THESIS

INFORMATION GOALS FOR A REGIONAL GROUND WATER QUALITY MONITORING SYSTEM FOR THE SAN LUIS VALLEY

Submitted by

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In partial fulfillment of the requirements

for the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 1994

COLORADO STATE UNIVERSITY

June 3, 1993

WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY DENNIS J. BAGENSTOS ENTITLED "INFORMATION GOALS FOR A REGIONAL GROUND WATER QUALITY MONITORING SYSTEM FOR THE SAN LUIS VALLEY" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

INFORMATION GOALS FOR A REGIONAL GROUND WATER QUALITY MONITORING SYSTEM FOR THE SAN LUIS VALLEY

The residents of the San Luis Valley of Colorado are dependent on ground water resources for agriculture, the economic base of the region, as well as most of their drinking water. The quality of this water, as a result of its extensive use, has become a concern in recent years. This concern has been expressed not only by local residents, but also the general public, as demonstrated by the numerous state and federal laws that address ground water quality issues. This concern tends to be addressed in a rather piecemeal fashion, particularly with regard to efforts to measure water quality in the San Luis Valley. Each concern and law appears to require its own separate monitoring program.

Can the information needs generated by both local concerns and legal mandates be integrated into a more coherent set of information goals that would guide a unified monitoring program? What information would such a program need to produce? The purpose of this research was to develop a set of water quality "Integrated Information Goals" defined as the integration of those information needs extrapolated from the laws, regulations, and groups

involved in water quality management in the Valley. In order to develop these information goals, the following tasks were defined:

1) Examine, through the review and identification of federal, state and local laws, regulations, implementing agencies, and concerned groups, the current structure of nonpoint source pollution management with respect to ground water quality in the San Luis Valley.

2) Based on the review in (1) above, define information goals for a monitoring design for the San Luis Valley.

3) Specify the Integrated Information Goals needed to support ground water quality management in the San Luis Valley.

   Upon completion of these tasks, five information goals were defined:

   1. Baseline water quality of the shallow unconfined and the deep confined aquifers,
   2. Source impacts to correlate water quality problems with land use practices,
   3. Water table levels,
   4. Water quality trend detection,
   5. BMP analysis.

Options for implementation of a monitoring system were also presented.

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ACKNOWLEDGEMENTS

This paper is very much an extension of the work done by other researchers in the San Luis Valley, and as such their efforts are acknowledged:

Steve Carcaterra	San Luis Valley Water Quality Demonstration Project
Dr. Deanna Durnford	Colorado State University
Cheryl A. Eddy-Miller	Colorado State University
Sherman Ellis, Gary Levings, Lisa Carter, Steven Richey, and Mary Jo Radell	NAWQA Project, U.S. Geological Survey
Susan LeStrange	Colorado State University
Dr. Jim Loftis	Colorado State University
Kelley Thompson	Colorado State University
Dave Ellerbroek	Colorado State University

I would like to thank the staff and faculty of the Department of Agricultural and Chemical Engineering for their guidance and support, as well as the Colorado State University Experiment Station for partial funding of my assistantship. In particular, I would like to thank Dr. Robert Ward, Dr. Jim Loftis, Dr. Deanna Durnford, and Dr. Freeman Smith for their support and advice.

Additionally, I would like to thank those who took the time to respond to my questionnaires and interview requests. I particularly appreciate the assistance of the local residents of the San Luis Valley and their concern, understanding and willingness to assist me. I hope that the value they receive from this research serves as partial payment.

Despite the great level of assistance I have received from all these individuals and agencies, they pale in comparison to the support I have received from my wife, Shirley. She has never doubted my abilities, even when I have. I greatly appreciate her patience and understanding.

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CHAPTER I

INTRODUCTION

A. Defining the Need for Water Quality Information

The Federal Clean Water Act and its amendments, the Safe Drinking Water Act, the Resource Conservation and Recovery Act, the Comprehensive Environmental Response, Compensation, and Liability Act, and numerous other related laws all have provisions calling for some form of ground water quality monitoring. Colorado law and regulations similarly call for monitoring of aquifers for various purposes. Other laws require that certain agricultural activities, well and septic tank installations, and underground storage tank maintenance be done in a specific manner to protect ground water resources. From a nonregulatory point of view, there are various environmental groups, government agencies, water developers, and others who are interested in the quality of ground water for vastly differing reasons.

