Baker 2003].

Snowpack accumulations in high-elevation forested watersheds provide an important source of water, particularly in the southwestern U.S. The distribution and accumulation of snowpack is largely determined by the density and spatial arrangement of forest over-story [Ffolliot et al. 1972]. Forests with a dense over-story canopy intercept a higher percentage of snow, thus exposing snow to losses from evaporation and sublimation [Baker 2003]. Forests with lower densities, such as restored forests, have a greater capacity to accumulate and retain winter snowpack. Increased snowpack accumulation and retention will prolong spring snowmelt and enhance groundwater recharge of regional aquifers [Baker and Ffolliot 2003]. The regional aquifers provide perennial baseflow to the Verde River and some of its tributaries.

Taken together, enhanced water yield, enhanced snowpack retention and decreased risk of catastrophic wildfire will result in significant benefits, or "watershed services" for downstream water users. Enhanced watershed services may serve as an important buffer to watershed health and water supply under increasing demand and uncertain environmental conditions.

2.3 STUDY PURPOSE

We estimate the WTP for irrigators in the Verde River watershed for projected increases in watershed services following landscape-scale forest restoration using the Dichotomous-Choice Contingent Valuation method. The study was conducted in the Verde River watershed of northern Arizona [see figure 1]. The study area was chosen because the 4FRI landscape-scale restoration initiative plans to restore approximately 121, 405 hectares in the Verde River watershed. The Verde River is representative of watersheds in the western U.S in which upstream forests are vital for capturing and delivering reliable, high quality water supplies. Surface water diverted from the main-stem of the Verde River through a ditch system supplies property owners with irrigable land and water rights with water for irrigation. Further downstream, water uses include hydropower, municipal supply to the greater Phoenix area, recreation, and ecological flows.

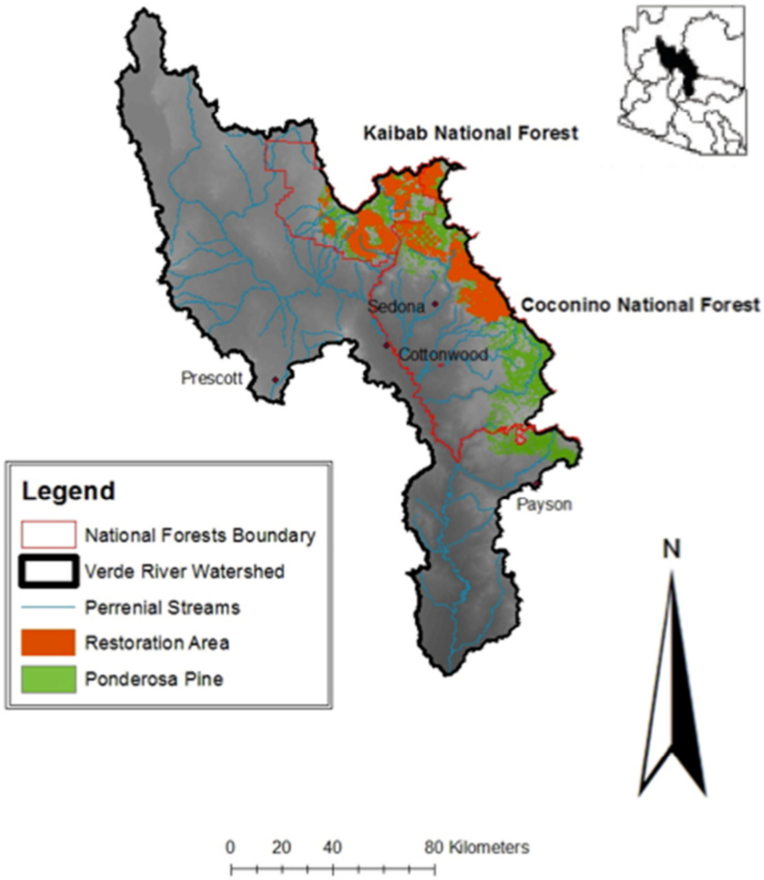


Figure 3: Forest restoration in the Verde River watershed of Arizona

2.4 METHODS

The contingent valuation method was applied to estimate the values of watershed services which might provide resources to support upland forest restoration. The Contingent Valuation method [CV] is a stated preference method of non-market valuation where respondents are asked to state their preferences for an environmental good or service that is not bought and sold in traditional markets. Many CV studies, including the one presented here, apply the dichotomous-choice elicitation format as recommended by Carson et al. [2003]. The Dichotomous-Choice CV method involves sampling a large number of respondents and asking if they would vote in favor of a referenda and pay a particular randomly assigned dollar amount.

