

WATER RIGHTS PERMIT SYSTEM (WRPS): A GIS-BASED TOOL FOR THE UMPQUA  
DRAINAGE BASIN

By

Kathy Thompson

---

A Thesis Presented to the  
FACULTY OF THE USC GRADUATE SCHOOL  
UNIVERSITY OF SOUTHERN CALIFORNIA  
In Partial Fulfillment of the  
Requirements for the Degree  
MASTER OF SCIENCE  
(GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY)

May 2014

Copyright 2014

Kathy J. Thompson

## TABLE OF CONTENTS

Abstract .....	v
Aknowledgments .....	vi
List of Tables .....	vii
List of Figures .....	viii
List of Abreviations .....	xi
Chapter One: Introduction.....	1
1.1 Prior Appropriation .....	1
1.2 Effects of Prior Appropriation .....	2
1.3 Implementation of GIS .....	3
1.4 Umpqua Drainage Basin Study Area .....	5
1.5 Mapping Water Rights.....	9
1.6 Motivation.....	11
1.6.1 Water Rights and Land Ownership.....	12
1.6.2 Water Rights Transfers .....	12
1.6.3 Water Rights and Land Use .....	13
1.6.4 Water Rights and Conflict Resolution.....	13
1.6.5 Water Rights and Regulation .....	14
1.6.6 Water Rights and Wastefulness.....	14
Chapter Two: Background .....	16
2.1 New Mexico.....	16
2.2 Nevada .....	18
2.3 Montana .....	21

2.4 Wyoming .....	26
2.5 Idaho .....	28
2.6 Utah .....	32
2.7 Colorado.....	34
2.8 Washington .....	36
2.9 Oregon .....	39
2.10 State Water Rights Research Summary .....	45
Chapter Three: Methodology.....	46
3.1 Oregon Water Resource Department.....	46
3.2 Research and Feedback.....	47
3.3 Development of Water Rights Distribution Information.....	48
3.4 Douglas County GIS.....	48
3.5 Definition of System for Development .....	49
3.6 Creating the Distribution Maps.....	50
3.7 Base Features .....	51
3.8 Aerial Images .....	53
3.9 Data development.....	53
3.10 Creation of Distribution Maps .....	59
3.11 Distribution on Laptop for Fieldwork .....	61
3.12 Distribution of Information on Water Rights Website .....	62
3.13 How the Website Works .....	63
3.14 Cartographic display.....	66
3.15 User Satisfaction.....	69

3.16 Project Implementation.....	69
Chapter Four: Results.....	71
4.1 Advancements Achieved Utilizing GIS.....	71
4.2 Problems Resolved with the System .....	72
4.2.1 Aggregation.....	72
4.2.2 Additional Attributes .....	74
4.2.3 Galesville Contract .....	74
4.2.4 Picklist.....	75
4.2.5 Cartography.....	76
4.3 Problems Created with the System.....	77
4.4 User Feedback and Adjustments .....	77
Chapter Five: Conclusion.....	79
5.1 Summary of Findings .....	79
5.2 Significance of Findings .....	81
5.3 Future Research.....	82
References .....	84
Appendix: Website Questionnaire and Response.....	87

## ABSTRACT

The distribution and management of water resources in the Western United States has become a critical issue. Limited and declining sources of water are regulated by legislation. The key regulatory principle is the prior appropriation doctrine that states the senior water rights holders are allowed to use water before any rights granted at a later date. Prior appropriation is significant during dry seasons or low water levels in streams. The regulation of such a system requires a water manager to research the current status and location of each water right and associate it to a parcel and address. Government agencies responsible for regulating water rights in western states have implemented digital mapping and geographic information systems to streamline this process. However, it is necessary to improve the accuracy and availability of the water rights information in digital form to implement an efficient system for compliance investigations during regulation seasons. This study demonstrates the methods utilized to develop an accurate geographic information system in the Umpqua Basin in Oregon to support the Watermaster responsible for regulation through prior appropriation requirements.

## ACKNOWLEDGMENTS

I would like to acknowledge the State Watermaster, Dave Williams, for his idea, mentoring and continued support for GIS for water resource management. Thank you to the Assistant Watermaster, Laura Duncan, for information required to successfully implement a water rights permit GIS at Douglas County and Terrie Franssen for continual suggestions from another perspective.

Thank you to the Douglas County Public Works Engineering Department. The support for the Enterprise GIS has enabled the development of this project. The dedication of time and resources has been very generous.

Also, I would not have been able to complete this process without the support of the Oregon Business and Professional Women. Thank you OBPW for supporting me both financially and intellectually.

I especially would like to thank the University of Southern California and the Professors that support the Geographic Information Science and Technology program. The opportunity for a degree in GIST would not exist without the dedication required to develop an education program for geographic information implementation.

I would like to thank my family for their exceptional patience during my learning experience. Acknowledgement of their sacrifice is duly noted.

**LIST OF TABLES**

Table 1: State Summary .....	45
Table 2: PLSS Features .....	52
Table 3: Departmental Feature Responsibility .....	52
Table 4: Place of Use Feature Attributes.....	59
Table 5: Point of Diversion Feature Attributes.....	59
Table 6: Feature Display by Scale .....	66
Table 7: Additional Attributes for Place of Use .....	74
Table 8: Additional Attributes for Point of Diversion .....	74
Table 9: Galesville Contract Information.....	75
Table 10: Attributes with List Tables.....	76

## LIST OF FIGURES

Figure 1: Watermaster Districts in Oregon (OWRD Map Library 2013) .....	5
Figure 2: Douglas County Umpqua Basin .....	6
Figure 3: Roseburg Area with Water Rights .....	8
Figure 4: PLSS configuration (OWRD Information Services 2010).....	9
Figure 5: Legal Description (Official Oregon State Records 2013).....	10
Figure 6: Example of Old Water Rights Map (Official Oregon State Records 2013).....	10
Figure 7: Document from 1911 (Official Oregon State Records 2013).....	11
Figure 8: New Mexico WATERS Areas of Abstraction (Campbell 2011).....	18
Figure 9: Nevada Permit Search Page (NDWR 2013).....	19
Figure 10: Tabular results of Nevada permit search (NDWR 2013) .....	20
Figure 11: General detailed results of permit search (NDWR 2013) .....	20
Figure 12: Nevada Mapguide ó Interactive Water Resource Map (NDWR 2013) .....	21
Figure 13: Digital Atlas of Montana Points of Use (NRIS 2013) .....	23
Figure 14: Digital Atlas of Montana Points of Diversion (NRIS 2013) .....	24
Figure 15: DNRC Query Results Table (DNRC 2013) .....	25
Figure 16: DNRC Query Results Map (DNRC 2013) .....	25
Figure 17: Wyoming Interactive Map Server (University of Wyoming 2008).....	27
Figure 18: Modified Wyoming Interactive Map Server (University of Wyoming 2008).....	28
Figure 19: Results of Permit for Irrigation Land Selection Tool (University of Wyoming 2008)	28
Figure 20: Idaho Irrigation Map Search Results (IDWR 2013) .....	30
Figure 21: Idaho General Mapping Tool for Water Rights (IDWR 2013) .....	31
Figure 22: Idaho General Mapping Identify Information (Britton 2013) .....	31

Figure 23: Utah water rights data results (UDWR 2013).....	33
Figure 24: Utah Map Viewer for water rights query results (UDWR 2013).....	34
Figure 25: Water Rights Research Form (CWCB 2013) .....	35
Figure 26: Colorado's Decision Support System Map Viewer (CWCB 2013).....	36
Figure 27: Washington Water Resource Explorer (DOE 2013).....	38
Figure 28: Water Resource Explorer Parcel Reference (DOE 2013) .....	39
Figure 29: Water Rights Information Query Form (OWRD 2013) .....	40
Figure 30: Water Rights Information Search Results (OWRD 2013) .....	41
Figure 31: Water Rights Information Query Results (OWRD 2013).....	41
Figure 32: Oregon Water Rights Interactive Map (OWRD 2013) .....	42
Figure 33: Water Right Information Search (OWRD 2013).....	43
Figure 34: Plat Card Search Results (OWRD 2013).....	44
Figure 35: PLSS Grid Discrepancy Example .....	55
Figure 36: Example of Additional Point for Image Registration.....	56
Figure 37: Comparison of State (purple) and County (blue) locations of permit 14247 .....	57
Figure 38: Permit 14247 Representing Actual use Location.....	58
Figure 39: Hand Drawn Distribution Map (Henry 2013) .....	60
Figure 40: Web Map Server Diagram.....	62
Figure 41: Natural Resource Website .....	64
Figure 42: Web Search Option .....	65
Figure 43: Web Search Results.....	65
Figure 44: Place of Use Symbology by Date .....	67
Figure 45: Water Rights Thematic Display by Date.....	68

Figure 46: Domestic Expanded Thematic Display by Date .....68

Figure 47: Aggregation Flow Chart .....73

Figure 48: Aggregation Results .....73

**LIST OF ABBREVIATIONS**

AW	Assistant Watermaster
CDSS	Colorado Decision Support System
CDWR	Colorado Division of Water Resources
CWCB	Colorado Water Control Board
DAM	Digital Atlas of Montana
DC	Douglas County
DNRC	Department of Natural Resources and Conservation
DOE	Department of Ecology
DWR	Division of Water Resources
DWRD	Director of the Water Resource Department
ESS	Engineering System Specialist
GIS	Geographic Information System
IDWR	Idaho Department of Water Resources
IIS	Internet Information Services
IMS	Interactive Map Server
IWRS	Integrated Water Resource Strategy
NAD	North American Datum
NDWR	Nevada Division of Water Resources
NMOSE	New Mexico Office of the State Engineer
NRIS	Natural Resource Information System
ODOR	Oregon Department of Revenue
OIWA	Oregon Instream Water Act

ORMAP	Oregon Mapping Program
OSE	Office of the State Engineer
OWRD	Oregon Water Resource Department
PDF	Portable Document Format
PLSS	Public Land Survey System
POD	Point of Diversion
POU	Place of Use
RWD	Roseburg Water District
UDNR	Utah Department of Natural Resources
UDWR	Utah Division of Water Rights
UofW	University of Wyoming
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WATERS	Water Administration Technical Engineering Resource System
WRC	Water Resource Commission
WRD	Water Resource Division
WRE	Water Resource Explorer
WRIS	Water Right Information System
WSDE	Washington State Department of Ecology

## CHAPTER ONE: INTRODUCTION

Fresh water is one of the most valuable resources on Earth. Currently the supply of fresh water is declining due to over-appropriation, climate change, and pollution. Over-appropriation is the practice of distributing more water for use than the recharge volume (Bastasch 2006). This includes in-stream, out-of-stream and ground water applications. Current models of climate change show warmer temperatures and less precipitation in the form of snow (EPA 2013). In the U.S. this is of particular concern in the mountainous western regions, because it will result in reduced snow packs for late season run-off (Western States Water Council 2008). The combination of reduced water flow and pollution exacerbate the problem of fresh water scarcity. The management of limited water resources is critical to the environmental health of regions in the western United States.

Water resource management systems are often implemented for a generalized evaluation of a defined area of interest. The process encompasses all aspects of water supply and demand (Davis 2007). The knowledge base within natural resource agencies is vital to the success of water management systems. The state agencies vary, but have similar missions, to serve the public by practicing and promoting responsible water management (OWRD 2013).

### 1.1 Prior Appropriation

In most western states, the allocation of fresh water is accomplished through a permit system that requires water users to first obtain a water right permit or certificate. When the water supply is not sufficient to meet the needs of all rights, distribution of the available water is based on the principle of prior appropriation. The prior appropriation doctrine basically states -first in time, first in right (Western States Water Council 2008). Essentially, all users are in line to

receive their allotment based on the priority date of their right. The oldest right receives their water before all other junior users. To assert rights to water through prior appropriation, users must plan for timely beneficial use of the water and move water from the source, referred to as a point of diversion (POD), to the place of use (POU).

Existing policies require regulatory authorities to distribute available supplies among the rights of record according to the prior appropriation doctrine during times of water shortages. In Oregon, this responsibility falls to Watermasters located in the different drainage basins (State of Oregon 2011). To ensure that senior water rights are being honored, Watermasters must curtail diversions of junior water rights. The Watermaster in charge of regulation must approach the correct physical address of the water rights permit holders to curtail diversion. This study provides a methodology utilizing GIS to determine the property ownership and address location of the water rights permits. Water managers in other states perform similar duties.

## **1.2 Effects of Prior Appropriation**

In the United States, the application of the prior appropriation permit system over the past 150 years has resulted in some undesirable consequences. Over-appropriation of the water resources during drier times of the year is one of the greatest concerns. During early migration west, resources were plentiful. People were encouraged to make what were considered beneficial claims to water. Initially, water was diverted for mining and farming (Bastasch 2006). Claims received a water right permit defining the location and the beneficial use. The demand for water increased with the population growth. The supply and demand for water resources continue to diverge. Many surface water sources in Oregon are fully appropriated and do not allow new water rights permits. It is important to accurately define the current and accurate place of use for water rights permits to avoid further over-appropriation of the resource.

The prior appropriation doctrine does not put a value on the type of beneficial use claimed by a water right (Toll 2001). A beneficial use is typically mining, industry, domestic, livestock, or irrigation. The value of in-stream use for habitat has only been recognized within the last 50 years. In Oregon, this was accomplished with the Oregon Instream Water Act (OIWA) passed in 1987 (State of Oregon 2012). The OIWA defines the minimum required water levels in streams to sustain local habitat. As the minimum levels are reached, regulation of water rights permits by prior appropriation requires disabling junior rights. There is no distinction between types of beneficial use. The results could allow a more wasteful use such as mining, even if livestock are thirsty.

There is no time limit on a permit in effect as long as it continues to be actively applied to the defined use. This promotes a "use it or lose it" wasteful attitude (Toll 2001) with the scarce resource. During times when rainfall is abundant and fields do not require watering, or when there are no livestock on the pasture, irrigation may need to continue in order to prevent the water right from becoming subject to forfeiture. If a water right is not exercised for beneficial use once every five years, it may be cancelled.

### **1.3 Implementation of GIS**

The use of geographic information systems (GIS) in water resource management has been common since the 1990s. The implementation has typically been for the estimation of available water within a drainage basin during any given time of year (Todorovic and Steduto 2003). A common beneficial use to analyze is irrigation. Beginning in the early 1990s, many state agencies translated paper documents defining water rights to scanned and digitized digital formats for research and historical representation (Harmon, Carine and Tippett-Huber 2013). The

determination of the latest place of use and point of diversion of the water right requires time consuming research of the digital information defining the water rights transfers through time.

Drainage basins may contain from several hundred up to several thousand water rights. It is essential that water managers have specific information describing the rights subject to regulation in order to provide timely distribution regulation. The regulation is required to protect in-stream fishery resources and senior consumptive users. Defined water levels are required to maintain in-stream habitat. When the water level falls below the defined amount, the regulation of the appropriated water use is enforced. The current appropriation of the water after all transfers are evaluated must be known. The process of transferring water rights may cause information to be obscured and difficult to determine the current status of the water right.

The purpose of this thesis is to define, develop, and test a Geographic Information System (GIS) that will meet the specific requirements of water managers. The Oregon State Water master responsible for the Umpqua Basin requested a geographic information system to allow access to the up to date and accurate location of the authorized place of use, points of diversion, ownership boundaries, and address points for all rights within the defined area of responsibility. Research uncovering the status of the defined appropriation of the water rights will determine the current amount of water allotment, the point of diversion, the type of appropriation, and the location of the distribution.

The development of the water rights permit GIS requires the research and digitization of the official state information. The results of the project are the digitized place of use and point of diversion for surface water rights. When combined with existing parcel and address information in the GIS, the system will be capable of determining the address and ownership of the

appropriated right to use the water. Water managers can identify the correct current owner of the beneficial use when regulation is required.

### 1.4 Umpqua Drainage Basin Study Area

Western states are divided into manageable water areas. Oregon is divided into five water regions and twenty districts. The Southwest region contains the Umpqua Basin. The Roseburg Water District (RWD) (District 15) is responsible for the management of the Umpqua basin (see Figure 1). A Watermaster is assigned by law to the Roseburg Water District. The boundaries of the RWD and the Umpqua Basin are coterminous. The boundary of Douglas County (DC) and the Umpqua Basin overlays results in a small area of the Umpqua basin that is not covered by DC data (see Figure 2). The Umpqua Basin is the study area for this project.



Figure 1: Watermaster Districts in Oregon (OWRD Map Library 2013)

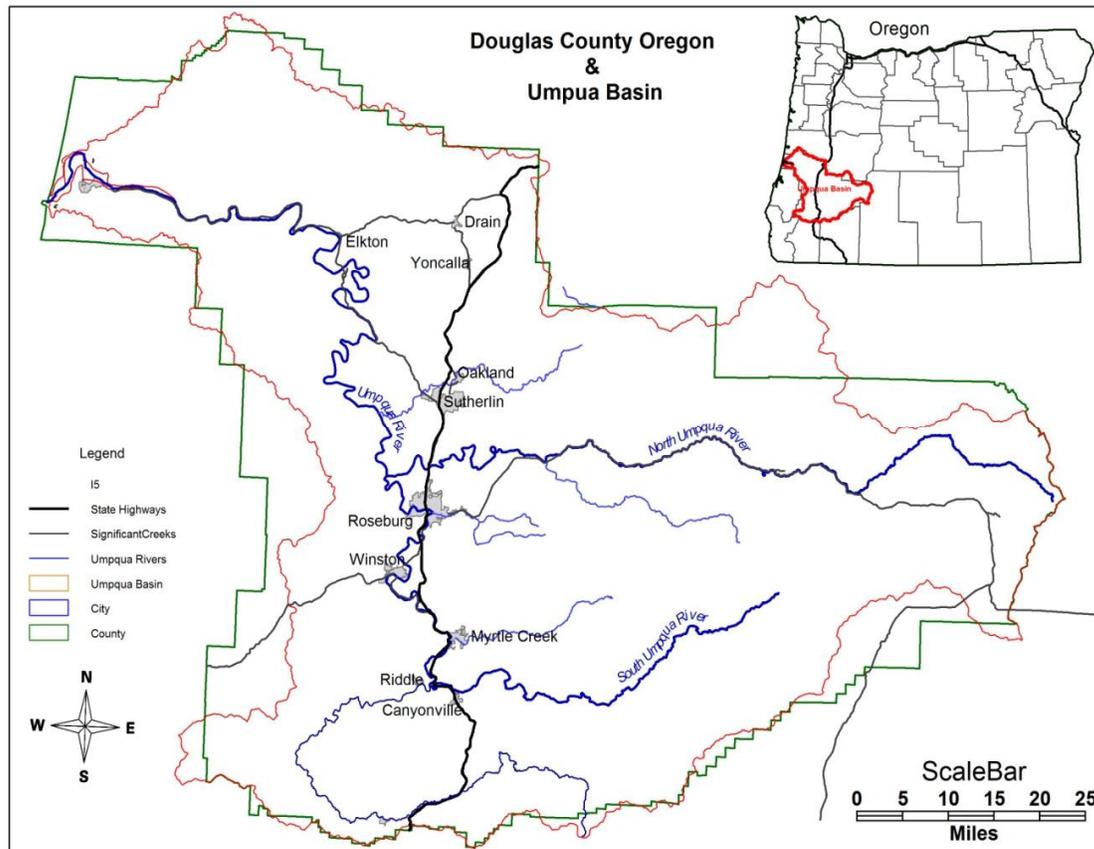


Figure 2: Douglas County Umpqua Basin

The Umpqua Basin contains three major rivers. The North Umpqua River and the South Umpqua River converge to create the Main Umpqua River. The two branches of the river run from east to west, converge, and continue to flow to the Pacific Ocean. The Umpqua Basin is almost entirely contained by Douglas County. The spatial relationship between the boundaries of the county and the drainage basin provides an excellent location for a pilot area for this project. It is a benefit to use this area to avoid crossing jurisdictional boundaries for required information. Many smaller tributaries create sub-basins that eventually converge with the major rivers. The

terrain is quite mountainous and collects rainfall within the forested lands creating many habitats dependent on the water source.

Major development around the Umpqua Rivers and significant creeks occur in the central area of Douglas County. The majority of the city population in Douglas County developed near the convergence of the North Umpqua River and the South Umpqua River. The largest city in Douglas County is Roseburg with a population of 23,000. The rivers and creeks near the area of population contain a large number of water rights. The results are an abundance of water rights requiring management (see Figure 3). The significant streams near Roseburg are North Deer Creek and South Deer Creek. These streams are an example of water sources often subject to regulation by the Watermaster during the summer or dry months of the year, typically from May to October.

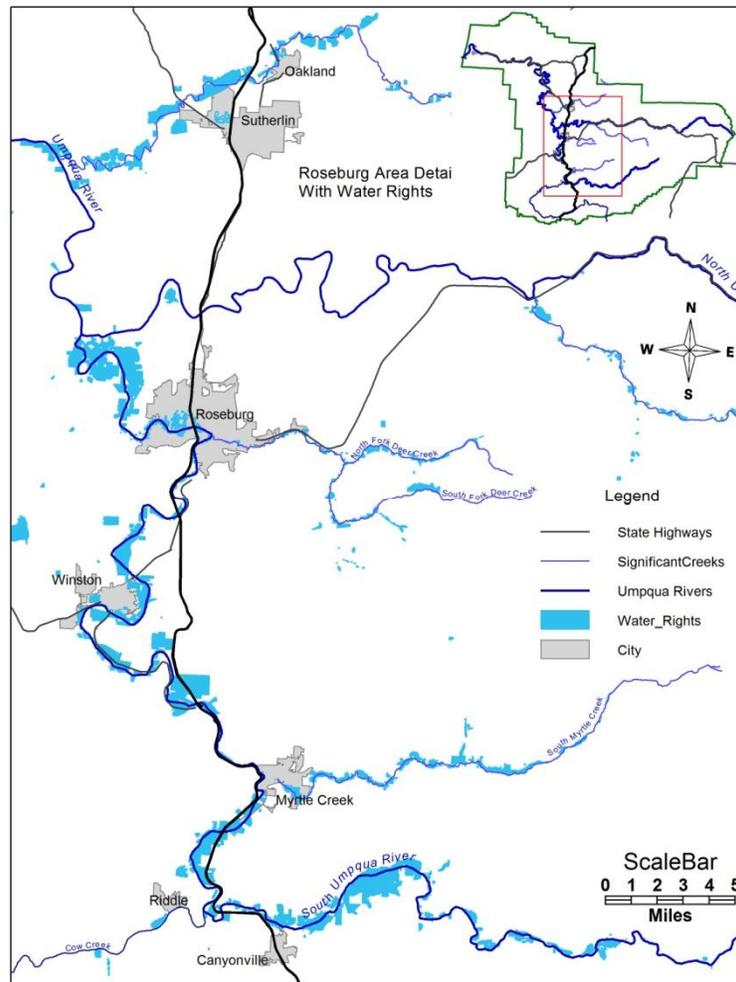


Figure 3: Roseburg Area with Water Rights

Resources are available for the development of a water rights permit system with high accuracy data. An enterprise GIS was developed beginning in 1989 for Douglas County with the proper planning of data acquisition and distribution as suggested by Roger Tomlinson (Tomlinson 2011). The Department of Natural Resources at Douglas County is now in the position to utilize the previous development of GIS for a departmental application. No GIS can succeed without the right people involved (Tomlinson 2011). The hardware, software, data and personnel are in place for the success of this project.

