THE STATE OF WYOMING

Water Development Office

6920 YELLOWTAIL ROAD TELEPHONE: (307) 777-7626 CHEYENNE, WY 82002

# GIS DATA FRAMEWORK PLAN

Prepared For: Wyoming Water Development Commission

6920 Yellowtail Road

Cheyenne, WY 82002

Prepared By: Trihydro Corporation and Wyoming Water Development Office

With Assistance From: Bear River Data Model Steering Committee

**Water Development Office**
Peter Gill
Jodee Pring
Dave Myer
Chace Tavelli
Jodie Pavlica

**Water Resources Data System**
Chris Nicholson
Rosemary Hatch
Tony Bergantino

**Trihydro**
Jim Vanderweide
Kyle Jordan
Derrick Thompson

**State Engineer's Office**
Beth Callaway
Charlie Ferrantelli

**Game & Fish Department**
Beth Hoobler
Mike Robertson
Drew Pearson

**Department of Environmental Quality**
Chad Kopplin
David Waterstreet
Sol Brich

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# 1.0 Introduction

The Bear River Data Model Pilot Study is a Wyoming Water Development Commission (WWDC) project approved and funded in 2016 in order to establish Geographic Information System (GIS) data standards and prepare data needed for water modeling in the Bear River Basin. It is a pilot study that is intended to provide a framework that can be implemented statewide.

The WWDC was established to provide the State's long-term water resource planning, and the financing and construction of water projects for public entities.

The main driver for this work is the need for better decision support tools, a push to decrease planning level data collection costs, and improve interagency coordination. Significant investments are put into creating GIS data in the preparation of planning projects, i.e. River Basin Plans, Watershed Studies, Master Plans, etc. This project leverages these investments by compiling existing data products and setting standards to improve consistency in data collection on future projects. The approach to GIS data described herein providing more accurate and timely information, reducing the duplication of effort between projects, and improving data sharing between Wyoming water agencies. Figure 1.1 conceptualizes the change in approach from a project based GIS to a Statewide water GIS that is envisioned with this GIS Data Framework Plan (Framework Plan).

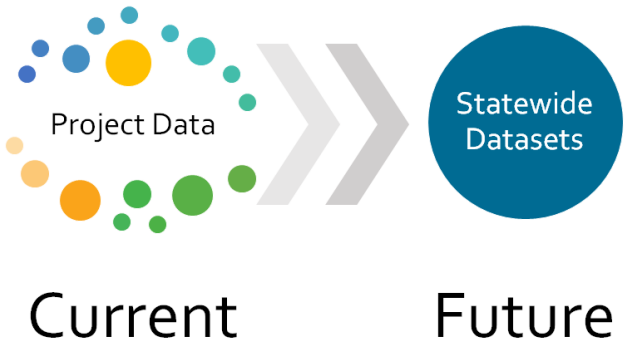


**Figure 1.1 Moving from a project based GIS to a coordinated approach to GIS management.**

The Bear River Basin was chosen as a pilot for this approach to GIS data management. Significant efforts have been taken in recent years toward creating a working hydrologic model in the Bear River Basin, making it a logical pilot study area for a data framework that could work for the rest of the state.

This project is being managed by Planning Staff at the Water Development Office (WDO) with assistance from Water Resources Data Systems (WRDS), and technical assistance from Trihydro. Our approach is being coordinated through a Steering Committee made up of State Agencies with ties to natural resource management. Feedback on the technical standards will be sought from the consultant community before a final standard is implemented.

Figure 1.2 provides a summary of the deliverables and

intended outcomes of the project. Deliverables, or outputs from this work include spatial database templates for future planning projects, a plan (this Framework Plan) that lays out a cooperative approach to managing and sharing the GIS data, GIS Standards Tech Memos that sets standards GIS, and a populated GIS database for modeling the Bear River Basin. Also included is a training document for staff and the consultant community.

Desired outcomes are described in Figure 1.2. The outcomes center around consistent River Basin Planning themes that can be found in the Wyoming Statutes and the State-wide plans. This includes documenting our water supplies and use, now and into the future, preparing for changes, justifying new water projects, and supporting similar state agencies. The most significant improvement to the River Basin Planning Program will be the result of more accurate data.

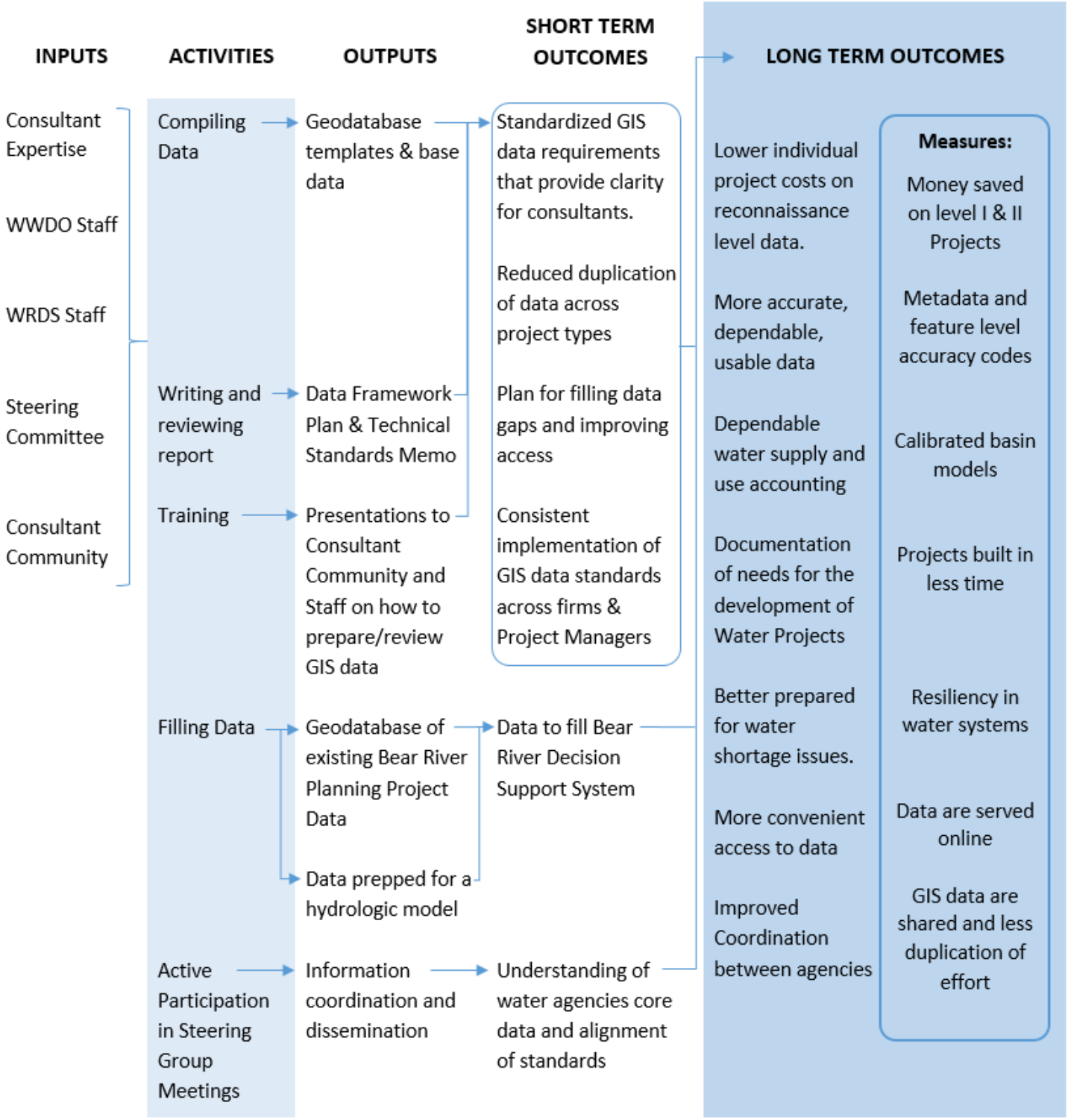


**Figure 1.2 Data Model Pilot Study Logic Model - Actions, Outputs (deliverables) and Outcomes of this Project**

Over the last decade, the Wyoming Water Development Commission has spent over 83 million dollars on water planning projects. A significant portion of this investment is put into creating GIS data and modeling in the preparation of River Basin Plans, Watershed Studies, Master Plans, etc.

Table 1.1 below provides a summary of the costs devoted to data creation and compilation over the last ten years. The data were compiled from twenty-four projects (six of each type) based on the cost of data heavy tasks. Since most projects do not have data specific tasks these numbers overestimate the actual cost of data management, but still serve as a useful indicator of the importance of data to every project.