With this proliferation of laws, regulations and various parties concerned with the quality of ground water, the local water users and managers of this resource may find themselves in a reactive rather than a proactive mode in terms of water quality issues. Yet the citizens of an agricultural area such as the San Luis Valley of Colorado often are tremendously dependent on ground water, and hence ground water quality. What are their specific needs in terms of information about the quality of this critical resource? Are those informational needs already supplied by the monitoring requirements found in the laws and regulations previously mentioned? Is the information from these monitoring programs accessible and useful to the local residents? Is it possible to design a monitoring system which will integrate the information needs of everyone involved in water quality issues for a given area? Can such a system be coordinated within the confines of a local San Luis Valley organization without bankrupting the local economy? Before any of these questions can be answered, there must be a clear understanding of what information is needed and by whom.

B. Purpose of Research

The purpose of this research is to develop a set of water quality "Integrated Information Goals" defined as the integration of those specific information needs extrapolated from the laws, regulations, and groups involved in water quality management in the Valley. These Integrated Information Goals therefore address legal and regulatory monitoring requirements as well as the information needs of the people of the San Luis Valley.

C. Tasks

The specific tasks to be undertaken in this research are:

1) Examine, through the review and identification of federal, state and local laws, regulations, implementing agencies and concerned groups, the

current structure of nonpoint source pollution management with respect to ground water quality in the San Luis Valley.

2) Based on the review in (1) above, define information goals for a monitoring design for the San Luis Valley.

3) Specify the Integrated Information Goals needed to support ground water quality management in the San Luis Valley.

Many agencies are already very much involved in water quality monitoring in the San Luis Valley. The purpose of this paper is not to rewrite these monitoring programs; rather it is an attempt to clarify the monitoring goals of each of these various laws, regulations and agencies in order to see where different agencies may have common goals. The determinations made in this work can then be developed by others into a functional ground water quality monitoring system that uses the existing resources in a more coordinated approach to the benefit of all parties involved.

D. Scope of Study

The scope of this research will include the integration of those information needs as defined by the laws, regulations, and groups involved in water quality management in the Valley. The resulting product will be the previously discussed Integrated Information Goals. This study will not actually site and design a regional water quality monitoring system, but simply lay the groundwork for such a design.

CHAPTER II

BACKGROUND

A. General Description of the San Luis Valley

The San Luis Valley is an intermontane valley located in south-central Colorado, at a latitude of 37° to 38°. A sketch of this area with respect to the Rio Grande upper drainage basin can be seen in Figure 4.1 (Hearne and Dewey, 1988). It is bounded on the east by the Sangre de Christo mountains and on the west by the San Juan mountains. In terms of hydrogeologic flow regimes, it can be thought of as synonymous with the Alamosa Basin. The two mountain ranges angle toward each other to form the northern boundary of the Valley as well, with the New Mexico border generally considered to be the southern boundary. The presence of the San Luis Hills at this border form a hydraulic barrier between the Alamosa Basin to the north and the Costilla Plains and the Taos Plateau to the south (Hearne and Dewey, 1988). The total enclosed area of the Valley is about 3200 square miles (Edelmann and Buckles, 1984) with a maximum north-south distance of 100 miles and 65 miles east to west. Elevation of the Valley floor averages 7700 feet, with an average slope of 0.001 toward the east.

On the average, the Valley receives less than 8 inches of moisture per year, with 11.55 inches measured at Alamosa being the wettest year in recent

