  Journal of Hydroinformatics | 02.3 | 2000

Migration from tabular to spatial data analysis techniques for water management in Idaho

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ABSTRACT

The State of Idaho has insufficient water supplies in many basins. Competition for water has spawned a complex system of administering water rights. Administration of water rights has historically been accomplished using paper records. During the 1970s a tabular, proprietary database was developed in conjunction with various mapping techniques. Emerging capabilities of Geographic Information Systems (GIS) are now facilitating administrators in the use of spatial data throughout their decision-making processes. This paper portrays various arenas where GIS is being used to enhance spatial capabilities related to water resources in the state, leading to improved and conjunctive management of surface and ground water.

Key words | conjunctive management, GIS, spatial analysis, water distribution

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INTRODUCTION AND BACKGROUND

Water is the lifeblood of the Western United States. As pioneers journeyed on the Oregon Trail toward the West Coast in covered wagons during the period from the 1840s until the 1860s, few stopped to homestead in the arid sagebrush territory that was to become Idaho.

The lure of gold finally brought attention to the Idaho area during the 1860s. Enterprising settlers began diverting water for irrigation, to provide food for fortune-seekers. During the past 140 years more than 3 million acres have been brought into agricultural production via irrigation projects throughout the state. While the Snake River seemed inexhaustible to early pioneers, this river and many others quickly became fully appropriated. Some form of regulation was required. Scores of water right decrees were granted by courts throughout the state near the turn of the century, and in 1903 a state agency was formed to provide for distribution of water based on the appropriation doctrine of water rights, where first in time is first in right. This agency, now called the Idaho Department of Water Resources (IDWR), is responsible for managing and administering the distribution of water.

Techniques for portraying water information have evolved during the last nine decades. Initial paper records were utilized to populate digital database tables, which are currently being dynamically tied to the physical location being referenced in the data. This paper discusses the recent emergence of these spatial techniques and tools being utilized in Idaho water management, and the major improvement in accuracy and efficiency resulting from these applications.

Data storage and availability

Historically, IDWR used paper files to track and manage water rights in the state. IDWR tabulated surface water rights by hand, and typed a list of rights for an IDWR-appointed watermaster to use in delivering water based on the appropriation doctrine of 'first in time is first in right'. These paper files have been microfilmed on an ongoing basis since the 1960s. During the late 1970s, IDWR entered pertinent data from these paper files into an electronic database, DBMS®. For the first time water rights could be compared within a particular area (i.e. by county or basin) to look at overall patterns or summations of information such as use, quantity, priority dates, or other categories.

In the mid-1980s IDWR upgraded this database system to ADABAS®, a proprietary database consisting of partially relational tables. This software increased functionality for comparing and analyzing rights, for conducting online queries and for generating reports. However it had no connectivity with other software IDWR was using, including IDWR's Geographic Information System (GIS) software ArcInfo® and ArcView®. In the late 1980s tests were conducted to determine whether data from the water right database could be exported and brought into ArcInfo®. Initial efforts focused on using the Public Land Survey (PLS) legal description for each right's place of use (POU) and point(s) of diversion (POD), and relating this information to the corresponding attribute found within the digital PLS, GIS theme. This produced a digital, spatial representation for each POU and POD, which could then be used within a GIS. These spatial locations were generalized to one or more 40-acre parcels. These efforts proved successful by showing for the first time that locations of rights could be viewed spatially in conjunction with other rights and other GIS layers. This test application exposed many of the limitations associated with moving toward a spatial database. Little if any of the ancillary data could be utilized, and many times this generalization to the 40-acre parcel was not sufficiently accurate to satisfy the intent of analysis. In addition, updates to the database that were found to be required based on the spatial analysis of the output required time-consuming re-entry into the database application.

To address these issues, IDWR began digitizing the actual POU and POD for all irrigation rights being adjudicated by the court. This task began in 1997 and is presently 25% complete, with 90% completion anticipated by 2005. The data will provide administrators with discreet water right boundaries while at the same time maintaining the data at a higher degree of positional accuracy. As a second step, IDWR began moving its tabular data to an open, Standard Query Language (SQL)-compliant database, SQLServer®. The third step of this evolution is the re-engineering of IDWR business processes that utilize water right information, including both adjudication and administration aspects. Design of the re-engineered processes, as discussed below, is anticipated to be completed by summer of 2000. Integration of these three elements will allow IDWR to fully integrate digitized water right locations with its corporate database information about those rights.

Data requirements

In Idaho there are presently three primary inputs for water management considerations: water rights, water quantity information, and water law, which is the legal framework consisting of statutes, rules and judicial guidance.

Water rights in Idaho are initially determined by IDWR, and are ultimately decreed by the District Court. At present Idaho has an administrative process that provides for the recording of water rights throughout the state. In addition, since 1987 the District Court and IDWR have been adjudicating all water rights for about 87% of the land area of the state in an action entitled the Snake River Basin Adjudication (SRBA), for which the location is depicted in Figure 1.

More than 183,000 claims to water rights have been filed in the SRBA, and to date the District Court has decreed more than 61,000 water rights. This process is anticipated to be largely completed by 2005 at a cost of more than $50 million. The adjudication process includes a determination of POU for each irrigation water right. Once located, each right is then stored and managed within GIS, allowing for further analysis and mapping of each feature. Figure 2 represents a typical layout for an individual right, depicting infrared imagery, the PLS, and a shapefile which outlines the POU and identifies the POD.

