CHAPTER 3: DELINEATION OF SOURCE WATER ASSESSMENT AREAS

3.1 INTRODUCTION

Colorado will be using a watershed-wide approach to delineate source water assessment areas (SWAA)s. As a “headwater” state, greater than 80 percent of Colorado’s surface water supplies originate in the upper portions of the mountainous river basins and eventually flows out of the state. In contrast, the eastern plains and the San Luis Valley in the south central part of the State are solely reliant on ground water as a source of drinking water.

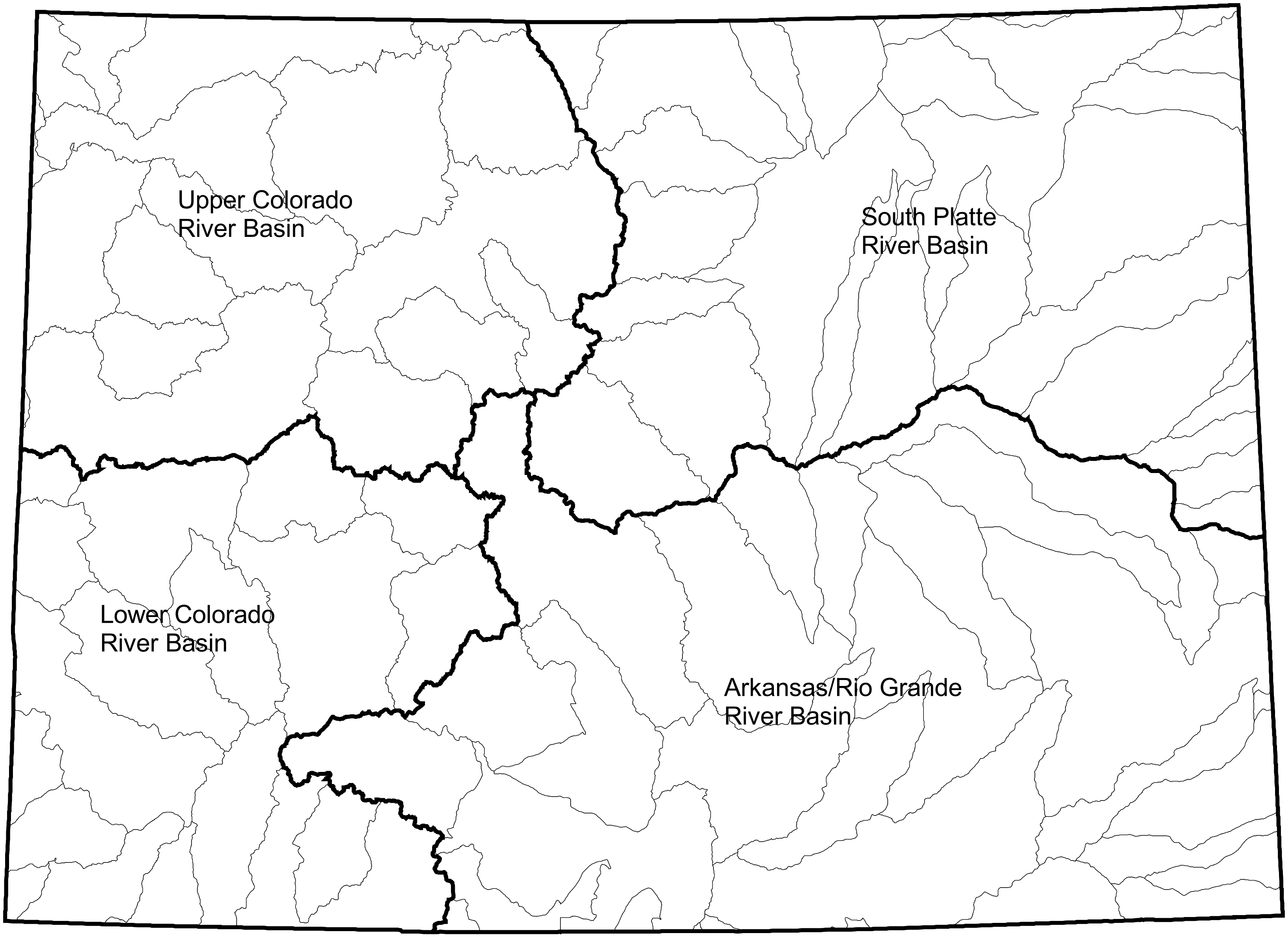
Delineation of the surface water sources will begin at the headwaters of the river basins and progress downstream. SWAAs will be defined within the watershed context using the 8-digit hydrologic units (HUCs) developed by the U.S. Geological Survey (USGS). A map of the four principal watersheds in Colorado with their 8-digit hydrologic units indicated appears as **Figure 3.1**. The hydrologic units define larger watersheds and were selected because they are designed for use as a comprehensive planning tool by the U.S. Water Resources Council and serve as a standard geographical framework for water and related land-resources planning. An equally compelling reason is the Water Quality Control Division's (Division) organizational decision to manage water quality within a watershed context.

