

**WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY  
SOURCE WATER ASSESSMENT PROJECT**

**FINAL PROJECT REPORT**

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**Project #: 424-001**

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# List of Acronyms

<b>CBM</b>	<b>Coal Bed Methane</b>
<b>CERCLA</b>	<b>Comprehensive Environments Response Compensation and Liability Act</b>
<b>CFR</b>	<b>Calculated Fixed Radius</b>
<b>DEQ</b>	<b>Department of Environmental Quality</b>
<b>DOQQ</b>	<b>Digital Orthophoto Quarter Quadrangles</b>
<b>DRG</b>	<b>Digital Raster Graphic</b>
<b>EPA</b>	<b>Environmental Protection Agency</b>
<b>GIS</b>	<b>Geographical Information System</b>
<b>GPC</b>	<b>Groundwater Pollution Control</b>
<b>GPS</b>	<b>Global Positioning System</b>
<b>NPDES</b>	<b>National Pollutant Discharge Elimination System</b>
<b>PLSS</b>	<b>Public Land Survey System</b>
<b>PSOC</b>	<b>Potential Source of Contamination</b>
<b>SDWIS</b>	<b>Safe Drinking Water Information System</b>
<b>SEO</b>	<b>State Engineers Office</b>
<b>SHWD</b>	<b>Solid and Hazardous Waste Division</b>
<b>SWAP</b>	<b>Source Water Assessment Program</b>
<b>TOT</b>	<b>Time of Travel</b>
<b>USEPA</b>	<b>United States Environmental Protection Agency</b>
<b>USGS</b>	<b>United State Geological Survey</b>
<b>VRP</b>	<b>Voluntary Remediation Program</b>
<b>WARWS</b>	<b>Wyoming Association of Rural Water Systems</b>
<b>WDEQ</b>	<b>Wyoming Department of Environmental Quality</b>
<b>WQD</b>	<b>Water Quality Division</b>
<b>WRDS</b>	<b>Water Resource Data System</b>
<b>WSGS</b>	<b>Wyoming State Geological Survey</b>



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# 1.0 INTRODUCTION

People who live in or visit the state of Wyoming enjoy pristine natural resources. One of the most important of these resources is drinking water. In 1973, the Wyoming legislature passed the Environmental Quality Act and directed the Wyoming Department of Environmental Quality (DEQ) both to preserve the surface and groundwater resources of the state, and to prevent, reduce, and eliminate water pollution.

In 1996, the United States Congress passed the Safe Drinking Water Act Amendments that required all states having the responsibility for administering the federal rules and regulations of this Act, or “primacy”, to develop a Source Water Assessment and Protection (SWAP) Program. Although Wyoming is the only state that does not have primacy, DEQ recognized the value and benefit of SWAP to help protect public water systems (PWS). During the 1998 legislative session, the Wyoming Legislature authorized DEQ to set aside 10%, or \$1.2 million, of the 1997 federal Drinking Water State Revolving Fund monies to develop a SWAP program and to complete Source Water Assessments.

The SWAP Program is a two-part program consisting of source water assessments and source water protection plans. The completion of a source water assessment involves determining a source water area for each PWS, assessing the sources of contamination within this source water area that have the potential to affect the drinking water supply, evaluating the susceptibility of the water supply to contamination by each of these potential sources of contamination, and finally, writing an assessment report that contains a summary of all the information gathered during the assessment. Due to Wyoming’s unique primacy status, the completion of source water assessments for all PWSs is voluntary. The DEQ has completed a source water assessment for each PWS that has requested one. Local governments, PWSs, and citizens can then use these assessment reports to develop a source water protection plan that outlines the measures that the community or PWS believes are appropriate to protect their drinking water supply. These measures may include management plans, clean up efforts, public education, or zoning changes.

## **DEQ Coordination**

DEQ contracted and worked closely with the Trihydro Corporation (Trihydro) and Lidstone and Associates, Inc. (Lidstone) to complete the source water assessments. Trihydro and Lidstone were selected because of their geologic experience, Geographic Information Systems (GIS) expertise, and their knowledge of many PWSs in Wyoming. PWS delineations were completed either by Lidstone or Trihydro based upon which firm was most familiar with the geology/hydrology of the area.



The Wyoming Association of Rural Water Systems (WARWS) also provided a great deal of assistance. WARWS published newsletters, helped sign up PWSs for assessments, and helped operators understand and review draft assessments. They also provided valuable input throughout the development and implementation of the SWAP program.

## 2.0 SOURCE WATER ASSESSMENT PROCESS

### Public Water Supply Data Collection

The first step in completing the Source Water Assessment was to compile all available information about Wyoming's Public Water Supplies into one location and format. This proved to be a meticulous process as the core PWS data sources described further in Section 3.0 each contained significant errors and omissions. A Microsoft Access database containing several linked tables was created to help manage the review of this varied information. This database became a key source in the delineation process for each PWS.

### Source Water Area Delineation

The next step in completing the Source Water Assessment was to delineate, or determine, the source water area, or the area that contributes water to the well or intake. In order to protect public water supplies, community leaders, planners, and PWS operators must have information regarding the land area that contributes water to the PWS's wells or intakes. Potential sources of contamination located upstream or upgradient from a water source could reach and possibly impact the water system and its customers. Trihydro and Lidstone delineated three contaminant inventory zones within each source water area for the purpose of identifying possible sources of contaminants that could affect drinking water quality. The inventory zones are described as follows:

- Zone 1 is called the "Accident Prevention" or "Sanitary Protection Zone" and is located within a 100 foot radius of the well or intake. The potential for contaminants released within this zone to affect the quality of PWS water is highest.
- Zone 2 lies immediately beyond Zone 1 and is called the "Attenuation Zone." Contaminants released within this zone are within close proximity of the well or intake and the chances of their reaching the well or intake is still high. Zone 2 for surface water systems included an area 1,000 feet on either side of the perennial streams that extended upstream of the intake either for a distance of 15 miles, or the distance from the intake to the headwaters of the drainage contributing water to that intake, whichever was the smallest. Zone 2 for groundwater systems represented a 2-yr time of travel (TOT) that was determined using the best, and most conservative hydrogeologic data available.
- Zone 3 is the area farthest from the well or intake. Contaminant sources within this zone are less likely to reach the well or intake in quantities that could affect water quality. Zone 3 for surface water sources includes the entire



stream drainage basin from Zone 2 to the basin headwaters. Zone 3 for groundwater sources extends from the edge of Zone 2 to the extent of the estimated 5-yr TOT.

Trihydro and Lidstone used readily available information to determine the locations of each well, spring, infiltration gallery, or surface water intake. No fieldwork or site visits to individual PWSs were conducted to verify the locational accuracy of the data. The location of each water source was initially obtained from DEQ or U.S. Environmental Protection Agency (EPA) databases. Information received from the respective PWS operators on their well information sheets, photographs of individual water sources, the Wyoming State Engineers (SEO) well information database, Wyoming Water Development Commission reports, and Trihydro/Lidstone company experience were also used to locate each water source as accurately as possible. A full discussion on these original data sources can be found in Section 3.0.