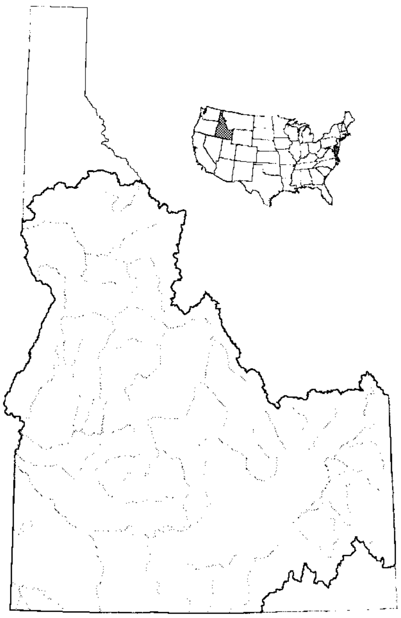

Figure 1 | Location of the SRBA in Idaho.

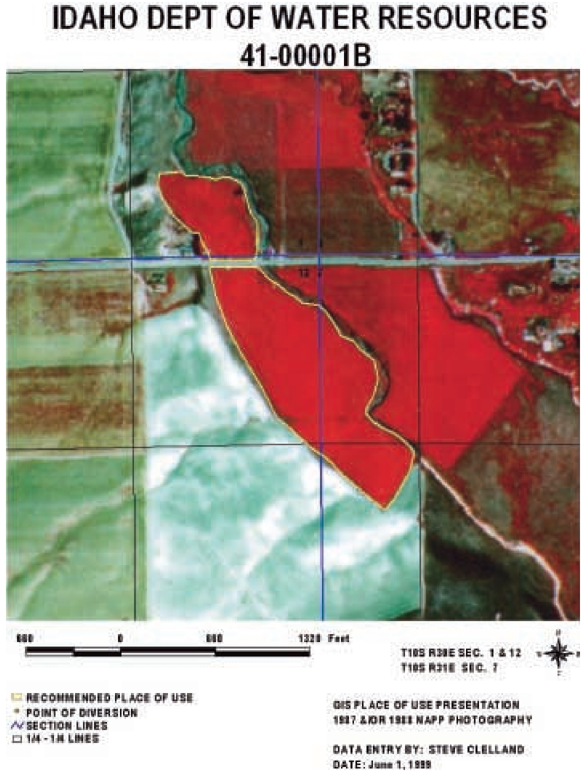

Figure 2 | Typical layout created in the SRBA.

At the completion of the SRBA about 30,000 such layouts will have been prepared.

Important and valuable by-products of the adjudication are (1) the shapefiles for irrigation uses, (2) 1:40,000 infrared photography throughout the irrigated portions of the state which has been geo-rectified to the Geographic Coordinate Database which depicts PLS information developed by the US Bureau of Land Management, and (3) land ownership information (for most counties). Additional information about the SRBA is available via the IDWR website at www.idwr.state.id.us.

Water quantity information is being collected throughout the state with an ongoing program of diversion measurements, stream gauging and depth-to-water inventories for wells. In addition, projects are underway to gather more detailed information in various basins. Examples are the Treasure Valley Hydrologic Project in the Boise River Basin, and the Eastern Snake Plain Aquifer Study, which are explained later in this paper. These efforts extensively utilize GIS for data management, manipulation and storage in support of selected modeling techniques being applied.

Water law in Idaho, including existing case law, statutes and rules, has been greatly influenced by the activities of the SRBA. During the period from 1997 through 1999, nine water-related Idaho Supreme Court decisions were issued which have served to define such diverse topics as the existence of partial forfeiture of a water right (whereby all or a portion of a water right is lost due to non-use for a period of five consecutive years), and the applicability of general provisions in a water right decree. In addition, the Idaho drought of 1987–1994 caused stresses on existing water supplies that led to unprecedented calls to discontinue pumpage of wells in many aquifers. Consequently, existing rules have been found to be inadequate, and IDWR has for the past three years been involved in a negotiation process to develop water management rules. These legal factors serve to provide constraints relative to the application of the GIS layers developed. However, a review of water law in Idaho, as compared with water laws in other western states, has led water managers in Idaho to

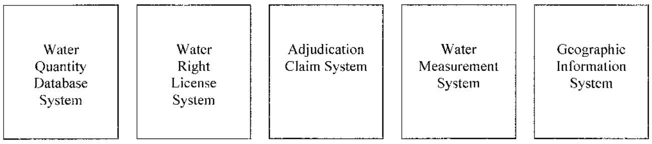

Figure 3 | Typical information systems.

conclude that Idaho has highly functional water law. This conclusion is evidenced by the rapid progress of the SRBA, which is unequalled by water right adjudication progress in other western states.

MIGRATION OF THE WATER RIGHTS DATABASE

From an historical perspective, many data processing systems developed by agencies have been focused on managing the licensing of water usage rather than general planning and policy decision making. In many cases, these systems were developed as stand-alone applications that had limited information sharing. Figure 3 illustrates a common scenario that is often referred to as ‘stove pipe systems’.

In addition, many of these systems had different data standards, different data exchange protocols, and limited support for any kind of spatial analysis. This lack of integration between information systems hindered the ability of administrators to fully utilize all the available tools in the water management ‘toolbox’.

In late 1998, IDWR embarked on a major program to upgrade and consolidate its information systems and business processes. Key objectives of this program include the incorporation of GIS technology, and integration of previously disparate business processes and data systems. A key feature of this system is management of spatial layers via the use of an off-the-shelf component called the Spatial Database Engine® developed by Environmental Systems Research Institute (ESRI). An electronic document management system is also integrated with the main database for storing non-structured information generated by the agency or received from its constituents. These two major components plus the main SQLServer® database are unified by a web-based user interface that guides the user through each business process. A simplified architecture diagram is shown in Figure 4.