As the table shows, River Basin Plans expend the highest portion of their budget on data of any of the other Planning Division project types. This is to be expected, as one of the main outcomes and most used parts of the River Basin Plan are the data on water supplies and use. (e.g., the Statewide Products http://waterplan.state.wy.us/frameworkplan.html ). These data provides the baseline for more local and detailed project types. The investment in data is necessary in order to develop projects and plan for the future. The intention of this project is to help organize this significant investment in data, specifically the GIS portion of it, by focusing on the core datasets that are needed, providing clear guidelines for formatting, and making it more accessible. By adding consistency to the data collection portion of projects, the data can live on well past the utility of the report, saving long-term project costs, and becoming a very effective tool for informing decision making.

| | % of Budget Going to Data Related Tasks | | | |
|---|---|---|---|---|
| **Project Type** | **Lowest** | **Average** | **Highest** | **Avg. Cost of Tasks** |
| Irrigation District Master Plan | 22% | 33% | 42% | $ 64,093 |
| Municipal Master Plan | 23% | 50% | 73% | $ 90,429 |
| River Basin Plan | 53% | 68% | 85% | $ 169,923 |
| Watershed Study | 26% | 48% | 58% | $ 152,293 |

**Table 1.1 Portion of budget spent on data related tasks by project type based on sample of 24 projects.**

River Basin Plans

Watershed Studies

Master Plans

Instream Flow Studies

Reservoir Studies

Small Water Projects

## 2.0 Existing GIS Program

This section summarizes the current data collection and management approach. GIS data are collected for all reconnaissance and feasibility plans done by the Planning and the Dams & Reservoirs Divisions. Level I reconnaissance and Level II feasibility plans often lead to Level III construction projects. GIS data are collected for three basic reasons: (1) to guide the development of a particular water project, (2) to understand and demonstrate Wyoming's water needs, and (3) to assist the sponsor with permitting requirements.

The data are collected by various consultants, at different scales, with differing expertise, for different reasons. This makes consistency difficult and long-term data management inefficient. Projects are managed by professionals at the WDO with varying experience in GIS. Data are managed through the University of Wyoming's Water Resources Data Systems which has not been involved in setting data standards. As a result, much of the legacy data lacks consistency and information about how, when, why, and by whom the data were collected. This metadata is important in that it lets others know what they are looking at and whether it is useful for future projects.

Currently, data collection requirements are laid out in project contracts within inventory and assessment tasks, project identification tasks, and deliverables tasks. In recent years a GIS task was added to most Level I and II projects in order to highlight and clarify formats and metadata requirements. When a project is reviewed by project managers the focus is on reviewing the report and the feasibility of proposed water projects. Often, the data is a by-product of this and is treated as such. The datasets are stored in the WDO on the received medium (DVD or USB Flash Drive) and a copy is sent to Water Resources Data System. They are then saved to the WRD's server and cataloged in their database. The boundary of the project study area is then uploaded to the Wyoming Water and Climate Web Atlas (http://www.wrds.uwyo.edu/wcwa.html) and linked to the online report. The GIS data are available upon request.

The WDO currently has five single-use licenses of ArcGIS Basic with one copy of 3D Analyst and Spatial Analyst

extensions available on a shared workstation for use by staff members. WRDS has access to the University of Wyoming's ESRI Enterprise Licensing. This level of licensing allows WRDS to use ESRI's ArcGIS Suite of software from desktop to server based technologies. The available software is currently working for the management of GIS data deliverables currently managed by WDO and WRDS staff.

The data compiled and created through water planning projects is significant. This project is not intended to encompass all GIS data applicable to a given project, rather it focuses on "core" datasets that are critical to Water Development business needs that span an individual project and not already maintained by another state or federal agency. Some data are collected to fulfill the needs of the public entity that is sponsoring the project. These data still must meet the metadata standards but do not need to fit into a specific data schema described in the GIS Standards Tech Memo. Figure 2.1 provides general information needed to complete each Planning Project. The black text represents items that would be included as "core" data, while gray text are items needed for the project type, but not included in the data schema.

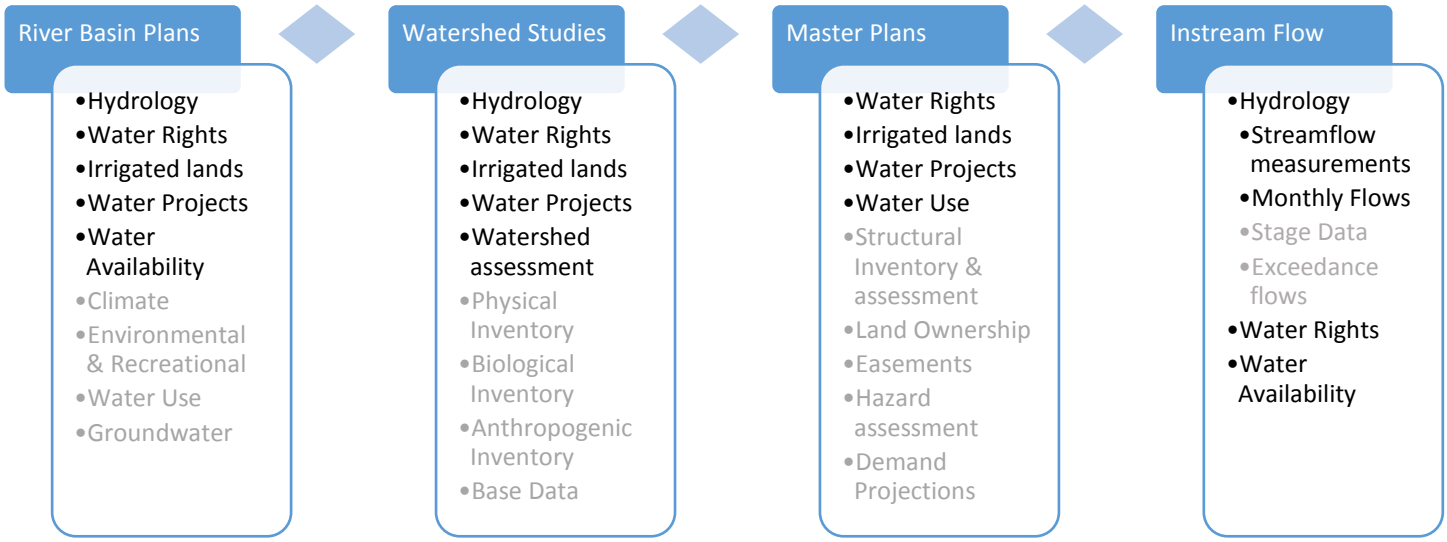


**Figure 2.1 Information typically collected through existing planning projects.**

# 3.0 Interagency Coordination and Consistency

The importance of interagency coordination and consistency was realized prior to this pilot study. The interaction between the WDO and other state agencies is imperative for successful water resource management in the state of Wyoming. A steering committee was formed by inviting key stakeholders within other state agencies that use WDO data or manage data that WDO requires as part of their project deliverables. The state agencies that were involved and attended the six steering committee meetings in addition to the WDO were as follows: WRDS, State Engineers Office (SEO), Wyoming Department of Environmental Quality (WDEQ), Wyoming Game and Fish Department (WGFD), and Trihydro Corporation.

In order to successfully continue to manage water resources throughout the state, interagency coordination is recommended as development of a DSS moves forward. Sharing the datasets between the agencies will build stronger and more reliable datasets over time. The core datasets that will be managed by WDO and identified through this study are useful to other state agencies in additional analysis. These stakeholders will benefit from each other if the datasets are kept consistent and available. Agencies will improve as spatial technologies continue to be developed and deployed throughout the state. This Framework Plan has laid out the process to implement better data sharing from the WDO. Providing other agencies with the WDO Bear River data model and core datasets will provide them with a base set of data on which each agency can build and expand upon the data model. This will start to build consistent data throughout the state.

There is one sponsored State GIS Initiative, working through the GIS Advisory Board and Technical Advisory Group (TAG). This group is represented by individuals from state agencies and entities that host/manage large GIS datasets. This Framework Plan was presented to the TAG on December 12, 2017, since this fits within their state-wide GIS dataset development initiative. Collaborating with the GIS Oversight Committee and TAG will benefit the WDO in understanding where and how to access other agencies datasets, and potentially privately managed datasets, that will support WWDC projects for water development.

Interagency coordination should continue as additional datasets are developed by each of the stakeholders and it is recommended that the steering committee members continue to meet on a quarterly basis to review the latest data development for each department. WRDS and WYGISC are currently enabling new technologies to host state-wide datasets, and WGFD, State Lands and WDEQ have provisioned the technologies as a team and are now providing

mapping services to share their information. SEO has and continues to improve their systems that provide the water community with water rights, flows and other water resource information. These key stakeholders will be able to better utilize each other's data as these spatial technologies are deployed.

# 4.0 Technology and Data for Water Resource Management

The data that are collected for the WDO projects are at the heart of the decision-making process for water resource management and water planning. The Bear River Data Model Pilot, Level I Study was the first step in creating a standardized GIS data model to store the data consistently and have the ability to build statewide datasets from the delivery of site specific projects, watershed studies, or river basin datasets. The end goal is to implement a Decision Support System (DSS) for use by WDO to support water resource decisions made based on the incremental improvements to data. The DSS consists of multiple datasets for inputs; it contains technologies and software to manage; it will analyze and share that data; it will allow people to ask the questions and assist in interpreting the results. Using these technologies and understanding the data that are input into the DSS are key to funding future water development projects and protecting a valuable resource within the State. The specific needs of a water resources DSS, and available tools, are discussed further in Section 4.1 and 4.5 respectively.