## 1.5 Mapping Water Rights

Water rights are defined with the use of the Public Land Survey System (PLSS). The PLSS is a survey grid definition over most of the United States to allow mapping of ownership. Maps became necessary during the westward migration to document land claims. Land claims often required the diversion of water for uses such as irrigation, livestock, and mining. The diversion of water required a water rights permit. The PLSS grid was utilized to define the place of use for water rights. An example of the national standards that define the numbering and division of the PLSS grid format is shown in Figure 4.

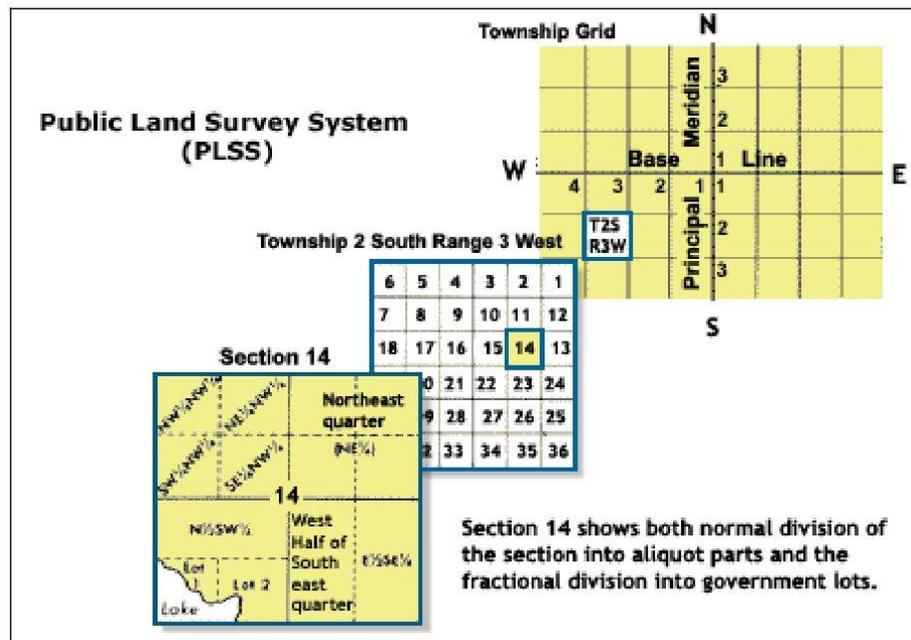


Figure 4: PLSS configuration (OWRD Information Services 2010)

The description on a water rights permit for the location of the beneficial use defines the area utilizing PLSS as follows: Number of acres in the quarter-quarter of a section in a township and range with the designation of the Meridian in which the area is located. Figure 5 shows the difficulty in legibility that is common with archived documents of this type. The legal

description reads as follows:  $3\frac{1}{4}$  acres in the SW $\frac{1}{4}$ ; Section Twenty (20) Township Twenty-seven (27) South, Range Five (5) West of Willamette Meridian.

*A description of the lands under such right, and to which the water hereby confirmed is appurtenant, or, if for other purposes, the place where such water is put to beneficial use, is as follows:*

**$3\frac{1}{4}$  acres in the SW $\frac{1}{4}$  of NW $\frac{1}{4}$ ; Section Twenty (20) Township Twenty-seven (27) South, Range Five (5) West of Willamette Meridian**

Figure 5: Legal Description (Official Oregon State Records 2013)

The legal description is often vague making it difficult to interpret exactly where within the quarter-quarter the actual place of use is located. A map will typically accompany the legal description but it is often very vague. Figure 6 shows a map depicting the water right by a small dark area. The map shows the interpretation of the legal description above. Parcel information is absent from the map.

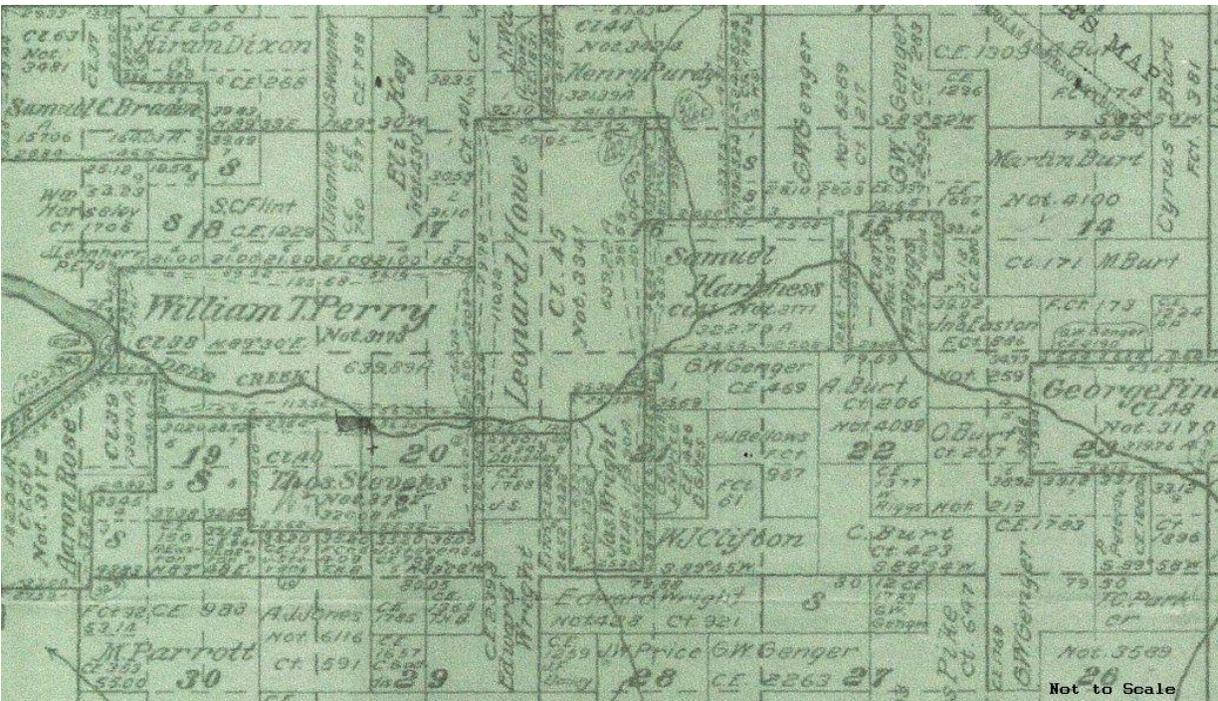


Figure 6: Example of Old Water Rights Map (Official Oregon State Records 2013)

This information is confusing when researching the place of use for water rights. There may also be hand written notes that try to further explain the situation. The letter in Figure 7, dated 1911, applies to the previous map. The Natural Resource Department would prefer to document the research they have done in a GIS and avoid duplicate effort. The handwritten document shown in Figure 7, also of difficult legibility, states that the river has changed course and the water right is actually on the other side of the water source.

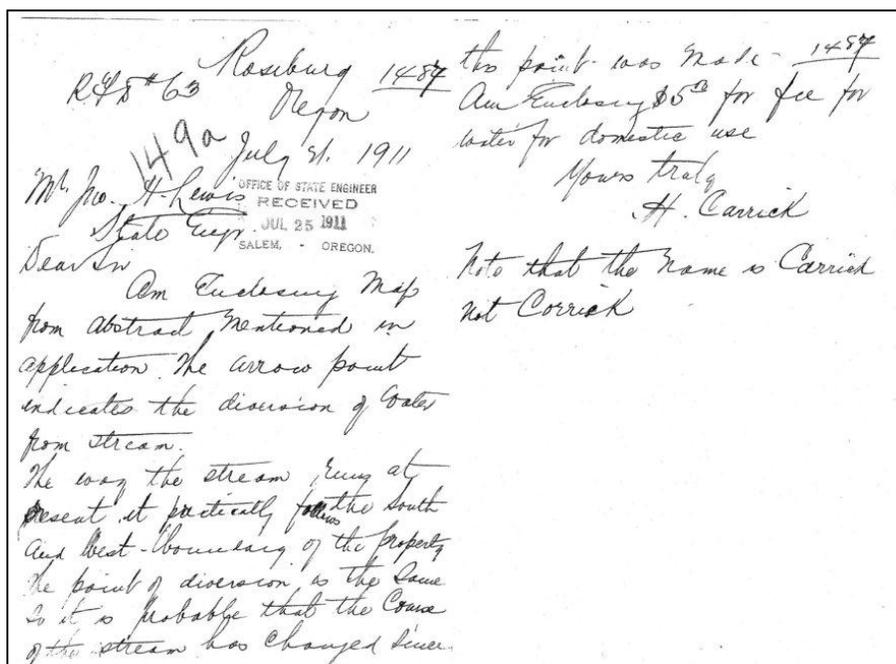


Figure 7: Document from 1911 (Official Oregon State Records 2013)

## 1.6 Motivation

Competition for limited water resources increases conflicts between water users. Water regulators must distribute water during times of shortage according to the prior appropriation permit system. This requires a detailed knowledge of the rights that will be regulated in order to avoid potential injury and financial liability. The water rights information exists in varying degrees of accuracy with historic records dating as far back as the mid 1800s. Changes in

mapping standards extend the amount of research required just to determine where a single right is located.

### **1.6.1 Water Rights and Land Ownership**

Land division activity further complicates the determination of the correct place of use for water rights. Large original irrigation rights covering ranches and farms, initially maintained by a single ownership, are often subdivided into multiple parcels. The location of the water right remains the same as the ownership of the land changes. Current landowner information is not available in existing water rights databases. It is difficult to determine which land is covered by a given right and whom to contact in the event regulation is necessary without accurate place of use and property ownership information.

### **1.6.2 Water Rights Transfers**

Locations that have fully appropriated the supply of water require the transfer of existing water rights to a new location for beneficial use. The transfer may refer to a place of use, point of diversion, or type of use. All of these changes require approval through a state transfer process. Current water rights permit mapping systems typically record the new location of the transferred water rights without the removal from the original use (Harmon, Carine and Tippett-Huber 2013). The legal documents maintain a record of the transfer and are available for historic research. A water rights permit system that is maintained within a GIS can display the up to date transfer status.

### **1.6.3 Water Rights and Land Use**

Land use practices are defined by a comprehensive plan for the regulation of development as the population increases in communities. Often without the detailed information regarding available, or most likely the lack of available water for human consumption, building permits are distributed for growth only to discover that there is no water available for domestic use. An up to date and accurate GIS for water rights permit distribution overlaid with land use would benefit planners in reviewing permit applications.

### **1.6.4 Water Rights and Conflict Resolution**

Scarce water resources provoke conflicts over water rights. Courts are often involved and require accurate, detailed representation of the location information. The use of GIS and knowledgeable personnel can make the water rights information easier and less expensive to obtain during conflict resolution. Documented spatial status of water distribution at the ownership level allows for the best available information to be represented. The information in the form of a GIS map presents the contending parties with understandable details that may resolve the conflict outside of the court system.

Although this project will result in water rights information that has great value to the Watermaster and the technical staff, only the official state information can be utilized for litigation. The value in the newly created information will be additional research that could define what is causing the conflict in the water rights. Perhaps a transfer process could be implemented to resolve the conflict and end the litigation with the proper authorities involved.

### **1.6.5 Water Rights and Regulation**

State agencies charged with administering water laws have developed GIS systems to assist in their regulatory requirements. Unfortunately, given staffing and budget constraints, these systems do not fully address the required details for regulation. The most common missing information is the land ownership boundaries and site addresses. Existing records do not show the rapidly changing information as the population increases and demands more water. At best, these systems only display rights at the quarter-quarter scale. The lack of accurate water rights and ownership information delays timely regulation and is often frustrating for other stakeholders needing water rights information. It is essential that a modern GIS system be developed with the resolution necessary to define water rights at the ownership level. Implementation of a GIS system for water rights and ownership would give a water manager and staff the tools and confidence needed to simply point and click in order to determine water rights on a given parcel.

Such a system would be very useful in Oregon and California where legislation to assess water rights administration fees is under consideration. Oregon Senate Bill 217 proposes a \$100 annual fee for all water rights (77th Oregon Legislative Assembly 2013). If passed, this legislation would require very accurate water rights location and property ownership information in order to correctly bill water users.

### **1.6.6 Water Rights and Wastefulness**

The accurate data can also be utilized in the case of developing a less wasteful system than the currently implemented prior appropriation doctrine. Water agencies must know what the current status of water use is before they can propose any beneficial changes in the management

of the scarce water supply. Administering the correct amount of irrigation required by specific crops would reduce excess waste of water.

In many cases, the actual use is not measured at the point of diversion. Measurements are made at strategic locations for general data and estimates are made for water resource studies. Actual use will require the detailed collection of information in the form of a GIS coordinated with a system of metering. Metering is not currently implemented at the level of individual water use. Individual water use metering is required for accurate representation of the distribution of the water. Major points of diversions are known locations of large volumes of water being diverted such as farms and ranches that request regulation when water flow is low. The first step in metering is being implemented at the major points of diversion until full metering is achieved. The major points of diversion can be linked to the GIS established for this project. However, metering is an ancillary benefit of the project and is not yet complete.

This study demonstrates that the implementation and distribution of the water rights permit information in the form of a web-enabled GIS assists the water managers with access to the information required to make timely and accurate decisions during the regulation process. Access to the information in digital map format is available to the Natural Resource Department at Douglas County. The data developed will enhance the abilities for analysis that requires a detailed scale for reliable results.

## CHAPTER TWO: BACKGROUND

The barriers to the management of a prior appropriation water rights permit system are inherent in the legacy of its implementation in the Western United States. Water rights have been claimed for over 150 years (Bastasch 2006). The lack of accurate and complete records in the early years caused conditions of over-appropriation of the scarce resource. Often the documented place of use (POU) of a water right is a reference to the Quarter-Quarter of the Public Land Survey System (PLSS). This is very vague information and does not provide for the accuracy needed in this project.

During the early 1900s, the Western United States implemented water rights management systems by law in an attempt to more accurately document the use of this scarce resource. Further documentation of the appropriation of water has been enhanced by technology developed in the field of geographic information systems. Many western states have developed a website for the purpose of managing and distributing water rights information. Several western states were examined to determine the usefulness of websites and digitizing of spatial information for the purpose of water rights permit regulation. The requirements for regulation purposes include the accurate spatial representation of the surface water rights place of use and point of diversion, property ownership, and location address. Examples of techniques and progress at the state level follow.

### 2.1 New Mexico

New Mexico has a very difficult task developing a more efficient water rights system as water rights date back to the 1600s (Rodriguez-Bejarano and Apodaca 1997). The New Mexico Office of the State Engineer (NMOSE) is in charge of administering the water rights. The OSE

has a strategic plan with four priorities: eliminate the water rights application backlog, protect New Mexico's water, complete water rights adjudication, and automate information and processing of its databases. Adjudication requires the research and establishment of an existing water right with beneficial use.

To establish the basic elements of water rights, the following information is necessary:

- Source of water
- Point of water diversion
- Place of use of water
- Proof of beneficial use of water
- Ownership of land where water is used for beneficial use
- Date of first use or priority data
- Amount of water use

The technical phase, which is mandated by law, requires the State Engineer to conduct hydrographic surveys of all watercourses and requires large amounts of manpower. The process must be done quickly with high precision and accuracy. The use of computers since the 1980s has helped with establishing hydrological surveys and database information. Beginning in the 1990s, a GIS based system was established to create an interface between the hydrological surveys and the database. The hydrological surveys were upgraded to digital format and interfaced with the database for a system called Water Administration Technical Engineering Resource System (WATERS).

WATERS is accessible on the NMOSE website (NMOSE 2013). The system allows several query options to research water rights. The results are in tabular and scanned document format. There is not an interactive water rights GIS application. Upon completion, WATERS

will allow a user to extract the water right file along with the individual parcel information. During the process, perfection of the location of the water rights in relation to the property owner will be improved. Areas of completion are defined in Figure 8.

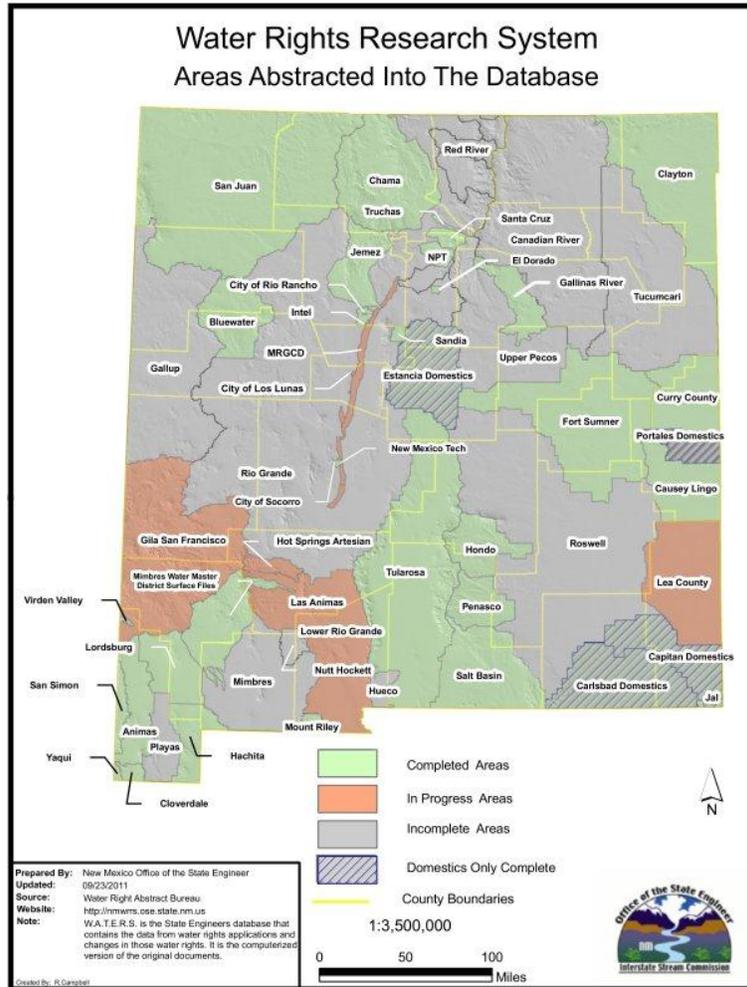


Figure 8: New Mexico WATERS Areas of Abstraction (Campbell 2011)

## 2.2 Nevada

The Nevada Division of Water Resources (NDWR) manages the water resources in the state. The responsibilities include quantifying water rights, monitoring water use, and distributing water according to court decrees. The state engineer is head of the NDWR. A deputy

administrator manages the water rights section of the division (NDWR 2013). There are several professional engineers and water resource specialist under the water rights section of the organization.

The water rights search tools in Nevada contain forms for queries of the data by application number, certificate, or name (see Figure 9). The query results provides a list of possible water rights permits in table form (see Figure 10). The results define the application number, status of the permit, certificate number, and owner. Selecting a results from the list takes the user to a detailed page where general informatin, scanned maps, and documents can be retrieved (see Figure 11).

Links | Contact Us

 State of Nevada  
Division of Water Resources

Home Forms Water Rights Programs **Mapping & Data** Hearings FAQ

### PERMIT SEARCH

Application Number:

Certificate:

Owner Name:

#### Search Help

Contextual help is available for some search options. Clicking on a control will bring up a series of potential options in this area. Controls that allow wildcards are specified.

Figure 9: Nevada Permit Search Page (NDWR 2013)

State of Nevada Department of Conservation & Natural Resources		Division of Water Resources Jason King, P.E. State Engineer	
Permit Search - Generated - 10/26/2013 Displaying 1 to 50 of 817 records		Showing all applications with: With an owner containing "smith" Start new search	
Previous			Next
Application	Status	Cert	Owner
10018	DEN		SMITH, L.R.
10050	DEN		SMITH, L.R.
10051	DEN		SMITH, L.R.
10052	DEN		SMITH, L.R.
10066	FOR	2749	SMITH, WM. R.
1008	CAN		SMITH, SYDNEY
10160	WDR		SMITH, IRVING
10170	CER	2764	SMITH CREEK RANCH COMPANY, LTD.
10222	CAN		SMITH, RAYMOND
10223	CAN		SMITH, RAYMOND

Figure 10: Tabular results of Nevada permit search (NDWR 2013)

Home	Forms	Water Rights	Programs	Mapping & Data	Hearings	FAQ
<b>GENERAL INFORMATION</b>						
Application: <b>10066</b>		Status: <b>FORFEITED</b>		Certificate: <b>2749</b>		<a href="#">Start new search</a>
General Information	Maps and Due Dates	Place of Use	Abrogations/Protests/Rulings	Ownership/Title		
<b>General</b>						
Owner(s):	FISCHBACHER, SIEGFRIED		Basin:	LAS VEGAS VALLEY - 212		
Sub Basin:			Basin Status:	DESIGNATED (PUID)		
Region:	COLORADO RIVER BASIN		County:	CLARK		
<b>Previous Applications (Base Rights)</b>						
No previous applications found						
Source:	UNDERGROUND		Source Description:			
Project Name:			Decree Name:			
Use:	IRRIGATION		Period End:	1231		
Period Start:	0101					
<b>Point of Diversion Information:</b>						
Qtr-Qtr:	Qtr:	Section:	Township:	Range:		
SW	SW	20	20S	61E		
Duty Balance:	85.33 AFA	Div Balance:	0.119			
Acre-Feet Storage:	0	Well Logs:	Well Log Nos.: 51835			
Remarks:						

Figure 11: General detailed results of permit search (NDWR 2013)

The website offers a link to a Mapguide ó Interactive Water Resource Map under the Mapping and Data tab (see Figure 12). The selection of this option returns the user to the home

page. There is no explanation for the inactive status of the interactive map. The link may be broken or planned for future development. There is also a link to data download options. The data available is general in nature and represents administrative hydrographic areas, and hydrographic line work. There are no locations to research digital POD, POU, Parcels, or address information.