Similar studies using CV have estimated values of non-market water-related ecosystem services. Loomis [1996] used CV to find a WTP of $73 annually among Washington residents for dam removal and restoration of ecosystem services and the associated fishery on the Elwha River. Pattanayak and Kramer [2001] used CV to estimate drought mitigation services provided by tropical forested watersheds in Ruteng Park, Indonesia. Loomis et al. [2000] used CV to estimate the value of five water-related ecosystem services on the Platte River in Colorado and found a WTP of $252 annually per household.

Our study contributes to the current body of research about the benefits of watershed services in several ways. First, while previous CV studies have estimated the WTP for various water-related ecosystem services, no known studies have estimated the value of additional water-related ecosystem services following a change in vegetation management, such as forest restoration. In addition, our study investigates the WTP for a specific group of downstream water users-irrigators in the arid Southwest. Finally, we use less commonly applied Bayesian estimation to obtain WTP estimates. Bayesian methodology is particularly useful for WTP because it provides a distribution of parameter estimates post-estimation without any additional simulation.

2.4.1 SAMPLE SELECTION

A sample was selected from surface water users within Yavapai County. Thirteen ditch associations divert water from the Verde River and its tributaries around the incorporated towns of Camp Verde, AZ and Cottonwood, AZ. Of the thirteen ditches, four were selected based on the number of users they serve and their engagement with previous studies. Once the sample was selected, addresses were obtained from the Yavapai County Assesor's office of properties that border the four sampled ditches.

2.4.3 FOCUS GROUP AND SURVEY DESIGN

A focus group was held with the leaders of the four sampled ditch associations to test and validate the survey instrument. A draft of the survey was distributed and completed by the informants and their recommendations were used to guide the survey design and development. After discussing the survey instrument, support in encouraging their ditch users to complete and return the survey was requested.

Data were obtained from a Dichotomous-Choice Contingent Valuation survey of sampled irrigators in the Verde River watershed. The survey was designed using the Dillman Tailored Design Method [Dillman 2007]. Water users were sent a signed cover letter, colored survey booklet, and a return envelope. A reminder postcard was sent, and non-respondents received a second mailing of the survey booklet. We also sent a reminder postcard to non-respondents for the second mailing.

Because obtaining accurate estimates requires detailed descriptions of the resources being valued and the contingencies in question [Loomis et al. 2000], the first section of the survey included a watershed map and diagrams of three different watershed condition scenarios [see Appendix]. Diagrams displayed three watershed conditions: “Current watershed condition,” “Restored Watershed Condition” and “Watershed Condition Following Wildfire” and the hydrologic responses associated with each watershed condition. Following these diagrams were attitudinal questions about forest restoration, water supply and the WTP question. The last section included demographic questions and solicited respondent’s comments.

The WTP question read as follows:

“Suppose you were asked to vote on a referenda suggesting water user contributions for maintaining watershed restoration. If the referenda were passed, water users would be charged an annual fee. By law all fees collected would be spent on forest restoration activities that would improve watershed services. If the water user contribution program were to cost you $ X annually, would you vote in favor of the referenda”,

where “X” equals a random bid amount inserted into surveys. Bid amounts ranged from $10 to $1000, weighted with higher frequencies from $10-$100 and lesser frequencies from $100-$1000. Bid amounts were selected based on average annual irrigation costs indicated by informants during the focus group session.

2.4.4 RESPONDENT CERTAINTY

After the WTP question, respondents were asked to rank their certainty of their response on a scale of 1 to 10, where 1 is “Not at all certain” and 10 is “Completely certain”. A large body of research exists on reducing hypothetical bias by using certainty responses [Champ and Bishop, 2000]. Hypothetical bias occurs when responses to hypothetical contingent valuation questions do not elicit true values. That is, hypothetical bias occurs when respondents answer a hypothetical question in a way that is inconsistent with their actual behavior. Champ and Bishop [2000] performed a split sample experiment where some respondents were asked their WTP to invest in wind energy for one year, while others were offered a hypothetical opportunity. Champ and Bishop [2000] find evidence of hypothetical bias—the WTP of the respondents with the hypothetical opportunity is higher than those with the actual investment opportunity. However, when respondents who were less certain of their answer to the hypothetical WTP question were coded as voting "no," the hypothetical bias was eliminated. Therefore, we choose to follow the approach suggested in Champ and Bishop [2000], and applied by Li et al [2009].