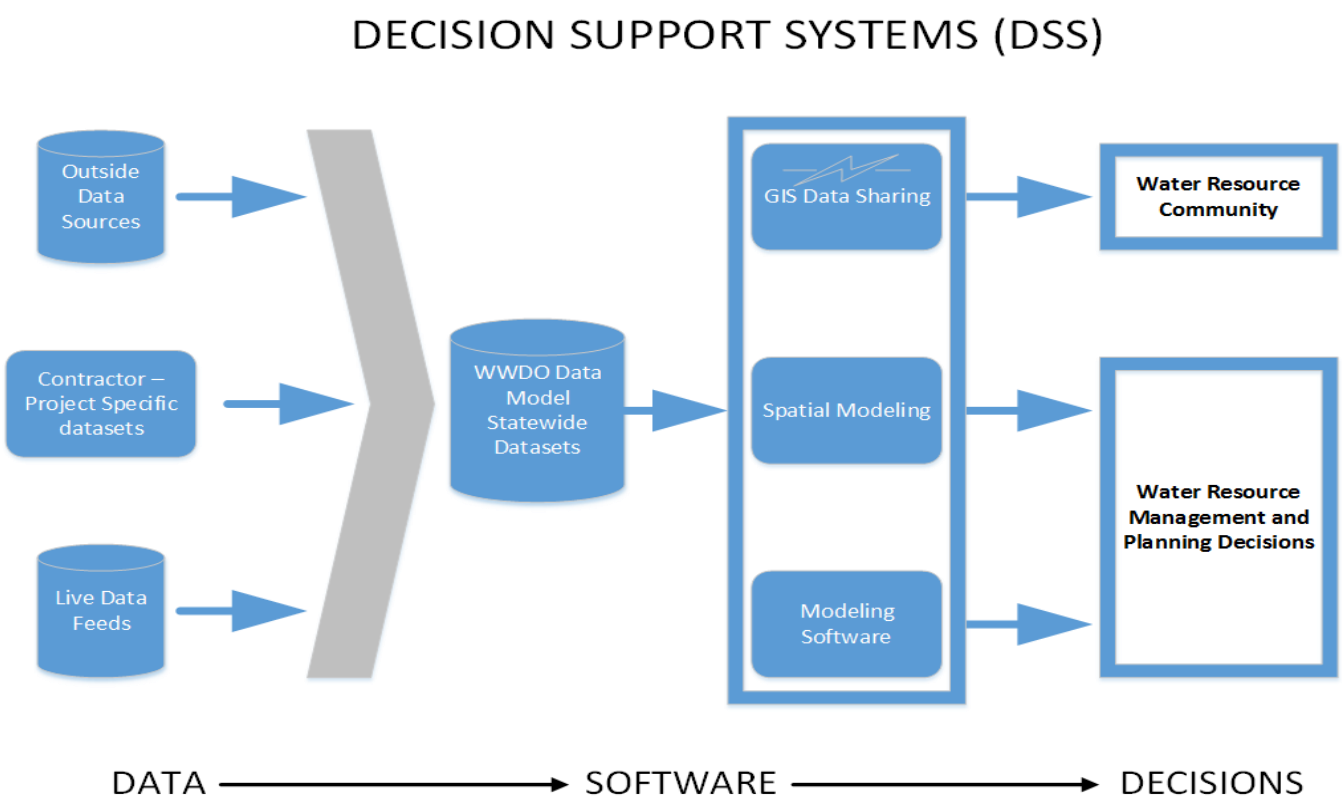


**Figure 4.1 Decision Support Systems (DSS) showing key components: input, analysis and outputs (data, software, & decisions).**

The sections below summarize the data and technology that will be used for water resource management and planning options.

## 4.1 Core Data and Long-term Data Needs

At the heart of this Framework Plan are the "Core Data." Data that are collected across project types and fit into Statewide water management needs. Defining the "core" datasets that are needed by WDO is important for lowering costs and answering questions around the management of water. Understanding the decisions that the data can inform is key to coming up with a dataset that will be useful. As described in Section 2.0, GIS data are collected for three basic reasons: (1) to guide the development of a particular water project, (2) to understand and demonstrate Wyoming's water needs, and (3) to assist the sponsor with permitting requirements. With that in mind these are some of the questions that the data should help inform:

- What areas have water legally available for new uses; how much is available?
- How are senior water users affected by new out-of-stream or in-stream use?
- Is there enough physical water to support a proposed project?
- What are the existing and future demands for water?
- What users/regions are most susceptible to drought? What is the typical streamflow at a given location?
- How much surface water is being diverted for municipal, agricultural, or industrial use?
- How much water is from reservoirs vs. direct flow?
- How much storage is in the basin, as a percentage of annual yield?
- Where are the major diversions in the watershed, listed according to priority date and permitted quantity?
- How much water is being diverted thru point "A" during a dry year?

A long-term focus for the WDO is to implement a statewide DSS that will provide consistency related to future water planning in the state. A DSS will allow WDO and the water community to access and maintain datasets in a statewide system readily available for modeling and analysis. A long-term data need for WDO is to make comparable analyses based on datasets that cover a larger, and more complete, series of time. Currently, many years lapse between updated basin plans, watershed studies, master plans and instream flow projects. The lack of consistent data between these studies does not allow for comparing changes over time. Evaluating the information could be based on a wet, dry, or normal precipitation year and there is no data to support the years between. The long-term need is to have current,

accurate information that allow the WDO to make decisions using the most current and accurate information.

The datasets shown below are repeatedly collected over different, or similar geographical areas, can support future projects, feed into future basin modeling efforts, and are not maintained by other organizations. Our goal here is to bring standards to these "core" data. There are many project specific data collected for each project depending the problem to be solved and the needs of the sponsor, we do not try to standardize these within the proposed framework. Project specific data need not adhere to the GIS data templates, but can be incorporated into the geodatabase if desired. Figure 4.2 shows the core datasets and how they are grouped within the four type categories (See Section 11 of the GIS Standards Technical Memorandum for details).

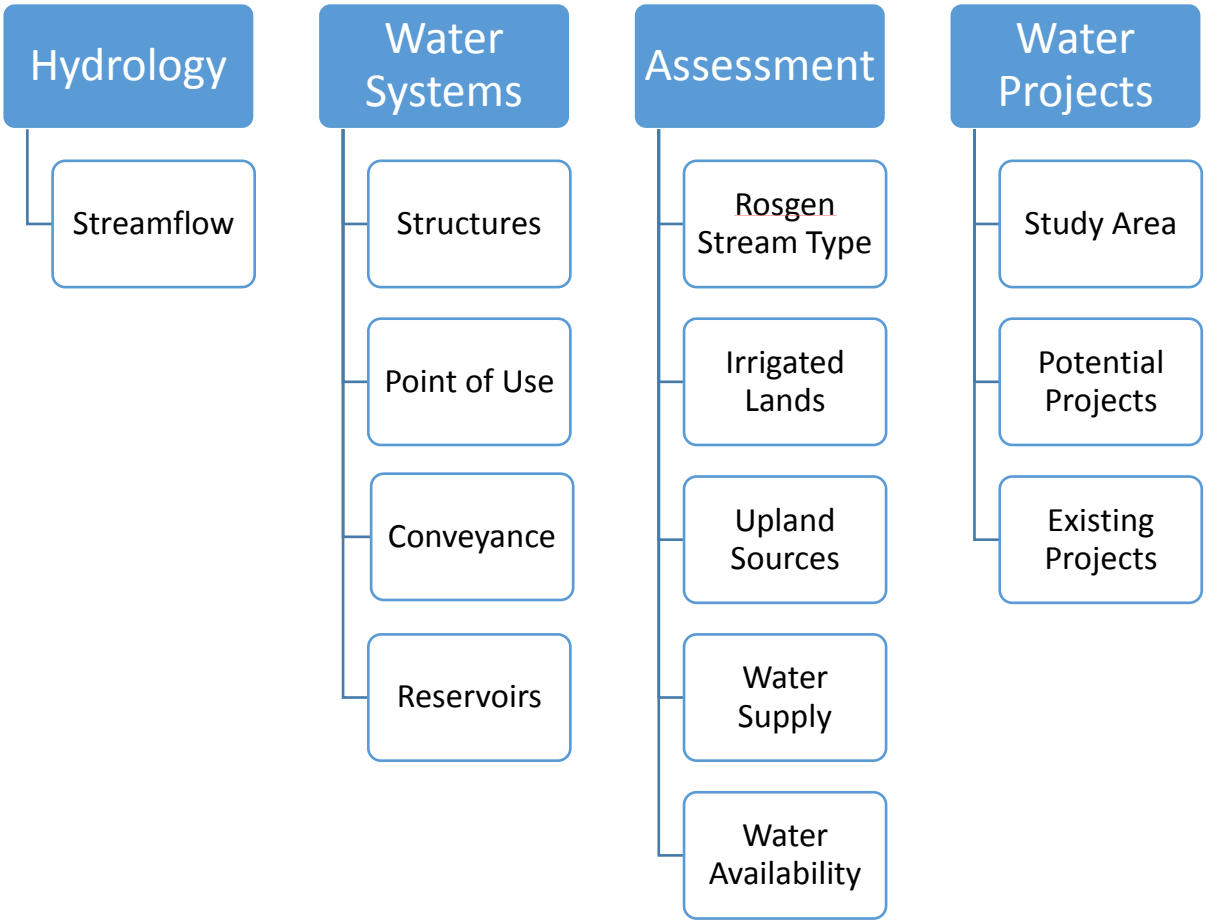


**Figure 4.2 WWDC "Core" GIS data by Feature Class and dataset.**

The Hydrology Feature Dataset will contain information from measured and modeled data. The Water Systems Feature datasets will contain information on the network to distribute water, with the continued focus on what is on the ground, rather than what is permitted. The Assessment Feature dataset organizes key data related to water use, changes over time, and ground conditions. The Water Projects Feature dataset allows the state to track WWDC potential and constructed projects, their size, costs, and how potential projects fit into future WWDC funding programs.