To determine the source water area for each well or surface water intake, Trihydro and Lidstone reviewed a variety of geologic, hydrologic, and hydrogeologic sources, and incorporated that data into a GIS. For PWSs utilizing surface water sources, Hydrologic Unit Codes and 7.5-minute U.S. Geological Survey (USGS) topographic maps were used to identify the basin perimeters that contribute water to the surface water intake. For those systems utilizing groundwater sources, Trihydro and Lidstone reviewed information from the following sources to develop source water areas: the EPA's sanitary surveys, the EPA's early 1980s reports on the occurrence and characteristics of groundwater in each basin of the state, the Wyoming State Engineer's Office (SEO) water rights database, University of Wyoming Master's theses, USGS geologic and hydrogeologic reports, Driscoll's Groundwater and Wells book, Wyoming Water Development Commission reports, Wyoming Water Research Institute reports, previous delineations completed by other consultants, the Wyoming Geologic Survey, and WARWS.

The methods and techniques that were used to delineate the contaminant inventory zones within each source water area were consistent for all surface water systems. However, for groundwater systems, professional geologists from Trihydro and Lidstone considered aquifer type (confined, unconfined, alluvial, etc.), flow system type (porous or conduit), and PWS type to determine which delineation method was appropriate for each well, as shown on Figure 1. For groundwater sources, Trihydro and Lidstone geologists used the most appropriate conservative methodology, which closely followed the EPA-approved Wyoming Wellhead Protection Program Guidance Document.

## Contaminant Inventory

An inventory of contaminant sources that lie within the source water areas and have the potential to adversely impact the quality of the water supply was completed within each contaminant inventory zone. Knowledge of potential contaminants may encourage communities to implement and manage a source water protection area, and enable a PWS to plan for necessary improvements in treatment capabilities, develop emergency response plans, or allow time to remediate the source of contamination. The principal contaminants of concern include those regulated under the Safe Drinking Water Act in addition to microorganisms such as *Cryptosporidium*, and exposure to nitrates.

There are two basic types of contaminant sources, point and non-point, that were evaluated based on their proximity and distance from the water source. Point sources are usually associated with a single location, like an underground storage tank, underground injection well, oil and gas well, coal bed methane (CBM) well, a solid/hazardous waste facility or a National Pollutant Discharge Elimination System (NPDES) outfall. Point sources are usually regulated and are required to have permits. In contrast, non-point source pollution results from certain land uses and land use patterns. Urban land use was considered of greatest concern followed by irrigated agriculture, non-irrigated agriculture, and then forested areas. Forested areas were included only to evaluate the potential risks of increased runoff and water quality problems following forest fires. All other land uses were considered low risk.

To evaluate the potential impact of these contaminants, an extensive inventory was conducted in Zones 1, 2, and 3 for both surface and groundwater sources. As part of the inventory, the assistance of local representatives and PWS operators was requested to verify the locations of regulated and non-regulated potential sources, land use boundaries, and to identify any historical sources of contamination.

Contaminant inventories for Potential Sources of Contamination (PSOCs) used information obtained from EPA, DEQ Water Quality Division, DEQ Solid and Hazardous Waste Division, DEQ Land Quality Division, DEQ Abandoned Mine Lands Division, Wyoming Oil and Gas Conservation Commission, the Wyoming State Geological Survey, the U.S. Department of Transportation, and the Wyoming Department of Agriculture Technical Services databases. Examples of regulated activities or facilities include wastewater treatment plants; confined animal feeding operations; underground injection wells; chemical or hazardous waste use, production, or storage sites; and landfills. These permitted contamination sources produce materials that are regulated by state or federal laws. These databases are also tabulated according to contaminant type in the susceptibility section. Information from citizens and PWS operators played a vital role in verifying land uses and locations of regulated PSOCs. Detailed information on these source layers can be found either in Section 3.0 of this document or in the individual GIS layer metadata.



## **The Susceptibility Analysis Process**

The final step in developing the source water assessment for each PWS was to analyze the susceptibility of each water source with respect to the identified PSOCs. DEQ defines the susceptibility of a PWS as the potential for each well or surface water intake to draw water that has been contaminated by pollutants at concentrations that would pose concern. Susceptibility must be determined for each water supply well or intake owned by the PWS. Contaminants may reach the intake or well by infiltration through geologic strata and overlying soil, direct discharge into surface or groundwater, overland flow, or contamination of upgradient groundwater. Contaminants may also enter the water source at the well, intake, or the conveyance. A conveyance is defined as the pipe, canal, or aqueduct between the well or intake and the first form of treatment, or where the water enters the distribution system if there is no treatment.

Water system susceptibility is related to three factors that were evaluated as part of this source water assessment. The first was the physical integrity of the well, intake, and conveyances. The second factor was the sensitivity of the land area through which potential contaminants may reach the well or intake. This included the geologic, hydrologic, and land cover characteristics of the watershed, well location, or aquifer source area. The third factor was the nature of the potential contaminants. Specific potential contaminants were grouped into two types; serious contaminants or other contaminants, based upon the health threat of a contaminant to human health. Potential contaminants included specific point sources and any land uses that may contribute contaminants to the water supply. For point sources, the type of potential contaminants, the location of the contaminant sources relative to the well or intake, and confirmation of a contaminant release were also considered.

Data that were used to quantitatively evaluate the susceptibility of each water source to potential contaminants were acquired from sources of data readily available for all PWS in the state. The susceptibility of each PWS is based on delineated source water areas, DEQ contaminant inventories, 1:100,000 scale land use maps compiled by the University of Wyoming, EPA sanitary surveys, EPA's Safe Drinking Water Information System database, and DEQ and Wyoming SEO well or intake permits.

### **Step 1: Well or Intake Integrity Score**

The first step in the susceptibility analysis was to determine the integrity score for each well or intake. The well or intake was assigned a score after being evaluated for a series of factors. The factors and the points associated with them are described below. Each well or intake received a score between 1 and 13. If sanitary surveys, permits, or completion records were not available or did not contain the appropriate information, a maximum score was assigned



for that particular factor as a default. Scores for each PWS water source are listed in the Well or Intake Integrity tables located at the back of each PWS assessment document.

If the well or intake was constructed prior to 1983, it was assigned 3 points, between 1983 and 1993, 2 points, and 1 point if constructed after 1993. The points assigned to completion dates reflect DEQ's confidence in the standards applied to the design, construction, and completion of wells and intakes at the time of construction. Conveyance structures were scored based on the length, the risk of damage, and the degree to which the transported water is exposed to contaminants. Short conveyances, less than 1 mile, received a score of 0 points, while conveyances greater than 1 mile received 1 point. Open conveyances and conveyances at risk to structural damage received 1 point.

Well integrity was also evaluated on the basis of four additional factors. The first and most critical of these was the presence of a surface seal that is in good condition. DEQ believes that the surface seal is a good indicator of the overall well condition. Wells that had a surface seal were assigned a score of 0 points and wells that did not have a surface seal were assigned a score of 5 points. The second factor was the presence of a good annular seal. However, this information is less easily obtained, so an assumption about the annular seal was made based on the presence of a surface seal. If a well had an annular seal it was assigned a score of 0 points, wells without an annular seal received 1 point. The third factor was the protection of the vicinity immediately around the wellhead from contaminant sources. This is usually accomplished by enclosing the wellhead in a well or pump house, or a fenced off area. If the wellhead was protected, the well received 0 points, but unprotected wells were assigned 1 point. The fourth factor is the protection of the wellhead from flooding. For instance, the ground around the wellhead should be sloped away from well to encourage water and any water-borne contaminants to move away from rather than towards the well. Wells that were considered protected from flooding were assigned 0 points, wells not protected were assigned 1 point.