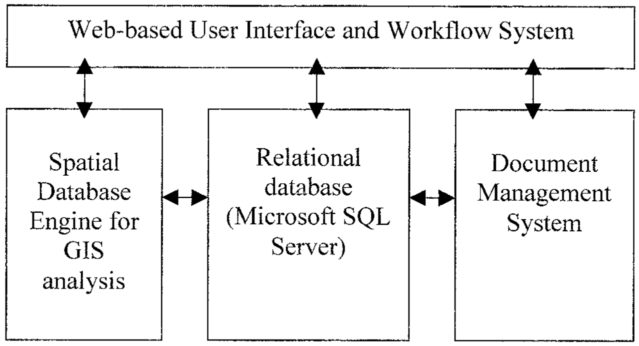

Figure 4 | Systems architecture summary.

Specific features built into the system for support of spatial analysis of water management data include:

- integrated storage of water rights license data, adjudication claims, and water measurement information;
- consistent collection of spatial metadata for all major business processes. This metadata includes traditional public land survey data as well as support for data collected utilizing Global Positioning System (GPS) technologies;
- data design for accurate representation of spatially overlapping water usage claims and permits; and
- explicit tracking of points of diversion and places of use with ground water or surface water sources and tributaries.

A key challenge in the system implementation has been the data cleanup and conversion associated with integrating previously stand-alone systems. Data conversion activities have included: standardization of water source and tributary names, identification of points of diversion for all water rights and claims, and accurate location of ground water wells.

Using ESRI’s Spatial Database Engine® (SDE) for digitized water rights

Since IDWR began digitizing water rights, this work was carried on from multiple locations into multiple files. The

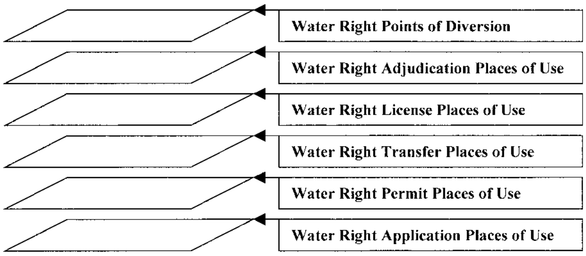

Figure 5 | SDE layers at IDWR.

issue of staff editing the digital data concurrently had been considered but no satisfactory solution had been found to eliminate conflicting edits. With the implementation of SDE, IDWR staff has a data management tool to lock features being edited while allowing access to the data.

SDE provides fast access to all digitized water rights from one source rather than many. It is tightly integrated with IDWR's SQLServer® database and allows an audit trail of changes to spatial as well as tabular entries. SDE is not trivial software and, particularly for editing and data security, has a long learning curve. It does solve most of the distributed data issues that IDWR has encountered. In addition, it provides integrity between spatial and tabular data.

As depicted in Figure 5, the IDWR data model utilizes six data layers in SDE, thus distinguishing between water right POD, and POU in five stages of water right maturity, from initial application to adjudicated water right. These layers are separated to facilitate administrative processing, but can be combined for analytical assessments. The spatial data are integrated in IDWR business process workflows by onscreen toggling from one application to another, and by automated spatial computations whereby locations determined in SDE are converted into PLS and are loaded into the water right database in a manner that is transparent to the water resource agent who is creating or updating information about the water right.

The IDWR Database Migration Project is proceeding toward an anticipated completion date of summer 2000.

INVESTIGATIONS IN WATER QUANTITY RELATIONSHIPS

There are two primary Idaho regions where IDWR and other entities are developing data for enhanced spatial water management. The first region is the lower Boise River basin, otherwise known as the 'Treasure Valley' of southwestern Idaho. Over 30% of Idaho's population lives in the Treasure Valley, primarily in the growing cities of Boise, Nampa, Caldwell, and Meridian. A hydraulically connected surface and ground water system, increasing water demands, and increasing scrutiny of water right appropriations and transfers are driving the need for enhanced management data, which will enable conjunctive management, whereby ground and surface water are managed and distributed recognizing their interconnection. The second region is that of the Eastern Snake River Plain—the breadbasket of southern Idaho. Agriculture in this region relies on surface and ground water irrigation; a thriving aquaculture industry depends on steady ground water discharge in the form of huge springs; and electrical generation requires adequate flows in the Snake River. These competing demands, coupled with land use changes, are motivating the implementation of conjunctive surface and ground water management. This section reviews the use of GIS in both the Treasure Valley of southwestern Idaho and the Eastern Snake River Plain, shown in Figure 6.

Treasure Valley hydrologic project

The challenge of effective water management requires (1) spatial data describing hydrology, water use, water rights and water quality; (2) fast data retrieval and processing; and (3) the ability to evaluate small- and large-scale characteristics of complex surface and ground water systems. GIS software allows the storage and retrieval of many types of data. Hydrologic models are used to guide data collection, and to evaluate complex interactive characteristics in these basins.

The use of GIS software has vastly enhanced the ability to process the large amounts of spatial data required for spatial data analysis. This format (1) allows

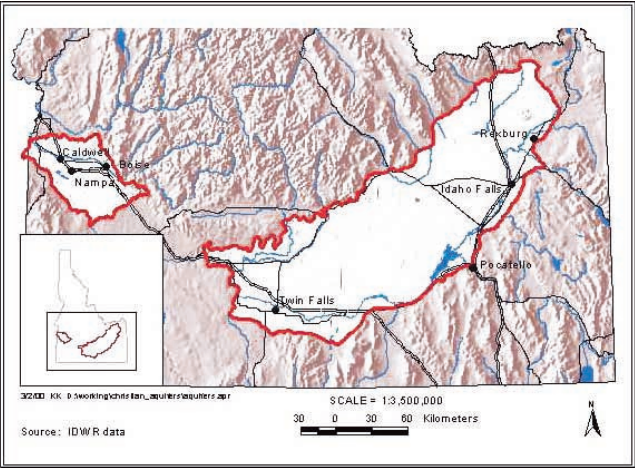

Figure 6 | Treasure Valley of southwestern Idaho and the Eastern Snake River Plain.

the storage of data on the basis of geographic location, (2) allows the creation of searchable databases, (3) enables the linking of various data, and (4) provides a format in which data can be disseminated. GIS is not only enhancing the ability to store and retrieve spatial data, but also to rapidly assemble and manipulate data for addressing specific conjunctive management questions at various scales (e.g., regional and local scales). The evolution of GIS and new modeling tools are enabling more rapid evaluation of new conceptualizations in regional flow models – or in submodels of smaller, local areas. Models that once took years to construct soon will take only months or weeks, or even days.