Data important to the water planning program are included in Table 4.1 below. The table describes the type of data and why it is important to the program, its status and availability, data gaps, sources, and which project type needs the information. The Status and Availability column is described in terms of completeness. Complete means that data is already developed and is suitable for most planning applications. On-going indicates data commonly created with projects but no complete dataset exists Data that is marked as a gap indicates a need for a new process to develop the data. GIS data gaps and options for filling them are described in Section 4.2.

**Table 4.1 GIS Data Gap and Priority Ranking Table**

| Category | Information | Status & Availability | Gaps | Recommended Source | Gap Filling Options | Statewide Data Weighted Score | | | Total of 35 Possible | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Conceptual Cost | Use Frequency | Maintenance | Priority Total | % of Possible Points |
| *Projects* | Potential Projects | On-going | Project specific | WWDC - Planning | | 10 | 10 | 1 | 21.0 | 60% |
| | Existing Projects | On-going: Complete through 2017 | | WWDC - Construction, Dams & Reservoirs | In house | 10 | 12 | 1 | 23.0 | 66% |
| *Streamflows* | Existing Streamflow (Wet, Avg, Dry) | Gap: On-going | Spatial coverage gaps: Lacking flows on smaller tributaries: Hydrographer Reports are generally not in digital format | USGS, SEO FLOW, Hydrographer Reports, WWDC - River Basin Plans, ISF Studies, Level I Watershed Studies | In house, based on RBP models | 10 | 16 | 1 | 27.0 | 77% |
| | Naturalized Streamflow | | | | In house | 10 | 16 | 1 | 27.0 | 77% |
| *Hydrography* | Hydrography (HUC, Waterbodies, Waterways) | Gap | Not attributed correctly | USGS - NHD High Accuracy, SEO Stream Names | Contract to develop NHD+, Get from SEO | 6 | 20 | 5 | 31.0 | 89% |
| *Diversion Records* | Surface Water Diversion Records | Gap: On-going | Spatial coverage gaps: Not all diversions are measured: Hydrographer Reports are generally not in digital format: missing data | SEO, Hydrographer Reports | In house, based on WRDS prior work | 6 | 12 | 5 | 23.0 | 66% |
| *Structures* | Irrigation Infrastructure (Diversions, turnouts, spillways, outlets, gauges. Etc.) | Gap: Accuracy and consistency varies | Spatial coverage gaps: Often need field verified | SEO e-Permit, SEO FLOW, WWDC - River Basin Plans, Watershed Studies, Master Plans, Reservoir Studies | Contracted to depth 1 level | 6 | 16 | 1 | 23.0 | 66% |
| | Wells | | Accuracy and consistency varies: Lack of pumping capacity data | SEO e-Permit, SEO FLOW, WWDC - Groundwater Basin Plans | Contracted to depth 1 level | 6 | 12 | 5 | 23.0 | 66% |
| | Structure Capacity and Efficiency | Gap: Accuracy and consistency varies | Not measured on all ditches or pipelines | WWDC - River Basin Plans, Watershed Studies, Master Plans, Reservoir Studies, Irrigation and Public Water System Surveys | Contracted w/Study | 2 | 6 | 1 | 9.0 | 26% |

| Category | Information | Status & Availability | Gaps | Recommended Source | Gap Filling Options | Statewide Data Weighted Score | | | Total of 35 Possible | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Conceptual Cost | Use Frequency | Maintenance | Priority Total | % of Possible Points |
| *Conveyance* | Conveyance | Gap: Very little exists | Few conveyance appurtenances are mapped | USGS - NHD, SEO - Digital Linen Plats, WWDC - Watershed Studies, Master Plans, Reservoir Studies | In house | 10 | 12 | 1 | 23.0 | 66% |
| | Conveyance and Efficiency | Gap: Accuracy and consistency varies | Not measured on all ditches | WWDC - River Basin Plans, Watershed Studies, Master Plans, Reservoir Studies, Irrigation and Public Water System Surveys | Contracted w/Study | 2 | 10 | 1 | 13.0 | 37% |
| *Reservoirs* | Size, Capacity, Use | Gap: Accuracy and consistency varies | Location, storage amount, service areas, users, and use is scant | NHD, SEO e-Permit, SEO FLOW, Historic Hydrographer reports, Reclamation, Irrigation Districts, discussions with water users | Contracted to depth 1 level | 10 | 14 | 5 | 29.0 | 83% |
| | Stage-Storage Curves | | | | Contracted w/Study | 2 | 10 | 5 | 17.0 | 49% |
| | Operation - Inflow/Outflow | | | | | 6 | 8 | 5 | 19.0 | 54% |
| | End-of-Month Contents | | | | | 6 | 10 | 5 | 21.0 | 60% |
| | Evaporation | | | | | 6 | 8 | 5 | 19.0 | 54% |
| *Assessment* | Geomorphology | On-going | | WWDC - Watershed Studies, WGF, BLM - PFC, AIM | Contracted w/Study | 6 | 8 | 1 | 15.0 | 43% |
| | Riparian Condition | On-going | | | Contracted w/Study | 6 | 8 | 1 | 15.0 | 43% |
| | Upland Water Sources | On-going | | SEO - e-Permit, WWDC - Watershed Studies | Contracted w/Study | 6 | 6 | 5 | 17.0 | 49% |
| | Water Supply | On-going | | WWDC - River Basin Plans, Water System Surveys, SEO reporting, depletion Plans | Contracted/In house | 10 | 14 | 1 | 25.0 | 71% |
| *Irrigated Lands* | Current Irrigated Lands | Gap: Not always the most recent: Outdated | Outdated info: Not updated every year: Lands not linked to POD, water rights, and/or conveyance structures: Dry/Wet years not always defined: Managed by multiple agencies | WWDC - River Basin Plans, SEO, discussions with water users | In-house | 6 | 12 | 1 | 19.0 | 54% |
| *Consumptive Use* | Crop Type | Gap: Accuracy and consistency varies | Crops change yearly: Basin specific | NASS, CropScape, Irrigation Surveys | Contracted w/Study | 10 | 8 | 5 | 23.0 | 66% |

* Water system components of drinking water and irrigation master plans vary in complexity.

## 4.2 Data Gap Analysis

As described earlier, this pilot study is designed to set new standards and improve data consistency that will provide the foundation for decision-making across future water planning projects. It allows decision-makers a method to efficiently access water resource data and have the confidence that it is accurate and consistent with the way others are using similar datasets. Towards this vision, this section of the feasibility study focuses on assessing the quality of existing data, identifying strengths and limitations, and identifying data gaps. This analysis fosters an understanding of the data available and supports discussions within and across agencies, organizations, and communities on how to bridge these data gaps.

The purpose of the following sections is to:

- Inventory data sets that pertain to "core" datasets that are critical to Water Development business needs
- Assess the adequacy of these datasets with respect to their spatial coverage, completeness, and quality
- Determine what additional data needs to be obtained to implement the necessary DSS datasets for projects

This inventory, analysis and determination of additional required data were conducted for the "core" datasets described on Figure 4.2 in Section 4.1. The inventory and assessment of existing data focuses largely on datasets that are readily available from State agencies (e.g. SEO), WRDS, or through communication with the necessary agencies.

Table 4.1 summarizes the existing data available, identifies gaps, provides sources, and identifies data gap filling options. It should be noted that this is a summarized overview of data needs and that specific detail regarding each dataset is not discussed in this memo. Instead the table focuses on summarizing the data needs to fill spatial and quality gaps for multiple water resources analysis and modeling needs.