2.4.5 METHOD OF ESTIMATION

We estimate the WTP function with a standard probit model using Bayesian techniques. Following Cameron and James [1987] The standard probit model is based on the assumption of an underlying WTP function

[1]

$$WTP_i = x_i'\boldsymbol{\beta} + \mu_i$$

where x_i is a vector of explanatory variables, β is a vector of estimated coefficients, and μ_i is a random error term. The WTP function is not observable to the researcher, yet latent WTP is represented by the respondents' "vote" on the WTP question. Let y_i represent the respondent's vote, =1 if "yes" and 0 if "no." Assume are independent and normally distributed with a mean 0 and standard deviation σ, and Bid_i is the randomly assigned bid amount for each respondent *i*. The probability of a "yes" vote given the explanatory variables and random error is equal to the probability that the individual's unobserved WTP is greater than the bid amount. Therefore,

[2]

$$\Pr(y_i = 1|x_i) = \Pr[\mathrm{WTP_i} > \mathrm{Bid_i}]$$

$$= \Pr[x_i'\beta + \mu_i > \mathrm{Bid_i}]$$

$$= \Pr[\mu_i > \mathrm{Bid_i} - x_i'\boldsymbol{\beta}]$$

$$= \Pr(z_i > \ [\mathrm{Bid_i} - x_i'\boldsymbol{\beta}) \ /\sigma]$$

where z_i is the standard normal random variable and σ is a variance parameter, *The standard probit model with n observations thus has the likelihood function:*

[3]

$$\mathrm{logL} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \left\{\mathrm{WTP_i} \log\left[1 - \Phi\left(\frac{\mathrm{Bid_i} - x_i'\boldsymbol{\beta}}{\sigma}\right)\right] + [1 - \mathrm{WTP}]_\mathrm{i} \log\left[\Phi\left(\frac{\mathrm{Bid_i} - x_i'\boldsymbol{\beta}}{\sigma}\right)\right]\right\}.$$

We estimate the probit model using Bayesian estimation and Gibbs sampling [Gelfland et al 1990]. Following Li et al [2009], let WTP represent a latent variable on *n* observations. WTP for an individual is then a function of the explanatory variables, x_i, and the other parameters of interest $\boldsymbol{\beta}$ and σ. β_0 and s_0 are the initial values of the parameters of interest, N denotes the normal distribution and IG denotes the inverse gamma distribution. Thus,

[4]

$$WTP_i \sim N[X_i'\boldsymbol{\beta}, \sigma^2]$$

and β and σ are independent with

[5]

$$\boldsymbol{\beta}|\sigma^2 \sim N[\beta_0, \sigma^2 B_0^{-1}]$$

[6]

$$\sigma^2 \sim IG[\frac{\gamma_0}{2}, \frac{\gamma_0 s_0^2}{2}].$$

The Gibbs sampler starts with initial values [in our case, the initial values are set =0] and draws β and σ through 20,000 simulations. We drop the initial 19,000 simulations. Unlike traditional Maximum Likelihood estimation techniques, because we use Markov Chain Monte Carlo (MCMC) methods to estimate WTP, we don't have to use additional simulation procedures to estimate WTP from the regression coefficients. WTP draws are a product of our estimation.

2.5 RESULTS

2.5.1 RESPONSE RATE

We sent mailings to 1,137 households. Ninety-nine surveys were undeliverable. Three hundred and thirty-five respondents returned their surveys, for a response rate of 32%. This represents a significant response rate given the contentious nature of water issues in the arid southwest. In Loomis et al.'s [2000] study, a response rate ranging from 25.7 % to 41% was reported, depending on whether or not all responses were recorded. Loomis's [1996] study of WTP for dam removal recorded a higher response rate: 77% for Clallam County residents, 68% for Washington State residents, and 55% for United States residents.

2.6.2 RESPONDENT ATTITUDES TOWARD FOREST RESTORATION

Among the attitudinal questions asked were questions about respondent's awareness of the restoration initiative in their watershed and how it may impact their water supply. Seventy-eight percent of respondents indicated that they were not aware of 4FRI before receiving our survey. Approximately 86% of respondents chose "yes" when asked if they believe that forest restoration will have a positive impact on their water supply. These results indicate that while most respondents were not aware of proposed restoration plans, most believed that restoration would result in additional watershed services.