The integrity of surface water systems was also evaluated based on three additional criteria. The first of these was the presence of a screen. A screen, or series of screens, will prevent debris from interfering with the water treatment process. The presence of a screen yielded 0 points, while intakes without a screen scored 3 points. Secondly, screens must be inspected and cleared of debris regularly to remain effective. Intakes that were not inspected regularly scored 2 points. Finally, access to the area immediately surrounding the screen location should be restricted. If the area around the intake was not protected, the intake scored an additional 2 points.

The integrity score measures the integrity of the overall well/intake from the completion data. This score consists of scoring from 1 through 13 for both wells and intake sources. The well completion date, risk of structure damage, and



conveyance length are scored on well and intakes. The rest of the well scoring is made up from presence of surface seal, wellhead protection, well susceptible to flooding, and the presence of an annular seal. The intake scoring takes into affect the presence of an intake screen, inspected regularly, area around intake restricted, and open/closed conveyance system.

## **Step 2: Water Source Sensitivity**

The second step in the susceptibility analysis was to determine the well or intake sensitivity score on the basis of aquifer or watershed conditions and the confirmed detection of chemical contaminants in raw or treated water. Wells were assigned a score between one and ten. Intakes were assigned a score of five or ten. Scores for the PWS water source are listed in the Water Source Sensitivity scoring tables located in the back of each PWS assessment document.

The inherent sensitivity of the aquifer or watershed was combined with indicators of contamination observed within the last five years. If no information was available, the maximum score was assigned as a default for that particular scoring criterion. Documented chemical detections at a well or intake within the last 5 years scored an additional 5 points. A chemical detection indicates that a pathway exists for contaminants to enter the system.

DEQ assumed that all surface water systems were highly sensitive to contamination (default score of 5 points) due to the fact that streams, rivers, and open conveyances directly and rapidly convey released contaminants. A maximum total of 10 points was possible for surface water intakes.

For groundwater systems, Trihydro and Lidstone determined the sensitivity of each groundwater source based on the type of aquifer in which the wells were completed. Porous flow confined aquifers were considered to be the least vulnerable type. Shallow alluvial, fractured, karst, and some unconfined aquifers are more vulnerable to contamination from surface contaminant sources. To evaluate the sensitivity of unconfined aquifers throughout the state, Trihydro and Lidstone used a statewide map of uppermost aquifer sensitivity that was developed using depth to water, recharge and overlying soil characteristics, land slope, vadose zone characteristics, and other hydrogeologic characteristics. Aquifer sensitivity, based on the map, ranged from 1-5 points. Wells that were completed in fractured rock or limestone aquifers received a score of 5 points. Shallow wells completed in alluvium (less than 65 feet deep), could be under the influence of surface water, and received a score of 5 points. Confined aquifers under normal porous flow conditions received a score of 1 point. Groundwater source sensitivity scores ranged from 1 to 10 points.



The sensitivity score consists of two parameters, well/intake type and confirmed chemical detection within the last five years. Wells can score between 1 and 10, while the surface intakes are score between 5 and 10 points. Both sources score 5 points with a confirmed chemical detection. The wells are scored by type which include unconfined aquifer, shallow well, Karst-fracture flow, and confined aquifer. The unconfined aquifer scores are base off of the statewide aquifer sensitivity layer by using a point on polygon spatial join. All surface water intakes receive 5 points due to the high potential of susceptibility.

**Step 3: Well or Intake Rating**

A well or intake rating was developed from the integrity and sensitivity scores. A water source sensitivity score was determined by adding the well or intake integrity score to the water source sensitivity score. A well or intake rating of low, medium, or high was assigned based on the total number of points scored; low (2-8 points), medium (9-15 points), high (16-23 points). The rating for each well or intake was then combined with the contaminant ratings to determine the final susceptibility for each respective well or intake.

The well/intake rating is the combination of the integrity and sensitivity scores. The overall scores range from 2 to 23. Each well/intake is assigned low, medium, or high depending on the combined score. This rating is used to calculate the susceptibility rating for each contaminant found within the delineation areas.

The table below illustrates the decision rules used to categorize each system’s Integrity and Susceptibility scores described in Step 3.

<b>Well or Intake Rating Scoring</b>			
	<b>Low</b>	<b>Medium</b>	<b>High</b>
Combined Integrity and Sensitivity Scores	2-8	9-15	16-23

**Step 4: Contaminant Rating**

The fourth step in the susceptibility analysis was to rate potential sources of contamination that were located within the contaminant inventory zones delineated for each well or intake. Three categories of contaminants were developed for this rating process: regulated point sources, non-point sources including land uses, and transportation corridor sources.

Point sources were evaluated using the following three critical pieces of information: the contaminant type; the location of the potential source of contamination in relation to the well or intake; and the contaminant release status. For the purposes of the susceptibility analysis, contaminants have been grouped into the following two types on the basis of their DEQ facility or contaminant codes: 'Serious Contaminants' and 'Other Contaminants.' Microorganisms, nitrates/nitrites and carcinogens are considered 'Serious Contaminants,' while 'Other Contaminants' includes the remainder of the contaminants listed in the federal drinking water standards. Point sources identified in the contaminant inventory will have one or both types of potential contaminants. The most serious contaminant type present was assigned a contaminant rating. This process was completed for each point source identified in the contaminant source inventory.

The point source contaminants were also rated on the location of the potential source of contamination in relation to the well or intake (Zone 1, 2, or 3). The last factor in determining a contaminant rating is the contaminant release status. This factor is an indication of whether a potential source of contamination has released contaminants into the environment. Documented releases are typically found with potential sources of contamination like facilities with permitted discharges, groundwater pollution control sites, and leaking storage tanks.

All Serious or Other contaminants that were identified within Zone 1 and Zone 2, regardless of whether a documented release of those contaminants had occurred, were considered a high risk to the well or intake. A known release of a contaminant identified in Zone 3 was considered a medium risk to the well or intake. Contaminants identified in Zone 3 that were classified as a no known release, were considered a low risk to the well or intake.

All point source PSOCs are shown on the source water area delineation map(s). The General Point Source Contaminant Rating Matrix located in the general tables section at the back of this document, shows how the point source PSOCs were rated. The point source PSOCs that are located within the contaminant inventory zones are tabulated in the Point Source Susceptibility Table along with these final contaminant ratings, also located at the back of this document. For further details on any of these sources of contamination, refer to Section 3.0 of this document or contact the appropriate agency listed in Appendix 1.