## 4.3 Data Priority Screening

Priority screening of the datasets included reviewing the comprehensive list of datasets developed in the data gap analysis and narrowing the list to the top priority datasets that would provide the greatest benefit to WDO and its projects. The top-ranked datasets are those that are used the most and cost the least. The initial screening was performed with the WDO PM and criteria was limited to:

- Use Frequency

- Cost
- Maintenance

Results were presented to the Steering Committee on June 5, 2017 and information gathered from the steering committee and the WDO was used to develop a weighted scoring matrix. The weighted scoring matrix was developed to assist in ranking the datasets based on several criteria weighted by varying importance. The weighted matrix treats the criteria independently and helps avoid the over-influence or emphasis on specific individual criteria. The weighted scoring matrix consisted of three categories or criterion. Weighting factors were applied to the three categories to express the importance of each category. The three categories and general rationale used in the scoring matrix include:

- Use Frequency – How often is a dataset used and can it be used for multiple projects as indicated in the data gap analysis? The Use Frequency is an average of Internal and External Use factors indicating:
    - Internal Use (WDO) – Includes datasets that are important to the WDO and its projects. For example, a study area dataset that is needed for River Basin Plans, Watershed Studies, Master Plans, Dams/Reservoir studies, and Instream flow studies will be ranked higher than a dataset that is only used in one study. Datasets that were used in the five projects types indicated in the Data Gap analysis received a 5. If the dataset is used in four project types it received a 4 and so on.
    - External Use (Interagency) – includes the ability of a dataset to have multiple uses within State agencies in addition to serving WDO needs. Other potential agencies include the WGFD, WDEQ, WSEO, etc. Datasets used by multiple agencies received a higher rating than ones that were only used by one agency.
- Conceptual costs - Estimated costs are the amount it takes for the WWDC to collect and/or acquire data. Datasets developed by other agencies were assumed to cost less than datasets developed for WWDC projects. Theoretical costs were determined for each dataset based on previous project experience and costs. Actual numbers were not developed. Datasets were grouped by low (<$5,000), medium ($5,000 to $50,000), and high (>$50,000) categories. A low-cost dataset received a 5, medium a 3, and high cost datasets received a 1.

- Maintenance – Will the dataset require long-term maintenance and if so how difficult is it to maintain? Datasets maintained by other state agencies were ranked with a 5. Datasets maintained by the WDO and WRDS were ranked with a 1.

Alternatives were ranked and scored in three steps. The first step determined the weighting factor for each category (i.e., relative importance) (Table 4.1). For example, Use Frequency is considered more important than costs because the higher the use of a dataset, the more likely funding would be pursued to create a statewide dataset. Assigning meaning to weighting factors is subjective, so a total of three weight factors are used in the scoring matrix as follows:

- Weight factor of 1 - This item should not weigh heavily in prioritizing data selection.
- Weight factor of 2 - The data should be collected and made available, but additional evaluation should be considered in future projects.
- Weight factor of 4 - This item is critical and should be weighed heavily.

A weight factor of 4 was used instead of a 3 to emphasize the importance that Use Frequency has on a dataset.

The second step involved rating the ability of each datasets to meet a specific criterion. A score of 0 to 5, with 5 being the highest, was assigned to each dataset for each criterion. A "0" was only assigned when a fatal characteristic that would make the data set completely impractical or impossible was identified. Ratings for each alternative's ability to meet the specific criterion are shown in Table 4.1.

The final step involved multiplying the weighting factor by the ranking values for each of the four categories (Table 4.1), adding these values, and ranking the alternatives by their total score. A perfect score would total 35 points.

## 4.4 Weighted Matrix Results

Based on the weighted screening matrix, the top five sets of information of highest priority that support the core datasets are:

- Hydrography (HUC, Waterbodies, Waterways) – 31 points
- Reservoirs – Size, Capacity, and Use – 29 points
- Existing Streamflow (Wet, Avg, Dry) – 27 points

- Naturalized Streamflow – 27 points
- Water Supply – 25 points

As would be expected, these five data sets are used the most frequently and are relatively low in cost to develop. Of the five data sets, two are easy to maintain and three require additional maintenance. In a six-way tie for the sixth spot of highest priority with a total of 23 points are:

- Existing Projects (projects that have been constructed by WRDS)
- Surface Water Diversion Records
- Irrigation Infrastructure (Diversions, turnouts, spillways, outlets, gauges. etc.)
- Wells
- Structure Conveyance
- Crop Type

Most of these six datasets were cost effective but placed lower because they are not used as much internally or across multiple agencies.

Results of this analysis are illustrated on Figures 4-3 and 4-4. Figure 4-3 is a ternary plot that takes into account each of the three criteria; Use Frequency, Cost, and Maintenance. The advantage of using a ternary plot for depicting compositions is that these three criteria can be conveniently plotted in a two-dimensional graph. Going in a clockwise motion, datasets located to the far right of each criterion are ranked higher than ones to the left. For example, the Ditch Conveyance Efficiency dataset is located near the top of the ternary chart. Using the lines through the chart, one could determine that the dataset is low in cost (within the lower 25% of the data sets analyzed); used frequently (upper 75% of datasets); and is low in maintenance (within the lower 25%).

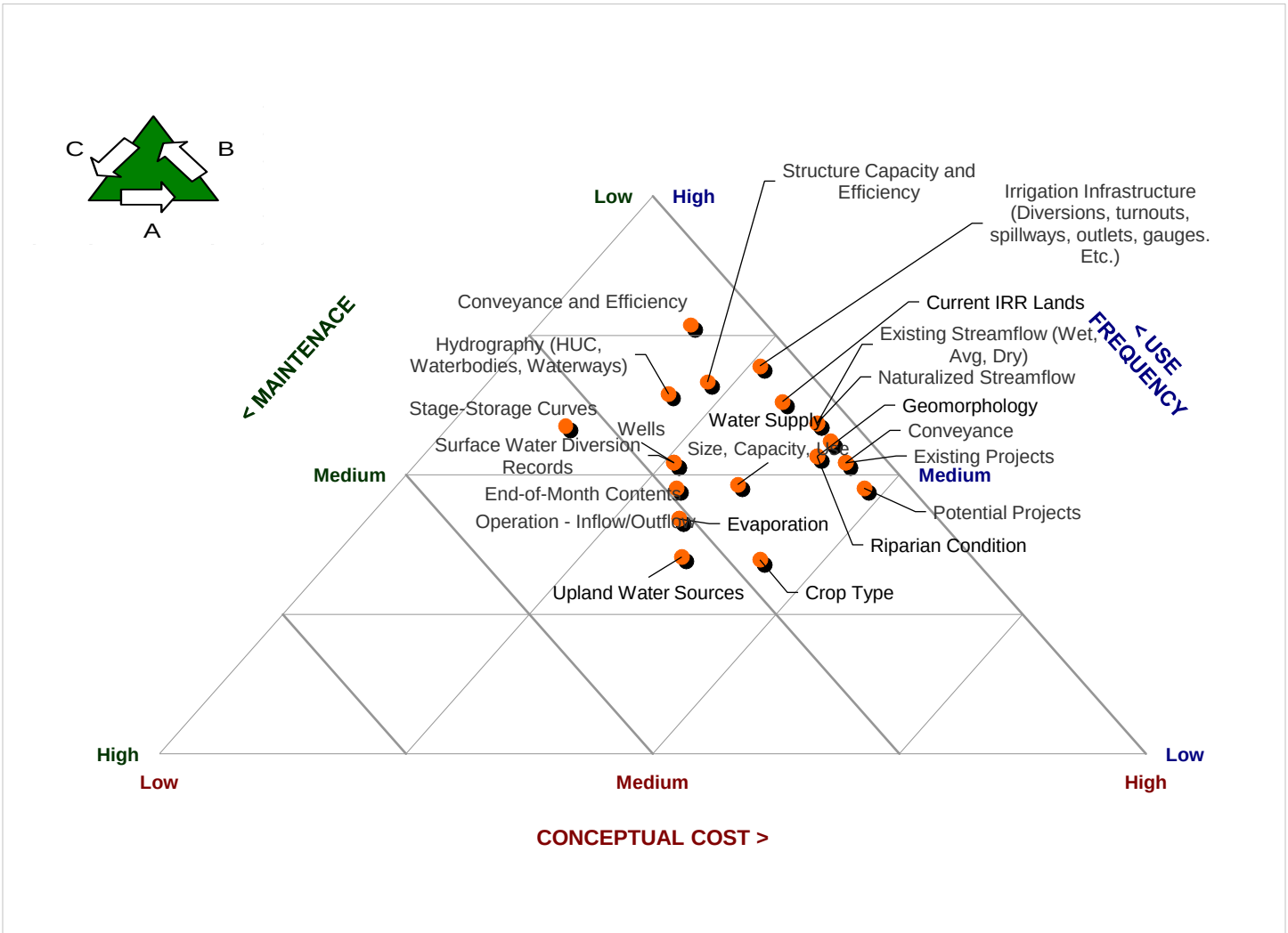


**Figure 4.3 – Data Gap Analysis Ternary Chart**

A second chart (Figure 4-4) analyzing the highest weighted criteria of Use Frequency and Cost was also developed to see what datasets came out on top if maintenance was not considered to be a factor. Results show that Existing Streamflow and Naturalized streamflow are used frequently, but are also higher in cost. Compared to the Hydrography dataset, the hydrography dataset is used more often and costs less. By analyzing both charts, a decision can be made as to which of the datasets should be considered a priority for future development.