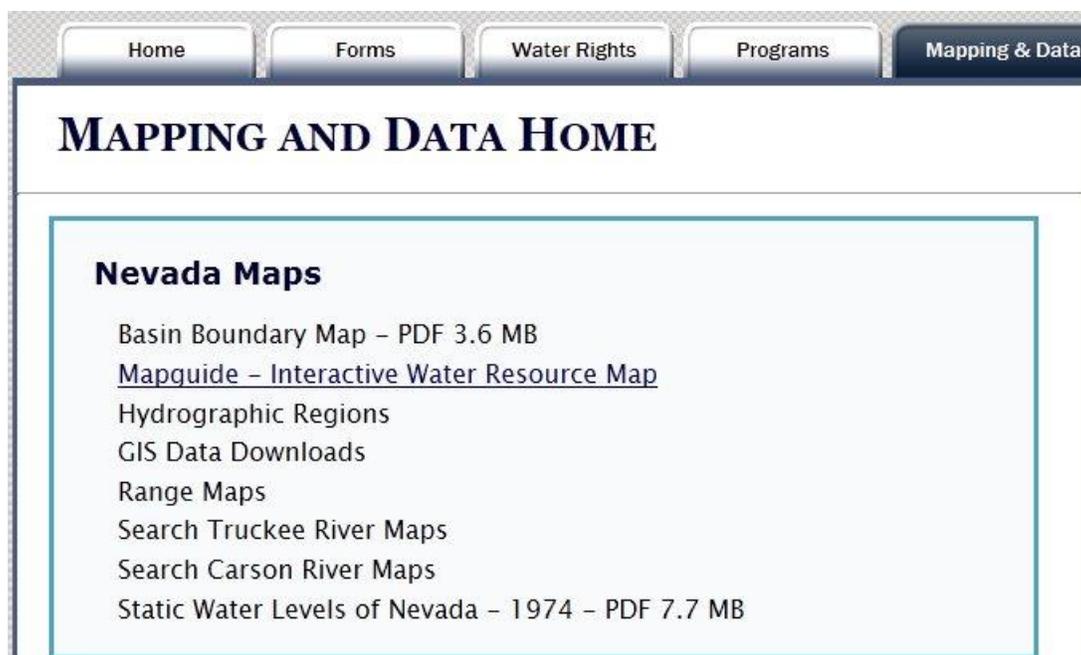


Figure 12: Nevada Mapguide ó Interactive Water Resource Map (NDWR 2013)

## 2.3 Montana

The Department of Natural Resources and Conservation (DNRC) manages the Water Resource Division (WRD) in Montana. The WRD promotes and coordinates the beneficial use, conservation, protection, and development of Montana's water resources (Montana Water Resources Division 2013). The DNRC and the Natural Resource Information System (NRIS) have created both a web search interface and an interactive map interface for water rights

information (Montana DNRC 2011). The interactive map is referred to as the Digital Atlas of Montana (DAM).

The Atlas allows the user to input search criteria and select the desired map data. The map displays with the data requested in the area defined for search criteria. There is no ownership information available in the Atlas selection options. Data available under water rights includes: points of diversion, points of use, points of irrigation, and points of reservoirs. It should be noted that the water rights locations are defined by a point of use within the quarter-quarter of the PLSS and does not define the actual acres and location that would be irrigated. The acres for irrigation are defined in a separate selection set that shows a range for irrigation area. The point of use is displayed showing the type of use. The types of uses include: irrigation, stock, domestic, lawn and garden, municipal, and other (see Figure 13). The map that displays the points of diversion includes ground water and surface water (see Figure 14). It is interesting that the points of use and points of diversion are not available on the same map. It is common practice in research to relate the point of diversion to the point of use when working with water rights. The interface for the Digital Atlas is difficult to locate compared to the query interface.

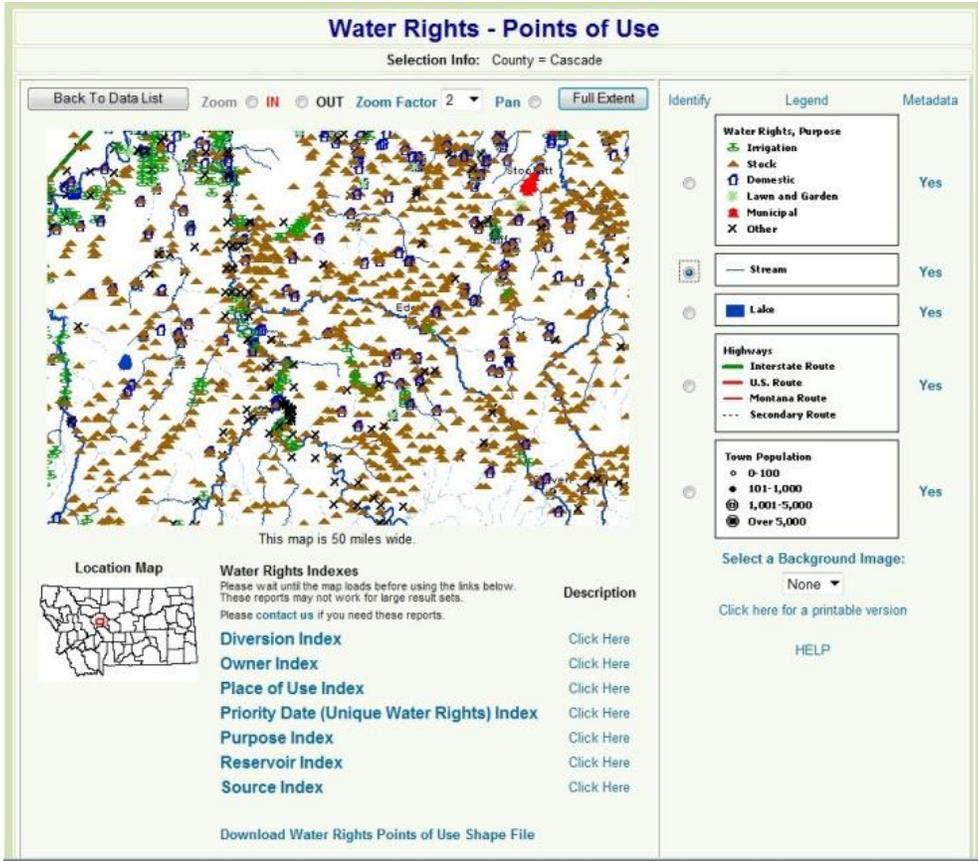


Figure 13: Digital Atlas of Montana Points of Use (NRIS 2013)

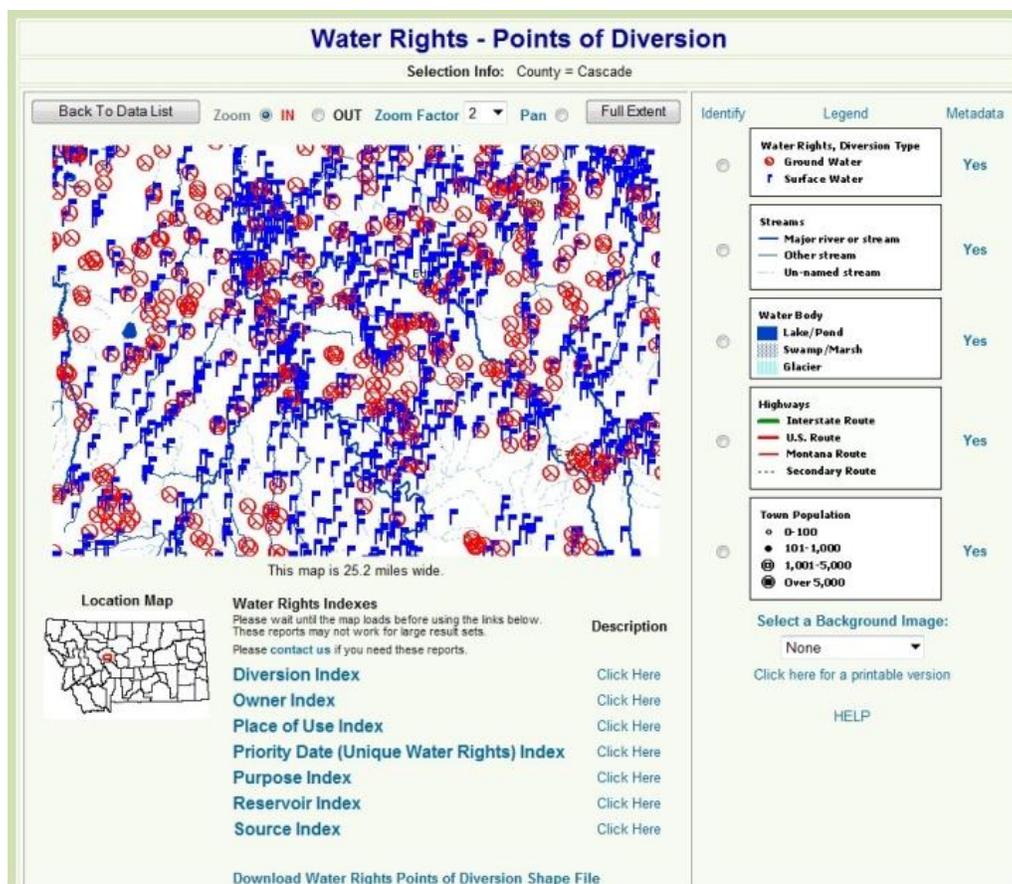


Figure 14: Digital Atlas of Montana Points of Diversion (NRIS 2013)

Either a water right number or name must be entered when utilizing the query interface to search for water rights. Once the information is entered, a table of query results is displayed as shown in Figure 15 . Selecting the desired water right number will take the user to a map of the results as shown in Figure 16. The resulting map allows the change of background, change of minimal feature display, and printing. The relationship of the POD and POU is noted as not the true geographic location. The POU is the centroid of the legal land description. This interface shows more detail for water rights research and is presented on the website clearly. This is a product of an organizational change in the Montana Government that took place in 2012-2013.



DNRC Water Right Query System

Home » Water Resources Division » Water Rights Query » simple Index Water Rights Web Guide (.doc)

[Modify Existing Search][New Search]

Click here for Water Right Data Explanations  
If you have problems, contact the DNRC Waterrights Help.

Click on column headings to sort.

Water Right	WR Type	Status	Purpose	Priority Date yyyymmdd (hhmm)	Src	Src Name	Means of Diversion	Owner	Flow Rate	Volume	Acres	Doc Image	Div Count & map	Use Count & map	Irr Count & map	Res Count & map	Issue Remarks	
<a href="#">39E 19001 00</a>	A	STATEMENT OF CLAIM	ACTV	STOCK	19470612	S	UNNAMED TRIBUTARY OF BUFFALO CREEK	LIVESTOCK DIRECT FROM SOURCE	SMITH LELAND				View	1	1		1	Yes
39E 19002 00	A	STATEMENT OF CLAIM	ACTV	STOCK	19470612	S	UNNAMED TRIBUTARY OF BUFFALO CREEK	LIVESTOCK DIRECT FROM SOURCE	SMITH LELAND				View	1	1		1	Yes
39E 71404 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	19910702800	G	GROUNDWATER	WELL	SMITH MARY F	15.00 GPM	5.10		View	1	2			
39E 71404 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	19910702800	G	GROUNDWATER	WELL	SMITH RANDY R	15.00 GPM	5.10		View	1	2			
39E 78369 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	19910618951	G	GROUNDWATER	WELL	SMITH MARY F	15.00 GPM	5.10		View	1	1			
39E 78369 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	19910618951	G	GROUNDWATER	WELL	SMITH RANDY R	15.00 GPM	5.10		View	1	1			
39E 78370 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	19910618951	G	GROUNDWATER	WELL	SMITH MARY F	15.00 GPM	5.10		View	1	1			
39E 78370 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	19910618951	G	GROUNDWATER	WELL	SMITH RANDY R	15.00 GPM	5.10		View	1	1			
39F 83576 00	A	GROUND WATER CERTIFICATE	ACTV	STOCK	199301041035	G	GROUNDWATER	WELL	SMITH LELAND	5.00 GPM	1.46		View	1	1			
39FJ 108911 00	A	STATEMENT OF CLAIM	ACTV	DOMESTIC	19631231	G	GROUNDWATER	WELL	SMITH LINDA B	5.00 GPM	5.20	2	View	1	1			
39FJ 108912 00	A	STATEMENT OF CLAIM	ACTV	DOMESTIC	19470930	G	GROUNDWATER	WELL	SMITH LINDA B	6.00 GPM	6.00	3	View	1	2			

Figure 15: DNRC Query Results Table (DNRC 2013)

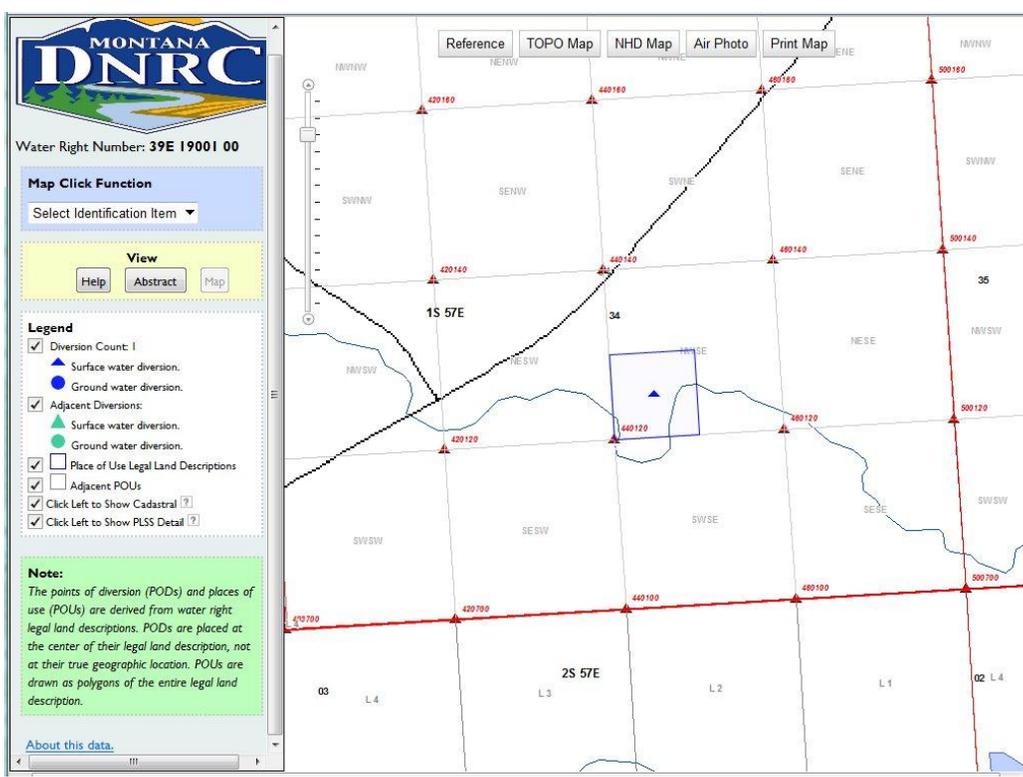


Figure 16: DNRC Query Results Map (DNRC 2013)

## 2.4 Wyoming

The Wyoming State Engineer is responsible for the regulation and administration of the water resources (Wyoming State Engineer 2013). The Water Resource Data System is housed at the University of Wyoming (UofW) under The Department of Civil and Architectural Engineering. The system offers a wide range of products and services. For water rights research an interactive map is provided by the UofW (University of Wyoming 2008).

The Interactive Map Server (IMS) can be accessed directly from the government site through the water and climate link (see Figure 17). The map allows the user to zoom in, turn on or off layers, and select specific irrigation boundaries for detailed information (see Figure 18). The help screen gives the user a quick glance of the tools available. There are several beneficial custom tools for data retrieval. Help is available that explains the use of the custom tools. An example is the view permits data button, which is the top left button under the data tools. The results of the permit data tool are shown in Figure 19 with ownership categorized by government agencies, state lands, Indian lands, and private lands. Ownership or address information for individual parcels is not available.

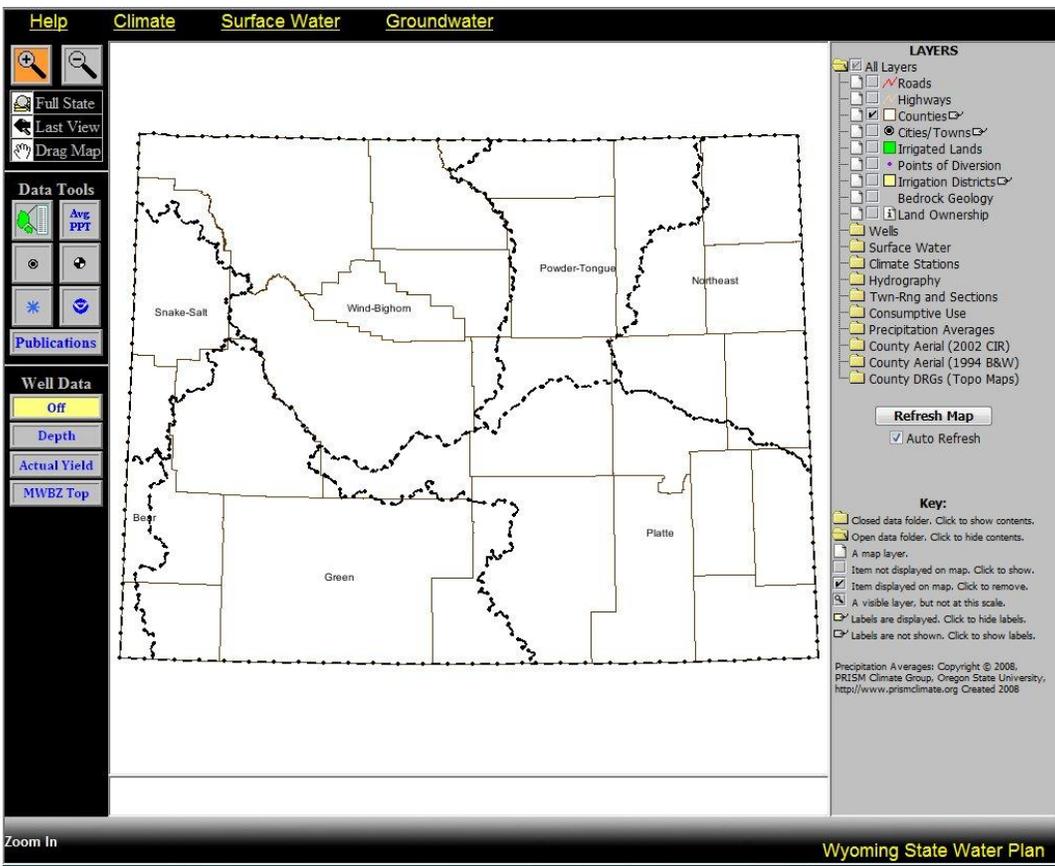


Figure 17: Wyoming Interactive Map Server (University of Wyoming 2008)

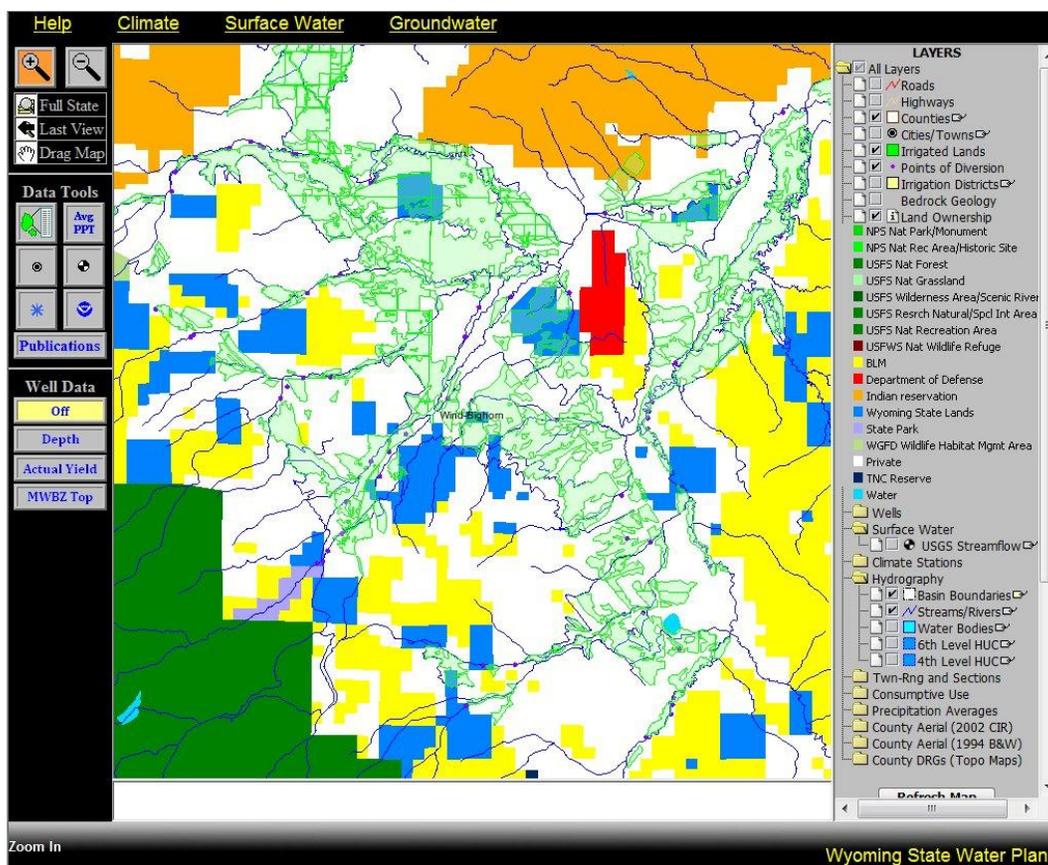


Figure 18: Modified Wyoming Interactive Map Server (University of Wyoming 2008)

Permit	Priority	Source	Facility	Use	Unit	Type	Status	Amount
13823	07-Oct-1915	Spring Branch	Barrett Ditch	IRR	SS	ADJ		
Terr.	15-Apr-1885	N. F. Popo Agie River	Big Cottonwood Ditch	IRR	OS	ADJ	24.80	CFS
Terr.	00-1888	N.F. Popo Agie River	Consolidated Ditch	IRR	OS	ADJ	.60	CFS
5950 Enl.	30-Jan-1958	N.F. Popo Agie River	Enl. Big Cottonwood Ditch	IRR	OS	ADJ	2.33	CFS
1860 Enl.	04-Apr-1908	N.F. Popo Agie River	Enl. North Fork Ditch	IRR	OS	ADJ	2.92	CFS

Figure 19: Results of Permit for Irrigation Land Selection Tool (University of Wyoming 2008)

## 2.5 Idaho

The Idaho Department of Water Resources (IDWR) manages the waters within the state borders. The agency is divided into water management and water planning divisions. The

governor appoints a director to head the two divisions. The water planning division provides digital water rights information through an interactive map (IDWR 2013). The maps and spatial data link provides access to a variety of categories related to water. These include maps and data download opportunities for administrative boundaries, national hydrographic datasets, watershed boundaries, place of use locations, and points of diversion.