Non-point sources of contamination were evaluated on the basis of the percentage of land use in the source water area for various activities. The General Land Use Rating Matrix is located in the general tables section of this document. For groundwater systems with modeled, calculated fixed radius (CFR) delineations, and delineations that were hydrogeologically mapped, the percentage of land use in Zones 1, 2, and 3 was evaluated. For all other delineations,

including surface water watersheds, groundwater under the influence of surface water, and area-wide aquifer delineations, only Zones 1 and 2 were evaluated. The percent land use, the land use contaminant rating, and the land use susceptibility ratings for each well/intake are also shown in the Land Use Susceptibility Table, located at the back of each PWS assessment document.

The transportation corridor contaminant ratings were determined by counting the number of each transportation corridor contaminant type within each contaminant inventory zone. The General Transportation Corridor Contaminant Rating Matrix shows how the transportation corridor contaminants were rated and is located later in this section. The transportation corridor contaminant rating and the transportation corridor contaminant susceptibility ratings are shown in the Transportation Corridor Susceptibility Table located at the back of each PWS assessment document.

There were three types of contaminants that were considered potential threats to the well or intake. The non-point sources consisted of the land use within the delineation. The point sources were known point locations of contaminant features, such as underground storage tanks or sewer discharge areas. The corridor sources included all railroads, pipelines, state highways and interstate highways that pass through the delineations.

A final susceptibility rating was determined for each type of contaminant by comparing the contaminant rating with the well or intake rating, using the decision matrix below. A final susceptibility rating was determined for each type of potential contaminant, land use, point source, and transportation corridor.

<b>General Susceptibility Rating Matrix</b>				
		<b>Contaminant Rating Matrix</b>		
		<b>High</b>	<b>Medium</b>	<b>Low</b>
<b>Well or Intake Integrity Rating</b>	<b>High</b>	High	High	Medium
	<b>Medium</b>	High	Medium	Low
	<b>Low</b>	Medium	Low	Low

**Non-point (Land Use)**

The non-point sources of contaminations were selected by overlaying and clipping each of the delineation zones (1, 2, and 3) with the statewide land use layer. Percentages were calculated on each type of land use within the given delineation and scored with a low, medium, or high. The susceptibility rating was calculated using the well/intake rating with the contaminant rating.

The decision matrix below illustrates how each land use type received a contaminant rating based on the percentage of land usage that corresponded to each contaminant inventory zone.

<b>General Land Use Rating Matrix</b>				
		<b>Land Use Contaminant Rating</b>		
		<b>Low</b>	<b>Medium</b>	<b>High</b>
<b>% Land Use</b>	<b>Urban</b>	<5%	5-10%	>10%
	<b>Irrigated</b>	<20%	20-40%	>40%
	<b>Non-irrigated Cropland</b>	<40%	40-80%	>80%
	<b>Forested Land</b>	<20%	20-40%	>40%

**Point (PSOC – Potential Source of Contamination)**

The PSOCs were selected by overlaying and clipping each of the delineation zones (1, 2, and 3) with the PSOC – Points layer. Each PSOC point within the delineation was scored by the type, either serious or other and if a known release occurred. The susceptibility rating was calculated using the well/intake rating with the contaminant rating.

The point source contaminant susceptibility rating was determined for each well or intake using the decision matrix below. The well/intake rating was compared with the point source contaminant rating for each contaminant inventory zone to produce each susceptibility rating.

<b>General Point Source – Contaminant Matrix</b>						
	<b>Zone 1</b>		<b>Zone 2</b>		<b>Zone 3</b>	
	Known Release	No Known Release	Known Release	No Known Release	Known Release	No Known Release
Serious Contaminants Microorganisms, nitrates/mitrites, carcinogens	High	High	High	High	Medium	Low
Other Contaminants Remaining primary and secondary drinking water contaminants	High	High	High	Medium	Medium	Low

### **Transportation Corridors (Linear PSOCs)**

The corridor PSOCs were selected by overlaying and clipping each of the delineation zones (1, 2, and 3) with the PSOC – Lines Layer. Each corridor feature that selected was counted and scored depending on the given delineation used. The susceptibility rating was calculated using the well/intake rating with the contaminant rating.

The transportation corridor susceptibility rating was determined for each well or intake using the decision matrix below. The ratings for each zone were determined regardless of the length that each pipeline, railroad line, or highway intersected each contaminant inventory zone.

<b>General Transportation Corridor – Contaminant Rating Matrix</b>				
		<b>Contaminant Inventory Zone</b>		
		<b>Zone 1</b>	<b>Zone 2</b>	<b>Zone 3</b>
<b>Transportation Corridor Rating</b>	<b>Pipeline</b>	<b>High</b>	<b>High</b>	<b>Low</b>
	<b>Railroads</b>	High	High	Low
	<b>State Highways</b>	High	High	Low
	<b>Interstate Highways</b>	High	High	Low

Final susceptibility ratings were obtained by the general land use rating, general point source rating, and general transportation corridor ratings that were compared to each well or intake rating matrix as shown on page 2-11. As a



result, each well or intake had three final susceptibility ratings (land use, point source, transportation corridor). The scoring followed this format to provide specific ratings for each well or intake.

## 3.0 SOURCES OF DATA

Sources of information described in this section ranged from crude spreadsheets to fully attributed GIS data. The data types and sources discussed in this section are organized by the same assessment process outlined in Section 2.0.

### Development of a Comprehensive PWS Database

Creating a complete and accurate GIS dataset of PWS intakes required the combination of multiple data sources. These data sources and their uses are described in detail below.

- SWAP Apps

DEQ/WQD's primary tracking database for Public Water Supplies is commonly referred to as the SWAP Apps database. This database contains key information such as PWS Name, contact name and address, SWAP status, water supply source, and the number of intakes. In a separate table, the database includes such critical information as well locations and well use information. Because this database contained every PWS in the state and if each had signed up for the voluntary SWAP program, the database served as the core database onto which many other tables were appended.

- UW GPS Files

DEQ contracted with the Wyoming Water Resources Center in 1996 and then later with the University of Wyoming Spatial Data and Visualization Center in 1999 to improve the known spatial coordinates for each community PWS in Wyoming using mapping-grade GPS equipment. The resulting file has latitude/longitude WGS84 coordinates for 1168 intakes across the State. This GIS dataset provided the primary spatial location for each of the intakes used in the SWAP project. All errors and omissions identified in this dataset were corrected using information from SDWIS, sanitary surveys, and PWS operator comments.

- WRDS

The University of Wyoming's Water Resources Data System maintained an Internet-accessible PWS database through 1999. This database contained much of the same information as the SWAP Apps table as well as some additional geologic and well completion information. Once Internet-based access to this database was disabled following the September 11, 2001 terrorist attacks in New York, the up to date status of certain portions of the information deteriorated. The project team utilized this series of tables to provide non-date sensitive well completion data such as casing material, confining layers, and known aquifer.



- **State Engineer's Office Well Database**

The Wyoming State Engineer's Office (SEO) provided a copy of their well permit database for the project. This database contained valuable information about depth to main water bearing zone, well yield, and static water depth. This data was linked into the main PWS database when the SEO well permit number for a PWS well could be determined.