The Division, in cooperation with the PWS and/or outside contractors, will handle identification and verification of the intake and well locations. The Division will conduct or contract for a limited number of site visits to verify the accuracy of the location data. The location of the intakes and the wells for the public water systems will then be indicated on a map created with a Geographic Information System (GIS), showing their relative position within the hydrologic units, or watersheds.

Once the task of locating the intakes and wells is complete and the locations are superimposed on the GIS maps of the SWAAs, a determination can be made of which systems are within the same hydrologic unit. Knowing the proximity of one system to another will help to identify the potential for water systems to work together to protect a shared source water protection area (SWPA). A SWAA becomes a SWPA once protection measures are developed and put in place. The determination will also reveal the need to divide the hydrologic units into smaller areas, and to employ other methods of developing protective measures following the assessments, where the location of the intake or well is not conducive to partnering with upstream water providers.

The delineation process will also examine the SWAAs for land ownership and use, and will identify wilderness areas and headwaters with high water quality use classifications. Approximately 1/3 of the land in Colorado is owned and managed by the federal government as National Parks, Forests, Wilderness Areas, and National Monuments, or as range or grassland. Identification of these lands within the SWAAs will expedite the delineation and contaminant inventory processes as many of the activities of concern will not be present, and those that are of concern can be categorized.

Figure 3.1 Map of Colorado’s Four Major Watersheds and USGS 8 Digit Hydrologic Unit Codes



Lands owned by the tribes will also be identified. The Southern Ute and Ute Mountain tribes own a significant amount of land in southwestern Colorado. The State has notified tribal representatives of the approaches being developed for SWAP and has invited their participation. The tribes will be kept informed of the progress made to protect source waters and will be provided information gathered on the individual SWAAs.

3.2 DELINEATION APPROACHES

The delineated SWAA defines the area or zone providing water to the surface water intake and/or the ground water well. The SWAA is also the area through or over which contaminants, if present, are likely to migrate and reach the drinking water well or surface water intake. For surface water systems, the SWAA will include that portion of the entire watershed area upstream of the public water system's (PWS's) intake structure that actually drains to the intake. In the instance of transbasin diversions, the SWAA will also include that portion of the entire watershed upstream of the diversion structure that actually drains to the diversion structure. In both cases, this region will extend up to the headwater boundary of the watershed; however, it will not extend beyond state line if the watershed crosses state boundaries.

For ground water systems, the SWAA will be the zone around the well that is defined in accordance with the methods recommended in the State's approved Wellhead Protection (WHP) program. For confined and unconfined aquifers, the recommended delineation methods are the calculated fixed radius, the semi-analytical model computer model, or hydrogeologic mapping. The semi-analytical model, WHPA 2.2, developed specifically for the Wellhead Protection program, is the preferred choice for these aquifers. The recommended methods for fracture-flow aquifers are drainage basin delineation and hydrogeologic mapping.

It should be noted that the delineated SWAAs would be refined during the susceptibility analysis to include sensitivity zones around the drainage network and/or the wellhead(s). These sensitivity zones will be instrumental in assessing the vulnerability of a PWS to potential sources of contamination within the SWAA. A description of the delineation approaches that will be used to define these zones will be discussed in Chapter 5.0.

3.3 GROUND WATER SOURCES

Colorado will use the delineation guidance developed for the Wellhead Protection program to assess and protect all ground water sources. The recommended approaches will be dictated by the aquifer type: confined, unconfined and fracture-flow. Ground water under the influence of surface water will be jointly delineated, using the surface and ground water delineation methods. **Figure 3.2** illustrates the major aquifers or groups of aquifers in Colorado. General types of aquifers are listed in **Table 3.1** for each of the major aquifer groups illustrated in Figure 3.2. Definitions for each of these aquifer types can be found in the Glossary of Terms.