The interactive maps allow the query and display from the IDWR database. Maps are divided by categories such as flood hazards, geothermal, environmental, hydro, irrigation, and a general mapping tool. The irrigation rights finder is customized to show only water rights for the beneficial use of irrigated lands. The legend is limited to PLSS, Water Rights, Recommendations, Irrigation Company, and backgrounds. The selection of a water rights result in the display of the water rights number, type, owner, and a printable detail sheet (see Figure 20).

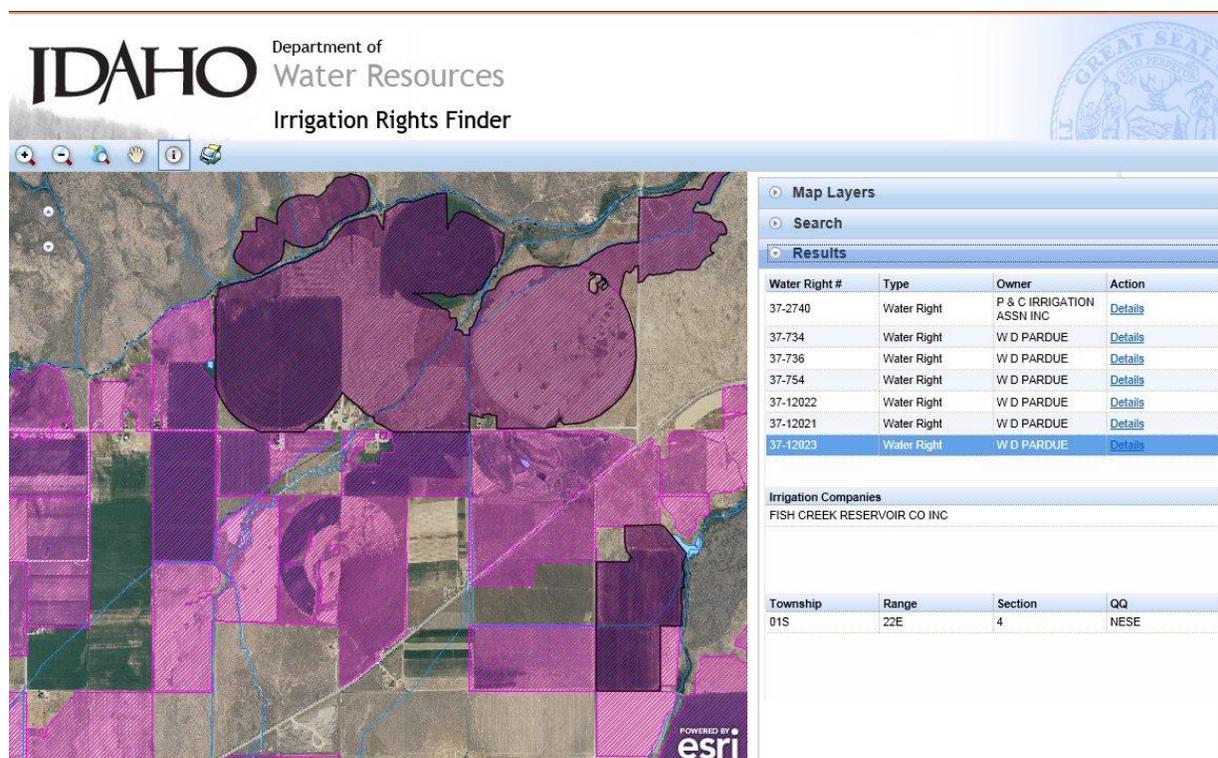


Figure 20: Idaho Irrigation Map Search Results (IDWR 2013)

The general mapping tool is the most beneficial for researching water rights in Idaho. The initial screen allows the user to find a location by coordinates, PLSS, city, county, zip code, address or stream. The layers available include base information, water, POD, and POU (see Figure 21). The user interface is intuitive and has detailed instructions for use. The identity tool is used to query additional information from the displayed features (see Figure 22). The POD and POU information is distinguished by status of the water rights. The divisions are adjudication claims, adjudication recommendations, permits and water rights. The parcel information is contained in a separate map and allows research by address. The use of GIS to bring the disparate features together is not utilized at the web level.

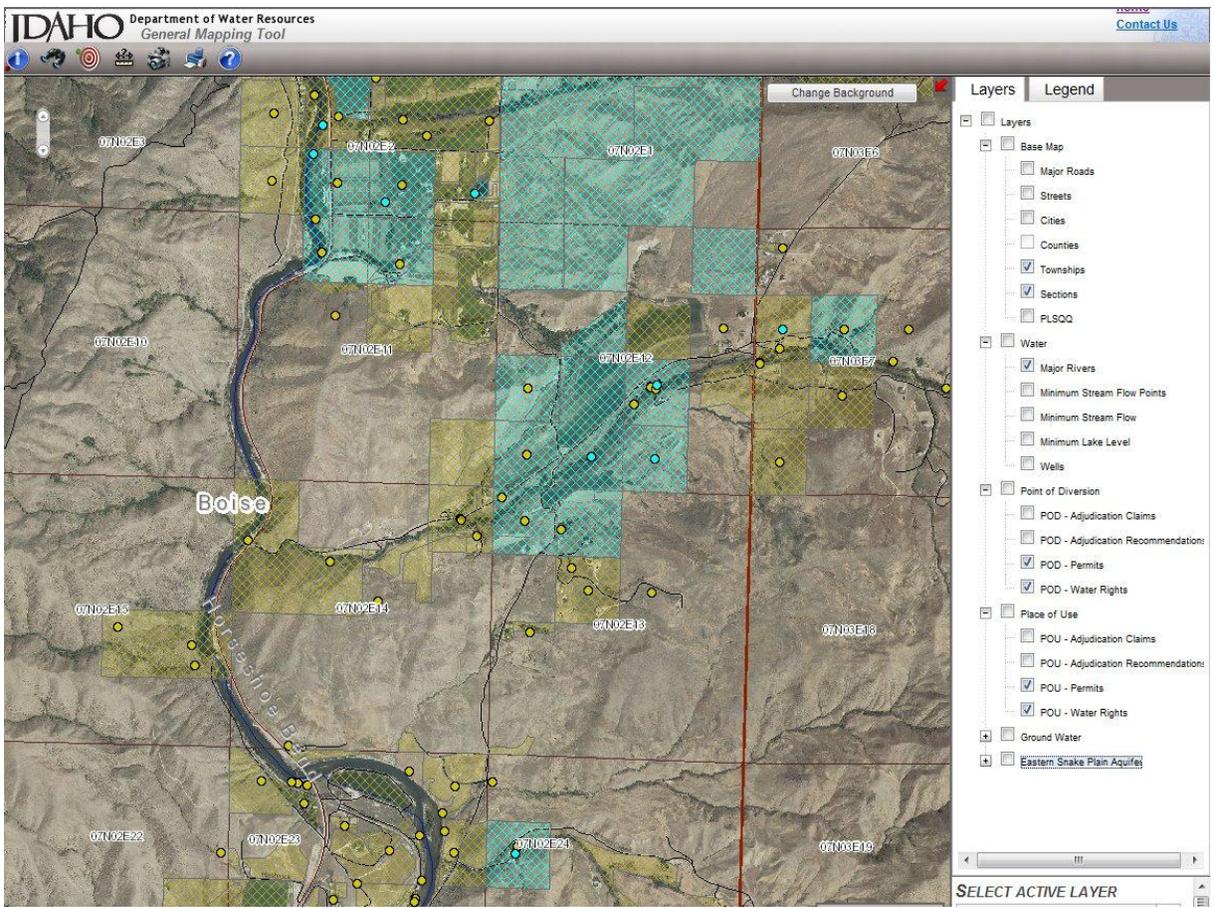


Figure 21: Idaho General Mapping Tool for Water Rights (IDWR 2013)

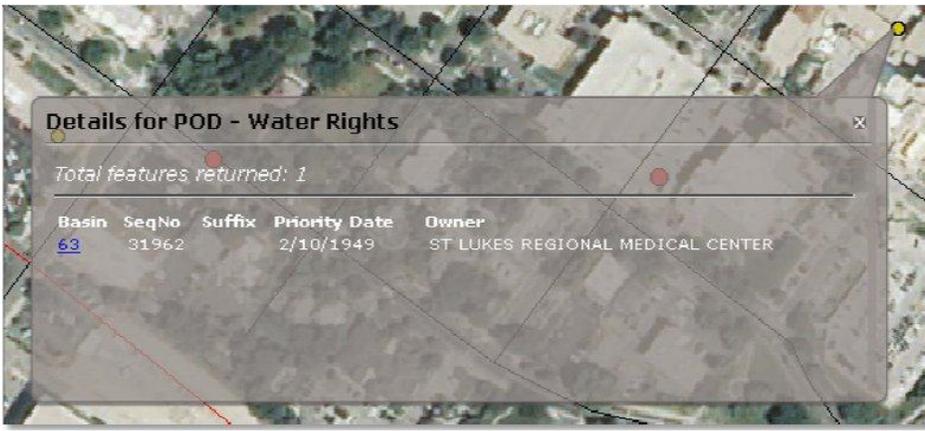


Figure 22: Idaho General Mapping Identify Information (Britton 2013)

## 2.6 Utah

The Utah Department of Natural Resources (UDNR) manages The Utah Division of Water Rights (UDWR). The Utah State Engineer is head of the UDWR and administers the appropriation and distribution of the State's water resources (UDNR 2013). The Utah pioneers began practicing extensive irrigation in the 1840s. The Doctrine of Prior Appropriation is the law for the management of the water resources. The water rights are defined by:

- A defined nature and extent of beneficial use
- A priority date
- A defined quantity of water allowed for diversion by flow rate (cfs and/or by volume (acre-feet))
- A specified point of diversion and source of water
- A specified place of beneficial use

The water rights records for the State of Utah reside in the recorder's office of the counties (UDWR 2013). Search tools for water rights information include both data query and an interactive map. The options for search criteria include: water right number, name/source, POD, POU, and water companies. The results are displayed in a table format that provides a link to detailed data about the water right (see Figure 23). From this page, the user can select either the Map Viewer or Google View to display the location of the desired water right. Figure 24 shows the result of the Map Viewer option. Additional information can be displayed as well as choices of background. There are no parcels available for the water rights permit area selected. They are listed in the legend county parcels (as available). No parcels are displayed when the legend entry is made visible in the area selected.

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 10/19/2013

WATER RIGHT: 25-10991 APPLICATION/CLAIM NO.: A28070a CERT. NO.: 5795  
 CHANGES: a35584 (Filed: 10/19/2009) Approved

---

OWNERSHIP\*\*\*\*\*

NAME: Brandon Thomas  
 ADDR: 127 North Main Street  
 PO Box 291  
 Clarkston UT 84305

---

DATES, ETC.\*\*\*\*\*

LAND OWNED BY APPLICANT? COUNTY TAX ID#:  
 FILED: PRIORITY: 04/24/1996|PUB REGAN: |PUB ENDED: |NEWSPAPER:  
 Protest/End: |PROTESTED: [No] |HEARINGS HLD: |SE ACTION: [Approved]|ActionDate: |PROOF DUE:  
 EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: |LAP, ETC: |LAPS LETTER:  
 RUSH LETTER: |RENOVATE: |RECON REQ: |TYPE: [ ]  
 PD BOOK: [ 25- ]|MAP: [ ]|PUB DATE:

\*TYPE -- DOCUMENT -- STATUS--\*  
 Type of Right: Application to Appropriate Source of Info: Ownership Segregation Status: Certificate

---

LOCATION OF WATER RIGHT\*\*(Points of Diversion: Click on Location to access PLAT Program.)\*\*\*\*\*[MAP VIEWER](#)\*\*[GOOGLE VIEW](#)\*

FLOW: 1.506 acre-feet  
 SOURCE: Surface Drain & Underground Seepage  
 COUNTY: Cache COMMON DESCRIPTION: 3 mi. E. Clarkston

POINT OF DIVERSION -- SURFACE:  
 (4) S 1353 ft N 1353 ft from NE cor, Sec 30, T 14N, R 1W, S1E4  
 Diverting Works: Source: Surface Drain & Underground Seepage

Stream Alt Required?: No

---

USES OF WATER RIGHT\*\*\*\*\* ELU -- Equivalent Livestock Unit (cow, horse, etc.) \*\*\*\*\* EEU -- Equivalent Domestic Unit or 1 Family

SUPPLEMENTAL GROUP NO.: 19717. Water Rights Appurtenant to the following use(s):  
 25-3284(CERT), 10991(CERT)

IRRIGATION: Sole Supply: 0.28 acres of the Group Total of 39.86 PERIOD OF USE: 04/01 TO 10/31

###PLACE OF USE:	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 30 T 14N R 1W S1E4							39.8600										39.8600
																	GROUP ACREAGE TOTAL:
																	39.8600

---

SEGREGATION HISTORY\*\*\*\*\*

This Right was Segregated from 25-3284, with Appl#: A28070a, Approval Date: / / under which Proof is to be submitted.  
 This Right as originally filed:

FLOW IN	QUANTITY IN	WATER USES						
CFS	ACRE-FEET	IRRIGATED	STOCK	DOMESTIC	MUNICIPAL	MINING	POWER	OTHER
	ACREAGE	(ELU)	(ELU)	(FAMILIES)	(FAMILIES)	(FAMILIES)	(FAMILIES)	(FAMILIES)
	1.506	0.2800						

\*\*\*\*\*E N D O F D A T A\*\*\*\*\*

Figure 23: Utah water rights data results (UDWR 2013)

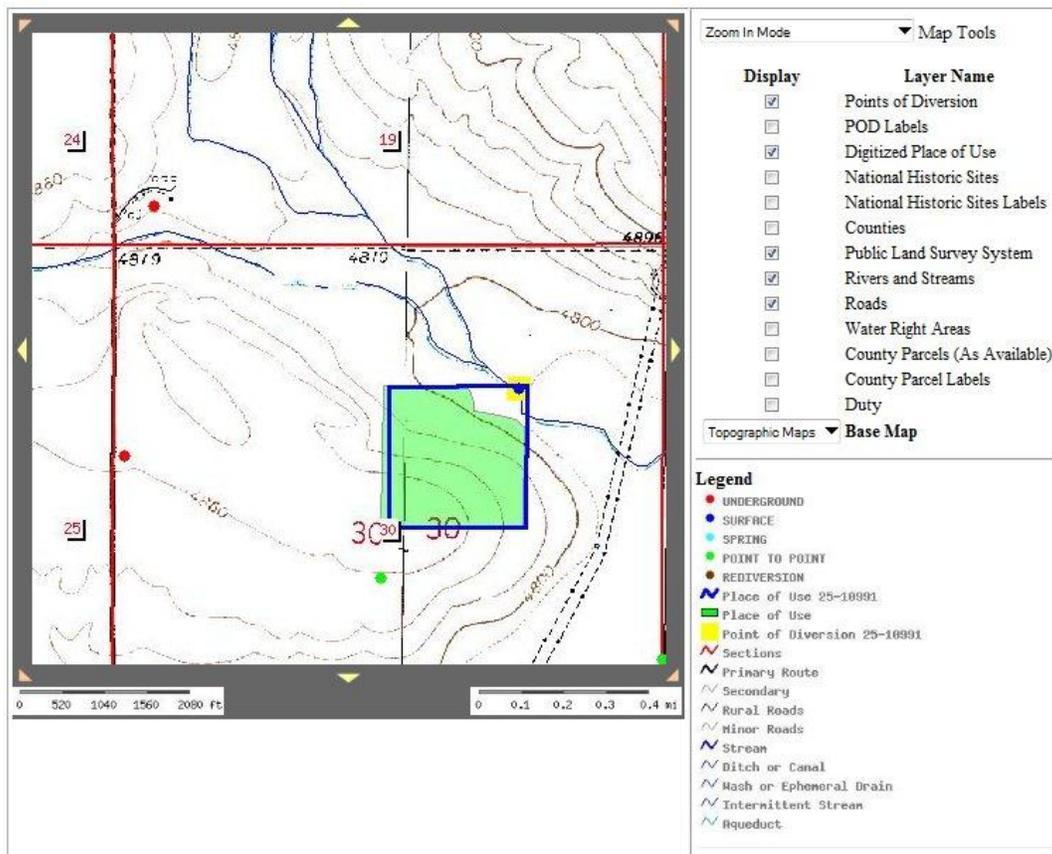


Figure 24: Utah Map Viewer for water rights query results (UDWR 2013)

## 2.7 Colorado

Colorado is the first state to provide for the distribution of water by public officials. In 1879, the state was divided into ten water districts and assigned a Water Commissioner to each area. The Water Commissioners divide the water in accordance to the Prior Appropriation Doctrine (CDWR 2013). The Office of the State Engineer (OSE) is responsible for measuring the water in each stream. Ditches divert water for irrigation in Colorado. By the 1890s many streams were over-appropriated. Management of water rights, exchanges, and transfers became an issue. Legislation in 1969 changed the name of the OSE to The Division of Water Resources (DWR).

The Colorado Division of Water Resources provides online tools for water rights research. The Water Rights tab provides a form entry screen. The search options include: Water Right Name, Case Number, Source, Priority Number, Legal Location, Use Decreed Amount, and Structure ID (see Figure 25). The user can then export the results and view associated documents. There is no link to an interactive map.

Division/Water District: All - Entire State 
 Date Last Refreshed: 2013-09-17

Structure Type: All Structures 
 Sort Order: Alpha (Structure)

Water Right Type: Transaction List

Water Right Name Case Number Source Priority Number Legal Location Use Decreed An

Water Right Name: Starts With  smith

[Help?](#)

Images	DIV	WD	ID	Water Right Name	Water Source	Q10	Q40	Q160
	1	1	10208	EHMANN, FRANK DET. #1	GRNDWTR-NNT DAWSON			SW
	1	1	10209	EHMANN, FRANK DET. #2	GRNDWTR-NT L DAWSON			SW
	1	1	10210	EMPIRE (OUTLET EMBANKMENT)	GRNDWTR-NT DENVER			SW
	1	1	10211	GEARY CREEK	GRNDWTR-NT ARAPAHOE			SW
	1	1	10212	GIBSON #1	GRNDWTR-NT LAR/FOX H			SW
	1	1	10238	KIOWA CRK WTRSHD K-38	GRNDWTR-NNT DAWSON			

Search results limited to 500 records. Please refine search for better results.

Output Options:  
 Water Rights Report by Structure Name (Adobe)

Web CDSS Water Rights Data Selector Version 1.09.12.32 © 2008 Division of Water Resources - State of Colorado

Figure 25: Water Rights Research Form (CWCB 2013)

The interactive map is The Colorado Decision Support System (CDSS) Map Viewer. The user can search on any available layer by highlighting the layer to make it active and select the binocular tool. Any layer that is visible may be selected with the information tool for more details. The map contains multiple layer categories that pertain to water management. A few of these categories pertain to climate, gages, diversions, and base map information. The user can also change the background and print the map. The diversions can be seen in Figure 26. The map

viewer does not contain place of use, parcel, or address information. The user interface is very intuitive and is a good research tool for water information only.

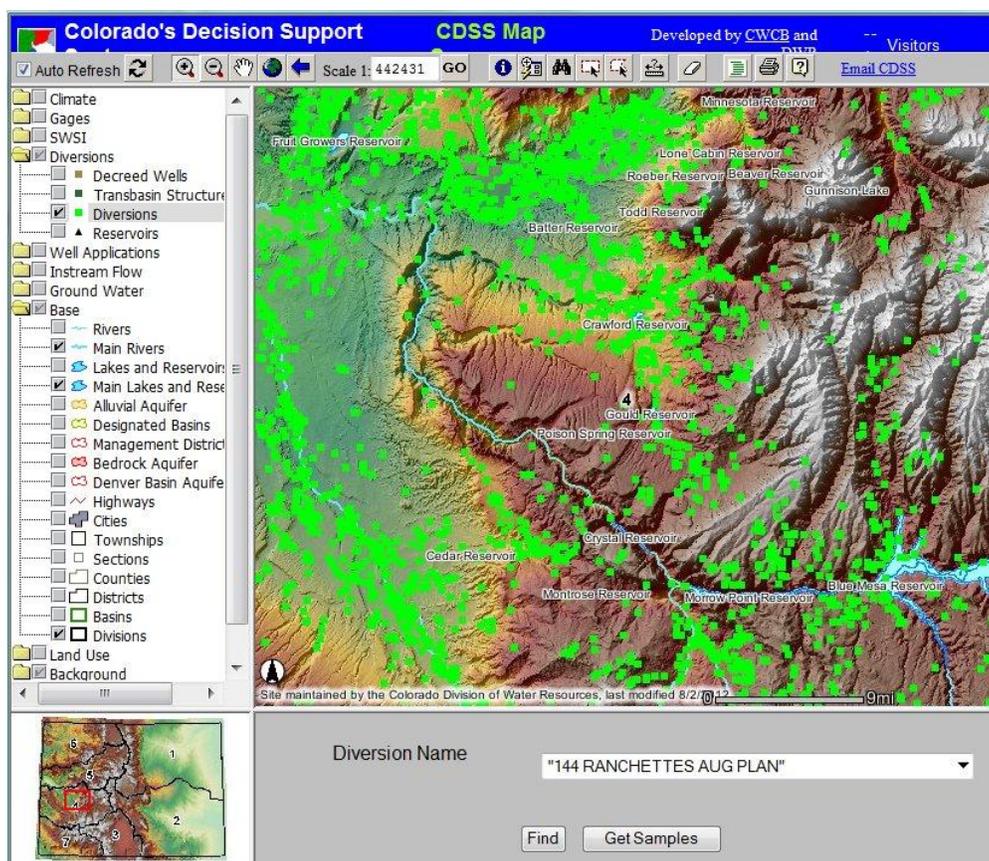


Figure 26: Colorado's Decision Support System Map Viewer (CWCB 2013)

## 2.8 Washington

The Washington State Department of Ecology (WSDE) manages water rights. Any use of surface water withdrawn after 1917 must have a permit or certificate (WSDE 2013). The purpose for use must be beneficial and define a quantity that is non-wasteful. The WSDE provides a map application for water rights research. The application is the Water Resource Explorer (WRE) and provides information on over 230,000 active water rights in the State of Washington (DOE

2013). Many water rights date back to the 1800s. The Water Resource Program has been using GIS since 1993.

The interface to the WRE allows entry into fields for search criteria or zooming directly into a location of interest on the map. Search criteria includes: document/record number, name of the person the water right was issued to, or priority date. Zooming into an area on the map is valuable if the user has no known criteria to enter into form fields (see Figure 27). The WRE allows the user to select layers for display, change the background and print. An information tool is available to select a parcel, gauging station, or shoreline photos, and receive details of the item. Parcel information is displayed with the water rights information. There is no address in the details of the parcel information (see Figure 28). This user interface is easily accessible and has an intuitive design.