- **WSGS Non-Community Wellhead Delineations**

The Wyoming State Geological Survey (WSGS) Hazards Division in the late 1990s produced wellhead delineations for approximately 602 non-community public water supplies. As a part of this process WSGS created a database documenting each of their assumptions regarding the geology and well conditions for each of the wells as well as their resulting CFR (calculated fixed radius) distances. This database provided unique information for some PWSs about assumed aquifer of interest and formation porosity. These assumptions proved valuable in revisiting the 172 non-community PWSs that had signed up for this project. In each case the project team reviewed geologic, hydrologic, and resulting delineation information from each of the systems.

## **Delineation Process**

To produce the actual source water delineations for the 389 public water supplies that have signed up for Wyoming's SWAP program a significant number of data sources were utilized in addition to the primary PWS data sources identified earlier. Specifically these additional sources served to supplement the tabular data compiled earlier and aid in the mapping of each delineation.

- **Sanitary Surveys**

Conducting a Sanitary Survey is required at least once per 5 years for each public water supply. A sanitary survey is a thorough on-site review of PWS facilities, operation, maintenance, and management. The result is a report that details not only water quality issues for a system, but also background and infrastructure information that can prove useful in creating delineations. Sanitary Surveys often have lat/long coordinates for each well or intake, system design information, and specific data on chemical detections. These surveys were used primarily to supplement missing data in the final database and to confirm intake locations and system design. Later the surveys provided valuable information for writing individual susceptibility analysis descriptions.

- USGS Digital Raster Graphic (DRG) quadrangles

As a background for the delineation maps, the project team used digital scanned images of USGS quadrangles at 1:24,000 through 1:250,000 scale. The use of USGS Quadrangles as a background is common in the cartographic field because they contain universally accepted depictions of roads, cities, hydrography, topography, and cultural features. These digital images, obtained through the Wyoming State Department of Administration and Information, contain photo-revised information through approximately 1983. The lone PWS that used an aerial photo as a background image was the Town of Wright which was established in the 1970s and is not shown on the digital USGS quadrangle.

- Bedrock Geology

A GIS version of the 1:500,000-scale bedrock map *Geology of Wyoming* by J.D. Love and Ann Christensen was used to determine approximate formation boundaries and outcrops in some of the delineations. Full metadata for this layer is included in Appendix 2.

### **Potential Contaminant Inventory**

Conducting the contaminant inventory described in Section 2.0 required the acquisition of data from multiple agencies and government programs. While any site can pose a risk to public water supplies if chemicals are managed carelessly, only data from government-permitted sites are commonly available statewide in a uniform format. For this project many sources of data were identified and reviewed. In several instances, sources of information were not used because the data they contained was duplicative and a more complete and accurate source was available elsewhere. In several cases, even though data from permitted facilities from several of the state departments had been converted to GIS format previously, they contained data of questionable accuracy and updating. The data would have been too labor intensive and time consuming to clean. These data layers were not used other than to supplement or verify the accuracy of PSOC datasets developed for this project. Primary data sources for this project listed by PSOC type were:

- Superfund

GIS data for Superfund (CERCLA) sites was obtained from USEPA Region VIII. The data identified three sites in the State and the point locations were spatially accurate within each site boundary. Each of these sites contained significant hydrocarbons and other carcinogens. Full metadata from EPA is available in Appendix 2.

- **Confined Animal Feeding Operations**

Source data for confined feeding operations in Wyoming was obtained from two programs within the DEQ/WQD. The Confined Animal Feeding Operation program (a part of WDEQ's NPDES program) has permitted 9 sites in the state that do not discharge liquid waste. These sites were added to the PSOC dataset based on Township, Range, and Section information using an automated routine which places the site location in the center of the designated section. In cases where the exact location was known the GIS point was manually moved based on the USGS DOQQ aerial photos. Additional confined animal feeding sites were added due to their NPDES (wastewater discharge) permits. These are more fully described in the Wastewater Discharge section. Generally, confined animal feeding sites are considered serious risks to water supplies due to the high concentrations of nitrates and bacterial organisms associated with animal wastes.

- **Groundwater Contamination**

Sites with documented groundwater contamination are tracked in DEQ/WQD Groundwater Program's GPC (Groundwater Pollution Control) database. Sites were placed in the GIS from this database using either Lat/Long coordinates (45 sites) or Public Land Survey information (210 sites). Twenty nine sites were not added to the GIS due to significant errors or omissions in the source locational information. Contaminant risk information was identified in the source database for many of the sites but not for all. The sites with this information were rated based on a comparison with EPA Safe Drinking Water categories. When a contaminant of interest was not identified for a GPC site, a "Serious" rating was assumed.

- **Storage Tanks and Underground Storage Tanks**

DEQ/WQD's Storage Tank Program provided information on 10,277 permitted storage tanks in Wyoming. Of these, 7,851 were successfully located using a combination of street addresses (7,692) and Public Land Survey descriptions (159). The 2,426 tanks not located were due primarily to non-existent Public Land Survey System (PLSS) coordinates and poorly described addresses. Tanks were then categorized by status (aboveground vs buried), integrity (the presence of leaks) and whether they have been removed. Tanks that have been removed were maintained in the database due to the potential of groundwater pollution from contaminated soils that may still exist around the excavated area. Accuracy of these points suffered dramatically where descriptive addresses on Wyoming's rural highways were used. Locations in urban areas however were typically within 150ft of their actual location.



- Mine Permits

The Wyoming Dept. of Revenue in cooperation with DEQ/LQD maintains a GIS layer of active mine permits. This layer depicts these permits as polygonal features but spatial accuracy remains unknown. These polygons were used with no changes to the locational data.

- Wastewater Discharge

The NPDES (National Pollution Discharge Elimination System) Permitting Program within DEQ/WQD maintains a detailed database. This database contains permits for any facility discharging used fluids to the waters of the State. For the purposes of this project temporary construction permits and inactive permits were excluded. Locational data in the source database ranged from detailed Lat/Long coordinates, to PLSS Coordinates, to addresses. Significant problems were encountered with the General NPDES permits as they often had multiple PLSS descriptions extending beyond 20 miles in length. Approximately, 24,976 wastewater discharge sites were identified as applicable for this project of which two thirds are associated with coal bed methane production.

- Oil and Gas Wells

Oil and Gas Well data were acquired from the Wyoming Oil and Gas Conservation Commission <http://wogcc.state.wy.us>. Permits having little or no potential for water supply risk such as those that have been expired or which were abandoned dry holes, were excluded. All Oil and Gas wells were considered to have “Serious” potential health risks.

- Pipelines – USDOT

GIS data for pipelines was provided by the U.S. Dept. of Transportation. This detailed and very accurate GIS layer showed active pipelines, pipeline ownership, and content (gas or fluid) throughout the state. The locations of these pipelines were determined to be politically “sensitive” by the U.S. DOT and this information was not made available to the PWSs. However, the pipelines were shown on the delineation maps.

- Roads & Railroads

GIS data for Roads and Railroads was obtained from US Bureau of the Census TIGER files. Based on a source scale of 1:100,000, this dataset includes lines ranging from Interstate highways down to 4WD trails. For the purposes of this project only roads that had potential for interstate transport of contaminants were included. These included Interstate Highways and Primary US Highways. All railroads were assumed to have the potential for the transportation of potentially hazardous substances.