The following list contains examples of the types of data that are being assembled for evaluating surface and ground water flow systems, and for conjunctive management:

1. Land elevation
2. 1:24,000-scale land use
3. Base cartography data (e.g., roads, political boundaries, etc.)
4. Hydrography (e.g., canals, streams, rivers, drains)
5. Hydrometric data (stream flows, discharges)
6. Irrigation district and canal company boundaries
7. Soil types
8. Surficial geology
9. Well logs (scanned images of selected logs)
10. Well log information (such as well location, lithology, depth, well construction details, yield, completion date, etc.)
11. Aquifer test locations and results
12. Ground water levels
13. Municipal water supplier service areas
14. Municipal withdrawals
15. Commercial/industrial withdrawals
16. Irrigation ground water withdrawals
17. River gains and losses
18. Irrigation diversions and returns
19. Water chemistry
20. Qualitative ground and surface water system descriptions
21. Bibliography of hydrologic and hydrogeologic reports

The land use data are being used to estimate hydrologic system characteristics such as recharge based on land use; changes in recharge based on changes in land use (Figure 7); and ground water withdrawals for irrigation.

Ground water flow models in the Treasure Valley and the Eastern Snake River Plain using the USGS MODFLOW code (McDonald & Harbaugh 1988) are being used to help guide data collection and evaluation of hydrologic system characteristics. Data collection is emphasized in areas or zones of local hydrologic importance and/or high parameter uncertainty. Uncertainty is being quantified on the basis of automated parameter estimation using PEST (Doherty 1998).

Automated parameter estimation enables more extensive testing of alternative flow system conceptualizations. This requires the rapid reconstruction of MODFLOW data files. Although the capability of using GIS data with MODFLOW pre-processors (such as the Groundwater Modeling System being developed by Brigham Young University) is rapidly evolving, we still are finding a need to create input files (such as recharge, river, drain, and well package input files) within ArcView. To rapidly recreate input files using GIS data we are developing a series of tools to assist with allocating and aggregating spatial data within different sized uniform and non-uniform finite difference grid cells. For instance, Figure 8 shows various land uses, each with a different seepage rate, being aggregated to calculate an average