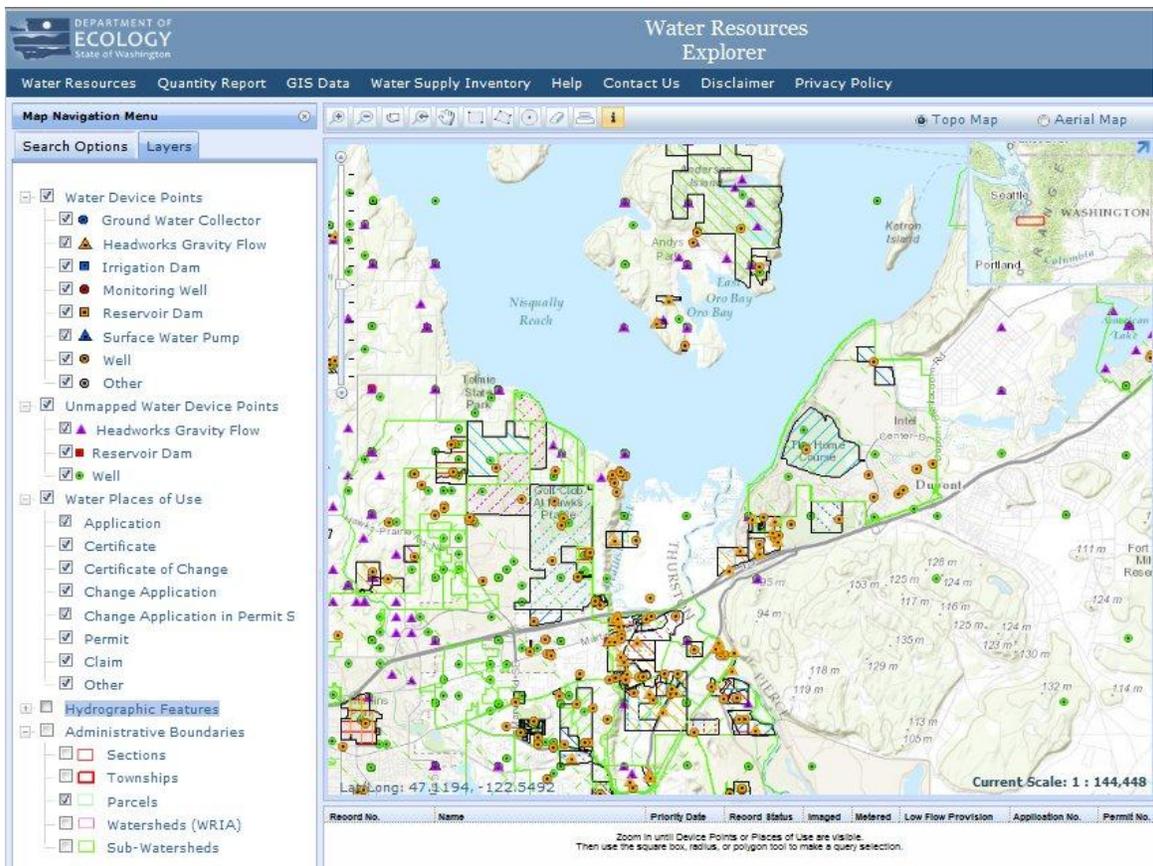


Figure 27: Washington Water Resource Explorer (DOE 2013)

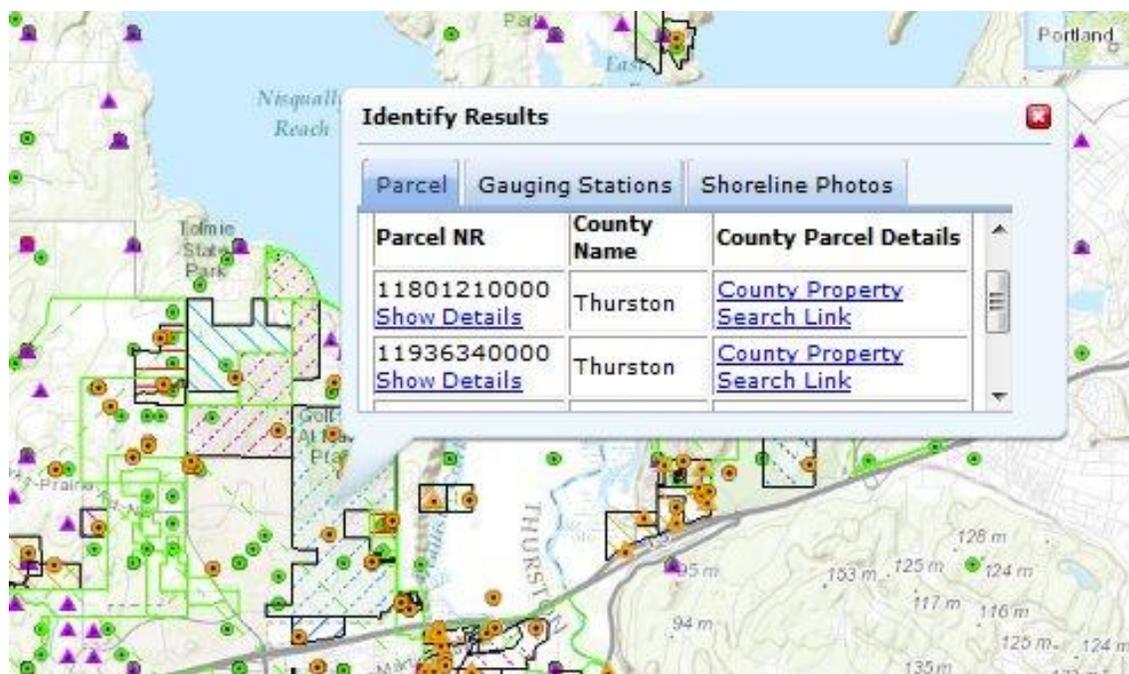


Figure 28: Water Resource Explorer Parcel Reference (DOE 2013)

## 2.9 Oregon

The Oregon Water Resource Department (OWRD) is the state agency that administers the laws governing surface and ground water resources (OWRD 2013). The Governor appoints the Director of the Water Resource Department (DWRD) and is the manager of policies set by the Water Resources Commission (WRC). The WRC is divided into five districts. Each district has a representative for an area of Oregon. The representatives meet four to five times a year to discuss all aspects of water management and develop strategic goals for the conservation of the resources. The State of Oregon has implemented an Integrated Water Resource Strategy (IWRS) adopted by the WRC in 2012. The fundamental purpose of the IWRS is to understand Oregon's water needs and provide a blueprint for future actions (State of Oregon 2012).

Oregon began developing a Water Right Information System (WRIS) in the 1980s. This is a database that contains all of the water rights records and transactions in the state of Oregon

(Harmon, Carine and Tippet-Huber 2013). The WRIS allows the user to query by permit or certificate number, location, name, or stream (see Figure 29). The search results then display a list of water rights that fit the criteria (see Figure 30). The user can then select the particular water right of interest to discover the details and documents pertaining to the selection (see Figure 31). The document links show the scanned images of the legal paper work filed in the vault in Salem. The paper map links show the scanned images of the associated location.

**OREGON**   advanced site map

**Water Resources Department**

**menu**

- About Us
- Contact Us
- News and Events
- Adjudications
- Commission
- Forms
- Ground Water
- Links
- Maps
- Publications
- Surface Water
- Water Law
- Water Management
- Water Rights

**Water Rights Information Query**

Search by file id Search by location Search by name Search by stream Help

**Search by location**

Township: 26 South

Range: 04 West

Meridian: Willamette Meridian

Basin:

Type of location: Points of Diversion

Starting priority date:

Ending priority date:

Type of use:

Type of right:

Display canceled rights?

**Sections**

6	5	4	3	2	1
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	8	9	10	11	12
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18	17	16	15	14	13
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19	20	21	22	23	24
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30	29	28	27	26	25
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
31	32	33	34	35	36
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 29: Water Rights Information Query Form (OWRD 2013)

## Water Rights Information Query Results

Records/Page: 10

	Contacts	Application	Permit	Certificate	Claim	Decree	Transfers	Status
<a href="#">Select</a>	APPLICANT: JULIA W KIDDER 906 S 50TH AVE YAKIMA, WA 98908	P82884						NC
<a href="#">Select</a>	OWNER: 35 WHISTLERS LANE ROSEBURG, OR 97470	S31153	S24551	33017			▸ <a href="#">N29</a> (Remaining)	NC
<a href="#">Select</a>	OWNER: HAZEL B LESTER BOX 105 WHISTLER'S LN ROSEBURG, OR 97470	S39743	S29561	33913				NC
<a href="#">Select</a>	OWNER: ROBERT/GLADYS WILSON BOX 80, WHISTLERS LANE ROSEBURG, OR 97470	S43337	S32393	36194				NC
<a href="#">Select</a>	OWNER: 87 WHISTLER'S LANE ROSEBURG, OR 97470	S31153	S24551	36597			▸ <a href="#">N29</a> (Confirming)	NC
<a href="#">Select</a>	OWNER: MARY JONES PO BOX 14 GLIDE, OR 97443	S44225	S33034	37201				NC

Figure 30: Water Rights Information Search Results (OWRD 2013)

Water Right Information Query Results	
<b>Contact Information</b>	<b>Documents</b> <a href="#">View all scanned documents</a>
<b>Current contact information</b> OWNER: HAZEL B LESTER ▸ BOX 105 WHISTLER'S LN ROSEBURG, OR 97470	<b>Application: S 39743</b> <b>Permit: S 29561</b> <a href="#">document</a> , <a href="#">paper map</a> <b>Certificate: 33913</b> <a href="#">document</a> , <a href="#">paper map</a> ▸ Signature: 5/24/1967 ▸ Type: Original ▸ <a href="#">View right with Web Mapping</a> ▸ <a href="#">View Places of Use from Water Rights in the Same Area</a>
<b>Water Right Information</b>	
Status: Non-Cancelled County: Douglas File Folder Location: Salem <a href="#">Watermaster District: 15</a>	
<b>Point(s) of Diversion</b>	
▸ <b>POD 1 - NORTH UMPQUA RIVER &gt; UMPQUA RIVER</b>	
<b>Place(s) of Use</b> <a href="#">Add TRS grouping</a>	
▸ <b>Use - DOMESTIC INCLUDING LAWN AND GARDEN (Primary); Priority Date: 4/15/1964</b>	
<b>Water Right Genealogy</b>	
--No genealogy records available for this water right, try the family link below instead.	

[View Water Rights in same Family](#)[Help understanding and working with the Water Rights Information System](#)[Report Errors with Water Right Data](#)[Return to WRIS Query](#)

Figure 31: Water Rights Information Query Results (OWRD 2013)

In 1987, the OWRD began developing a GIS to manage water rights. The procedures involve the registration of the scanned map images onto a PLSS base. The process is defined clearly in the Water Rights Compilation document (Harmon, Carine and Tippett-Huber 2013) and has been modified to adjust for technical enhancements in both hardware and software. The water rights can now be viewed in an interactive map on the WRD website. Access to the map is available by selecting view right with Web Mapping option on the query results page (see Figure 31) or directly from the Maps page on the Oregon Water Resource Department website. The map provides search, measure, zooming, layer control, and printing. There are no parcels or address layers available.

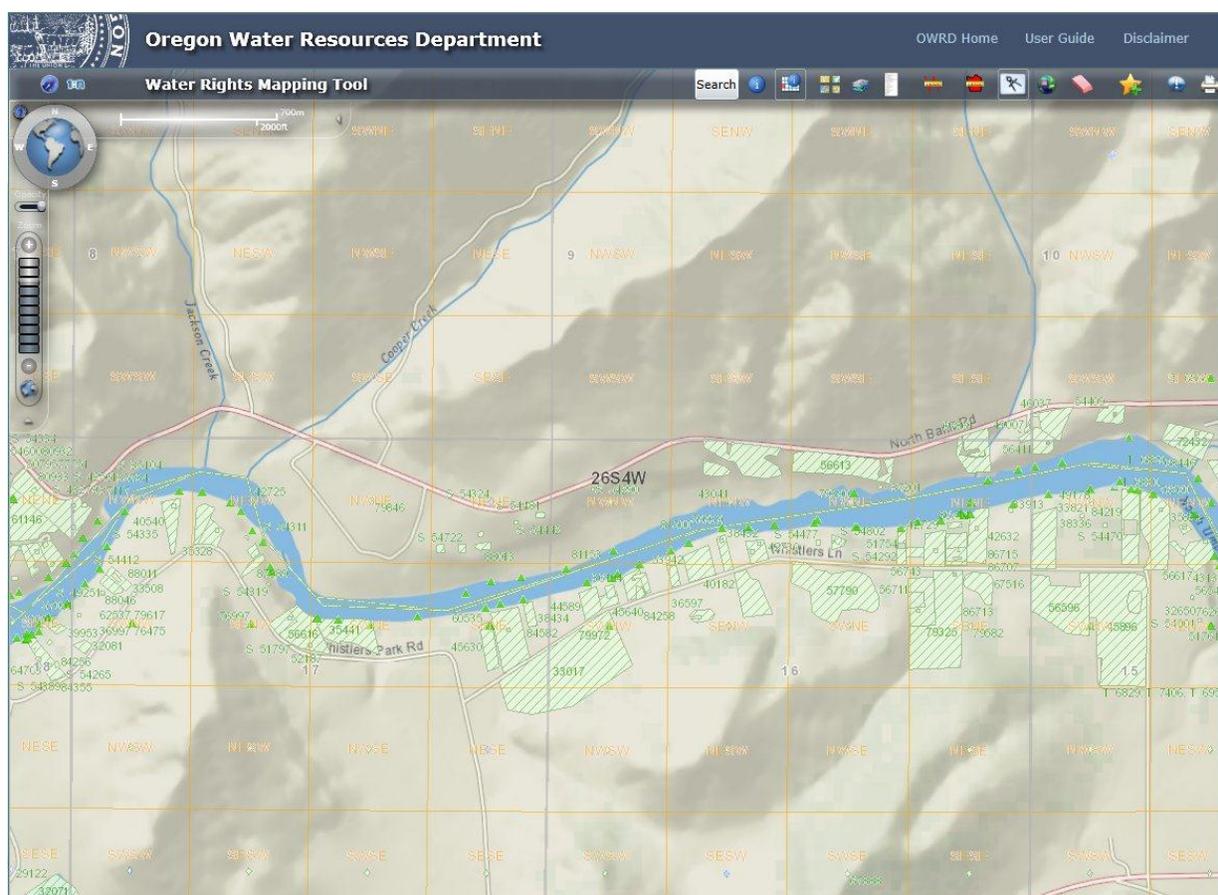


Figure 32: Oregon Water Rights Interactive Map (OWRD 2013)

There is however a plat card option on the water rights search page (see Figure 34). Search criteria required is location information in the form of township, range, and section. The resulting information is a Portable Document File (PDF) of the area with parcels lines displayed (see Figure 34). There is no information on the parcel owner or the address. The parcel lines are collected from the various counties where they are maintained.

The screenshot shows the Oregon.gov website interface for the Water Resources Department's Water Right Information Search. The header includes the Oregon state seal and the text "OREGON.gov" with a "TEXT SIZE: A+ A- A • TEXT" option. Below the header is a dark blue bar with the text "Water Resources Department". A left-hand navigation menu lists various categories: About Us, Contact Us, Adjudications, Commission, Dam Safety, File Pickup, Forms, Groundwater, Jobs at WRD, Links, Maps, Publications, Surface Water, Transfers, Water Law, Water Management, Water Rights, and Well Construction and Compliance. The main content area is titled "Water Right Information Search" and contains a dark blue bar with the text "Welcome to the new and improved WRIS - Your source for water right information". Below this, there is a paragraph of introductory text about the WRIS system and a disclaimer. At the bottom of the main content area, there are four hyperlinks: "Water Rights Information Query", "Platcard", "POU Summary Report", and "POD Summary Report".

Figure 33: Water Right Information Search (OWRD 2013)

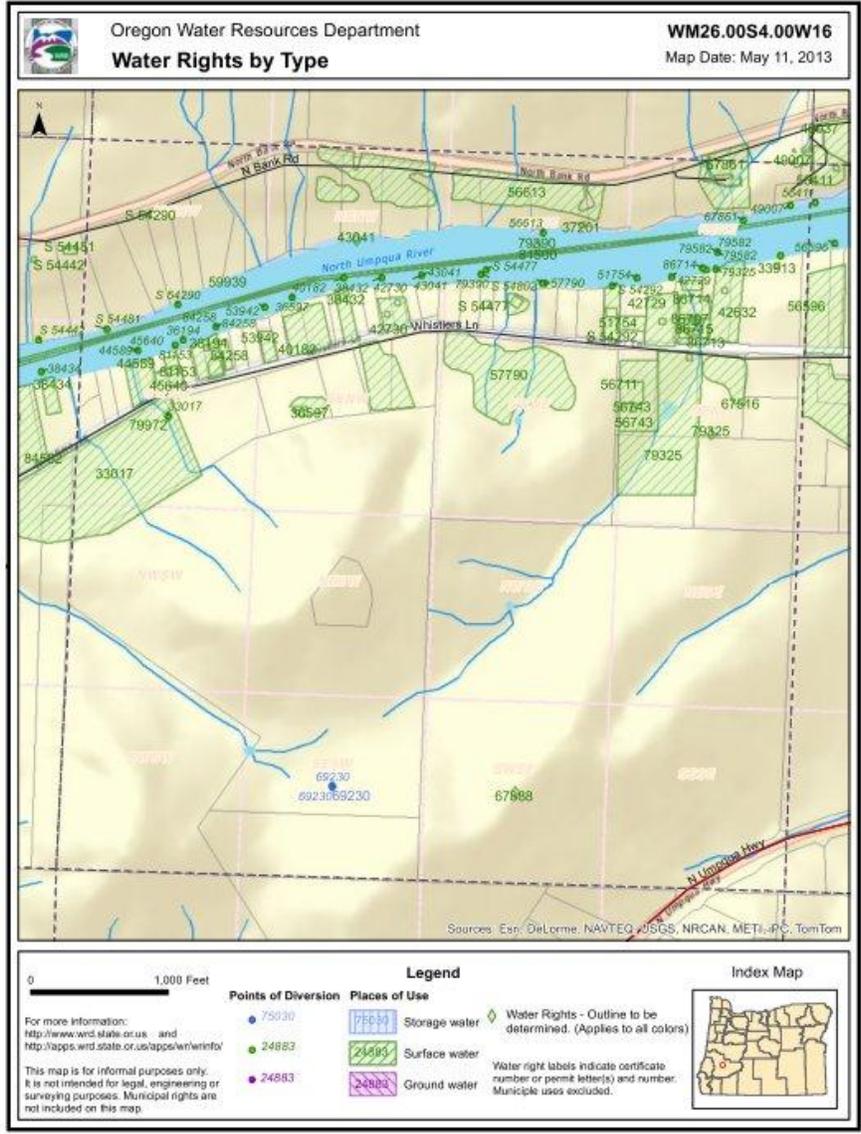


Figure 34: Plat Card Search Results (OWRD 2013)

Overall, Oregon has a web-based tool for researching water rights information that is defined well and easy to use. The information required for water rights research is available in multiple formats such as maps or documents. The digital data is available in the form of an Esri Geodatabase, which allows for the overlay of state water rights information with local county data for further analysis or research. The state water rights data contains a link back to the water rights query results page that contains supporting documents (see Figure 31).

## 2.10 State Water Rights Research Summary

Water rights web research capabilities for states are represented in Table 1. An initial step for the development of a fully interactive website involves the digitization of original documents. The majority of the states researched have reached this level with the exception of New Mexico. Those states with the digital records have created a query form for research of the documents with tabular results. The development of an interactive water rights research map requires the vector digitization of the previously scanned documents. Choices pertaining to the information that is available on the interactive map vary by state. The majority of the states choose to portray both the POD and POU. Although the detail of information varies, most states choose to display this vital information. Only Washington shows an overlay of parcels with the water rights information. This is quite valuable and requires a well-developed and accurate set of data on a statewide basis. No state allows research of water rights by the address of the parcel owner. The address and parcel owner are the additional requirements for an interactive map to be able to be applied to fieldwork or regulation of water rights. Demonstrating such functionality is the major objective of this project.

Table 1: State Summary

State	Form Query	Map Query	POD	POU	Parcel	Address
NM						
NV	X					
MT	X	X	X	X		
WY		X	X	X		
ID		X	X	X		
UT	X	X	X	X		
CO	X		X			
WA	X	X	X	X	X	
OR	X	X	X	X		

## CHAPTER THREE: METHODOLOGY

Technological advances such as geographic information systems have improved the ability to make decisions about the availability of water. It is through this technology that the recognition of the declining source of fresh water is understood and communicated to the population. It is necessary to improve the quality and availability of the defined appropriation and actual use of the scarce water supply to support current and future management options.

This GIS project benefits the state Watermaster and the Douglas County Natural Resource Department. The personnel are able to significantly reduce the time for preparing distribution maps used during regulation. They are also able to produce more variations of maps including permit applications. The GIS technology allows the combination of additional layers of information such as parcel ownership and address locations. A web application distributes the combined water rights, parcel, and address locations for water rights research as needed.

### 3.1 Oregon Water Resource Department

In Oregon, water rights information is available at the state's Water Resource Department (OWRD). The official documentation defining the legal description, point of diversion, place of use, and type of use is stored at the state office in a vault. The varying formats that hold the definitions of the status of a right to use water are confusing and time consuming to decipher. Formats include anything from paper maps on file, microfilm documents, and descriptions from the mid 1800s to a web-based interactive research tool. While this information is held at the state level, the details of ownership, as well as other underlying and changing information, are not. The ownership or parcel information is maintained at the county level and not related to the

state water rights data. Also, the state information is not detailed to the level required for regulation during defined and measured low stream volumes.

The objective of this study is to demonstrate and test a geographic information system that will allow designated water managers of a local drainage basin to understand how the current allocation of water is related to the ownership and location address. This work involved the development of a dataset of GIS information that represents the actual location of water rights permits. Each permit map image was registered to the PLSS, digitized, and relocated when necessary to the appropriate location. Due to the varying quality and accuracy of the official filed map, the results of this process may be in conflict with the legal location displayed within the OWRD. The OWRD does not adjust the location of the place of use or point of diversion to account for inaccuracies or other discrepancies in the official document when digitizing. The purpose of this project is to locate the water rights permit on the correct property for the regulation process and therefore will remain internal to the Natural Resource Department at Douglas County.

### **3.2 Research and Feedback**

The determination of prior appropriation status enables the mandatory obligation of allocating the limited resource during the dry months of the year. Fieldwork by local experts verifies the accuracy of the resulting system and allows feedback for corrections. The communication from field to office is beneficial in the constant task of maintaining accuracy of the current condition of the scarce resource and appropriation.

The methodology of this study results in the development of digital water rights distribution maps that demonstrate the current status of permitted use of surface water. The first steps include the collection of available data from existing resources. The sources include state

documents, county documents, and previous research. Accuracy of the researched information is evaluated and documented during the digitizing process. Required data for attributes within the GIS are defined and populated.