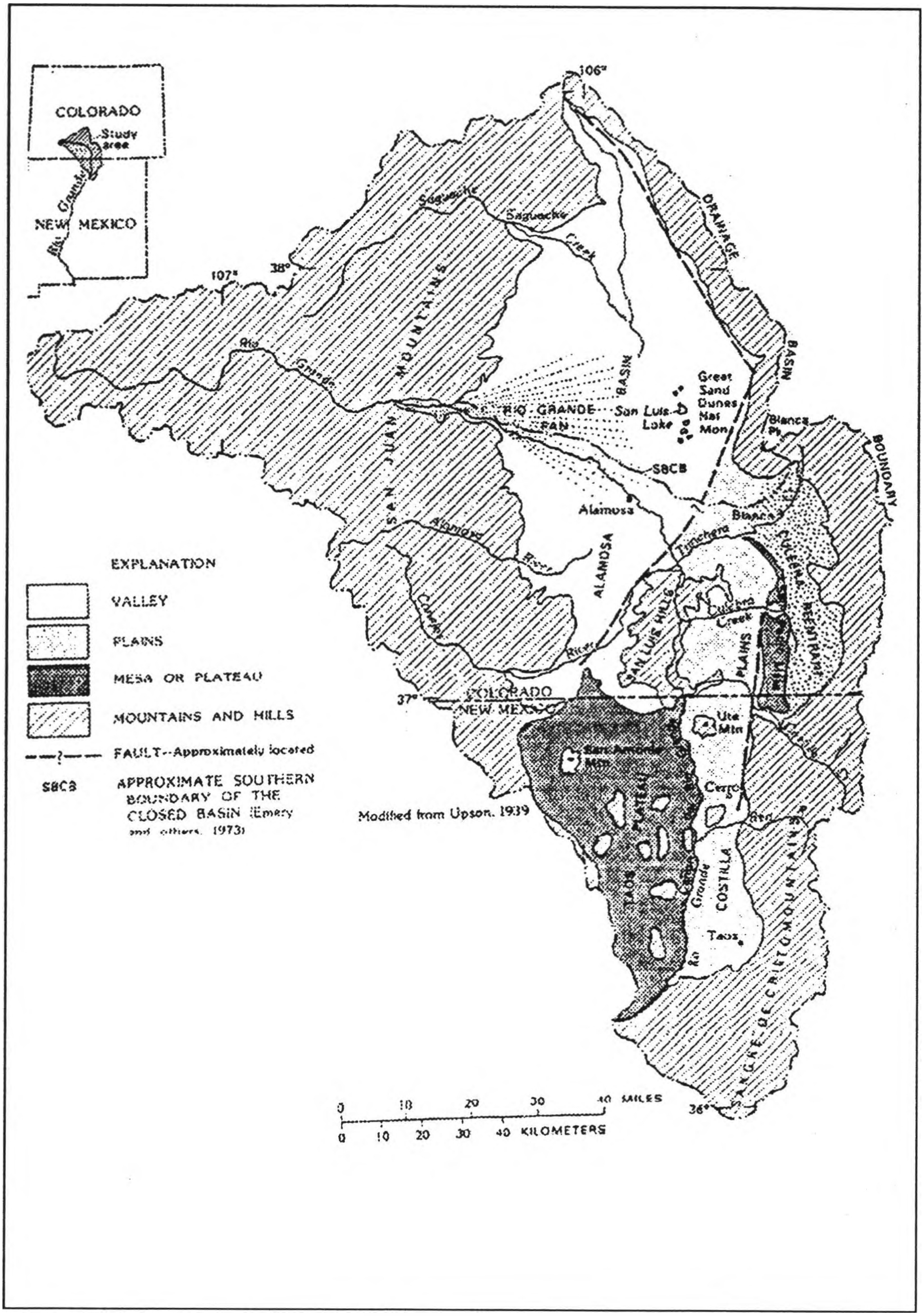

Figure 4.1. Rio Grande Drainage Basin (Hearne and Dewey 1988).

history (Doesken and McKee, 1989). The San Juan and Sangre de Christo mountain ranges that border the Valley on the west and east 'squeeze' moisture out of the prevailing westerly winds, leaving the Valley literally dry as a desert. Yet this same process ultimately provides the substantial amounts of water available to the Valley and the Rio Grande.

Due to the high altitude and dry air, nighttime temperatures drop sharply from daytime highs. This, combined with the generally cool climate, results in a short growing season. Using a 28° threshold, the growing season averages 107 days at Manassa, 141 days at Del Norte, and 142 days at Crestone (Doesken and McKee, 1989). Thirty-two degree threshold growing seasons are as short as 82 days. Growing seasons tend to increase as you move away from the Valley center and the Rio Grande toward the perimeter.

A cross-section of the San Luis Valley showing hydrologic, geologic, and vegetative features is shown in Figure 4.2 (Jodry *et al.*,1989). A simplified sketch of the upper level geology and ground water movement of the region is given in Figure 4.3 (Hearne and Dewey, 1988). The thin band at the top is the upper segment of the Alamosa Formation, consisting of Tertiary sands and gravels. This is the upper unconfined aquifer of the San Luis Valley. It is clear from the figure that the large snowfalls that occur in the surrounding mountains are responsible for the abundance of water in the Valley in the form of ground water recharge. The unconfined unit ranges from approximately 40 to 100 feet thick throughout the central portion of the Valley, and extends to a greater depth along the Valley edges where the confining clay series is absent (Hanna