- **SHWD**

The DEQ Solid and Hazardous Waste Division (SHWD) provided data for sites that treat, store, or dispose of solid wastes. Locations in the source database are stored in at least one of three forms: Lat/Long, PLSS, or street address. Lat/Long values were used by the GIS when possible as they were assumed to be the most accurate. Only 9 sites had valid Lat/Long values. Street addresses were then used to locate urban sites. Using an automated routine (ESRI's Streetmap) to create points from addresses and a GIS layer of roads, 1,571 points were created. Finally an additional 79 sites were located using PLSS descriptions. Once combined, the sites were categorized by type and contaminant risk level.

- **Injection Wells**

Injection wells are defined as any facility where "injection" of "fluid" into the subsurface occurs. An "injection" is the emplacement of "fluids" regardless of whether the injection requires the application of pressure or not, and a fluid is defined as any liquid, gas or semisolid which can be made to flow. Examples include deep disposal wells that inject below the deepest aquifer (Class I), mineral recovery wells (Class III), and shallow disposal facilities such as large leachfields and automotive service station floor drains (Class V). The source information included descriptive street addresses, PLSS locations, and GIS information. Urban street addresses were prioritized and processed using an automated GIS routine to locate the sites. PLSS coordinates and GIS points were then used to populate the remaining dataset. Sites were then categorized by type of contaminant being injected and rated for contaminant risk.

- **VRP**

Wyoming's Voluntary Remediation Program (VRP) was created in 2000 as a mechanism where landowners could reach decisions about required remedial activities and utilize contaminated sites in a productive manner. Sites in the program range from former refineries to lumber yards. Thirty five sites were added to the GIS based on street address or PLSS description.

- **Digital Aerial Photography**

USGS Digital Orthophoto Quarter Quadrangles (DOQQ) are a group of statewide digital images based upon 1994 grayscale aerial photos. They are considered to be approximately 1:12,000-scale data and were originally flown in the summers of 1992, 1993, and 1994. The project used these images often to verify and correct the locations of PSOCs.

## Susceptibility Analysis

Several additional data layers were required to create well and intake ratings for the susceptibility analysis process.

These primary layers were:

- Aquifer Sensitivity

The project team utilized the Wyoming Aquifer Sensitivity dataset (Hamerlinck and Arneson, 1998) in the intake rating scoring process. This GIS dataset, produced at the University of Wyoming, is a modified USEPA DRASTIC Model that uses geologic and hydrologic information to quantify how susceptible an unconfined aquifer is to contamination on the land surface. These ratings were directly input into the intake susceptibility scoring process.

- Land Use

A modified version of the Wyoming Land Use layer created by the Wyoming Ground Water Vulnerability Mapping Project (Hamerlinck and Arneson, 1998) was utilized in the sensitivity analysis. The final land use layer utilized by the project team contains irrigated agriculture, dryland agriculture, and urban areas from the Vulnerability Project. Land use data pertaining to forest coverage was obtained from the University of Wyoming Gap Analysis Project's Managed Lands GIS layer. Golf courses and additional urban areas were added by the SWAP project team based on 1992 aerial photos.

- SDWIS

EPA's Safe Drinking Water Information System (SDWIS) contains information about PWSs and any violations of EPA's drinking water regulations that have occurred in the last five years. While much of the PWS infrastructure information contained within SDWIS is either duplicative of the information maintained in Wyoming's SWAP Apps database, the project team did use it to fill in various omissions in the final PWS database tables. The primary value of SDWIS to the project, however, was supplying susceptibility information about contaminant detections for each PWS.

## 4.0 DATA COMPILATION AND QUALITY CONTROL

Appropriately synthesizing data from so many data sources proved to be a more difficult process than initially anticipated. Ultimately no single data source was either complete or without error. Data layers initially believed to be trustworthy proved to be problematic. Because of these inaccuracies, data errors, omissions, and contradictory data, the data compilation process became far more than a simple exercise of database linking. The project team was required to spend a great deal of time and effort reviewing and comparing information from every source to create the final SWAP database. This section describes much of this data manipulation and review process to develop the final products.

### Initial ArcView Draft Application

An initial GIS application was developed for the project using ArcView 3.2a. This version of the ArcView software was utilized over newer versions because of its ability to link programmatically to MS-Access databases. This temporary GIS application was used to develop the final PWS locations, compile PWS intake details, define delineation boundaries, and compile the final PSOC layers.

### Compilation and Evaluation of Electronic Data

Compilation of the initial comprehensive dataset for PWS intakes proved to be a meticulous process. The PWS data sources described earlier each contained significant errors and omissions. The locational layer produced at the University of Wyoming, initially thought to be the most spatially accurate, had several significant errors and several other issues that warranted additional investigation. Geologic and system infrastructure information was supplemented using data from the SEO, WRDS, and SDWIS databases. To begin this process a common database field was created in each of the tables that contained a unique ID for each well or intake. SEO well permit numbers were identified when possible for each well to tie in any well log and pump test data that was available. WRDS and SDWIS portrayed information only to the system level and not to the individual intake. Ultimately a new comprehensive database structure was developed to serve the SWAP program through this project and into the future. Information included in the new database structure includes infrastructure data (number of connections, population, etc.), geologic information (aquifer type and assumed conductivity), and system use information (maximum pumping rates). These tables were then used to develop the delineation methods described in Section 2.0.

Once all PSOC data sources had been converted to a GIS format and the accuracy of the PSOC locations had been assessed, each layer was then modified to create a uniform data structure. This uniform data structure consisted of new fields specifying site name when available, site type, relevant comments, data source, and a specific source ID number or permit. This final field is critical for each site in that at any time if a question arises regarding an individual PSOC site, this Source\_ID can be used to refer to the specific source database record. A user can use this linking field to review the original database information provided to Trihydro. When possible, this ID number is the actual DEQ permit number for the facility.

### **Draft Maps and PWS Operator Review Process**

A routine was developed in the GIS application to automate the production of the initial draft delineation maps for each water system. The maps were scaled and printed on appropriately sized paper. Maps showed PWS wells and intakes for the relevant system and surrounding systems, source water delineations separated by type (surface water vs. groundwater), PSOCs, and background images (USGS quadrangles showing topography, roads, and streams). PSOCs were labeled with a unique ID number, and a table showing individual site information was included either on the map or as a separate document when necessary.

In November 2003 each participating PWS was mailed three items to assist in verifying data. First, a document describing the SWAP program, data evaluation methods, data sources, data limitations, and tasks for the PWS operators was included. Second, a table or tables detailing all known and assumed information for each of the wells/intakes was added. Finally the draft delineation map or series of maps was attached for review and revision by the operator. The operators were asked to edit the maps and tables and send the edited documents back to Trihydro and Lidstone. The draft mailings generated many constructive questions and concerns by the participating operators. Operators were asked to assist in several ways:

- Provide input regarding where incorrect, or incomplete data was used
- Provide input pertaining to delineations that did not match the operator's understanding of the local geology and hydrology
- Provide input to verify the presence of PSOCs, based both upon PSOC type and location within the delineated source areas.