Figure 3.2 Map of Colorado's Major Aquifers

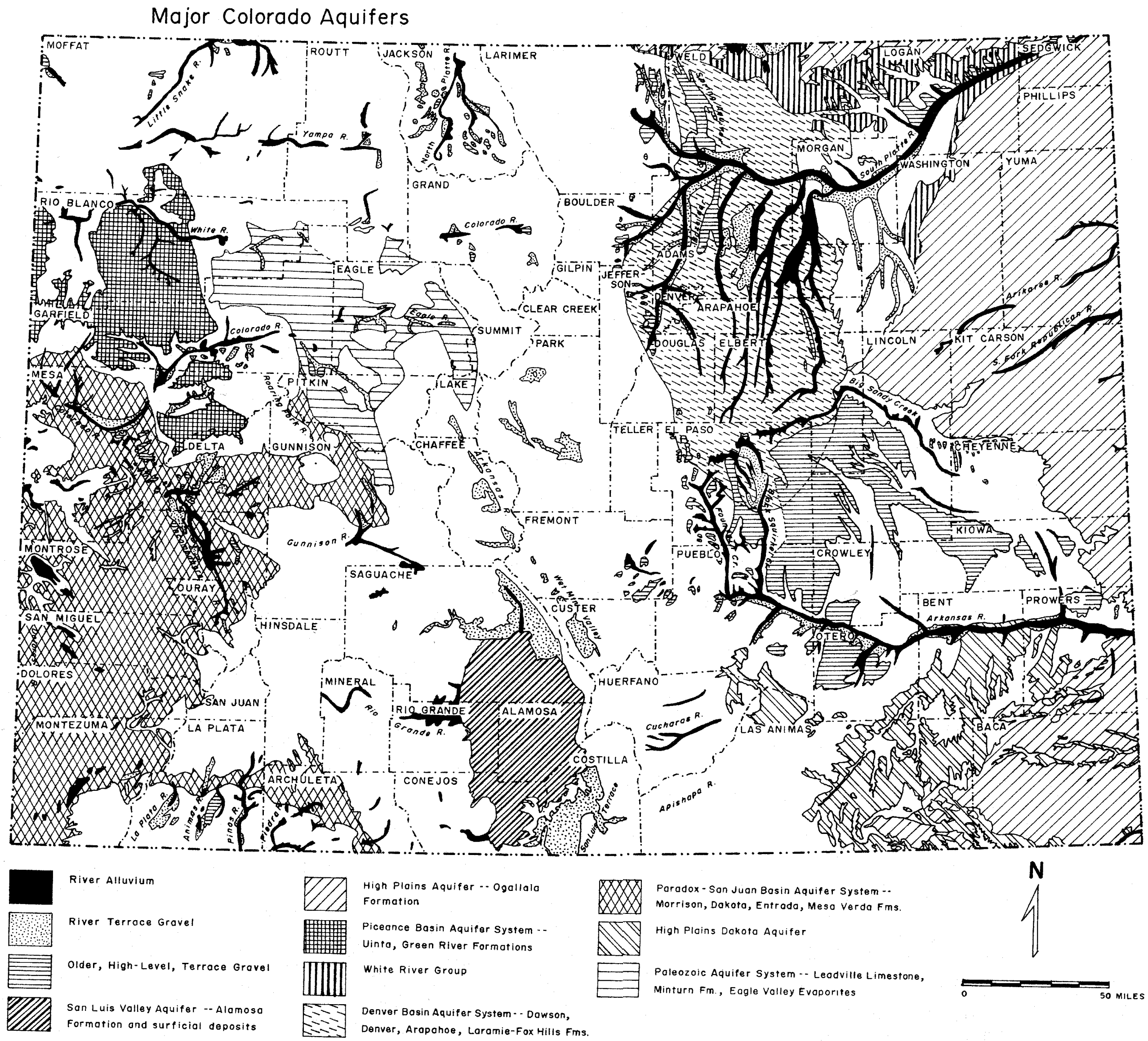


Table 3.1 Major Aquifers in Colorado and Their General Aquifer Type

Aquifer Name	Classification
River Alluvium	Alluvial
River Terrace	Alluvial
Older, High-level, Terrace Gravel	Unconfined
San Luis Valley	Confined/Unconfined
High Plains	Confined/Unconfined
Piceance Basin Aquifer System	Confined/Unconfined
White River Group	Confined/Unconfined
Denver Basin Aquifer System	Confined/Unconfined
Paradox-San Juan Basin Aquifer System	Confined/Unconfined
High Plains Dakota	Confined/Unconfined
Paleozoic Aquifer System	Fracture-flow/Karst

Delineation Methods

Three methods for delineating wellhead protection areas are recommended in the Colorado Wellhead Protection Plan. These include the calculated fixed radius, utilizing the semi-analytical computer model that was developed by the U.S. Environmental Protection Agency (EPA) for the wellhead protection program, and hydrogeologic mapping. A more complete description of the three methods can be found in the Colorado Wellhead Protection Plan.

Calculated Fixed Radius

The calculated fixed radius method is recommended for systems located in confined and unconfined aquifers where the aquifers have small hydraulic gradients. The calculated fixed radius is based on the concept that as wells are pumped, the water table is drawn down around the well. A cone-shaped zone is then created where the water level has dropped. This "cone of depression" around a well is essentially circular in shape in areas where the hydraulic gradient is small; where there are no major sources of recharge such as ponds, canals, rivers; or where no barriers to flow such as the sides of valleys, volcanic dikes, or other low-permeability zones exist. These factors make it suitable for application in areas such as the eastern plains and the San Luis Valley.