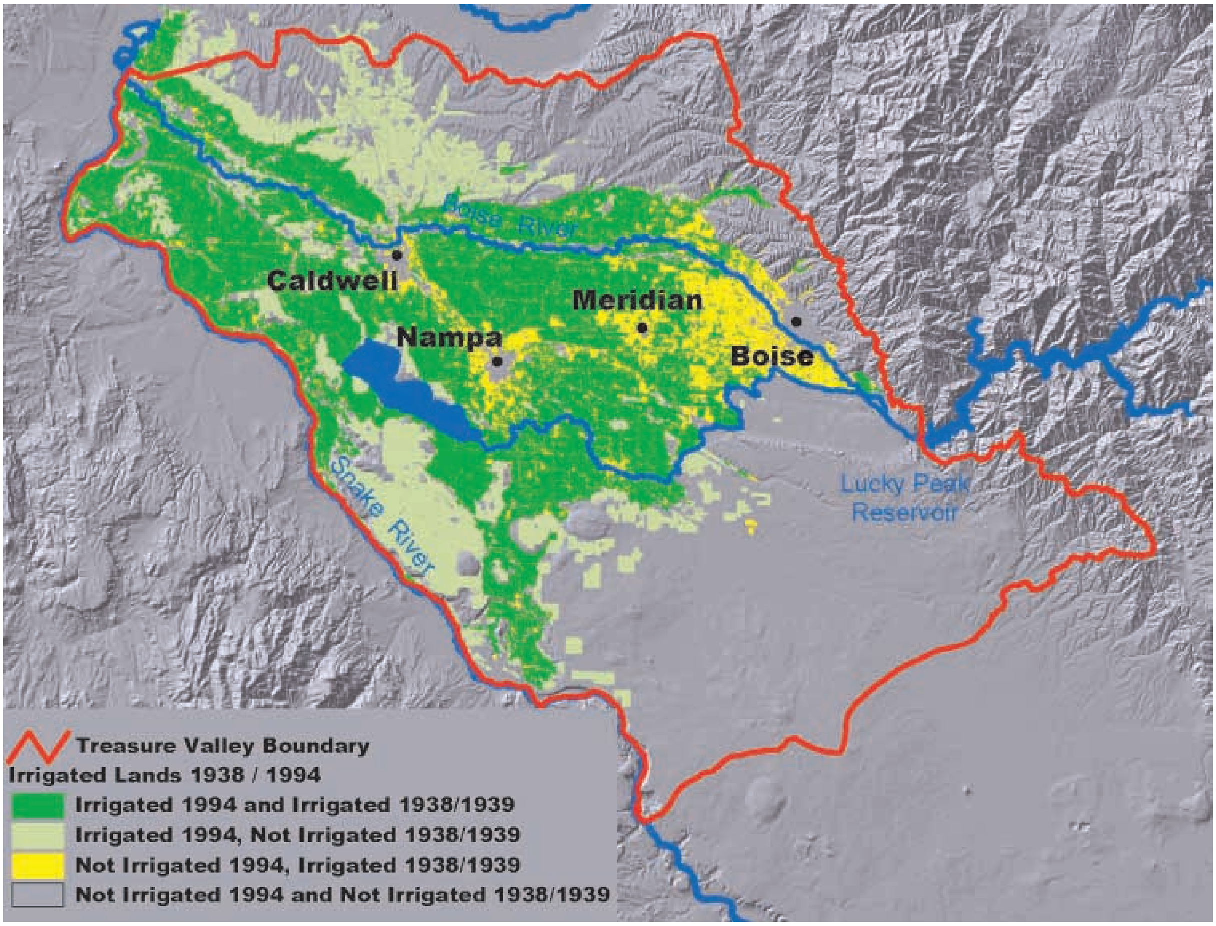

Figure 7 | Changes in Treasure Valley irrigated lands between 1937/38 and 1994 (IDWR data).

recharge rate estimate within each of four model cells. Similarly, these tools are being used to quickly develop input data for the MODFLOW (1) well package using point data (measured well discharge) and polygon data (estimated per-capita pumping for a small community) or (2) river package using 1:24,000 scale hydrography containing channel characteristics data.

In summary, the development and use of a comprehensive GIS database allows for the faster construction of hydrologic models than was possible just a few years ago. Automated calibration tools are increasing the speed at which models can be calibrated, which increases opportunities for exploring alternative flow system conceptualizations. Regional models are used to guide data collection and storage in a GIS database, and to evaluate regional hydrologic characteristics. The GIS database and calibration tools enable more rapid model construction, which is especially important for the rapid construction of submodels that focus on specific local surface and ground water interaction questions. Analogous to automobile manufacturers in Detroit, we are rapidly moving toward 'just-in-time model construction' in using GIS data to quickly address water management issues.

Eastern Snake Plain Aquifer research

Similar to the Treasure Valley, surface and ground water modeling efforts are currently being applied to the Upper Snake River Basin. Here too, GIS is playing a critical role

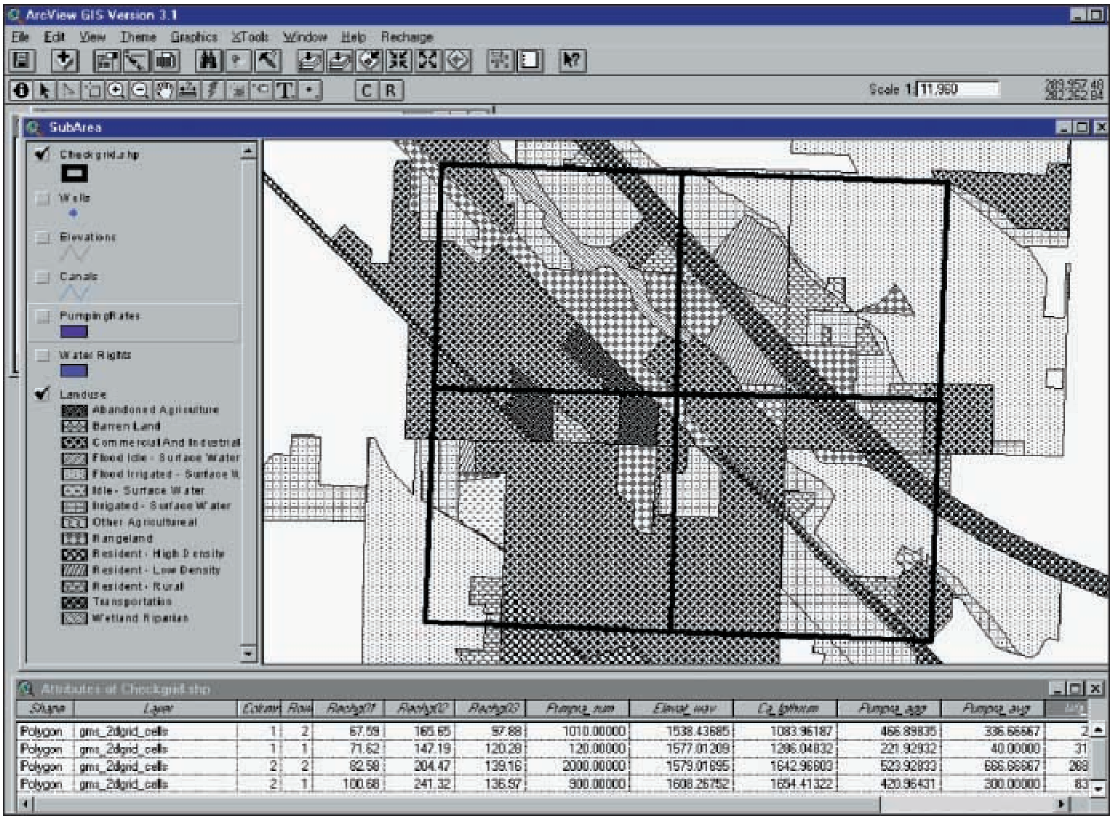

Figure 8 | ArcView screen showing a tool to aggregate infiltration rates associated with various land uses into uniform or non-uniform finite difference cells.

in the management, manipulation and display of data but on a much broader scale.

Water is distributed in this basin in accordance with the most sophisticated water administration in Idaho. As described by Sutter & Carlson (1983), a computerized system has been used for water accounting on the river and its tributaries since 1977. This system has been continually improved, and now detailed information on reservoir levels, flows by reach and water user accounts, including storage and natural flow, is available to interested parties on the Internet. The next major advance in water delivery in the region will be incorporation of ground water, thus enabling conjunctive management of ground and surface water.