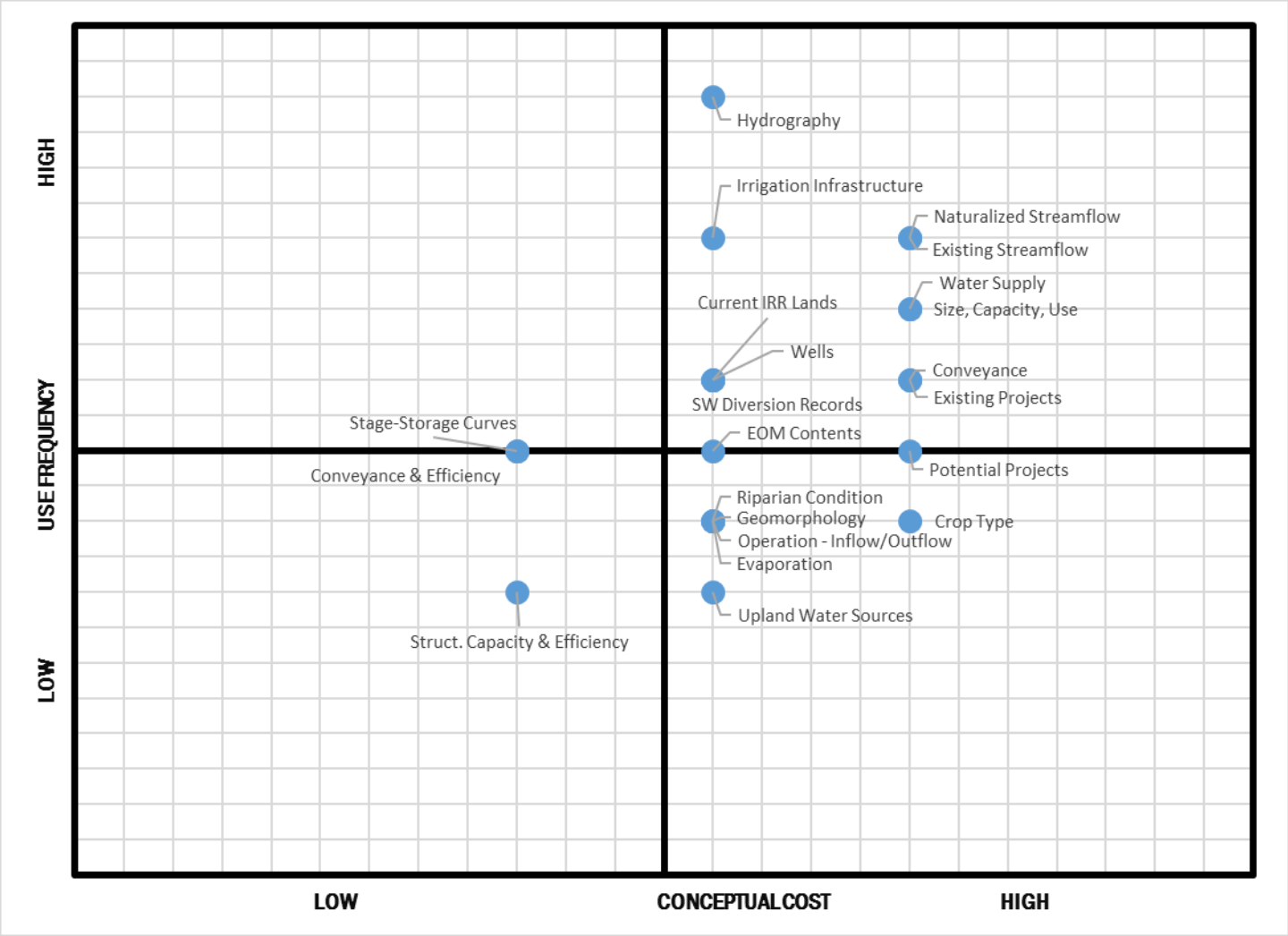


**Figure 4.4 – Data Gap Analysis Quadrant Chart**

## 4.5 Tools to Manage Data

A DSS can be a valuable tool for making decisions based on disparate data sources. The basis of this project was to identify the data and related inputs to develop a model to store and manage information for the WDO. The goal was to produce a data model that could centrally store data for a DSS allowing the data to be used in different technologies for modeling and analyses. As seen in Figure 4.1, the data inputs come into the standardized data model, the data model can be accessed and used by different technologies and ultimately decisions are made using the outputs. A DSS has

three major components: inputs, analysis, and outputs. This section addresses the analysis software and related technologies.

**GIS**

As stated in Section 2.0, recently a GIS task was added to Level I and Level II studies funded by WWDC. GIS is software that is used by the majority of the water community. It has capabilities to create data, analyze data and produce maps for use and decisions. GIS has many capabilities but ESRI's Model Builder has the most potential to assist in automated GIS tasks that in the past have consumed many man-hours. Using Model Builder a user can build a spatial analysis model and use it many times to get the final dataset for analysis. This project has a task to build a spatial model to access the data model and produce a GIS layer showing a Depth I detail of e-Permit data. The Depth I detail of e-Permit data procedures can be found in section 6.0 of the Bear River Data Model Pilot Project: GIS Standards Technical Memorandum. The e-Permit Conversion Spatial Tool developed for this project will take input files from the e-Permit system and map out the Points of Diversion and Point of Use data as a GIS feature class.

**Surface Water Modeling**

There are many surface water modeling software application and with the StateMod application utilized the most for producing basin and watershed water availability analysis. The surface water modeling software is best used to calculate quantities of water either flowing or permitted. Inputs for surface water modeling vary with each software package. Using GIS or other software, the end user can prepare the model inputs since the data model has a consistent data structure. Below is a listing of the most common surface water modeling software.

- River Basin Plan Spreadsheet Models
- StateCU
- StateMod
- SWAM
- RiverWare
- USACE Hec-Ras Suite

The Green River DSS Feasibility Study (2011) was done to explore the development of a fully functioning DSS based on StateMod and StateCU. This study found the development of the DSS could help the Water Development Office and the

State Engineer's Office be proactive in the development and management of water resources throughout the state. As stated in the 2011 Study, "The analysis tools (of a DSS) change raw data into useful information that can be applied by decision makers to address anticipated planning issues, and to answer "what if" and "how much" water supply and demand questions that arise in the future." The implementation of this Framework Plan is necessary to set data consistency, collection, storage and maintenance in order for the analysis tools of a DSS to function in answering the "what if" and "how much" questions. Building state-wide core datasets are recommended to facilitate the future development of a DSS.

The Green River DSS Feasibility Study provided an estimated cost of $1.93 million over a three year time frame to develop, staff and implement a DSS for the Green River. These costs included staffing of four full-time equivalent employees, two positions as SEO data entry staff and two DSS dedicated staff members who would reside within the WRDS organization. The accumulated cost of these staff members over a three year implementation phase was estimated at $777,000. An additional $45,000 of funding was estimated to complete e-Permit and Aquarius development efforts. This portion of the funding would no longer be needed due to the completion of these tasks by the SEO. The highest cost to implement a DSS for the Green River was a modeling-specific effort and the cost was listed at $1.1 million. The costs developed under the feasibility study would produce a DSS similar to the Colorado DSS, which is currently in place. The data collection subtasks were estimated at $512,000, if the effort was contracted to a consultant to complete the datasets. There was undocumented costs associated with the data collection efforts within this feasibility study. The undocumented data collection effort consisted of current WDO and WRDS staff and one full-time field staff to truth the data and collect additional field data.

This Framework Plan was developed to set the foundation of the data requirements that are needed to implement a state-wide DSS. The implementation of this Framework Plan would prepare the core datasets to be collected with an end goal of being utilized in a state-wide DSS. Based on the data gap analysis, review of historical data, and the research of new data collection methods, the recommendation is to provide funding to develop the highest priority core datasets on a state-wide basis. Section 5.4 Data/DSS Development Recommendations provides costs and procedures to develop statewide datasets for the highest priority data needed and most frequently used in modeling. Estimated costs to develop the core datasets would be $200k - $400K. The ongoing cost would be $100K - $200K per year to update the most frequently used datasets, such as irrigated lands.

**Ground Water Modeling**

Ground water modeling software to evaluate ground water for municipalities and the effects of surface to ground water interaction are needed for analysis. Typically, this type of analysis project is for smaller areas and not basin-wide studies. Listed below are a few of the industry standards groundwater modeling software:

- ModFlow
- Groundwater Vistas
- GSFlow

**CADD Products**

There is a limited number of CADD based software that is used to model water. The majority of CADD based software is used for Municipal Masterplans. This software is used in the design and analysis of water systems, which are fed by groundwater wells or permitted surface water usage. Below are two of the most used software for modeling mechanical water systems:

- Flow Master
- WaterGEMS

**Server Based Technologies**

One of the outputs for the DSS is GIS Data sharing as shown in Figure 4.1. The sharing of datasets is possible by using GIS server based technologies. These technologies allow interactive maps and the ability to perform basic geoprocessing, such as clip and ship datasets. This gives the end user the ability to pull a subset of the regional dataset and download the data for use in additional analysis. Another key use is to share the statewide datasets with other state agencies so they can benefit by accessing the latest water resource information.