The calculated fixed radius is easy and relatively inexpensive to apply. It is an attractive option where there is a limited amount of hydrogeologic information available on the aquifer in question. If information or resources to delineate the SWAA are lacking, then a default 2.5 mile fixed radius may be acceptable in place of the calculated fixed radius.

Analytical Modeling

Colorado's preferred method for delineating SWAAs for water systems in confined and unconfined aquifers involves utilizing the analytical computer model WHPA 2.2, which was developed for the EPA specifically for this purpose. The model requires the input of various hydrogeologic parameters, which are used to calculate the shape of the well's capture zone. Information required to run the model includes the locations and pumping rates for the supply wells, slope and direction of the water table surface, and aquifer transmissivity, porosity, and thickness. Much, if not all, of this information can be found in well permits, and from USGS or other technical reports.

Hydrogeologic Mapping

Hydrogeologic mapping is appropriate in areas where the aquifer consists of fractured bedrock, where unconsolidated deposits are limited in areal extent, the aquifer is comprised of widely varying types of deposits, hydraulic boundaries exist, and/or in areas where springs are used by PWSs. Modeling with hydrogeologic mapping incorporates the configuration of the aquifer into a ground-water flow model. In all cases, the aquifer may be either unconfined or confined. Protecting wells and springs which receive water from fracture-flow aquifers is difficult because of the variable and often indefinable location of fractures that contribute water to the well or spring. In order to provide adequate protection for fracture-flow aquifers, hydrogeologic mapping should be used to delineate boundaries such as aquifer boundaries or flow boundaries, or the boundary of the contributing drainage basin. For the special case where drainage basin boundaries are delineated for fracture-flow aquifers, the method will be referred to as the “basin delineation method.”

Although the wellhead protection program focused on the community systems, SWAP will include all public ground water supplies, community and non-community alike. The majority of Colorado’s PWSs use ground water as a source of drinking water, of which the vast majority are transient and non-transient non-community water systems. Recognizing that the workload impacts of applying the same delineation approach to transient and non-transient non-community ground water systems would be easier to manage, the State proposes to have its contractor(s) use the following delineation methods for these systems.

For transient non-community water systems (TNCWSs) located in confined and unconfined aquifers, a default 2.5-mile fixed radius will be used around the wellhead. Where TNCWSs are located in fracture-flow or karst aquifers, the “basin delineation method” or the more traditional hydrogeologic mapping method will be used. For non-transient non-community systems (NTNCWSs) located in confined and unconfined aquifers, either the fixed radius method or the default 2.5 mile fixed radius will be used, depending on which one provides the largest SWAA. The concern with non-transient non-community systems is that they tend to serve the public over a greater period of time than transient non-community systems, and therefore, require a greater degree of protection. Where these systems are located in fracture-flow or karst aquifers, the SWAA will be delineated in the same manner as TNCWSs.

SWAA Boundary Delineation Criteria and Thresholds

The recommended threshold and criteria for defining the SWAA boundary in confined and unconfined aquifers are a five-year time of travel (TOT) for the calculated fixed radius and analytical modeling methods. Obviously, where a default fixed radius of 2.5 miles is utilized, the SWAA boundary is defined by the boundary encompassing the resulting circular region. When hydrogeologic mapping is used for delineating porous aquifers, the recommended threshold and criteria includes the five-year TOT and/or the smaller of the distance to aquifer boundaries or ground water flow divides. The recommended threshold and criteria for fracture-flow aquifers are the drainage basin boundaries and the distance to them for the "basin delineation method", and the aquifer or flow boundaries and the distance to them where the more traditional hydrogeologic mapping is used.

Inclusion of Recharge Areas in Delineating SWAAs

In delineating SWAAs for PWSs using ground water as their source of drinking water, consideration will be given to including aquifer recharge areas within the SWAA if the location of the recharge area is known or can be easily defined. If the aquifer recharge area is within or intersects the five-year TOT zone or 2.5 mile radius defined around the well, the PWS needs to be concerned about the contributing watershed. In some instances, the recharge area can be a significant distance from the wellhead, causing the TOT to the well to be considerably longer. In this situation, the contributing watershed would be of less concern. As a precautionary measure, however, the PWS may want to consider including the contributing watershed in the SWAA even if the TOT is greater than five years.

In the case of a well located in a fracture-flow aquifer setting requiring the use of hydrogeologic mapping to delineate the SWAA, the delineation method itself suggests including the drainage basin surrounding the wellhead in the SWAA. As pointed out in Colorado's Wellhead Protection Plan, particular attention should be given to the recharge area of the drainage basin in this situation.