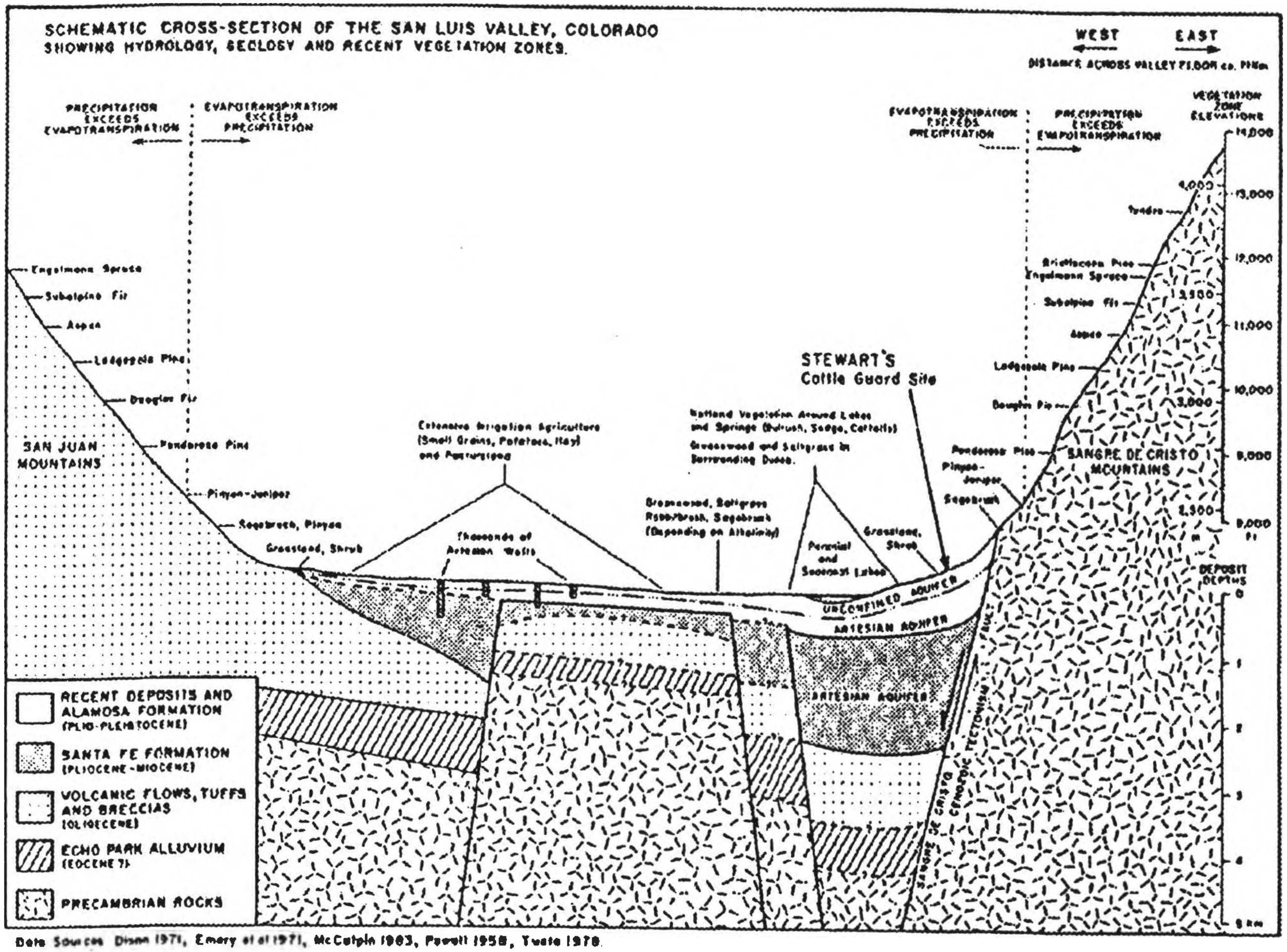

Figure 4.2. Cross-section of the San Luis Valley showing hydrology, geology and vegetation (Jodry *et al.*, 1989).