# 5.0 Implementation

A phased approach to implementing this Framework Plan is. With data standards and development opportunities with low to no cost implemented first. Followed by more advanced software systems and data management to follow. Model development will be pursued in focus areas where it can have specific applications related to improved water management and new water projects. Costs and schedules attached to phases are rough estimates and would need to be refined before a recommendations could be made to WWDC.

## 5.1 Recommended Data Collection Procedures

Most GIS data will be collected incrementally over time, with each project building on the data of those that have come before. Care has been taken to align standards with GIS data that was previously collected. Geodatabase templates will be designed specific to the project type ( i.e., a Watershed Study would get a geodatabase that has core datasets required).

Each project geodatabase will only contain the core datasets; other data necessary to that specific project would not be included in the template. Ancillary data or project specific data could be delivered as part of the geodatabase, as specified by the Project Manager and Sponsor. The Framework Plan and GIS Standards Technical Memorandum should be referenced in requests for proposals and the annual solicitations for WWDC funded projects, with tasks in the proposal detailed to make sure data collection requirements of each project are clear. Data will be reviewed for completeness by the Water Development Office and WRDS when draft project deliverables are received. This can be implemented with an adjustment in the review process and training.

## 5.2 Maintaining the GIS

Managing large amounts of data created and updated by different consulting firms makes it difficult to keep the latest data available. This project will provide the WDO with a consistent way to store datasets within a data model that allowing the ability to develop statewide mapping layers. Ongoing maintenance of these data will reside with staff members at WRDS. WRDS currently manages the WDO datasets in multiple databases and web pages, allowing a limited number of datasets to be downloaded and viewed due to the completeness of metadata. Using the Bear River data model and the GIS Standards Technical Memo sections 2.0 and 3.0, WRDS will be able to update and maintain a master Geodatabase more readily with a standard coordinate system and metadata. Changing operations to manage a master

geodatabase should be done in phases. The implementation phases developed under this project are detailed within Section 5.3. The maintenance of spatial data will evolve as the phases are implemented by WDO and WRDS. The current spatial data maintained by WRDS are a file based system. But as new technologies are implemented, the data should be migrated into a Relational Data Base Management System (RDBMS) and Geodatabases. Implementing the new RDBMS and Geodatabases will allow for improved data sharing and maintenance procedures that will include versioning and multiuser editing.

## 5.3 Accessing the GIS Data

The current ability to access the historical report data is limited through the WWDC website, the State Water Plan site houses roughly 350 GIS datasets from past reports. Not all of the data is accessible at this time and the resources it takes WRDS to compile datasets and deliver the data to the requesting parties within the water community is large. The section below lays out a phased approach to implementing technologies to access the datasets in the future. Table 5.3 documents the phases, benefits, and cost.

**Phase I** would link additional newly submitted geodatabases to the WWDC website for downloads. River Basin Plan data is currently available for download from the WWDC website. This should be expanded to include existing Level I and Level II public data. For new projects, GIS data templates should be posted online by project type, i.e. Irrigation District Master Plan, Watershed Study, etc. The project specific geodatabase templates are being posted online through additional website development and hosted by WRDS.

**Phase II** would use ArcGIS portal services registered as an Open Data site through ArcGIS Online (AGOL) to share the Level I and Level II data to the public. The public data would be searchable and accessible through an industry standard interface using AGOL and project specific data could be used and improved upon by multiple users outside of the organization. Once the data is hosted and managed through AGOL, the WDO could set up and manage additional web maps to share pre-determined maps to the public in addition to the water and climate atlas. Current staff at WRDS and WYGISC would use existing licensing, software and hardware to implement the ArcGIS portal technologies and manage the data content locally, while sharing the data through a public portal.

**Phase III** would enhance the current Wyoming Water and Climate Atlas (Atlas) by re-developing the current functionality and adding new functionality, such as a 'clip and ship' for datasets based on users input. The customization would be based on the latest ESRI server technologies. The second part of this phase would include developing an Open Data side

through AGOL to allow users to query the spatial data outside of the Atlas platform. Long-term maintenance of this site would require an outside entity with software development staff along with the current WRDS Staff managing the GIS data locally and sharing through the Open Data site.

**Phase IV** would be an ArcGIS Enterprise solution, including ArcGIS Portal and Enterprise Geodatabase (EGDB), that allows the WDO to host and manage mapping services that could be edited and maintained by outside entities of the WDO. This phase would be the highest level of data sharing and management by multiple agencies across the water community. The core datasets that are managed by WDO would be updated by the consultants using direct access to online editing services. This phase is possible using the existing hardware, software and licensing provided by WYGISC; the highest cost being staff training and technical knowledge.

**Table 5.3 Data Access Implementation Cost by Phase**

| Phase | Title | Description | Benefits | Cost |
|---|---|---|---|---|
| I | Post data to WRDS website | Implement new data model and post by project type on WRDS website. | Access to latest datasets in consistent format. | Current WRDS Budget |
| II | ArcGIS Portal/AGOL solution | Use ArcGIS portal to create services, registered with ArcGIS online for use in an Open Data site. Existing WRDS ArcGIS Server services can be registered with the University of Wyoming, managed by WyGISC AGOL license and shared publicly. Users can browse and download data quickly and easily in an industry-standard interface. | Access to public data layers served through ArcGIS online. Searchable data and download. Hosting of the data would remain on WRDS servers and hosted through AGOL. Expanded security and sharing of data models. This option allows WRDS to control datasets and allow for improved sharing through multiple online platforms. | Combination of WRDS and WYGISC staff along with Training |
| III | Improve Wyoming Water and Climate Atlas and other data access tools | Improve Atlas by adding functionality, such as Clip and Ship for data layers. In addition to these improvements, develop Open Data site, using the University License, that allows users to query all spatial data outside of the Atlas platform. | Customize and host on WRDS servers, control over interface and functionality. The WWDC Report/Products search functionality will be developed as a custom widget. The clip and ship functionality can be added as a geoprocessing service. | $80K - $150K for the customization provided by an outside consultant. |
| IV | Live editing application | Implement ArcGIS Portal, EGDB, and other front end services to open up collaboration and live editing of spatial data for consultants. | Allows sharing/editing of authoritative data sources managed by WWDC by allowing all consultants direct access to online editing services. | Utilize WYGISC EGDB and Portal hardware and software. WRDS training to host and manage the editing environment |

## 5.4 Data/DSS Development Recommendations

GIS data standards will help build a more robust and useful planning program. Some datasets are best developed on a project-by-project basis while others would be contracted to be developed statewide. This would reduce the overall cost of level I projects and serve as common base data for the state.

Statewide base data should be developed to improve consistency and eliminate redundancy. A common level of data development across the state will inform the design of water projects, document the use of Wyoming's water, and facilitate permitting. The core datasets, which apply to all WWDC planning projects and contribute to interagency coordination should be developed at a statewide scale. Based on the data gaps analysis, the core datasets that should be developed statewide could be characterized as infrastructure, water availability, and WDO project development.

**Infrastructure** includes human and natural water systems. These data will assist with project design, modeling, and permitting.

- Water systems (depth 1) - Diversion structures, wells, gauges, Point of Use (to the quarter-quarter location), large conveyance structures, and reservoirs. This effort would focus on the significant diversions in a basin. Development of this data would be based on the existing water systems mapping that is included in master plans, NHD structures and line work, River Basin Plans, Watershed Studies, Dams and Reservoirs Studies, e-Permit downloads of adjudicated and un-adjudicated rights, scanned plat maps, and Green River Basin water rights mapping.

  Data would not be verified on the ground or linked to measuring sites. Data would conform to database standards described in this document.

  - Estimated Cost $75,000
  - Schedule: 6 month time frame
  - The major conveyance structures would be captured from available sources.

- Hydrography – this data would be developed for incorporation into high resolution NHD Plus. The estimated cost and schedule would be dependent on the size of the basin. A small basin would require around $20K to complete.

- Estimated Cost: $20,000 to $35,000 per basin to develop the data
- NHD Plus was completed for the United States in 2003. The High Resolution NHD Plus project is progressing and the state of Wyoming has portions of 3 drainage basins completed. The completion of the entire State of Wyoming would require up to 1 year with the appropriate resources.
- High Resolution NHD Plus is currently underway. A progress map can be located at: https://nhd.usgs.gov/NHDPlus_HR.html

Working with local entities and watershed groups, water systems should be further developed in order to facilitate a scenario based modeling tool that would inform projects to resolve water resource issues.

**Water availability**. A statewide analysis should be done to inform areas of the state with water shortages. These data will assist with drought planning, modeling, and permitting. A low cost approach that could be maintained on a biannual basis will capture the variation in water supply best. Development would build off of existing irrigated lands data using imagery from NAIP and Landsat for irrigation water use.