3.4 SURFACE WATER SOURCES

Surface water sources of drinking water include streams, lakes, rivers, and ground water under the direct influence of surface water. Delineation of SWAAs for surface water systems will utilize the topographic boundary method, which will result in assessment areas of varying size. Depending on the location of a PWS intake within the watershed, the delineated SWAA may be relatively small if located in the headwaters region, or relatively large if located further down the watershed. In a given watershed, delineation of the SWAAs for individual PWSs will begin with PWSs located at the top of the watershed (i.e., the headwater area) and proceed downstream through the watershed. With respect to PWSs located further down the watershed, the potentially large size of the SWAA presents some challenges from a technical standpoint, as well as a watershed management standpoint. From a technical standpoint, the large size of the area presents problems due to differences in the map scale involved. From a management standpoint, the large size of the area may present problems with facilitating cooperation among PWSs in the watershed, and generating public interest.

In all cases, the delineated SWAA will include that portion of the entire watershed area upstream of each PWS's intake that actually drains to the intake structure (i.e. the catchment area). Where transbasin diversions of water are involved, the SWAA will also include that portion of the entire watershed upstream of the diversion structure that actually drains to the diversion structure, as well as that portion of the watershed(s) that drains to all open-channel conveyances (i.e., streams, canals, and ditches) from the point of diversion to the eventual point of intake. In both cases, the region will extend up to the headwater boundary of the watershed; however, it will not extend beyond the state line if the watershed crosses state boundaries.

As shown in Figure 3.1, the state's major watersheds consist of smaller watersheds which have been identified and represented by the U.S. Geological Survey (USGS) as 8-digit code hydrologic units. In many instances, the 8-digit code hydrologic units cover very large areas and may need to be sub-divided into smaller 11-digit or 14-digit code units. In either case, the State recognized that these hydrologic units provide a convenient framework in which to begin to identify and group individual SWAAs and, hopefully, to facilitate cooperation among the PWSs and the public.

A more detailed description of the delineation methods that will be used to define SWAAs is provided below.

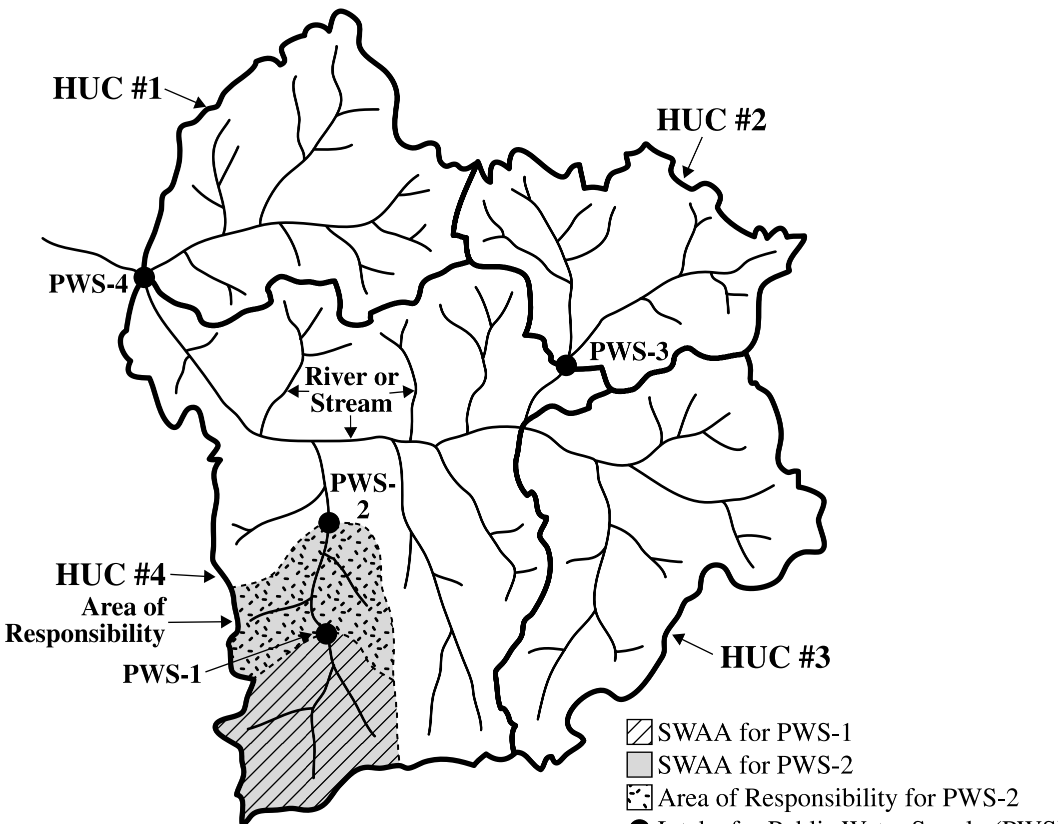
Delineation Methods

Watershed Boundaries/Hydrologic Units

Delineation of SWAAs within a major watershed can be viewed as being analogous to constructing a puzzle. **Figure 3.3** helps to illustrate this concept and how the State proposes to delineate SWAAs within a major watershed.