### **3.3 Development of Water Rights Distribution Information**

The digital information for this study is limited to the requirements of the regulation of surface water. The initial information is implemented from the available database and GIS datasets from the Oregon Water Resource Department. The Oregon datasets are based on development utilizing information available at a scale of 1:24000 (Harmon, Carine and Tippett-Huber 2013). This is a common cartographic scale utilized by the United States Geological Survey (USGS). The information is a representation of information contained in the legal rights of record. It does not reflect actual use, transfers, loss, or reduction of use (Harmon, Carine and Tippett-Huber 2013). Additional accuracy and geographic location of the current use is required for this study. Precise analysis of the water use is enabled by the spatial representation of the current location of the water rights permit appropriations.

### **3.4 Douglas County GIS**

Additional information is implemented from the Douglas County Oregon GIS. Details of the land ownership and address locations are maintained at this level. Accuracy of the ownership information has increased over the time that the system has been utilized. The land ownership information was first completed in 1992. Address information was developed in 1995. Both datasets have been corrected, updated, and verified up to 2013. It is possible to map at a scale that shows details of the relationship of the water rights to the ownership information. As required for the success of the model, the reliability of available information is high.

The accuracy of ownership information in Oregon has increased over recent years. An aggressive program to develop a seamless parcel dataset in Oregon is organized by the Department of Revenue. The program is referred to as ORMAP (ODOR 2013). It allows for counties to obtain grants to develop or improve the parcel base maps in each county. Within this program, many counties have developed a parcel base map that would allow for the development of current accurate water rights information in GIS format. Individual counties maintain a record of the accuracy of the parcel information they maintain and can determine if the base layer is suitable for overlay of accurate water rights information. The development of detailed water distribution maps in additional areas of Oregon requires the evaluation of these datasets.

### **3.5 Definition of System for Development**

The hardware utilized for this project is owned and operated by Douglas County (DC) for the purpose of doing business utilizing GIS. The Windows 2008 server is internal and protected by a firewall for security purposes. The configuration includes the services for Internet Information Services (IIS) and license management for required applications. It is also the SQL 2008 server that maintains the required spatial and non-spatial databases.

Since 1992, software from Intergraph Corporation is utilized for GIS at DC. This project is enhanced by the use of the existing resources. The website is developed and maintained through a product called GeoMedia Webmap Professional V06.01.11.19. The purpose of this application is to support the development of a geographic website with tools, queries, and custom maps. It is open source and fully customizable. The creation, analysis, and editing of geographic data is accomplished with GeoMedia Professional V06.01.11.13 and GeoMedia V06.01.11.13. These products are licensed from Intergraph and run by trained personnel at DC. Each product

has similar capabilities and is assigned to the appropriate level of expertise and required job duties.

As the Engineering System Specialist, my position involves the system administration, database management, project management, development, implementation, distribution, training and technical support for the Enterprise GIS at Douglas County. The Watermaster of the Umpqua basin initiated a request for water rights permit information to be digitized utilizing the Douglas County System. The existing software, hardware and personnel were available to implement the project at no additional cost. The Engineering System Specialist and the Assistant Watermaster dedicated time to develop an up to date accurate water rights permit GIS sufficient for use during regulation season as requested.

### **3.6 Creating the Distribution Maps**

The maps required for use during low water flow regulation time periods are referred to as distribution maps. Early distribution maps were created by hand on Mylar with liquid ink and pens. These are a major source of reference as the maps show the relationship of water rights within a drainage basin. Typically technicians who are familiar with the information and hold considerable field knowledge have produced the distribution maps. There is no reference to parcel or address information on the early distribution maps. The next version of distribution maps was created with a static drawing program called ACDsee v4. ACDsee is a software application for image editing. The assessor parcel maps are the image for base data. Water rights information was drawn on the assessor map image. Due to the constant change of parcel information, the water rights maps have to be redrawn. Continually updating these maps from year to year requires hours of research and duplication of previous work.

Each major stream in the main Umpqua basin requires a set of maps for fieldwork. There are several creeks to regulate. Some fall below required in-stream water flow before others and are the focus of initial mapping. These include Calapooya Creek, North Deer Creek, and South Deer Creek (see Figure 3).

An additional area of regulation is Cow Creek. The Galesville dam located in the flow of Cow Creek supplies both power and water to the area. During regulation season, it is possible to buy a contract to use water from the reservoir to supplement the loss of water from Cow Creek flow. The contract information is maintained in a Microsoft Excel spreadsheet by the Natural Resource Department office manager. The contract number, acres, and owner are added to the water rights permit information in GIS as attributes. Galesville contract information in the GIS enables personnel in charge of regulation to determine the status of the contract when contacting the water rights users.

### **3.7 Base Features**

GIS reduces the time required for base geographic information to be referenced when additional purposes are employed. Base data at Douglas County is overlaid to ensure up to date information is utilized. The base data includes PLSS, rivers, roads, parcels, site address, and aerial images.

Douglas County personnel are tasked with the development and maintenance of highly accurate base features. The defining base data is the original Public Land Survey System (PLSS) grid that was developed for the United States for mapping. Douglas County Surveyor, Fritz Ingram, calculated or located the coordinates for these points within the Douglas County (DC) boundary for the development of the DC GIS in the early 1990s. The most complete coordinate

system available was the North American Datum (NAD) 1927. Table 2 shows a complete list of the PLSS features.

Table 2: PLSS Features

<b>Feature Name</b>	<b>Description</b>	<b>Attributes</b>
PLSS_Points	All points calculated or found that form the basis of the linework	PointNumber, Reliability
Township	36 mi sq grid of township and range designation	Township Range Number
DLC	Donation Land Claim	Name, Number
Section	One mi sq 36 per township/range	Number
Quarterline	One quarter division of a section	
Sixteenthline	One quarter division of a quarter section or sixteenth	
GovernmentLot	Similar to sixteenth but numbered area	Number
Meander	Meandering line often along waterways	

Additional base features were developed utilizing the PLSS grid for reference. The base features include rivers, roads, parcels, and site address points. The additional features are developed and maintained with the greatest known accuracy. Several county departments are responsible for updates and corrections as changes occur and errors are determined. Table 3 shows a list of these features and the responsible department.

Table 3: Departmental Feature Responsibility

<b>Department</b>	<b>Feature Responsibilities</b>
Surveyor	PLSS
Engineering	Roads
Assessor Cartography	Ownership
Planning	Address
Natural Resources	Water and Permits

### **3.8 Aerial Images**

In addition to the feature information, Douglas County continues to utilize resources for aerial imagery. Aerial images range from contracted flights at high resolution to the 1 m resolution images available from the United States Department of Agriculture (USDA). The images available to DC date back to 2000 and continue with 2004, 2005, 2009, 2010, 2011, and 2012. Actual use of irrigation rights can be determined by viewing the image at the location of the place of use. Images also provide the location of domestic use with the display of buildings and aid the technician when locating the actual place of use within the parcel.

An enterprise GIS which serves multiple departments with central data storage and access, as defined by Peter L. Crosswell (Crosswell 2009), exists at DC. The enterprise GIS includes the Survey, Assessor, Planning, and Engineering departments. The addition of the information from the Natural Resource Department is an example of the ability to build on an enterprise GIS by department. The Natural Resource Department is benefitting from previous development at Douglas County.

### **3.9 Data development**

The water rights permit geographic information system is required by the Natural Resources Department at Douglas County. The purpose of the system is to benefit the regulation of water resources during times of low water or drought. The system defines the Place of Use (POU) and the Point of Diversion (POD). Water rights regulation is defined by first in right, first in use and therefore requires the collection of the priority date at a minimum.

A water rights permits system must track the transfer of location of use, type of use, or point of diversion. The official state water rights relational database accomplishes this task and is

not duplicated. The water rights permit system developed for the Douglas County Natural Resource Department maintains the up to date permit location for the distribution maps. The process involves the research and creation of a POU and POD defined by a permit with all transfers applied. All water permits must follow a process through the OWRD for approval. As approvals of new water rights or transfers are made, notification is sent to the appropriate Watermaster. The notification process enables updates to the more detailed and accurate data at the county level. The update procedure is applied during development and maintenance of the data.

Research in the study area is accomplished utilizing available data from The Oregon State Water Resource Department. The research and data collection is performed by a knowledgeable Assistant Watermaster at Douglas County. The State Watermaster approves the results of the findings to finalize the process. The process begins with a search of the ODWR database by Township, Range and Section. A list of permits in the area is collected and the permit documents are downloaded. The format is Portable Document Format (PDF) and the file is stored in the water rights directory on the county server. The document typically contains map information as well as text, title and permit number. The map area is copied and pasted into an image software program called IrfanView to be saved as a .tif image file for further processing. Clipping the map area eliminates excess information not necessary for the actual location of the water rights image in the GIS.

GeoMedia Professional is utilized for tools to register the image to the PLSS grid from the base GIS information. The results on more current water rights permits are often quite accurate but vary with the source for the base map. Occasionally the shape of the PLSS on the permit map and the digital PLSS in the Douglas County GIS system do not coincide. The

conflict is due to the popular implementation of a square PLSS grid on the water rights permit map when the digital PLSS is not square (see Figure 35). The image is in black and the vector PLSS data is colored. Interpretation and adjustments in the raster to vector registration results in the best fit possible. In the example, PLSS registration points were selected near the water rights information and the remainder of the section was allowed to float.

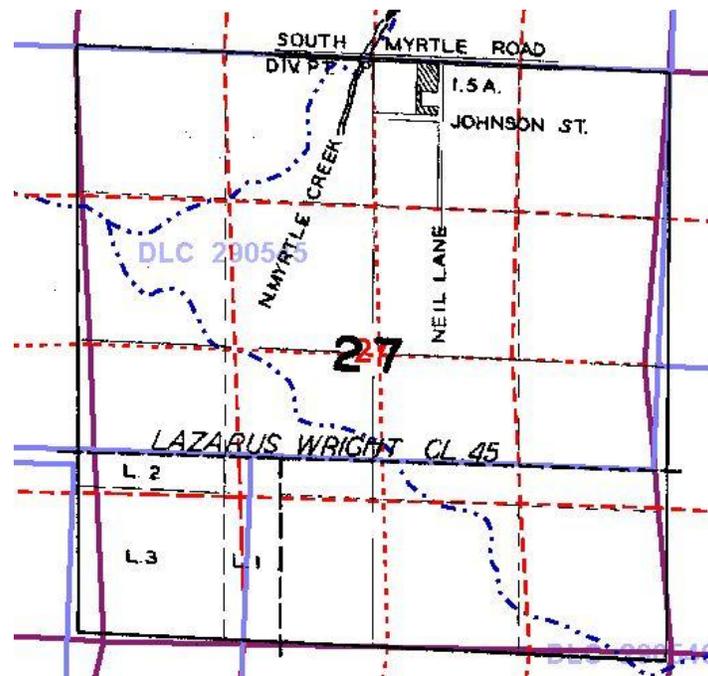


Figure 35: PLSS Grid Discrepancy Example

The result of image registration is a background image that can be utilized for heads up digitizing of the POD and POU. The image registration process is performed by the Engineering System Specialist (ESS) as a service to the Natural Resource Department. Approximately 2000 permits have been captured in this manner during 2012 and 2013. Each permit varies in time depending on conflicts of information. The average time for raster to vector registration is 5 minutes each.

Raster image registration requires a minimum of three points to define the relationship between the image and the vector information. An image may only have two points that reference the PLSS grid. In this case a point may be added to the vector information to use during image registration. A point at the location of the spring was added to the example in Figure 36. The listed distances from the quarter corner were used to create the third point.

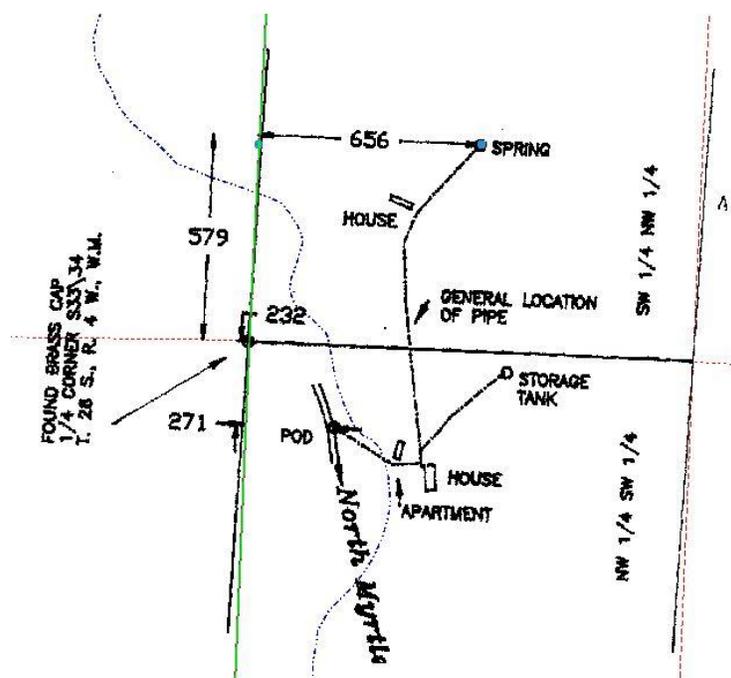


Figure 36: Example of Additional Point for Image Registration

GeoMedia is utilized by the Assistant Watermaster (AW) to digitize the POD and POU information into a water rights geodatabase. The actual shapes of irrigation areas are maintained. The AW references the PLSS, aerial image, and parcel information to analyze the resulting POU. Adjustments are made to show the intent when the digitized location does not represent the actual place of use. The adjustment may show discrepancies when compared to the official state location.

When moving or adjusting the shape of the water right results in a difference from the official state information, the Watermaster exams the results and determines the intent of the document. The resulting information is needed by the Watermaster to determine the parcel and address for the water rights permit. The actual location of use and property owner must overlay to determine the address to visit when regulation is necessary. An example showing conflict of state and local information is seen in Figure 37 and Figure 38.



Figure 37: Comparison of State (purple) and County (blue) locations of permit 14247

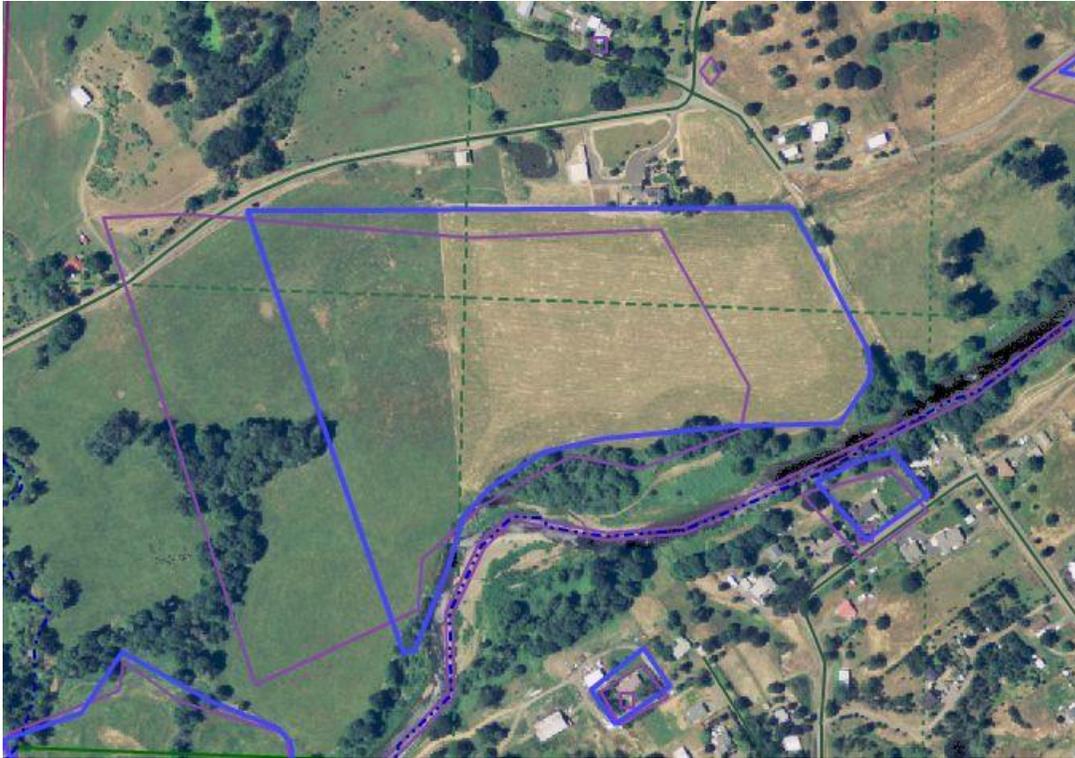


Figure 38: Permit 14247 Representing Actual use Location

Each water right would have to be examined and a transfer process followed to correct the official state documents to the actual location of use. This is a lengthy and controversial process beyond the scope of this project. The differing result may be due to the accuracy of image registration, errors in the original map document, or illegible original information. The state encourages feedback on discrepancies to continue the enhancement of the accuracy in their digital system.

After the geographic information is digitized, associated attribute information is entered for the POU and POD. The attributes are defined for POU in Table 4 and POD in Table 5.

Table 4: Place of Use Feature Attributes

<b>Attribute</b>	<b>Description</b>
PermitNumber	Legal reference to permit
Acres	Total Acres for permit (irrigation)
WaterSource	Creek where POD resides
Priority Date	Date of legal appropriation
GV_ContractNumber	Galesville contract number
GV_PermitNumber	Galesville permit number
GV_Acres	Galesville Acres for use (irrigation)
GV_Name	Name on Galesville contract
ColorPattern	Color pattern desired for thematic display

Table 5: Point of Diversion Feature Attributes

<b>Attribute</b>	<b>Description</b>
PermitNumber	Legal Reference to Permit
WaterSource	Creek where POD resides

### 3.10 Creation of Distribution Maps

Distribution maps have been the traditional method of taking information about water rights permits into the field for regulation. Each stream requires a set of 8.5 x 11 in. sheets to display the water rights to be regulated. An example is seen in Figure 39. The contents of the map include rivers, roads, and permits. The permits are patterned to show the date range that a water rights appropriation falls into. Issues with the paper format are typical. Detailed areas are difficult to decipher. They become worn and are difficult to update. The content is missing address information, making it difficult to insure that the regulator is at the correct location. This is the major reason an upgrade to process and procedure is necessary.

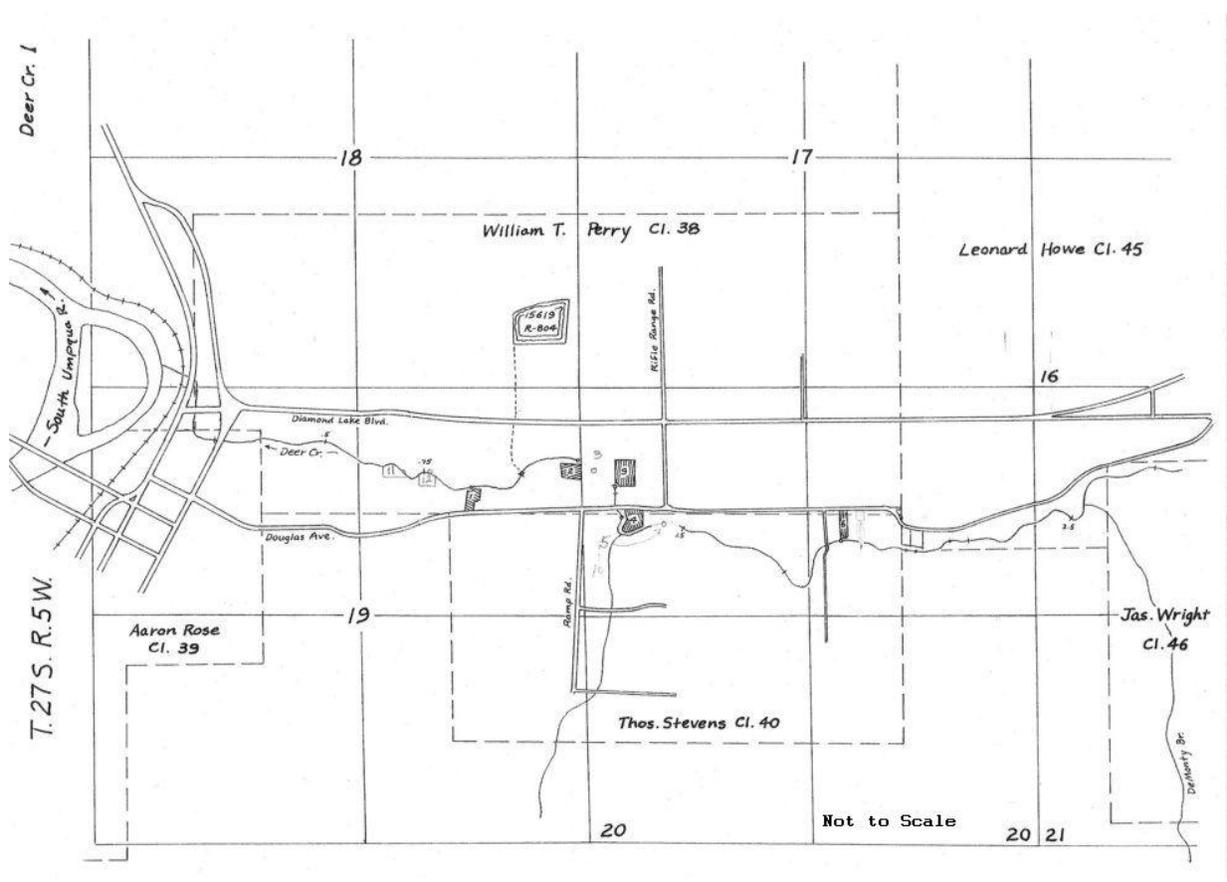


Figure 39: Hand Drawn Distribution Map (Henry 2013)

Distribution maps continue to be created with the water rights permit GIS. There is a transition period from the previous system on Mylar to the digital system. The transition time overlaps a regulation season and requires the use of both resources. Updated base information is available on the water rights permit website to verify details required before entering the field. Additional benefits will follow as the system is fully implemented and digital information can be distributed to the field electronically. A pilot project on a laptop was performed to test the data distribution process.

### **3.11 Distribution on Laptop for Fieldwork**

The process to distribute the required field information in a geodatabase format is simple. GeoMedia produces a Microsoft Access database that contains all of the features required for the distribution maps. The base data is the same as required by field personnel. The information is collected and symbolized exactly the same and distributed on a view only application call GeoMedia Viewer. The symbology is transferred utilizing a library database that contains definitions for styles and legends. The standardization of maps and symbology enhances the update process to a portable device. The benefit of the digital format of the information is the ability to zoom and pan to see the details of parcel and address information. The details reduce the guesswork of the field personnel when regulating water rights. Feedback from field to office for quality control, usefulness and updates is also implemented.