Much is known about ground water in the Eastern Snake Plain Aquifer (ESPA), but more is needed. The use of GIS is fundamental to efforts focusing on better understanding ground water flow and surface and ground water interaction in the Snake River Plain. For example, managing regional ground water withdrawals requires information about aquifer responses to changes in pumping, changes in ground water recharge, or to the degree of hydraulic connection between the Snake River, its surface water tributaries, and underlying aquifers. Assessments of this information are improved if analysts have good understandings of spatial attributes such as the ground water flow patterns depicted in Figure 9.

Data gathering and database development are progressing in a manner similar to the Treasure Valley. IDWR and the University of Idaho jointly developed a ground water flow model, which has recently been migrated to MODFLOW. This model consists of two separate programs, a recharge module and an aquifer response module. In addition, IDWR is defining 'aquifer response zones' based on studies by Johnson & Cosgrove (1999) and Johnson *et al.* (1999). The purpose of the

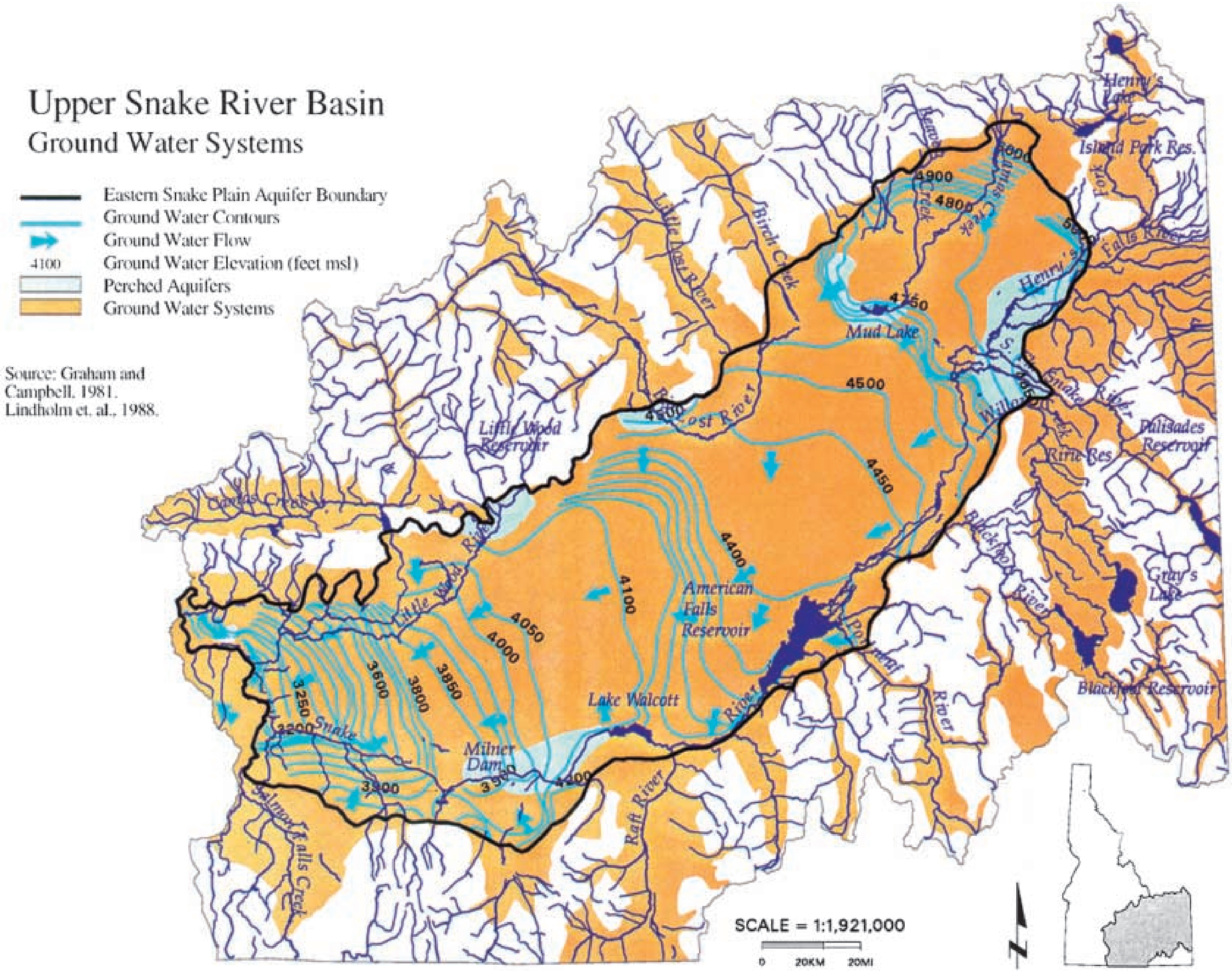

Figure 9 | Ground water flow in the Eastern Snake Plain Aquifer.

response zones is to assess the impact of ground water pumping on reaches of the Snake River that are hydraulically connected with underlying aquifers.