As Figure 3.1 demonstrated earlier, the State's major watersheds consist of smaller watersheds contained within the topographic boundary of the major watershed. These smaller watersheds have been identified by the USGS and are represented by 8-digit hydrologic unit codes (HUCs). General examples of these units are shown as HUCs 1 through 4 in Figure 3.3. These watersheds, in turn, contain smaller drainage basins within their watershed boundary. The smaller drainage basins also could be represented by 11-digit and 14-digit HUCs, if a more manageable land area is required. At this time, these smaller drainage basins are not shown in Figure 3.3.

Figure 3.3 Source Water Assessment Area Delineation Method Concepts



Construction of the puzzle begins with delineation of SWAAs in the headwater areas of the major watershed. These headwater areas will tend to be contained in the smaller watersheds (i.e. the 8-digit HUCs) located higher in the major watershed. For any headwater drainage within the smaller watersheds, delineation of SWAAs will begin with the PWS located at the highest point in the drainage. An example of a SWAA in this case is presented in Figure 3.3 for PWS-1, which is located in HUC #4. As stated before, the delineated SWAA will include that portion of the entire watershed area upstream of the PWS's intake structure that actually drains to the intake structure (i.e. the catchment area). This region will extend up to the headwater boundary of the watershed. The SWAA for PWS-1 is shown by the dashed boundary and shaded region extending upstream from the intake structure for PWS-1.

As delineation proceeds for PWSs located further downstream in the headwater drainages or the smaller watersheds, their SWAA will start to include SWAAs delineated for PWSs located upstream of them. This is illustrated simply in Figure 3.3 for PWS-2. In this example, the area of the watershed that drains to the intake of PWS-2 includes the SWAA for PWS-1 and the region between PWS-1 and PWS-2. This source water region for PWS-2 is shown by the dashed boundary and shaded region extending upstream from the intake structure for PWS-2.

As the small headwater drainages (and smaller watersheds) start to coalesce with each other into larger streams, the SWAAs will become increasingly larger for PWSs located further down the drainage network. In these cases, more pieces of the puzzle start to come together as the SWAAs for these PWSs will start to include SWAAs for all of the PWSs located upstream in the smaller catchment areas. While it is the intent of the State to work with the PWSs to provide information about PSOCs in the watershed that could potentially impact their drinking water source, an individual PWS may not be able to affect action by their upstream neighbors to identify and/or curtail sources of contamination without working together cooperatively. Theoretically, the PWS at the bottom of the drainage or watershed could be expected by others within the watershed to shoulder an unfair portion of the workload. To help deflect this situation and foster cooperation among all PWSs and stakeholders within the drainage or watershed, the State will identify two areas within a PWS's source water assessment area. These regions will be known as the "area of responsibility" and the "area of interest" for each PWS. These regions will become more important in the other phases of the source water assessment (i.e., contaminant inventory and susceptibility analysis) and during the protection phase of SWAP.

The area of responsibility for a PWS will include that portion of the delineated SWAA located between its own intake and the intake of the PWS located immediately upstream, which drains to its own intake. This region is identified in Figure 3.3 for PWS-2. Each PWS will be encouraged to participate with interested stakeholders during the contaminant inventory and susceptibility analysis to identify PSOCs and assess the risks posed by the most significant sources within their own area of responsibility. If neighboring upstream PWSs do the same, then cooperation will have been fostered within the drainages and watersheds.

The area of interest for a PWS will be synonymous with its SWAA. Again, this will be the region of the watershed up to its headwater boundary that drains to the intake of the PWS, as described before. The area of interest for a PWS will include its own area of responsibility and the areas of responsibility for all PWSs located upstream of it. If PWSs located upstream have taken care of their areas of responsibility, then each PWS will have a clearer picture of the sources of contamination within their area of interest and the vulnerability of their water source to these sources.

For PWSs located at the bottom of the smaller watersheds, their SWAA will include the entire drainage area of the smaller watershed and all SWAAs delineated within. This situation is illustrated in Figure 3.3 for PWS-3, which is located in HUC #2. Similarly, for PWSs located at the bottom of a smaller watershed (i.e., 8-digit HUC) which is located further down the major watershed, their SWAA will include the entire drainage area within the smaller watershed (8-digit HUC) it is located in, as well as the drainage areas of all other 8-digit HUCs above it. This situation is illustrated in Figure 3.3 for PWS-4, which is located at the confluence of HUC #1 and HUC #4. In this case, the SWAA for PWS-4 would include the four smaller watersheds, HUC #1 through HUC #4.