A pilot area encompassing the North Fork Deer Creek and South Fork Deer Creek is implemented during the transition from Mylar distribution maps to digital maps. The system has only been produced and tested in the summer of 2013. Anticipation of new technology implementation in the future will include tablet style hardware and direct access to original data sets as opposed to updated copies. It will take another year to prove the benefit, approve funding and implement an upgrade. The resources were available to implement the laptop approach at the cost of the Engineering System Specialist time to develop and instruct the natural resource technical personnel.

The laptop approach also enables the field personnel to takes notes in digital format. Typically a hardcopy of a list of permits is created and notes are taken in the field. After return to the office, the notes are transferred to a digital copy. The laptop approach eliminates duplication of effort.

### 3.12 Distribution of Information on Water Rights Website

Web technology provides tools for the distribution of GIS information to more users. With the data created and stored in a geodatabase, further distribution is accomplished by utilizing the Internet Information Services (IIS) provided by Microsoft Windows Server 2008. The resources for web creation already exist at Douglas County and require no additional resources other than time and expertise by the Engineering System Specialist (ESS). The application provided by Intergraph Corporation for web map creation is GeoMedia WebMap Professional. The process of implementation of this application can be seen in Figure 40. The web map server processes both input and output of the GIS. It provides the services required by the Internet application and the interface for publishing a map on the defined website. It is pertinent to have proper hardware resources for enterprise use.

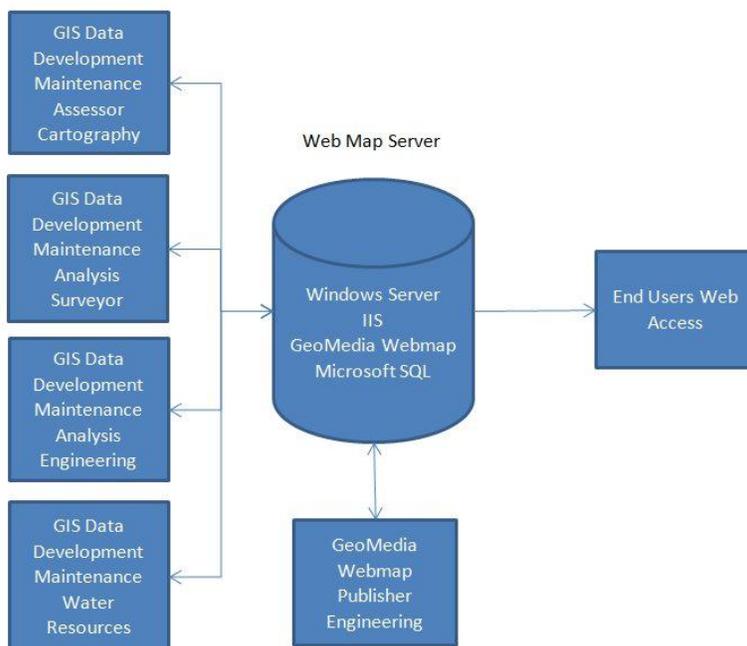


Figure 40: Web Map Server Diagram

The enterprise approach to GIS provides consistent upgrades of base data and the water rights permit information. Personnel in the Natural Resource Department can view the area they are assigned to regulate to verify the information on their distribution maps. This is especially important for changing information such as ownership and water rights transfers. As the entire Umpqua basin is not fully completed, some areas still rely on older technology. The website allows the users to verify addresses and updated parcel information. The ability to zoom and pan to create a detailed area map is also a great benefit as this previously had to be accomplished by hand.

The water rights permit website is internal to Douglas County due to the sensitivity of the information and the confusion it may cause to the public. The Watermaster and Natural Resource Department personnel are provided a resource for determining the current status of the water rights in the area. Because it is researched and created within the Natural Resource Department, the Watermaster can trust that it is correct and avoid duplicate research time.

In the future, mobile technology will be the base for distribution of the information to the field personnel during regulation. Access to detailed and updated information increases work flow.

### **3.13 How the Website Works**

The water rights website for the Natural Resource Department is created for the internal use of the department. The function of the water rights website is similar to the Douglas County public website. The Natural Resource Department personnel who use the public website already have experience in the tools to operate the water rights website for their use. The websites are fully interactive and allow for queries and movement throughout the map as needed. The initial screen of the water rights website can be seen in Figure 41.

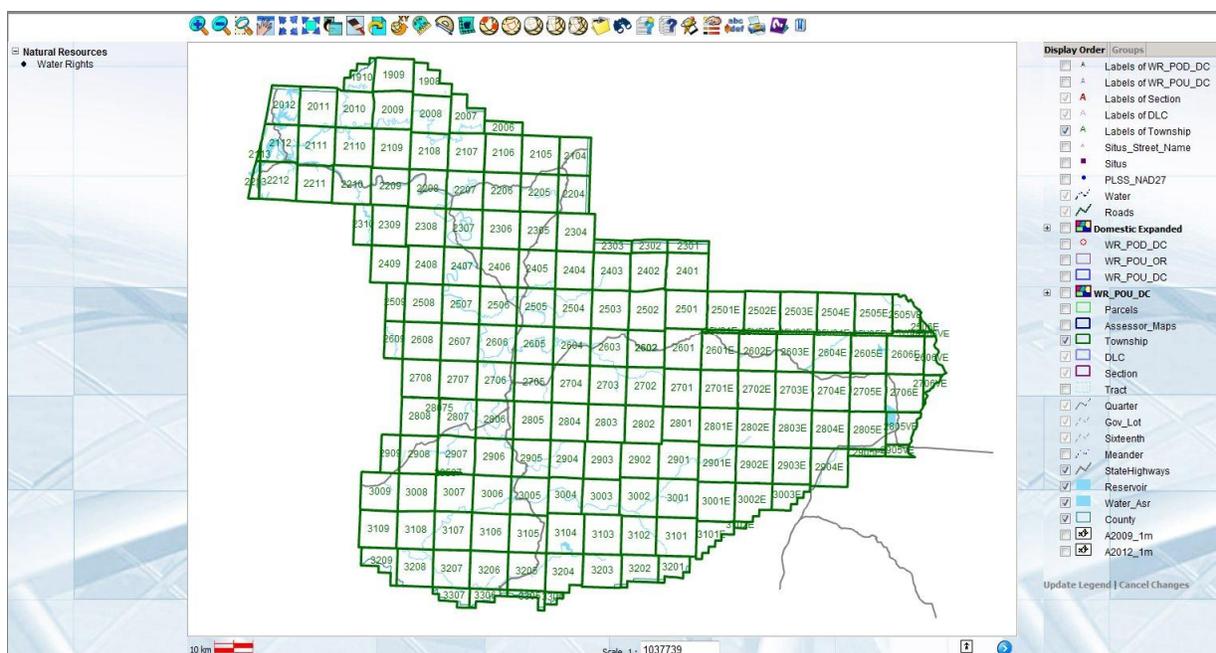


Figure 41: Natural Resource Website

The tools across the top of the website provide options for managing the map display and performing queries on the data. The binoculars activate predefined queries. The queries allow a user to zoom to a desired known location in only a few clicks. The search options allow the entry of a PLSS combination, address, or permit number. An address is common knowledge that a person may have when looking for a permit. A common sequence utilizing the search options is shown in Figure 42. The results of the search are shown in Figure 43. The user enters the request, presses find, and drops a pushpin for a specific address or the top pin for all results. The map will zoom to the selected location and one can proceed to the next task. A help button is provided to define the tools, features and general use of the system.

Figure 42: Web Search Option

Address	Notes	Number	Streetdir	Streetname	Streetsuffix	Unitnum
215 SE FOWLER ST		215	SE	FOWLER	ST	
223 SE FOWLER ST		223	SE	FOWLER	ST	
233 SE FOWLER ST		233	SE	FOWLER	ST	
243 SE FOWLER ST		243	SE	FOWLER	ST	
253 SE FOWLER ST		253	SE	FOWLER	ST	
263 SE FOWLER ST		263	SE	FOWLER	ST	
273 SE FOWLER ST		273	SE	FOWLER	ST	
283 SE FOWLER ST		283	SE	FOWLER	ST	
285 SE FOWLER ST		285	SE	FOWLER	ST	
293 SE FOWLER ST		293	SE	FOWLER	ST	
295 SE FOWLER ST		295	SE	FOWLER	ST	
317 SE FOWLER ST		317	SE	FOWLER	ST	
337 SE FOWLER ST		337	SE	FOWLER	ST	
367 SE FOWLER ST		367	SE	FOWLER	ST	
377 SE FOWLER ST		377	SE	FOWLER	ST	

Figure 43: Web Search Results

The legend area allows the user to turn features on or off and change the display style. Feedback from the initial users resulted in the default color selection and is typically useful for everyone. A common process is to allow more detail to be displayed in the map as one zooms to

a location. This is controlled in the legend entry properties. Some items are defined to display by scale (see Table 6). The ability to turn the scaled items on is grayed out at an invalid scale. The remaining legend items that are not already displayed are turned off until it is necessary to view them.

Table 6: Feature Display by Scale

Feature Name	Minimum Scale	Maximum Scale
Water	1	50000
Section	1	100000
DLC	1	100000
Tract	1	20000
Gov_Lot	1	20000
Sixteenth	1	20000
Roads	1	50000
Water_Asr	50000	1000000

The toolbar contains several methods to select geographic information from the map interface. The option to select a set of permits in an area is quite valuable for the field personnel. One procedure is to draw a polygon around an area containing water rights permits. The selection option produces a data list similar to the results in Figure 43. The Excel icon allows the user to export the data to a common Microsoft Excel format. The resulting Excel file is used to create a list of the permits for regulation. The digital format of the list also provides a location for taking notes when in the field. Manual creation of the same list requires a great deal of time.

### 3.14 Cartographic display

Cartographic standards for water rights permit mapping have been defined over many years. The standards are followed to maintain familiar recognition of the information. The main distinction of the place of use (POU) is the priority date. One entry in the website legend is the thematic display of permits according to important date ranges (see Figure 44). The addition of four of each category is to distinguish adjacent water rights within the same time frame for visual

purposes on the map as seen in Figure 45. The map display shows the status of the permits and allows for a selection of the newest water rights to be located. The newest dates are the first to be shut off from use.

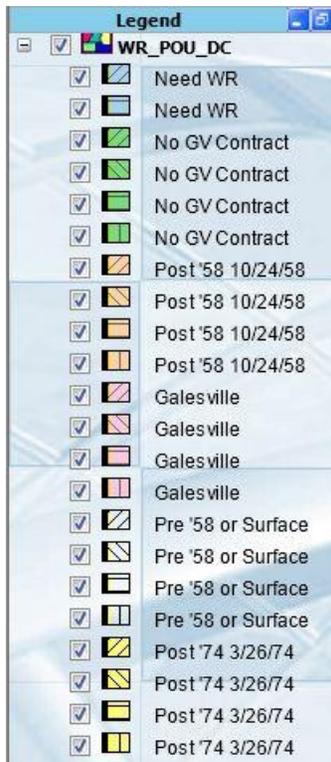


Figure 44: Place of Use Symbology by Date

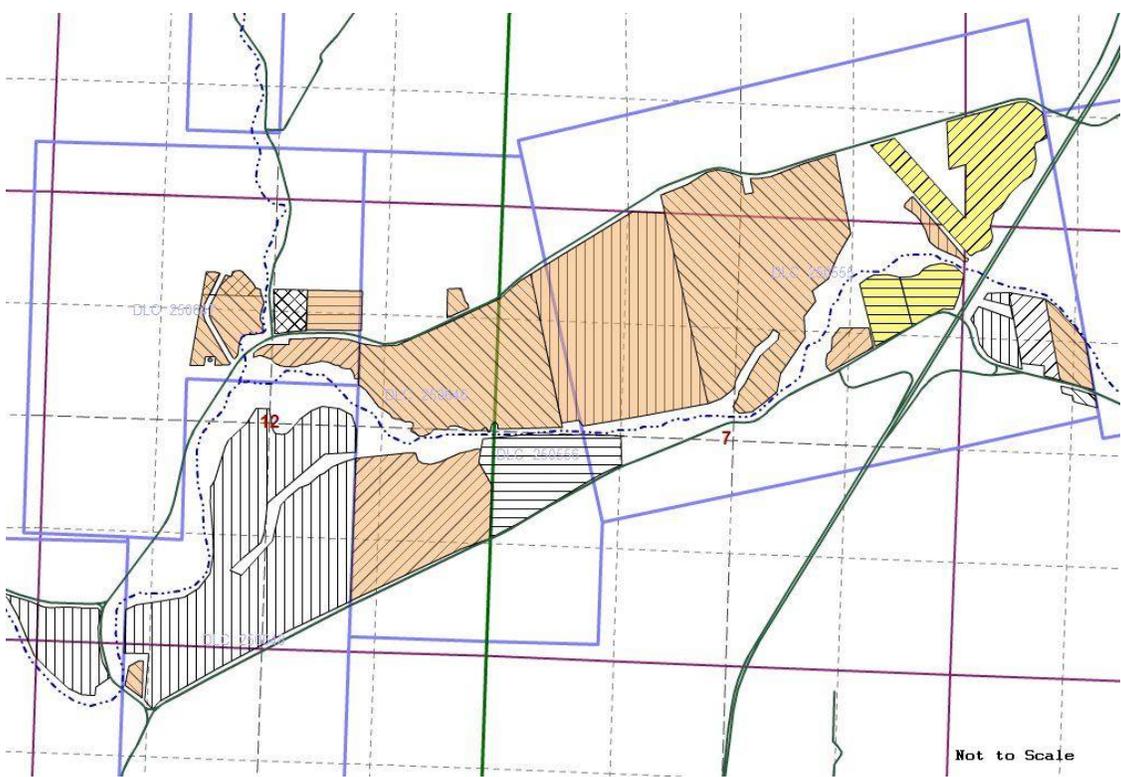


Figure 45: Water Rights Thematic Display by Date

The domestic expanded locations also contain priority dates. The website legend entry is a thematic distinction on priority date as seen in Figure 46. Domestic expanded permits allow for domestic use and up to five acres of irrigation around the area. When regulation requires less use, the domestic portion of the permit is allowed while irrigation is not. The result is the permit holder can water trees or shrubs around the dwelling but not the yard.



Figure 46: Domestic Expanded Thematic Display by Date

### **3.15 User Satisfaction**

A survey of functionality is a good technique to gauge the needs and satisfaction of the GIS users (Crosswell 2009). The survey is used to determine if the services being provided meet expectations of the user. The particular topics addressed for the water rights permit GIS include:

- Shortcomings in the hardware or software
- Problems or shortcomings with the GIS data
- Effectiveness of training
- Ideas and suggestions for changes

Individual presentation of the Water Rights Website to the Natural Resource Department GIS users was performed due to time schedules and responsibilities. A brief demonstration revealed the basic tools for moving around the map, turning on and off map layers, and query capabilities. User feedback was documented and implemented. A survey of functionality was presented after allowing time for the user to practice and test the system. The questionnaire and responses can be seen in the appendix.

### **3.16 Project Implementation**

The key to overall project implementation is the detailed and accurate location of place of use and point of diversion for water rights in the Umpqua basin. The data collected is a subset of all of the information available for water rights. The official state information is stored in a complex relational database beyond the necessary information for water rights regulation. The required data sets for regulation are defined in Table 4 for POU and Table 5 for POD. The Watermaster and Assistant Watermaster are invaluable to the success of the project. The Engineering System Specialist and the existing base hardware, software and data provided an

excellent starting point. The final result is a system that can continue to be maintained and expanded as needed for future requirements.

## CHAPTER FOUR: RESULTS

The results of the initial implementation demonstrate a success but also hint at additional needs. Feedback from the users and especially the Assistant Watermaster (AW) in terms of implementing the data was very helpful. As the AW was learning about GIS at the same time as developing the data, the capabilities of GIS were just being realized. Additional uses of the system were determined as well as the time saved in daily work.

### 4.1 Advancements Achieved Utilizing GIS

The advantages of utilizing GIS technology are many. One of the most obvious benefits is the ability to combine the data from many resources to answer questions. In this project, the addition of parcel and address information was a necessity. The recording of research from many sources on paper and previously digitized information allows the Watermaster to trust the information without repeating the research process each time water rights information is required. The time saved will increase as additional streams are completed and the digital information is utilized instead of paper maps. As personnel understand more about the capabilities of GIS, they will realize additional information they can gain from the system.

The ability to quickly produce a water right map for a customer at the counter is an immediate benefit of the system. Often people inquire about water rights on their property. Previously it was difficult to decipher exactly which property the water right was assigned to. With the digital information in a GIS, the property can be queried by the address and the water rights in the area displayed. A map can be produced quickly and printed. This previously could take days of research. A complete water rights map can now be generated within about 15

minutes if all the related streams are in the web-enabled map. Savings in both time and resources are accomplished.

## **4.2 Problems Resolved with the System**

The purpose of this project is to create a current and accurate digital water rights permit system using GIS for use in water rights regulation. The digital information created and stored at the state level is a good research tool but does not meet the detail or accuracy required by the Watermaster. The state water rights system also does not combine the parcel or address information required. The Natural Resource Department water rights permit system represents the intended or actual use of the water rights. Natural Resource Department personnel are able to match the water rights to an address for fieldwork during regulation season.

### **4.2.1 Aggregation**

Although the water rights website is a visual tool for checking the location of a right before regulation, GIS has the ability to combine spatial information for this purpose. Further processing to aggregate parcel and address information into a distribution list is beneficial for fieldwork. The results give the field personnel a current list that can be used with or without the map. The tools to accomplish the aggregation or combination of spatial data are available within the GeoMedia desktop software used during development of the water rights GIS. The process is defined in Figure 47. The parcels are analyzed for the existence of an address point within the boundary and populated with the address if positive. The results are then analyzed for the existence of a water right permit within the boundary and populated with the permit information.



Figure 47: Aggregation Flow Chart

The resulting table containing the permit, parcel and address information is seen in Figure 48. The first six columns contain information from the parcel feature. This includes tax information and complete ownership name and address. The address and city information is aggregated from the location address point feature. The permit number and water source information is aggregated from the permit place of use feature. The aggregations results from GeoMedia can be exported to a Microsoft Excel spreadsheet for portability, familiarity to the user, and allow notes as necessary.

TAXID	PROP_ID	NAME	ADDR1	ADDR2	CSZ	SitusAddress	SitusCity	PermitNumber	Source
280627BB00100	R56956	Powers, Douglas M; James G Succ Co T	Powers Family Trus		Albany,OR 97321	2021 WINSTON SEC WINSTON		19477	South Umpqua
280627B00400	R56942	Findlay, Tom & Jan	480 Parkinson Rd		Winston,OR 97496	480 PARKINSON RD WINSTON		19477	South Umpqua
280627BB00101	R56963	Powers, Edna Tr	Powers Loving Trus	1234 Mockingbird Dr		1871 WINSTON SEC WINSTON		19477	South Umpqua
22061500300	R35655	Letsom, Barbara J	33127 E Saginaw R		Cottage Grove,OR 9	4128 STATE HIGHW. DRAIN		19573	Elk Creek
22061500300	R35767	Letsom, Barbara J	33127 E Saginaw R		Cottage Grove,OR 9	4128 STATE HIGHW. DRAIN		19573	Elk Creek
22061601600	R37119	McFarland, Keith E &	5462 Highway 38		Drain,OR 97435	5462 STATE HIGHW. DRAIN		19603	Elk Creek
22061601600	R37127	McFarland, Keith E &	5462 Highway 38		Drain,OR 97435	5462 STATE HIGHW. DRAIN		19603	Elk Creek
32052301700	R56379	Tanner, Nellie E Opp	P.O. Box 337		Azalea,OR 97410	1294 QUINES CREEK AZALEA		1968	Quines Creek
32052301701	R56386	Goheen, Steven & L	P.O. Box 232		Azalea,OR 97410	1600 QUINES CREEK AZALEA		1968	Quines Creek
32052301700	R56393	Tanner, Nellie E Opp	P.O. Box 337		Azalea,OR 97410	1294 QUINES CREEK AZALEA		1968	Quines Creek
32052301701	R56400	Goheen, Steven & L	P.O. Box 232		Azalea,OR 97410	1600 QUINES CREEK AZALEA		1968	Quines Creek
25061501500	R26480	Walczak, John J & Jonnie Samuel	644 Cole Rd		Oakland,OR 97462	644 COLE RD OAKLAND		19747	Calapooya
25061501000	R26496	Basque, Dana E & L	Basque Joint Revoc	1320 Wilcox Road	Oakland,OR 97462	1320 WILCOX RD OAKLAND		19747	Calapooya
25061501700	R26600	Hunsaker, Floyd Ear	512 Cole Rd		Oakland,OR 97462	512 COLE RD OAKLAND		19747	Calapooya
25061501700	R26608	Hunsaker, Floyd Ear	512 Cole Rd		Oakland,OR 97462	512 COLE RD OAKLAND		19747	Calapooya

Figure 48: Aggregation Results

### 4.2.2 Additional Attributes

Minimal attributes were defined for features during the initial development process. After further evaluation of the data, it was determined that additional attributes would be required for future use. The additional attributes are listed in Table 7 for POU and Table 8 for POD. For the POU, the type of use is important for analyzing the volumes of water associated with specific applications. The permit status allows tracking of transfers and is associated with the transfer number and applied transfers. The last regulated date allows historical analysis of regulation requirements. For the POD, the appropriated flow allows volumes to be associated with the meter information. The permit status allows tracking of transfers of POD locations.

Table 7: Additional Attributes for Place of Use

Attribute Name	Description
TypeOfUse	Type of beneficial use (drop down list)
PermitStatus	Active or transferred (drop down list)
TransferNumber	Permit transfer number
AppliedTransfers	List of transfers applied to original permit
LastRegulatedDate	Historical information for analysis

Table 8: Additional Attributes for Point of Diversion

Attribute Name	Description
Appropriated Flow	Flow from source in cfs
Metered	Yes/no (drop down list)
Metered Flow	Metered flow in cfs
PermitStatus	Active or Transferred (drop down list)

### 4.2.3 Galesville Contract

The Natural Resource Department at Douglas County is responsible for Galesville Dam. The Galesville Dam was constructed in 1985 for the purpose of flow control, water supply,

power generation, and recreation. Water supply is managed by a contract system as a secondary source of water during low flow. It is important to know who has paid to use the water under contract as a secondary source when the surface water right is unavailable. The Natural Resource Department maintains a spreadsheet containing the contract information. Table 9 shows the corresponding fields in the water rights POU attributes feature. Using GIS to join the permit numbers from the water rights map to the Galesville contract allows the digital update of the GIS attributes. The existence of the digital contract information was unknown at the beginning of the project and was an enhancement to the system. The combination of the data removes duplicate effort in the data entry process.