The methods for preparing an initial draft of response zones in the ESPA were identified by Anderson *et al.* (1999). A steady state response function was used to compute responses from cells in a MODFLOW model. The zones were created by assessing the impact of pumping within the aquifer on the four reaches of the aquifer that are hydraulically connected to the Snake River. Each of these areas was further divided into three sub-areas, based on the relative impact on the river reaches, thus creating eleven zones. The zones were further subdivided, based on proximity to sub-reaches, resulting in the creation of seventeen zones. These zones were adjusted to (1) encompass contiguous irrigated boundaries, (2) coincide where possible with administrative boundaries, (3) eliminate tributary areas, (4) add the Rexburg bench due to contiguous irrigation and direct impact on the Ashton to Heise reach, and (5) coincide with the PLS. These zones were compared with existing administrative boundaries of water delivery organizations

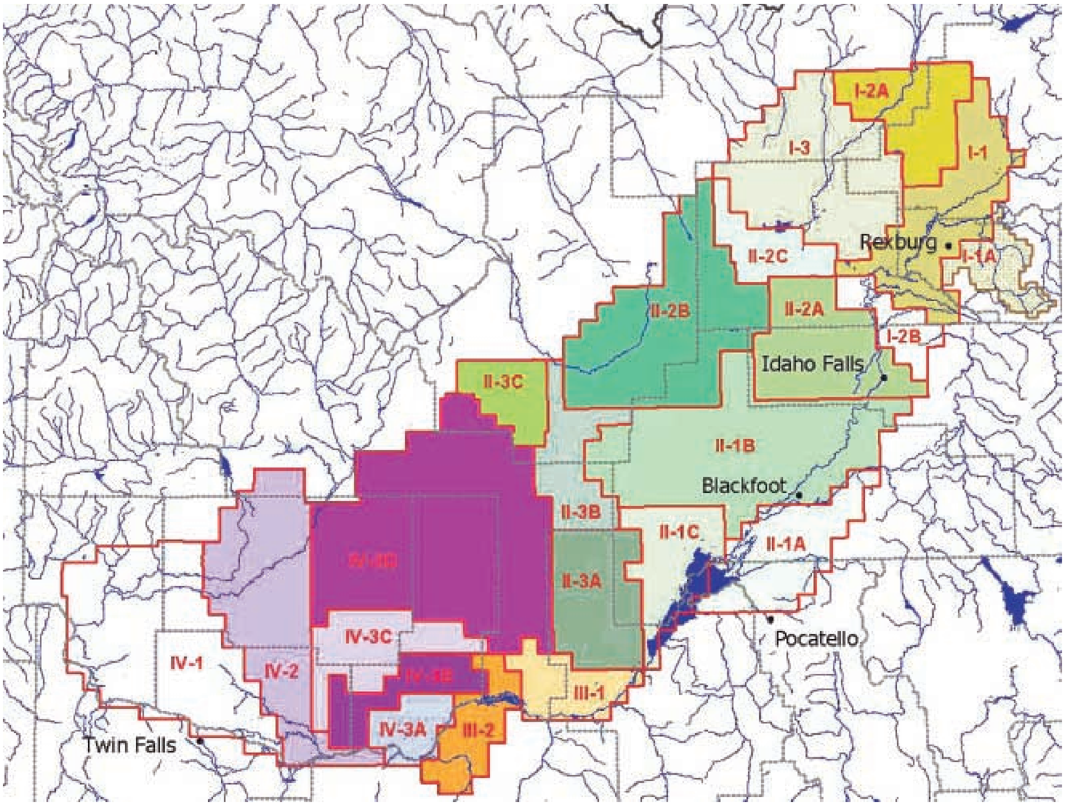

Figure 10 | January 2000 draft of ground water response zones for Eastern Snake Plain Aquifer.

and districts, resulting in the 22 distinct units shown in Figure 10.

The resulting ESPA ground water response zones provide a defensible basis for evaluating effects of changes in ground water recharge on hydraulically connected reaches of the Snake River. The zones can be used as part of a technical framework to implement conjunctive management. They are based on the best information available and will change as new and better data are developed.

UTILIZING GIS IN MANAGEMENT OF WATER DELIVERY IN IDAHO

GIS data development

IDWR's spatial data model for water rights is evolving. Originally, the model required unique combinations of water right POUs to be digitized as separate polygons. This provided quick acreage calculations and did not stack features on each other. Its drawbacks were intensive data entry requirements to resolve all water right overlaps for a particular polygon and a tabular query to select all the polygons associated with a particular right.

The new data model for POU will have a single shape for each water right. Where the POU completely overlaps between two or more water rights, only one shape will be digitized. If POU overlaps are not completely coincident, a separate shape will be digitized for each water right. The drawback to this model is that acreage calculations will need to account for the partially overlapping area between rights.

The spatial model for PODs requires one point for a POD location. Many rights may be linked to a point. This minimizes digitizing and assures coincident location.

In situations where water rights have been digitized, water managers can precisely depict locations of water use and can thus make determinations of which lands should be irrigated by water rights with various priorities. In situations where water rights have not been digitized, GIS can still be used for water management, as described in the following section.

Assessing the impact of Wilderness Area Reserved Water Rights

A recent Idaho Supreme Court ruling found that the US Forest Service (USFS) has reserved water rights for four wilderness areas in Idaho, in re SRBA/Potlatch v. United States, 1999 WL 778325, (Idaho) (Oct. 1, 1999). This decision has been interpreted by IDWR to impact all upstream water rights. Most wilderness areas are located in high mountain regions and the impact of a reservation of water for an area would not impact many upstream users. In the case of the Gospel Hump and Frank Church/River of No Return wilderness areas, this impact could be considerable (see Figure 11). A significant portion of the Salmon River drainage is upstream of where the river flows along or through these areas. IDWR needed to make an assessment of how many rights might be impacted if the ruling is upheld.

Few of the water rights in the upstream area are digitized at this time. PLS locations of all rights' PODs in all possible affected basins were exported from ADABAS as a text file. Other attributes of the rights were also exported. These text files were imported into tables in ArcView® GIS. The PLS information is linked to a PLS theme in ArcView to spatially highlight all POD locations.

As depicted in Figure 11, a theme was created of the watershed upstream of the wilderness areas. This theme was overlaid on the PLS POD locations theme. PODs within the upstream areas were highlighted and linked back to tables of water right information.