As the locations of the intakes are determined and mapped, the appropriate configuration of the SWAAs will emerge. Where there are overlapping SWAAs among PWSs located in the same hydrologic unit, the PWSs will be encouraged to work together in assessing and protecting the area in question, as mentioned above. Where cooperative arrangements can be made to include protecting the area contained within a hydrologic unit(s), the hydrologic unit(s) can conceivably become a source water protection area. If cooperative arrangements are not feasible, the State will work with the individual PWSs to assess the area that influences the water source serving a single PWS.

The State and its contractor(s) will assume the lead in locating the intakes and/or wells, delineating the SWAAs, and developing maps of the SWAAs. Location information for intakes and/or wells currently on file will be verified for accuracy, and data on the locations of intakes and/or wells for which this information is not complete or available will be collected by contractors. The PWS will be furnished a copy of the map indicating the location of the intake(s) or well(s) within the SWAA, and will be asked to verify it.

The opportunity to aggregate the PWSs within the SWAA and to have them partner will be evaluated on an ongoing basis as the SWAA boundaries are defined. The State is also willing to consider other configurations for delineation that may foster partnering among PWSs. Any alternative approach to setting SWAA boundaries will be evaluated on the ability of the proposal to adequately demonstrate that the alternative SWAA includes, at a minimum, that portion of the entire watershed area upstream of the PWS's intake structure that actually drains to the intake structure. This region must extend up to the headwater boundary of the watershed. Those that fail to meet this test will not be approved.

The State will encourage partnering of water providers located within the same source water assessment area. Where locals are averse to or not interested in working together on basin-wide assessment and protection, they will be treated individually. An effort would be made to work with these communities to become involved in a future watershed-wide approach. The State will strongly encourage PWSs to work together wherever possible, as it will result in getting larger areas of the SWAAs completed within the timeframes allowed. In addition, the partnering concept should foster working relationships among the PWSs on SWAP, and possibly result in cost savings for them.

Assessment of Minimally Impacted Areas

Colorado's size, diverse topography and the location of many of the PWS intakes will often result in large land areas in a SWAA. The State will attempt to simplify the process with the identification of land use and ownership within the SWAAs. The goal of this exercise is to focus on the location and use of the federally owned parcels. Large tracts of these federal lands are National Parks and Forests, some with designated wilderness areas that, theoretically, should not pose significant contamination problems for the SWAAs. An evaluation of the land uses will help to determine if there may be any serious concerns. Where none are indicated, the State will be able to assess large land expanses similarly, and expedite the delineation and contaminant inventory processes.

A similar approach will be used to identify headwater streams that have been classified as and maintain high water quality designations. In both instances, the areas will be periodically reevaluated as the SWAP program evolves to ensure that the land uses and activities, which allowed them to be categorized as non-threatening, have not changed.