As another effort to verify existing data, the Trihydro team called each system to discuss the draft review process. Trihydro also set up an interactive booth at the Spring 2004 WARWS conference in Casper, WY. Many of the PWS



operators (approximately 60%) sent back constructive comments, changes, and suggestions that were incorporated into the final datasets. Several of the delineations were modified to incorporate new or revised data provided by the operators. These changes included revised intake locations, new intakes, more detailed geologic information from well logs, and more detailed system use information. Additionally, PSOC changes were incorporated from notes and revisions on the draft maps. Often PSOCs were moved to better reflect their actual ground location, but PSOCs were also completely removed, or were added to best reflect the present conditions based upon the knowledge of the operator. PSOCs that were added by operators included a wide variety of sites such as underground fuel storage tanks, small confined feeding operations, septic leachfields, and industrial facilities that concerned the operators. Each of these changes was noted in their appropriate database table.

## 5.0 SUSCEPTIBILITY FINAL REPORTING

A new ArcView-based GIS application was developed to produce the final susceptibility reports. This tool was initially designed to serve Trihydro and Lidstone in creating final susceptibility reports for the 389 PWSs signed up for SWAP program. Later as it was refined, the application was modified slightly to serve WDEQ and WARWS in the future in revising current reports as conditions change and even to produce new reports. The final destination of the tool is on a WDEQ laptop that can be used in the field to update changes specific to each PWS.

The susceptibility scoring process described in Section 2 is accomplished using a multi-step Visual Basic for Applications (VBA) procedure within a customized ESRI ArcView GIS Version 9.0 application. This final ArcView Version 9.0 application was developed to replace the earlier Version 3.2a application in order to utilize newly available cartographic technologies not available in the earlier software product. A **Users Guide** for the application is included in Appendix C. In addition to PWS and PSOC locations, the GIS application includes the following background layers:

- Digital USGS quadrangles
- 1990 digital aerial photos from USGS
- Roads
- Streams
- PLSS (Public Land Survey System)
- Land use
- Watershed (Level 6 Hydrologic Unit Codes)
- Bedrock Geology
- Aquifer Sensitivity
- County Boundaries

This GIS tool makes the end user responsible for entering the sanitary survey information into a SWAP database through the GIS interface. The GIS then calculates the well/intake Integrity and Sensitivity. The remainder of the scoring process was entirely automated in the GIS to spatially relate the well/intake location to potential contaminants.

There are three reports that can be produced using the GIS interface; the susceptibility report for each PWS, the executive susceptibility summary, and the well/intake information sheet. The fourth option is to produce a map for the PWS including well/intake locations with their delineations and all contaminant sources. For further details on creating these reports, a user should refer to the **Users Guide** included as Appendix C.



## **Problems Encountered**

There were a number of minor problems encountered during the coding of the customized tools to run the scoring process. Due to the wide range of delineations and valid values in the database the code was written to fit most cases. Visual Basic code was written to select the proper delineations for the given well/intake based on proximity. While this logic works properly on over 99% of the systems, there are some exceptions. Specifically, the delineations for Cheyenne, Douglas, Gillette, and Rawlins were too complicated for this approach. These systems contained one of the following characteristics that caused errors in the susceptibility scoring process:

- Split Delineations – Douglas and Gillette, for example, had groundwater delineations that feature multiple Zone 2s and Zone 3s because of complicated geology for a single intake. The automated routine selects only the zones that are closest in proximity to the intake and would ignore the other.
- No Zone 2 or no Zone 3 for an intake – Cheyenne uses multiple intakes on an engineered streambed near Rob Roy Reservoir. The contributing watershed could not be hydrologically separated into a Zone 2 and Zone 3 delineation. The automated routine incorrectly selected the closest zone 2 delineation which was actually for a different intake.
- Delineations that are a long distance from the intake – Cheyenne, for example, had a groundwater well whose delineations are a significant distance away from the wellhead. The automated routine incorrectly selects a closer delineation for the scoring.

Correcting these errors was a manual process. Trihydro and Lidstone highly recommend that an experienced GIS/database professional assist in the scoring for any future systems that contain one or more of these characteristics. The changes must be made to the SWAP.mdb database directly and should be made with extreme care. Once the scoring tables in the SWAP database are completed the GIS will then produce corrected reports from the database. To correct an error, the following steps must be taken:

- Report errors were identified and flagged by the professional geologist during the QA/QC process
- Manually open up the MS-Access SWAP database (**SWAP.mdb**)
- Delete the erroneous PSOC records in tables **tblpoint** (containing PSOC point features) and **tbllinepoint** (containing PSOC linear features) by:
  - Sorting of each table by the **Well\_Id** field.
  - Identifying and deleting the incorrect records
- Adjust the values in table **tblnonpoint** (containing polygonal land use percentages).
  - Sorting the table by the **Well\_Id** field.
  - Manually correct the percentages and scores using the correct delineations.

- Retain all records (corrected and original) from table **tblNonPoint!**

Each time the scoring was calculated for a system, the records for that system were removed and completely replaced in all scoring tables. If errors remained in the scoring reports, the manual scoring table editing process was completed again in its entirety.

It was also possible that PSOCs would need to be *added* to the scoring tables in a scenario where an intake contained multiple Zone 2s or Zone 3s. Fortunately, in those scenarios for the systems that had signed up for the program, there were no additional PSOCs to be added. If, in the future, PSOCs do need to be added to the scoring tables to produce accurate susceptibility reports, some complicated adjustments may be necessary. One possibility would be to run separate scoring sessions on each of the Zones using backup copies of the SWAP database. These individual tables in the backup databases would then need to be merged into the final SWAP.mdb database. These techniques are not straightforward and should be attempted with extreme care. Trihydro strongly recommends creating backups of the SWAP database before attempting.

## 6.0 FINAL REPORT QA/QC

Final quality assurance and quality control must ensure that an accurate work product reached each PWS. The accuracy was vital for each PWS manager to use the report in a constructive way to aid in the protection of the water supply. Final quality assurance and quality control occurred via two mechanisms: accuracy and applicability of the final maps and the accuracy of the report body. Also, because of the project dynamics, system names and system manager information must be accurate for the report to reach the proper personnel. Many of the data accuracy issues continued to influence the final reporting efforts and were dealt with during the final stages of the reporting.

### 6.1 SWAP PROGRAM PARTICIPANTS

Participation in the SWAP program was voluntary. Since the initial sign up efforts initiated in 1999, some PWSs had since declined participation, changed names and/or ownership, and many PWSs, especially the federal and state administered PWSs, signed up for the program after work on the project had begun. One of the key issues at the end of the program was to ensure that all who signed up received an accurate, stamped delineation. This process involved:

- Comparing the initial sign-up list with the most current application list provided by Kim Parker, the DEQ project manager.
- Comparing each report to the checklist of submittals that were included in each report.

### 6.2 DELINEATION ACCURACY

Each map, from the initial draft maps that were sent out in January 2004, to the final maps submitted in June 2004, went through an exhaustive review by both Trihydro and Lidstone personnel. The first part of this QA/QC effort involved ensuring that the correct delineation methods were applied to each well or intake. This process involved:

- Verifying the correct flow regimes present.
- Verifying of the intake locational data.
- Verifying of source information data (geology, well depth, hydrology, etc.).