- Irrigated lands
  - Cost $15K - $20K for Bear River Basin.
  - Schedule: 3 months of effort
  - Tasks to undertake for the classification of irrigated lands:
    - Classification of NAIP imagery, NAIP Imagery updated biannually
    - Unsupervised classification will be sufficient. Double the time estimate for this item if using supervised classification. Additional user interaction will increase the cost by $4K.
    - Convert to polygons and select within a distance of permitted Points of Use
    - Assumption that the Point of Use data has already been compiled for the area of interest
    - Data review, QA/QC

**Project Development**. These data will assist with program tracking and agency transparency.

- WWDC Potential Projects

- Cost $25,000 – $40,000
- Schedule: 4 – 6 months of effort
- The effort to compile the potential projects should focus on the most recent watershed studies and river basin plans. The data will be compiled from existing reports by digitizing the potential projects within GIS and populating the attributes based on the GIS Standards Tech Memo.
- The estimated cost would be driven by the level of effort to research former projects. This estimate is based on utilizing the most recent watershed studies and river basin plans.

Project specific data should be developed consistent with the standards described. This will allow the data to be used in the DSS.

A **Bear River Water Management StateMod Model** should be developed that facilitates the development of water supply projects through local stakeholders groups. The system would allow for scenario modeling of new projects, water supply management alternatives, and permitting constraints. Using the data that has been developed as part of this study by putting it into StateMod to model available water.

- Estimated Cost: $20,000 to $35,000 with existing data.
- In comparison, the total modeling costs for Meeks Cabin StateMod model was $106,000.

Proper documentation is needed on data and all data developed with a project should follow protocol described in the GIS Standards Tech Memo. This document should be provided online along with the project based GIS templates.

## 5.5 Training

Training and ongoing education is critical for Project Managers and Consultants. Beyond what is done through this contract, outreach and education should be done to inform consultants of standards, how to comply, and how to access the data. This will also improve the results as standards mature and software and data needs change. Outreach and education should be done by WRDS and Water Development at engineering and GIS conferences, annual webinars, and with online documentation. Project Managers should be given basic training on how to verify data integrity, make basic maps, and access metadata.

Annual training for new project consultants should be part of every new project cycle. A webinar following consultant selection would outline how to access existing data and templates, collection standards, and documentation.

## 5.6 Agency Implementation Costs

The cost of basin planning over the past 10 years has exceeded $83 million dollars, with a significant portion (33%-68%) of that funding being consumed by data management. The purpose of this Framework Plan is to develop data standards and structure to reduce the cost of future data development. The costs lined out below; address the implementation of new data standards and metadata requirements; providing new technologies to access the data; providing training for WDO project managers, the water community, and the WRDS staff to manage the new data standards and technology; and providing a basis for developing state-wide datasets for the high priority data most frequently used by the WDO and the water community.

Metadata, standards and data model structure costs:

> The metadata standards and data model structure that were produced as a result of the Bear River Data Model Pilot Project will be implemented for the 2018 project solicitations. The costs incurred by the agency will consist of managing the new master geodatabase as project data are delivered within the new data model. The ongoing maintenance of the master geodatabase will lie with the WRDS staff and is detailed in Section 5.5. The technical training for WRDS staff is estimated at $1,000 - $3,000 for classroom training provided by ESRI. WRDS staff and WDO Project Managers will attend the trainings that are budgeted through this project and outlined below.

Technology for sharing data costs:

> WRDS is currently collaborating with Wyoming Geographic Information Science Center (WYGISC) to store and host WDO Project GIS data. WYGISC supports and maintains the hardware, software and the appropriate licensing level through ESRI to have a long-term, stable hosting environment for sharing GIS data. At this time, there is no additional cost to WRDS and WDO to use the WYGISC platform or licensing. However, there may be associated startup costs related to implementing ArcGIS Portal and EGDB directly on the WRDS servers. In the future there could be a need to contribute funding to WYGISC if the hosting environment needs to be upgraded due to high use by the water community. WRDS staff is not familiar with these server technologies at this time and the agency will incur costs for training, this training costs was explained in section 5.5.

Training for staff and ongoing training costs:

This pilot project has budgeted three training sessions at $18,300 which will kick-off the training of the new data standards and how to correctly populate the Geodatabase templates. The training will consist of internal training for WDO project managers and outside trainings for the water community. It is recommended that one of the trainings will be a webinar that is recorded for later training use. The webinar will be a detailed look at the data model, geodatabase templates, e-Permit spatial tool and metadata standards.

The second recommendation is to hold yearly training events with the selected contractors of WDO projects after contracting has been completed. The training should be performed by WRDS and/or WDO staff members that have high level of understanding on the data standards.

Data Development costs:

Throughout the process of developing the Framework Plan, performing the data gap analysis and developing the structure of a WDO Master Geodatabase, we have found and recommend that the data development migrate from project specific datasets to state-wide datasets. The core datasets have been identified and the data gap analysis has set the priority of the datasets and potential sources for this data.

Data development costs are the highest. As documented in the 2011 feasibility study, $1.1 million was estimated to develop data for modeling specific efforts and, as stated in Table 1.1, data development per project ranges from 33% to 68%, irrigation district studies to water basin planning respectively. Section 5.4 of this document describes a few of the highest priority datasets and the cost to develop those on a state-wide basis. These high priority datasets could be two types of data; one type is data that can be built once and maintained over time and the second type of data needs to be updated entirely on a routine basis.

The type of data that is built once and maintained will have a high cost to develop but then the maintenance of the data would be low cost and performed by WRDS or WDO staff. An example of this type of dataset is the WWDC Potential Projects, estimated to cost $25,000 - $40,000 to develop the first time. After it is developed, the incoming project deliverables can be appended manually within a few hours by WRDS staff to maintain the data over time.

The data that needs to be updated entirely on a routine basis, such as irrigated lands, would demand funding

every two years based on the release of the NAIP imagery. The estimated costs for the Bear River Basin irrigated lands is up to $20,000. If irrigated lands were to be developed state-wide, the cost would range from $150,000 - $200,000 and it would have to be funded every two years to be properly maintained.

Developing data on a state-wide basis would facilitate the ability to develop a Wyoming DSS in the future. This Framework Plan has set the basis for standardized data collection and the ability for state-wide datasets to be cohesively stored within the WRDS data environment.

# 6.0 Conclusion

This Bear River Data Model GIS Data Framework Plan is meant to provide the foundation of a new methodology in the development of water resources throughout the State of Wyoming. This pilot study used the Bear River Basin as the study region due to the significant amounts of data and past efforts in developing the data within the region. This plan sets the stage to develop datasets based on state-wide data versus the current methods of developing data by region specific to WWDC commissioned projects. An overall goal of the WDO is to develop a Decision Support System that will allow them to implement and use technology to make critical decisions more efficiently and frequently. This pilot study has identified the core datasets that will be maintained and managed by WDO and WRDS staff. Additional datasets besides the core datasets will be delivered to WDO as support data for projects conclusions, however the goal of this Framework Plan and data model was to identify the critical datasets that are required to understand water resources throughout the state. The geodatabase templates that were developed will introduce a consistency for the incoming datasets; allowing the datasets to form statewide datasets and be managed as a complete dataset. Along with this Framework Plan, a GIS Standards Technical Memorandum was developed to guide the water community as they develop datasets to follow the metadata standards and spatial data standards. Project specific geodatabase templates were built containing the core datasets and attributes needed as deliverables to assist in keeping consistency in the data provided by the water community.

The creation of a Steering Committee and a series of meetings were part of this Pilot Study to assist and understand other state agency data needs and capabilities. The Steering Committee assisted in guiding the pilot study team through the development of the core datasets, agency interaction and data sharing, implementation of this Framework Plan, information on the technology that is being deployed throughout the state, training needs and the understanding of short and long-term data maintenance needs. These items are addressed within the Framework Plan and recommendations were made to move this plan forward.

As this GIS Data Framework Plan, GIS Standards Technical Memorandum and Geodatabase templates are implemented, improved data development, management and sharing will be more efficient and reduce costs of the overall project data development. There is a cost associated with implementing this Framework Plan and the spatial data standards, however it is minimal compared to the data development costs discussed within Section 1.0 of this document Changing the current data management methodology and managing statewide datasets will improve efficiencies of data collection

efforts, as well as reduce the individual WWDC project costs. At the same time, these efforts will improve the decision making power of the WDO staff and prepare the WDO to implement a DSS to make statewide water resource development decisions.

# 7.0 References

2011, Erin M. Wilson, P.E., Leonard Rice Engineers, Inc., Green River Decision Support System Feasibility Study, Electronic Document available at WRDS Website: http://library.wrds.uwyo.edu/wwdcrept/Green_River/Green_River-Decision_Support_System_Feasibility_Study-Final_Report-2011.html

2017, Trihydro Corporation, Bear River Data Model Pilot Project: GIS Standards Technical Memorandum