Respondents were also asked to rank the importance of water issues considering the full range of issues they face. On a scale of 1 to 5 where 1 is "Not Important," 2 is "Slightly Important," 3 is "Moderately Important," 4 is "Very Important," and 5 is "Extremely Important," the average was 4.6, indicating that water issues remain a pertinent issue to our respondents.

Respondents were asked to rank their concern for the following threats to their water supply on a scale of 1 to 5, where 1 is "Not at all Concerned," 2 is "Slightly Concerned," 3 is "Moderately Concerned," 4 is "Very Concerned" and 5 is "Extremely Concerned":

- Catastrophic Wildfire
- Over-allocation of Water
- Drought
- Global Climate Change

Our data show respondents are less concerned about climate change than they are about *over allocation of water* and *drought*, however the mean for *climate change* is 3.02 indicating that respondents are, on average, "Slightly Concerned" about climate change. While *wildfire* was expected to be a threat of particularly high concern, respondents were, on average, less concerned about *wildfire* than they were for *over allocation of water* and *drought*.

2.5.3 RESPONDENT CERTAINTY

Following the approach suggested by Champ and Bishop [2000], we present results with WTP responses recoded as "no" for those with certainty levels less than 8. Average respondent certainty was 8.2 [see figure 2]

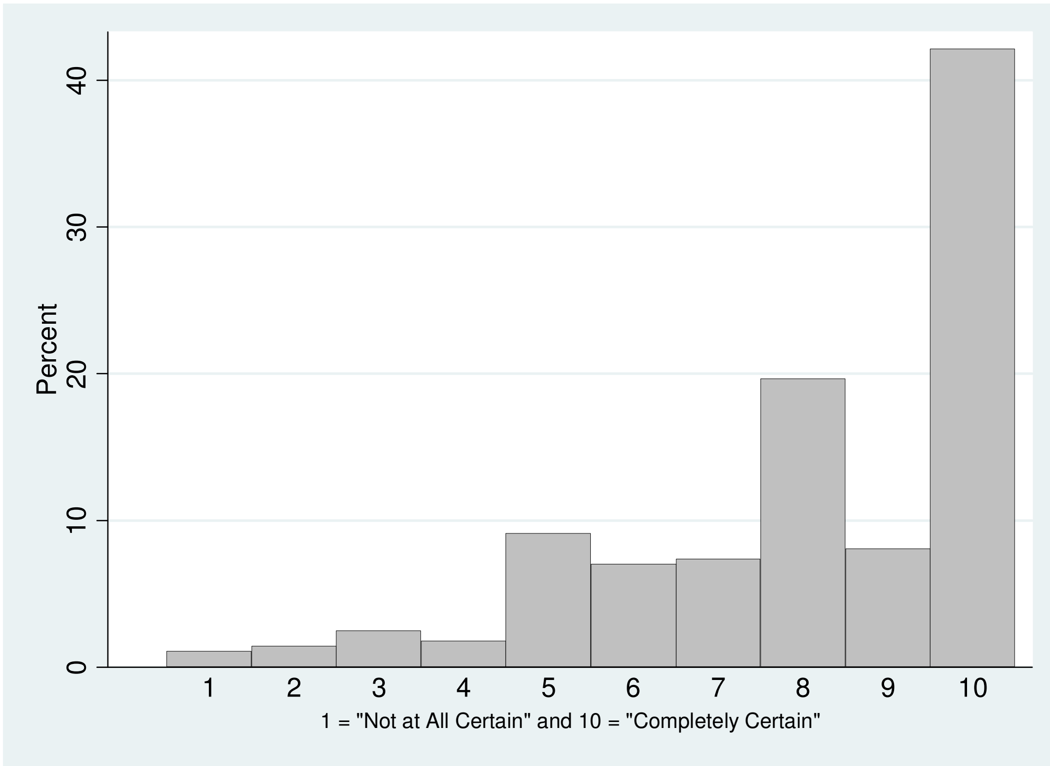


Figure 4: Respondent certainty on willingness to pay question

2.5.4 WTP ESTIMATES

WTP is obtained using the parameter estimates from the probit. Following Hanneman [1984], WTP from a standard probit is

$$\frac{-\alpha}{\hat{\beta}_{Bid}}$$

Where

$$\alpha = \hat{\beta}_0 + \left(\hat{\beta}_1 \times \bar{X}_1\right) + \left(\hat{\beta}_2 \times \bar{X}_2\right) + \cdots + \left(\hat{\beta}_{K-1} \times \bar{X}_{K-1}\right)$$

for all the explanatory variables except for $\hat{\beta}_{Bid}$. We predict WTP as a function of the following explanatory variables:

- *Awareness*: Is the respondent aware of 4FRI?
- *Degree of Concern for Water Issues*: On a scale of 1 to 5 where 1 = Not at all Concerned and 5 = Very Concerned
- *Over-Allocation of Water*: On a scale of 1 to 5 where 1 = Not at all Concerned and 5 = Very Concerned
- *Drought*: On a scale of 1 to 5 where 1 = Not at all Concerned and 5 = Very Concerned
- *Irrigation Costs:* Reported Annual Irrigation costs [categorized]
- *Annual Income:* Reported Annual pre-tax household income [categorized]

The probit results are reported in Table 1.

Table 1:Bayesian Probit Model Results

Variable	**Coefficient**	**Std Deviation**	**p-level**	**Means**
Constant	-2.423036	0.927681	0.0030	
Bid	-0.001508	0.000877	0.0380	
Awareness	-0.249727	0.296411	0.1970	0.2261
Positive Restoration Impact	0.771327	0.491482	0.0500	0.9226
Over-Allocation of Water	0.042740	0.152011	0.3770	4.1400
Drought	0.439531	0.160951	0.0030	4.1875
Irrigation Costs	-0.138822	0.068383	0.0200	5.5620
Annual Income	0.132567	0.042268	0.0000	6.0290

Mean WTP $183.50

The estimated coefficient on *Bid Amount* is negative and shows the Bayesian equivalent of statistical significance. The estimated coefficient on *Awareness* is negative and not statistically significant. Although not significant, the estimated coefficient on *Awareness* weakly indicates that respondents aware of 4FRI are less likely to vote "Yes." The estimated coefficient on *Positive Restoration Impact* is positive and statistically significant, indicating that respondents who believe that forest restoration will have a positive impact on watershed services are more likely to vote "yes." The more concerned a respondent is about *Over-Allocation of water*, the less likely the respondent is to vote "yes." The more concerned respondents are about *Drought Risk*, the more likely they are to vote "yes" on the WTP question. The more the respondent currently pays in *Irrigation Costs*, the less likely they are to vote "Yes." Respondents that report a higher income are more likely to vote "Yes" on the WTP question.

Using Hanneman's [1984] formula, the mean WTP from the estimated coefficients is $183.50 annually. We also calculate the mean WTP and a 95% confidence interval using the draws from the Gibbs Sampler. The entire distribution of the WTP estimates is shown below [see figure 3]. The mean WTP from the draws is $197.69 with a 95% CI lower bound of $153.57 and upper bound of $241.39. In other words, we can be 95% confident that the true mean WTP is between $153.97 and $241.39.