This was accomplished by using different data sets and incorporating a semi-quantitative data confidence process. Data that were received from the PWSs following the draft mailings took precedence and were recorded into the comprehensive data set upon receipt. The team considered these data to be the most accurate and up-to-date data. Suspect locational and infrastructure data that were not corrected or clarified by the PWS were evaluated and corrected using the following methods:

- Comparing the suspect data with the SEO online database, and, where hard copy data were available, the latest well permit data were used.



- Comparing the suspect data with data presented in the available Sanitary Surveys.
- Comparing the suspect data with data documented in other available reports (WWDC reports, basin studies, local engineering and design reports etc.).
- Contacting the PWS by telephone.

In most cases where the data were suspect, the team used the data obtained from the SEO database. However, there were many examples of data inconsistencies between the SEO data and the data provided in the Sanitary Surveys. Where the discrepancies could not be resolved and the PWS operators could not be reached, the experience of the professional geologist dictated which data source was used in the delineation.

Geological and hydrological data that were suspect were evaluated and corrected by:

- Comparing data available in hard copy geologic or hydrologic reports.
- Utilizing the local knowledge database from the senior geologists and engineers on the project team based on familiarity with the area in question.
- Comparing the data to the 1:500,000 geologic map that functioned as the geology base layer for the GIS
- Contacting the PWS by telephone.

When no other available data were present and additional feedback via phone contact was not accomplished, the geology according to the GIS geology layer was used to construct the delineation. Geological and hydrological edits were completed in the GIS system. Final conformation that the data edits were included in the final scoring were conducted by junior geologists.

### **6.3 SUSCEPTIBILITY SCORING ACCURACY**

Next to the accuracy of the delineated source areas, the final score that each well or intake received needed to be as accurate as possible. Unfortunately, the data for the PSOCs was the most unreliable. As a result, during the final reporting stage, accuracy and completeness of the scoring data was a manual process. The final scores were verified by comparing the final scoring table printouts to the data that was input into the scoring algorithm. This process included comparing the list of PSOC's on the output scoring table to the PSOCs identified on the delineation maps and verifying that PSOCs were not duplicated in the scoring tables.

## 6.4 FINAL REPORT REVIEW

The final reports that were sent out to the participating PWSs were stamped by professional geologists registered in the State of Wyoming. A final review comparing the list of submittals required to the report body and tables was conducted by Brian Smith of Trihydro and Mark Stacy of Lidstone. All reports were reviewed and corrected before they were stamped and sent to the PWSs.

## 6.5 FINAL QA/QC RECORD

The final QA/QC record was tabulated in a spreadsheet. The QA/QC record documents the SWAP process from the beginning of the project. The record documents vital elements of the process including but not limited to:

- PWS Contact Name.
- Contact Number.
- Date when the Draft Delineation was Mailed.
- Date of Follow-up Calls.
- Date Any Feedback was Received.
- Date Edits were Incorporated into Database.
- Aspects of the Scoring Data Review.
- Date the Scoring Edits were Incorporated into the Database.
- Dates of Final Reviews.
- Date of Final Mailings.

Even though an exhaustive QA/QC process was implemented, the team identified and corrected a large number of inaccuracies and inconsistencies, there may still exist a significant number of inaccuracies within the database.

**FIGURE**

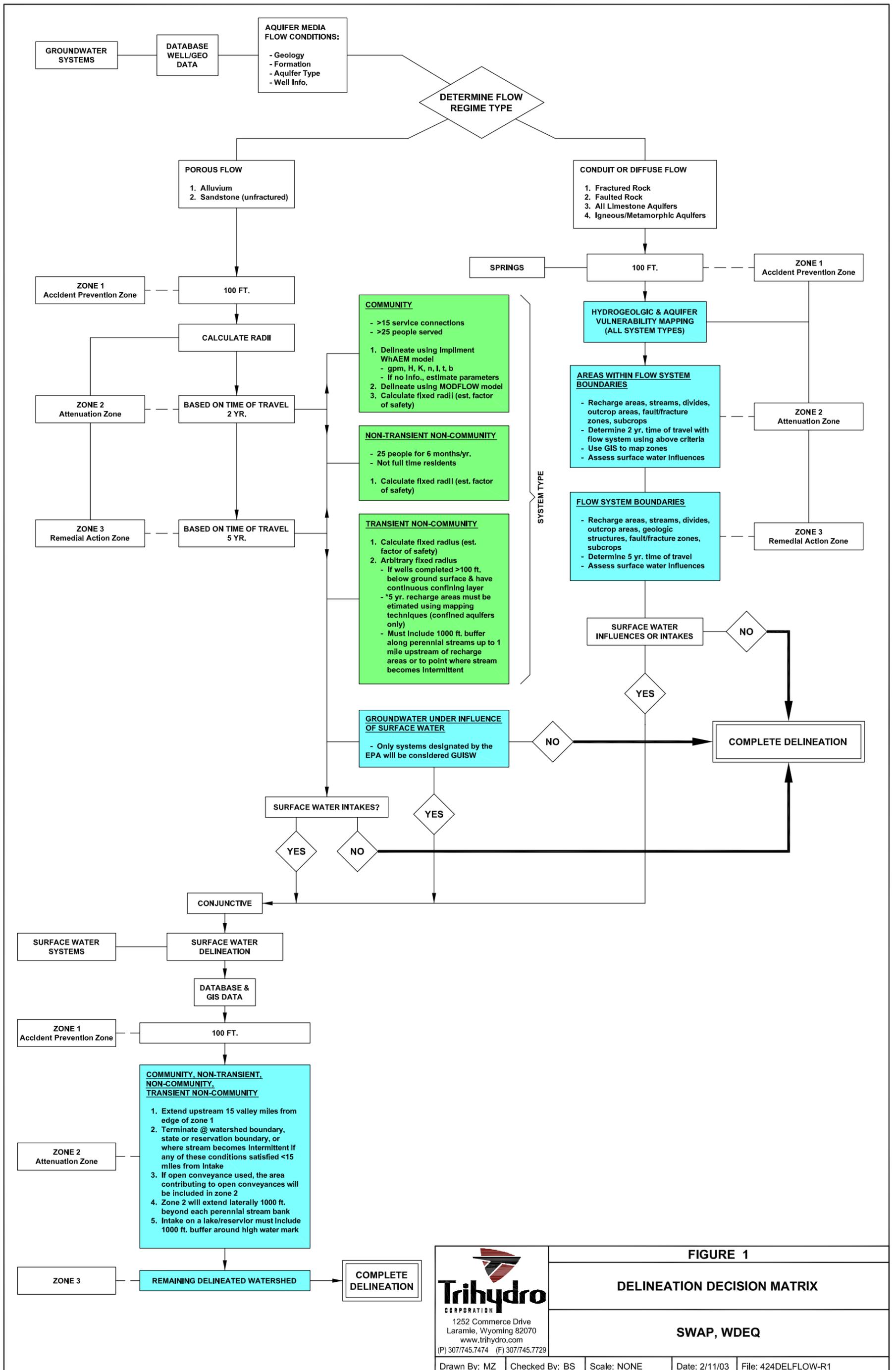


FIGURE 1

DELINEATION DECISION MATRIX

SWAP, WDEQ