Approximately 2500 water rights were found to be junior to the wilderness areas. This included both surface water and ground water rights based on conjunctive management policies currently in effect. IDWR has issued a

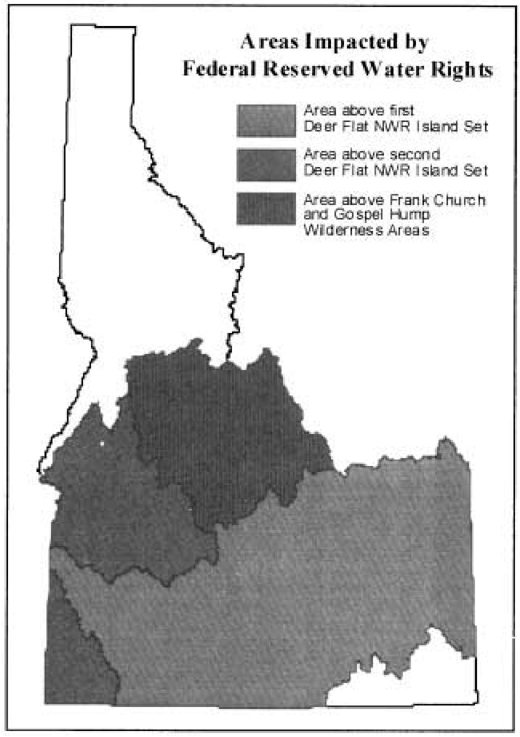

Figure 11 | Areas impacted by Federal Reserved Water Rights.

moratorium on the processing of water rights in the upstream areas until appeals of the court's decision are concluded. A similar analysis was conducted for the water rights potentially affected by the Deer Flat Federal Reserved Water Rights, for which the area of impact is also depicted on Figure 11. This type of analysis can be conducted using GIS tools whenever the need arises.

FUTURE IMPLEMENTATION AND RESEARCH

Presently IDWR is moving toward enhancing spatial analysis capabilities in all areas discussed in this paper. All business processes in the regulatory division of the agency have been re-engineered. One major business process, well construction, has already been migrated to SQLServer®, the adjudication and water rights processes are expected to be fully migrated by the summer of 2000, and other business processes are intended to be migrated over the next two years.

The development of these tools will enable significant advances in water management throughout the state. As an example, consider a typical response to a water distribution concern during the 1990s. If advised by a water user of a water management problem, IDWR would dispatch a Water Resource Agent to conduct an on-the-ground investigation. Typically the agent would use a topographic map and a tabular listing of water rights to aid in the investigation. The on-site review would provide enough information to enable a return to the office for a search through the paper or microfiche files. The resulting assessment would be conveyed to the offending water user, typically via correspondence or an order. The process would typically require several days of effort, and response time was often measured in days or weeks.

Availability of spatial tools enables a different approach. We anticipate more remote spatial monitoring of water use by either IDWR or some other water distribution entity, thus reducing the need for neighbour policing, and reducing the reliance on water user initiation of investigations. When spatial monitoring detects an apparent water use discrepancy, the agent will be able to review a variety of GIS layers to conduct an in-office investigation, in many cases eliminating or reducing the need for on-site investigation. Telephone and e-mail contact with the water user will be facilitated when the agent and the water user can simultaneously view maps via the Internet. In this way many of the discrepancies can be resolved quickly, thus reducing the response time for water management issues. In addition, advanced considerations such as conjunctive management of ground and surface water can be addressed on a wide-scale basis by IDWR, resulting in fairer distribution of water.

At present 32 technical and regulatory personnel at IDWR have access to and routinely utilize ArcView® software. This number is expanding to include virtually all regulatory personnel, resulting in expanded utilization of existing spatial products and the need for additional products and layers.

Continuing research and thus increasing understanding is a cornerstone of advancing management capabilities. Research in the Treasure Valley Hydrologic Project is ongoing with a three-person team. Modeling capabilities have already been developed, and finalization of this research effort is planned for 2002.

Research in the Eastern Snake Plain Aquifer is also ongoing. Presently the work effort is estimated to be the equivalent of a five-person team, with effort being contributed by IDWR, the University of Idaho, the US Bureau of Reclamation, the US Geologic Survey, and the Idaho Water Resources Research Institute. Modeling techniques are reviewed periodically, and consideration is now directed toward the advisability of evolving from a two-dimensional to a three-dimensional model. Immediate refinements include re-calibration and preparation of a year 2000 land use layer to compare with those developed for 1980 and 1992.

CONCLUSIONS

IDWR's tabular data model is inadequate for the types of analyses staff are called upon to conduct. Within the context of water management, staff have not had the tools to accurately identify and model surface and ground water right uses and interactions. With the advent of digitized water right locations and a new database model, more accurate results are possible.

The use of GIS in water right determinations enables a significant improvement in the ability of the State of Idaho to manage its water. First, the use of shapefiles and the resulting ability to view or print full color maps have significantly improved the accuracy of depicting spatial attributes such as POD and POU for water rights. This increased accuracy, and the ability of water users and the public to understand these spatial elements as depicted on the maps, have increased public acceptance and support of IDWR determinations.

Second, the use of GIS in conducting water quantity analysis and research such as the projects in the Treasure Valley and the Eastern Snake Plain Aquifer serve to enhance the understanding of hydraulics within the basins and decrease the turnaround time necessary for assimilating data required in these modeling efforts.

Third, the use of these tools in presenting information to the courts and administrative bodies results in more efficient implementation of rules and statutes because of the increase in understanding by all the participants.

Thus, the recognition that data utilized for water management are largely spatial in nature, and the development of tools and products that clearly portray these spatial attributes, serve to increase the effectiveness of water management in the state. Digitizing water rights is a long-term commitment, and the refinement of database design is ongoing. Implementation of spatial analysis techniques will be the basis for twenty-first century water management in Idaho.

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