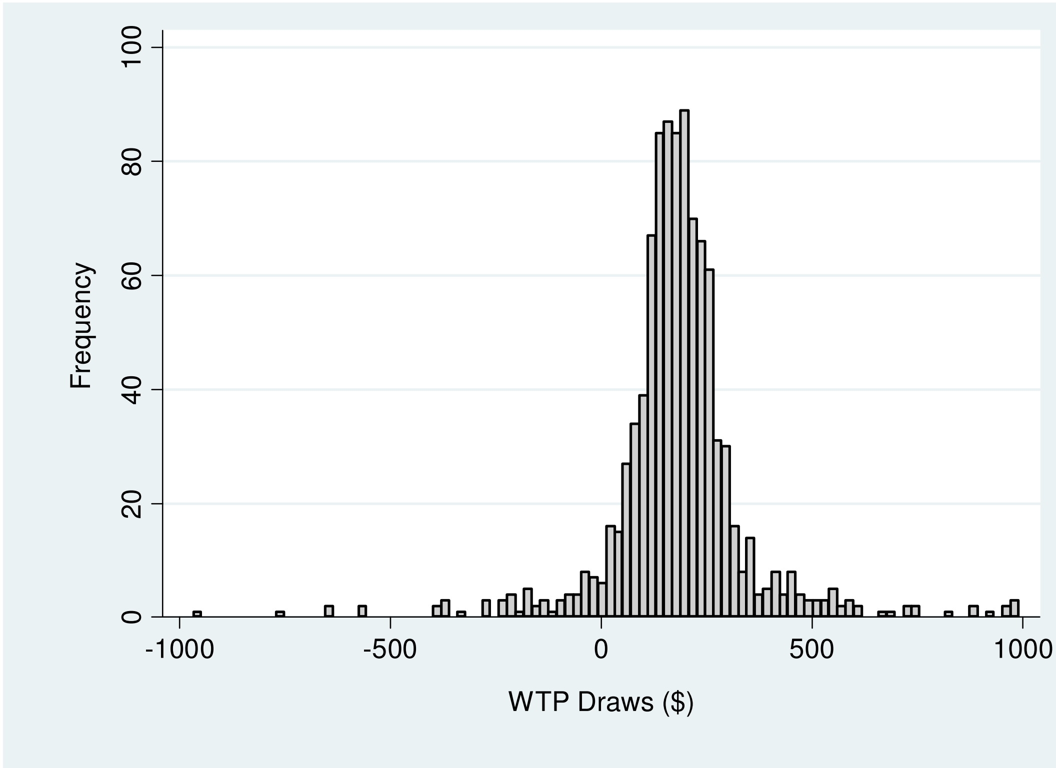


Figure 5: Distribution of willingness-to-pay estimates

2.6 DISCUSSION AND POLICY IMPLICATIONS

Our results have significant implications for demonstrating the value of additional watershed services following forest restoration. Our sample consisted of 1,137 irrigators, and there are approximately 2,181 irrigators in the Verde River watershed receiving potential benefits from 4FRI restoration. Using our average WTP estimate, if there are 2,181 irrigators who would benefit from 4FRI, this represents an annual aggregate benefit of 2,181 * $183.50 = $400,214. In Loomis et al.'s [2000] study, they found that the WTP of $252 annually per household for additional water-related ecosystem services yielded an aggregate benefit of $19 million to $70 million. These benefits were more than enough to justify the $12.3 million cost of conservation easements and water rental necessary to deliver improved ecosystem services. Loomis' [1996] study of Washington resident's WTP for dam removal yielded an estimated WTP of $73 per household annually, yielding an aggregated benefit of $138 million annually for the state of Washington. Although somewhat geographically distant from upstream forested watersheds, our results indicate that downstream irrigators value upstream forests that capture and deliver water.

While the WTP amongst irrigators may be significant, irrigation represents only half of total use of water from the Verde River. Water diverted to the greater Phoenix area from the Verde River averages approximately 93.1 million cubic meters [Yvonne Reinink, Salt River Project, personal communication] while irrigation in the study area accounts for only 41.8 million cubic meters annually [Poole et al. 2011], with much of those diverted flows returned to the main-stem Verde River. Capturing the true value of additional watershed services from forest restoration would require estimation of WTP amongst other downstream user groups.

While wildfire was expected to be perceived as a major threat to water supply, wildfire was not a significantly greater concern to respondents than over allocation of water and drought. Although wildfire is considered by experts to be the greatest threat to watershed health throughout the region, drought and over-allocation of water are prevailing concerns to irrigators. This may be due to the geographic distance between upstream forests and downstream water users.

Estimating this WTP of water users for water related ecosystem services from forest restoration is important because the willingness of different water users to invest in watershed health may determine the future health of western forests and their ability to provide ample amounts of high quality water. It must be noted that the values estimated in this study represent one of several different water user groups. Future studies estimating the WTP for other water users, such as recreation, municipalities and hydropower would contribute to the total demand for watershed services for different user types. The WTP of these other user groups may provide more than enough funding to completely offset landscape-scale restoration costs.

2.7 CONCLUSION

In this study, we estimated the WTP of additional watershed services from landscape scale forest restoration. From our sample of 1,137 irrigators, we found that the average annual WTP per household was $183.50 for an aggregated benefit of $400,000. We found that statistically significant predictors of WTP were respondents' awareness of forest restoration, degree of concern of water issues, over-allocation, drought, annual water costs and annual income. Our study provides evidence that downstream irrigators are willing to invest in the upstream watersheds that provide important watershed services. Policymakers and other stakeholders may be able to ensure the long-term financial sustainability of large-scale forest restoration and healthy watershed by capturing the non-market demand for improved watershed services.