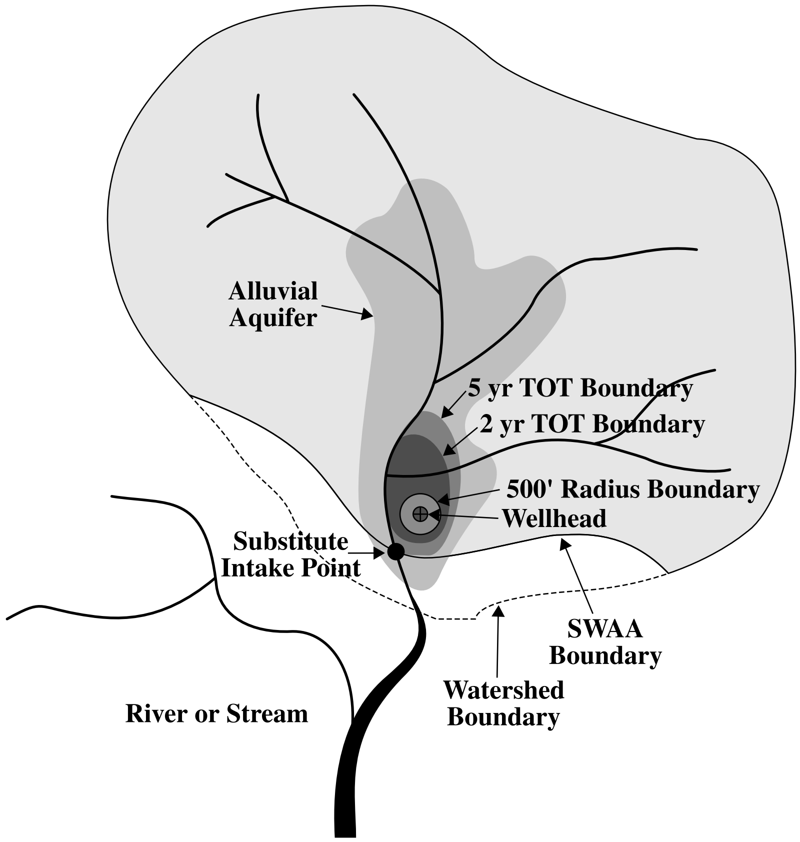
Ground Water/Surface Water Combinations

Colorado has a number of areas where there is a documented hydraulic connection between the surface and ground water. PWSs located in the river valleys or alluvial aquifers are examples of this hydrogeologic arrangement, as are fracture-flow formations where most of the flow through the fractures eventually discharges into the stream. These situations, referred to as "ground water under the influence of surface water," are consistently treated as surface water systems under the drinking water rules. Delineation of combined groundwater/surface water sources will begin with identification of the situation. Records maintained by the State Engineer's Office will provide information on the streams and aquifers where this connection is known to exist. The SWAA delineation for ground water systems also may provide an indication if the WHPA 2.2 model used, as it should account for the surface water barrier.

The SWAA for this condition will be defined using the following steps. The first step will involve delineating a SWAA for the ground water component using the methods described earlier. The SWAA for the well will be defined by either a 5-year TOT zone or a default 2.5 mile fixed radius. In either case, the point on the TOT zone or fixed radius that is furthest downgradient will be used to define an adjacent point on the nearby stream. This point on the stream will serve as a "substitute" intake point to help define the SWAA for the contributing watershed. The SWAA for this condition will include that portion of the entire watershed that actually drains to the substitute intake point on the stream. An example of a delineated SWAA in this situation is illustrated in **Figure 3.4**.

As the program evolves, the State may be able to develop the capability to quantify the loading of one system to the other, and re-evaluate the SWAAs based on the new information that emerges. The SWAA boundaries may be redefined at this point if the data support such an action. The contaminant inventory will be conducted within the delineated SWAA. The susceptibility analysis would need to account for the influence of PSOCs on both surface and ground water sources and make the necessary adjustments in calculating the impacts.

Figure 3.4 Example of Source Water Assessment Area Delineation for Ground Water Under the Influence of Surface Water.



3.5 INTAKE AND WELL LOCATIONS

As mentioned earlier in this document, one of the critical steps in source water delineation is the accurate location of the surface water intakes and the ground water wells for public water systems. A concerted effort is underway to collect this information using GPS units which provide the latitude and longitude readings for the PWS intakes and wells. The State will assume the lead in collecting this information, and may contract to have it completed within the timeframe established in the Safe Drinking Water Act. It is the goal of the State to complete the task of locating all PWS wells and intakes in the year 2000.

The locations of all PWS intakes and wells will be indicated within the hydrologic units on a GIS map. The computer support to digitize this information and enter it into the GIS is already in place. The accuracy of the GPS units will be checked periodically, and the PWSs will be enlisted to verify the locations of their intakes and/or wells.

3.6 ASSESSMENT MAPS

The delineated SWAA will be indicated on a GIS map, and will illustrate:

1. The location of the drinking water source intakes or wells; and
2. The SWAA and aquifer recharge areas, if possible.

The recharge areas indicated will include those within the SWAAs of wells in unconfined, confined and fracture flow aquifers. Where the ground water is under the influence of surface water, the SWAA will include the area around the well and upgradient to the boundary of either the aquifer or the watershed.

3.7 INTERSTATE COORDINATION

As a headwater state, most of Colorado's streams originate in the mountainous areas and flow east or west out of the state, depending on which side of the Continental Divide they are located. The Ogallala Aquifer, the source of drinking water for a large area of the eastern plains of Colorado, is also the principal drinking water source for parts of South Dakota, Nebraska, Kansas, Oklahoma and Texas. There are also streams that drain into Colorado from Wyoming, and the San Juan River traverses the Colorado and New Mexico borders.

To help ensure cooperation and consistency in SWAP with neighboring states, Colorado has offered to organize and host a series of meetings on SWAP activities for the Arkansas River, Rio Grande River, and Platte River basins. Contact has been made with SWAP coordinators in New Mexico, Kansas, Nebraska, Texas, and Wyoming, as well as other downstream states, to determine interest in interstate coordination on SWAP. All neighboring and many downstream states have indicated a willingness to participate. Three meetings will be held for each basin. The aim of the meetings will be to exchange information on the individual state's activities, and to determine how to best coordinate efforts to meet the requirements of SWAP for the shared rivers and aquifers in a consistent manner. Arizona has organized a similar effort for the Colorado River Basin states. Colorado will be participating in this effort.