Table 9: Galesville Contract Information

<b>Galesville Spreadsheet</b>	<b>Water Rights POU</b>
Contract Holder	GV_Name
Source of Water	WaterSource
Expiration Date	
Permit	PermitNumber
Contract No	GV_ContractNumber
River Mile	
Acres	GV_Acres
Acre Feet	
Total Cost	

#### 4.2.4 Picklist

A GIS requires accurate data entry for future analysis. After a small amount of work was completed, maps and analysis became available. It became apparent that certain attributes had limited options for entry and should be managed by a pick list for selection. The addition of a pick list for data entry reduces the volume of human error. Intergraph Corporation provides instructions to create a pick list within the geodatabase in the GeoMedia User Guide supplied with the software (Intergraph Corporation 2013). The process is essentially a relationship

between tables that an application understands when data is entered into an attribute field. The application displays the options in a defined table for selection and entry. The drop down list is implemented on the attribute fields defined in Table 10.

Table 10: Attributes with List Tables

<b>Attribute</b>	<b>List</b>	<b>Feature</b>
WaterSource	List of regulated creeks	POU and POD
ColorPattern	List of color pattern styles	POU
TypeOfUse	List of Beneficial uses	POU
PermitStatus	Active or Transferred	POU and POD
Metered	Yes/No	POD

In addition, the power of analysis with a GIS depends on consistent data. For example, to query the permits on a particular water source, the name of the water source must always be the same. North Fork of Deer Creek is not the same as Deer Creek. This aspect was discussed with the Assistant Watermaster and improvements have been accomplished. It is a good idea to check the data after a short period of development time to establish consistency when a new GIS technician is in training.

#### **4.2.5 Cartography**

The symbology of the Webmap was based specifically on the existing distribution maps. The existing maps did not include parcel, address, or the state information, therefore, random color choices were made for the website. Standards for feature display are implemented a Douglas County for water, roads, and PLSS. A thematic display of the place of use by date was requested through user feedback. The requested display was created utilizing colored polygons with variations of cross-hatching to portray the date ranges for regulation. The date range information was collected during data entry and utilized for this purpose.

### **4.3 Problems Created with the System**

Due to the project procedure including adjustments to the POU and POD location from the original scanned location, the final result may not match the official state record. The act of creating an accurate representation of the intended or actual POU creates a dataset unable to be distributed for public use. Water rights are a complicated issue and when people disagree over water, only the official state records can be utilized during litigation. The ability to combine the state GIS data with the detailed information at the county level makes this very clear.

As this data is very controversial, the Watermaster still relies on the available legal documents and the hardcopy maps with his notes about the parcel location of a permit. The new technology is slowly being implemented in the natural resource department but it takes time for change. The combination of permit location, parcel ownership, and address is beneficial for regulation purposes. Field work is still required for verification of the automated results for actual implementation.

### **4.4 User Feedback and Adjustments**

The feedback from the users was very positive. The water rights web interface is familiar and the information they need is displayed clearly with informative attributes. Through discussion during development, most updates or changes were made early in the process. A few color changes were made to clearly distinguish features. Thematic legend entries were defined to distinguish date ranges for POU and domestic expanded locations. The greatest desire of the users is to move forward to digital field technology. This would include the distribution of the digital website and data to a device such as a tablet computer. The requirements would include all of the functionality now available on the desktop but include portability with updated

information. The mobile technology would also enable updating of information that is incorrect directly from the field without having to take notes and return to the office for input.

## CHAPTER FIVE: CONCLUSION

This project has for the most part been a success. The ability to overlay multiple map features in a digital format for viewing and analysis is a great enhancement to paper maps that are limited in detail. The application to water rights permits is controversial when adjustments from the official state documents are made. It is very rare in GIS that detailed and accurate data do not produce a positive result. This project produces a desired result for a particular purpose of which water rights regulation is the key. Water regulation is contentious and unpleasant to perform, thus the accuracy of knowing exactly where to go is extremely important. Imagine the results if a Watermaster turned the water off for the wrong location. Confidence of accuracy is increased when the Watermaster is involved with the development of the water rights permit system.

### 5.1 Summary of Findings

GIS can be implemented in many disciplines. The successful results depend on the knowledge base of the discipline itself. This particular study was performed on the very controversial subject of water rights permits and the regulation of the prior appropriation doctrine. An understanding of the functionality of the existing water rights permit system is necessary to capture all of the information required for a successful implementation of GIS. Roger Tomlinson was correct when he said that one must ask probing questions to get the information you really need to plan for a GIS (Tomlinson 2011). Required details are not always apparent during the first discussions concerning the development of a system. It is important to plan several discussions with all the people involved to ensure a complete system. This system involved many small stages to get to the final product. A full understanding of the water rights permit process would have resulted in a complete system from the beginning. The later addition

of desired information resulted in the need to revisit data to populated attributes. The later addition of information results in more time required for completion.

The addition of departmental information into an enterprise GIS creates the combination of disparate data. In a GIS, the results need to be analyzed for unintended discrepancies. In the case of water rights permit information, the original documents only reference PLSS. The original document PLSS and the GIS PLSS may not be represented the same. Knowledge of the origin of the PLSS location and reliability is necessary for informed decisions during data entry. The results are dependent on the decisions made at the time of creation.

The purpose of this study is to combine the water rights information with parcel information. There is no reference to the parcel information on the original water rights permit document. The location of the water rights permit on the correct parcel may require the relocation of the permit information after digitizing is complete. The parcel information must be accurate and current to be referenced for location of the water rights. This process requires knowledgeable personnel from the area. The process at the state level does not include the discretion of local knowledge and does not always result in the same location of the digital permit information.

The final process of developing a combination of water rights, parcel, and address information for regulation purposes is not exact. Spatial analysis in a GIS is dependent on the accuracy of the data. The automated results should be analyzed before entering the field. A website is created for this purpose. The technician can visually check the locations to be regulated and verify the address to physically approach. Having the information digitally in the field is even more beneficial for verification.

## 5.2 Significance of Findings

The application of prior appropriation is common in the western states. The rural mountainous regions depend on snowfall and rain for the source of water. The water rights permit system is implemented to manage the water sources. Many areas are over-appropriated and require regulation when water sources are low. The use of GIS in a mountainous area is demonstrated with this project. The results can be applied in similar locations that require regulation. This type of detail is not yet applied throughout the state of Oregon. The results of the research of other states did not show that the combination of permit, parcel and address information is common practice.

The implementation of this system in other areas is dependent of the desire of water managers. The research to track all transfers to determine the current use and digitally store the information is time consuming. The base data must be accurate and updated on a regular basis. Local government agencies are tasked with this responsibility while the state agencies are responsible for water rights information. Cooperation between the two agencies is required for the final results. There should be a path of communication when discrepancies arise to determine the cause and adjust as necessary.

The benefits of developing an accurate and current water rights permit system include general enhancements to data access and map creation. The time required to create water rights permit maps for the public is greatly reduced. This is a common daily task and is often not provided by water management agencies due to the time involved. With the implementation of the water rights permit GIS, a public service could easily be provided.

The collected information includes the authorized use and volume of water allowed. With the amounts updated due to transfers, actual use can be determined through query tools in a GIS.

Without the removal of the place of use and update of the transfer values to the current status the results would be inaccurate. This is an improvement over state information that does not change but only record the transfer information. The state system must remain intact to record the history. The Watermaster in charge during regulation must know the current status of the permit. The current status is also important for determining the actual use compared to the available source of water to avoid further over-appropriation.

### **5.3 Future Research**

The data collected in this study provides information that can be utilized for further analysis. The accuracy is required for the results to be trusted by water managers. Future water management may be enhanced by knowing the type of use and amount of resource involved. Water use could be better managed by type of use as well as date of appropriation. The strict application of prior appropriation may not be as beneficial in the future as water levels decline. An accurate water rights permit GIS could help determine the details for decision makers.

Both surface and ground water resources are extracted for human use. This project only addresses the surface water rights permit system. The collection of ground water information would greatly enhance the capabilities of the water managers to determine actual use. The collection of GIS data for both ground and surface water is necessary to represent the entire water cycle. Ground water is accessed by drilling wells. The data is contained in well logs and requires an extensive amount of time to collect the location and details in digital format. Similar requirements such as accurate base data, time and personnel would be required.

The future distribution of the water rights permit GIS to the field is beneficial. Time is reduced in the collection of information on paper and then transferred in the office. Field

equipment allows one time entry and verification of the data. Technology is currently available to implement this benefit but requires resources and authorization to implement.

GIS implementation often provides benefits that are not realized until the system is complete. The process of obtaining a water rights permit is accomplished in multiple steps. The first step involves an application for the permit. With the GIS in place, a permit map is created in minutes compared to days by hand. After approval of a water rights permit, a certificate must be produced showing the actual location on a map. With the permit previously defined in the GIS, duplication in drafting for the creation of the certificate map is avoided. This is a great savings in time and resources. It will be interesting to see additional applications of the system as future water management requirements rely on the existence of digital up to date information.

## REFERENCES

- 77th Oregon Legislative Assembly. "Senate Bill 217." *Oregon Legislature*. 2013. [http://www.oregon.gov/owrd/LAW/docs/2013\\_WRD\\_LC\\_659\\_SB\\_217.pdf](http://www.oregon.gov/owrd/LAW/docs/2013_WRD_LC_659_SB_217.pdf) (accessed 2013 9-11).
- Bastasch, Rick. *The Oregon Water Handbook; A guide to Water and Water Management*. Rev. Ed. of: Waters of Oregon. 1998. Corvallis, OR: Oregon State University Press, 2006.
- Britton, Ben. "Idaho Department of Water Resources Interactive Map." *Idaho Department of Water Resources*. 2013. <http://maps.idwr.idaho.gov/mapall/help/UsersManual.pdf> (accessed 2013 10-11).
- Campbell, R. "WATERS PDF." *OSE New Mexico*. 2011 23-9. <http://www.ose.state.nm.us/PDF/Maps/WATERS-Abstract.pdf> (accessed 2013 18-10).
- CDWR. *Colorado History of Water Rights*. 2013. <http://water.state.co.us/SurfaceWater/SWRights/Pages/WRHistory.aspx> (accessed 2013 20-10).
- Crosswell, Peter L. *The GIS Management Handbook*. Frankfort, KY: Kessy Dewitt Publications, 2009.
- CWCB. *Colorado's Decision Support System*. 2013. <http://165.127.23.41/website/cdss/viewer.htm> (accessed 2013 20-10).
- Davis, M. "Integrated Water Resource Management and Water Sharing." *Journal of Water Resources Planning and Management* 133, no. Special Issue: Transboundary Water Sharing (2007): 427-445.
- DNRC. *DNRC Water Right Query System*. 2013. <http://nris.mt.gov/dnrc/waterrights/default.aspx> (accessed 2013 19-10).
- DOE. *WSDE Water Resource Explorer*. 2013. <http://www.ecy.wa.gov/programs/wr/info/webmap.html> (accessed 2013 19-10).
- EPA. *Water Resources Impacts and Adaptations*. 2013. <http://www.epa.gov/climatechange/impacts-adaptation/water.html> (accessed 2013 3).
- Harmon, Bob, Meredith Carine, and Linda Tippett-Huber. "Water Rights GIS Compilation Procedures." *Interactive Water Rights Maps*. 2013 8. [http://www.oregon.gov/owrd/maps/docs/owrdprocedures9\\_1.pdf](http://www.oregon.gov/owrd/maps/docs/owrdprocedures9_1.pdf) (accessed 2013 25-10).
- Henry, Don. "Douglas County Distribution Maps." *Distribution Maps*. Roseburg: Douglas County Natural Resource Department, 2013.
- IDWR. *Idaho Department of Water Resources*. 2013. <http://www.idwr.idaho.gov/> (accessed 2013 10-11).
- Intergraph Corporation. *GeoMedia User Guide*. Huntsville, 2013.

- Montana DNRC. "Water Rights Web Guide." *Montana State Library MT.Gov Connect Web Archive*. 2011. <http://wayback.archive-it.org/499/query?type=urlquery&url=http://www.nris.mt.gov/dnrc/help/WaterRightsWebGuide.2011.doc&dates=> (accessed 2013 18-10).
- Montana Water Resources Division. *DNRC Water Resource Division*. 2013. <http://dnrc.mt.gov/wrd/default.asp> (accessed 2013 18-10).
- NDWR. *State of Nevada Division of Water Resources*. 2013. <http://water.nv.gov/index.cfm> (accessed 2013 26-10).
- NMOSE, New Mexico Office of the State Engineer. *New Mexico Water Rights Reporting System*. 2013. <http://nmwrrs.ose.state.nm.us/nmwrrs/index.html> (accessed 2013 28-9).
- NRIS. *Atlas of Montana*. 2013. <http://maps2.nris.mt.gov/mapper/> (accessed 2013 18-10).
- ODOR, Oregon Department of Revenue. *ORMAP*. 2013. <http://www.ormap.net> (accessed 2013 28-9).
- Official Oregon State Records. "Water Rights Application File." *Water Rights Document*. Salem: Certified Water Rights Examiner, 2013.
- OWRD Information Services. "Atlas of Water Rights by Type and Use." *Oregon Water Resource Department Atlas*. 2010 09. [http://summit.wrd.state.or.us/maps/docs/OWRD\\_2010\\_WaterRightsAtlas.pdf](http://summit.wrd.state.or.us/maps/docs/OWRD_2010_WaterRightsAtlas.pdf) (accessed 2013 12-11).
- OWRD Map Library. "Map Library." *Water Resource Department*. 2013. [http://apps.wrd.state.or.us/apps/gis/gis\\_map\\_library/](http://apps.wrd.state.or.us/apps/gis/gis_map_library/) (accessed 2013 3-10).
- OWRD. *Oregon Water Resource Department*. 2013. <http://www.oregon.gov/OWRD/pages/index.aspx> (accessed 2013 25-10).
- Rodriguez-Bejarano, Dario, and Ted Apodaca. "Esri library of user conference professional papers." *Water Rights Adjudication in New Mexico: Applications of GIS and IS*. 1997. <http://proceedings.esri.com/library/userconf/proc00/professional/papers/PAP419/p419.htm> (accessed 9 7, 2013).
- State of Oregon. *Oregon's Integrated Water Resources Strategy*. Salem: Oregon Water Resources Department, 2012.
- State of Oregon. *Water Rights in Oregon*. An Introduction to Oregon's Water Laws. Salem, OR: State of Oregon Water Resource Department, 2011.
- Todorovic, Mladen, and Pasquale Steduto. "A GIS for Irrigation Management." *Physics and Chemistry of the Earth* 28 (2003): 163-174.
- Toll, Michael. *Reimagining Western Water Law: Time Limited Water Right Permits Based on a Comprehensive Beneficial Use Doctrine*. 2001: HeinOnline 82 U Colo, 2001.
- Tomlinson, Roger. *Thinking About GIS*. Fourth. Redlands, CA: Esri Press, 2011.
- UDNR. *Utah Division of Water Rights*. 2013. <http://www.waterrights.utah.gov/wrinfo/default.asp> (accessed 2013 28-9).

UDWR. *Utah Water Rights Information*. 2013. <http://www.waterrights.utah.gov/> (accessed 2013 19-10).

University of Wyoming. *Wyoming State Water Plan Interactive Map*. 2008. <http://ims2.wrds.uwyo.edu/Website/Statewide/viewer.htm> (accessed 2013 26-10).

Western States Water Council. "Water Laws and Policies for a Sustainable Future: A Western States' Perspective." 2008.

WSDE. *WSDE Water Resources Home*. 2013. <http://www.ecy.wa.gov/programs/wr/rights/water-right-home.html> (accessed 2013 19-10).

Wyoming State Engineer. *Wyoming State Engineer's Office*. 2013. <http://seo.wyo.gov/home> (accessed 2013 26-10).

## APPENDIX: WEBSITE QUESTIONNAIRE AND RESPONSE

Water Rights web application survey: <http://engine/pubnat3/default.asp>

Name: Tom Strahl

Title: Engineering Tech

Date: 10/23/13

1. How useful and intuitive is the interface?  
Is great for on the ground location and knowing the status of the water rights.
  2. Do you need additional instruction?  
Did not use for regulation this year - I'm sure more extended use would require a bit of instruction.
  3. Do the tools accomplish what you require?  
What I have used worked fine.
  4. Are the entries in the legend complete for your use?  
Yes
  5. What would you like to see added?  
Have not used it enough to discover what needs to be added.
  6. Do the legend entries (features) display in a visual style clearly?  
Yes, very well.
  7. Do the legend entries display at an appropriate scale?  
Yes, the scaling seems appropriate.
  8. Are the tooltips (info when cursor hovers over a feature) beneficial?  
Very helpful in making sure you have located the right parcel.
  9. Are the attributes (information) of the features beneficial and complete?  
For what I have used it for the information supplied is adequate.
  10. Do the supplied queries support your use?  
So far!
  11. Have you tried to create your own query?  
No
  12. Would this information be beneficial in the field? Example: during regulation season.  
Very beneficial - you always have questions in the field and to look up info would be very helpful.
-

Water Rights web application survey: <http://engine/pubnat3/default.asp>

Name: CURT ACKLEY

Title: NATURAL RESC, TECH

Date: 10-22-13

1. How useful and intuitive is the interface?  
GOOD FOR LOOKING UP ADDRESSES + OWNERSHIP OF WATER RIGHTS
  2. Do you need additional instruction?  
NOT SO FAR
  3. Do the tools accomplish what you require?  
YES
  4. Are the entries in the legend complete for your use?  
YES
  5. What would you like to see added?  
BE ABLE TO USE IN THE FIELD
  6. Do the legend entries (features) display in a visual style clearly?  
YES
  7. Do the legend entries display at an appropriate scale?  
YES
  8. Are the tooltips (info when cursor hovers over a feature) beneficial?  
YES
  9. Are the attributes (information) of the features beneficial and complete?  
YES
  10. Do the supplied queries support your use?  
YES
  11. Have you tried to create your own query?  
NO
  12. Would this information be beneficial in the field? Example: during regulation season.  
YES IT WOULD
-

Water Rights web application survey: <http://engine/pubnat3/default.asp>

Name: TERRIE FRANSSEN

Title: GIS TECH

Date:

1. How useful and intuitive is the interface? Very, I like the fact that you can choose your area of interest without having specific information to complete a search.
2. Do you need additional instruction? The website is pretty straight forward, but it would be nice to have more detailed help on all of the neat tools that are available.
3. Do the tools accomplish what you require? Yes, this site has some great measuring tools as well as options to customize your final printout.
4. Are the entries in the legend complete for your use? YES.
5. What would you like to see added? A HYPERLINK TO THE ORIGINAL DOCUMENT FOR EACH WATER RIGHT, WOULD BE VERY HELPFUL AND A MORE COMPLETE HELP OPTION.
6. Do the legend entries (features) display in a visual style clearly? YES, NICE COLOR CHOICES, I LIKE THE FACT THAT YOU CAN CUSTOMIZE COLORS, LINETYPES, ETC.
7. Do the legend entries display at an appropriate scale? YES.
8. Are the tooltips (info when cursor hovers over a feature) beneficial? YES, IT IS VERY HELPFUL TO HAVE THE WATER RIGHT NUMBER AS A TOOLTIP.
9. Are the attributes (information) of the features beneficial and complete? THIS WEBSITE LOOKS TO BE A WORK IN PROGRESS SO NOT ALL WATER-RIGHTS WERE AVAILABLE WHEN I ACCESSED THE SITE.
10. Do the supplied queries support your use? YES FOR MORE COMPLEX QUERIES THE WEBSITE ALLOWS YOU TO ENTER YOUR OWN IF YOU ARE AN ADVANCED USER.
11. Have you tried to create your own query? YES, YOU NEED TO KNOW THE DATA BUT IS FAIRLY EASY TO USE.
12. Would this information be beneficial in the field? Example: during regulation season. YES, HAVING A VISUAL AIDE OF WHERE THE ACTUAL WATER RIGHT IS WOULD BE VERY HELPFUL. HAVING SUPPORTING DATA ABOUT THE WRIGHT WOULD ALLOW THE PERSON IN THE FIELD TO MAKE INFORMED DECISIONS AT THE SITE.

Water Rights web application survey: <http://engine/pubnat3/default.asp>

Name: Laura Duncan

Title: Assistant Watermaster

Date: October 21, 2013

1. How useful and intuitive is the interface?  
Very useful for looking up water rights and determining the place of use.
  2. Do you need additional instruction?  
Yes, I occasionally need Kathy to assist me but it is getting less frequent.
  3. Do the tools accomplish what you require?  
Yes.
  4. Are the entries in the legend complete for your use?  
Yes, I like the ability to add entries if needed.
  5. What would you like to see added?  
In the near future we need to add a well symbol and a water tank symbol.
  6. Do the legend entries (features) display in a visual style clearly?  
Yes, Kathy has make adjustments to the visuals that make it clear for our needs.
  7. Do the legend entries display at an appropriate scale?  
Yes, Kathy has incorporated scaling on the appropriate features for our needs.
  8. Are the tooltips (info when cursor hovers over a feature) beneficial?  
Yes, however the parcels need a tool tip for tax identifications.
  9. Are the attributes (information) of the features beneficial and complete?  
Need to add one for type of use
  10. Do the supplied queries support your use?  
Yes
  11. Have you tried to create your own query?  
No
  12. Would this information be beneficial in the field? Example: during regulation season.  
Absolutely, this could make our job much more efficient to have this information available to us out in the field. Water rights are very complicated and require as much information as possible for accuracy.
-

Water Rights web application survey: <http://engine/pubnat3/default.asp>

Name: DAVE WILLIAMS

Title: WATERMASTER

Date: 10-21-2013

1. How useful and intuitive is the interface?  
VERY USEFUL & INTUITIVE
2. Do you need additional instruction?  
YES, WHEN NEW TOOLS/UTILITIES ARE INTRODUCED
3. Do the tools accomplish what you require?  
YES
4. Are the entries in the legend complete for your use?  
YES, WITH ABILITY TO ADD AS REQUIRED
5. What would you like to see added?  
ABILITY TO LINK PERMIT TO CERTIFICATE  
CREATE A LINK TO LANDOWNER/ASSESSOR DATABASE
6. Do the legend entries (features) display in a visual style clearly?  
LEGEND CAN BECOME CLUTTERED/OBSCURED WITH TOO MUCH DETAILED
7. Do the legend entries display at an appropriate scale?  
YES
8. Are the tooltips (info when cursor hovers over a feature) beneficial?  
ABSOLUTELY
9. Are the attributes (information) of the features beneficial and complete?  
YES
10. Do the supplied queries support your use?  
MOSTLY, NEED TO ADD LANDOWNER/CERTIFICATE INFO
11. Have you tried to create your own query?  
NO, WE JUST ASK KATHY IF WE NEED TO DO THIS
12. Would this information be beneficial in the field? Example: during regulation season.  
ABSOLUTELY! WOULD GREATLY ASSIST IN REGULATION  
ACTIVITY BY PROVIDING TAX LOT RESOLUTION  
& LANDOWNER INFORMATION FOR INDIVIDUAL  
WATER RIGHTS!