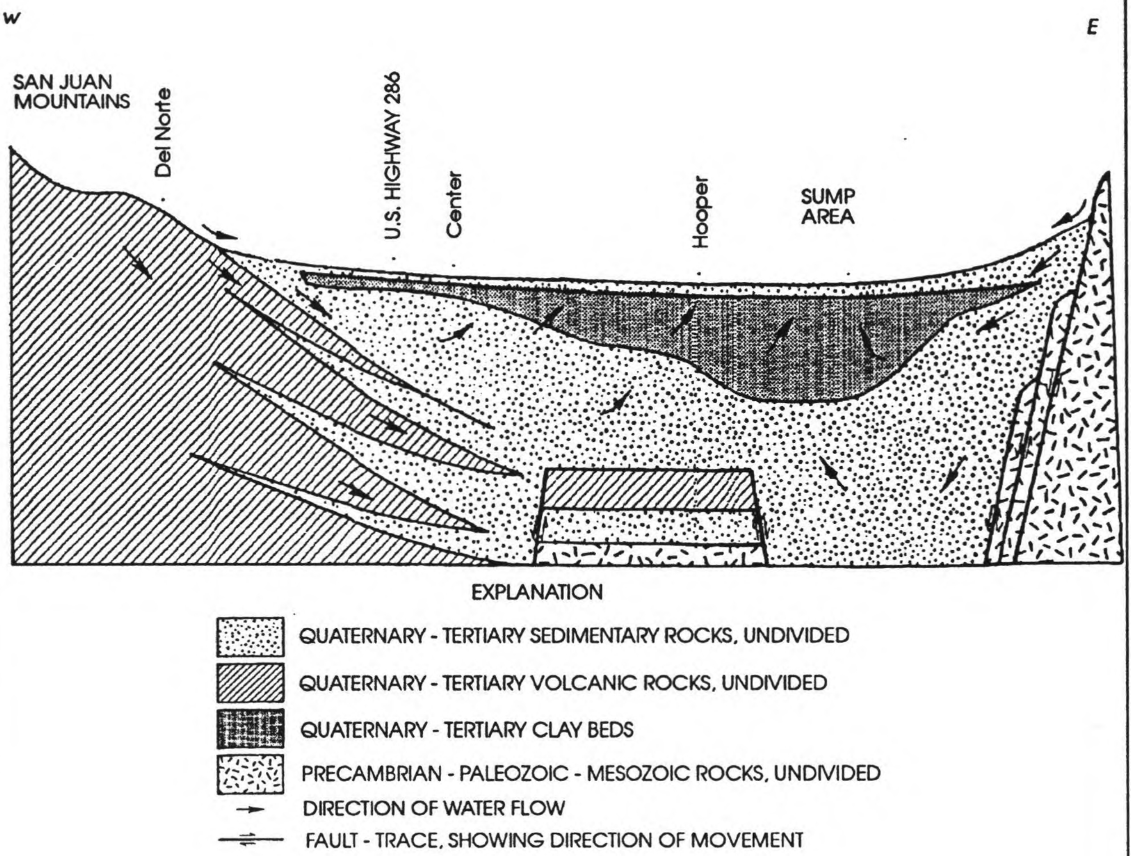

Figure 4.3. Cross-section of the San Luis Valley (Hearne and Dewey 1988).

and Harmon, 1989). Hydraulic conductivities vary from about 35 to 235 ft per day and generally increase to the west (Emery *et al.*, 1973 and Powell, 1958). Also, it is noted that the hydraulic conductivities can change significantly over short distances. The water table is generally very near the surface.

Beneath the unconfined aquifer is a confining blue clay layer which varies from 10 to 80 feet thick at 50 to 130 feet below the surface (Emery *et al.*, 1971). As seen in Figure 4.3, this layer thins out and disappears at the Valley edges. In the area of the San Luis Hills, this clay layer is replaced with volcanic material deposited from the Culebra Range.

Below the clay layer is the confined aquifer system. There are actually two major components: an upper active confined layer with hydraulic conductivities ranging from 2 to 199 feet per day (Emery *et al.*, 1973), and averaging 30 feet per day, and a lower passive confined layer with generally poor quality water and low hydraulic conductivities. The active unit ranges from 500 to 1000 feet thick along the Valley's western edge to over 5000 feet thick in the Baca Graben, while the top of the passive unit varies from 2500 to 15,000 feet below the surface (Hanna and Harmon, 1989). The piezometric head levels are typically near or above the surface (Helgren *et al.*, 1989).

As noted, the hydrology of the aquifers is also visible in Figure 4.3. At the edges of the Valley, runoff from the surrounding mountains enters the upper and lower aquifer layers. The principal source of this runoff is primarily in the Rio Grande, the largest stream in the Valley. Thus, it becomes the principal contributor of water to the artesian aquifers (Powell, 1958). At this point, the gradient is such that the upper aquifer drains into the lower. At the center of the Valley, this gradient reverses (see Figure 4.3) and the lower aquifer recharges the upper by leakage through the confining layers. Additional recharge of the upper aquifer occurs through irrigation. This is believed to have generated another interesting hydrologic phenomenon of a closed basin caused by a ground water divide (see Figure 4.1). The resultant recharge from unconsumed irrigation water to ground water may have raised the hydraulic head by as much as 50 to 100 feet creating the ground-water divide (Powell, 1958). It should be understood that the ground water divide discussed here is relevant to the upper aquifer only. Although the lower aquifer does appear to leak upward through the confining layers and recharge the upper aquifer, the remainder of the water appears to move southward below the shallow ground water divide and into the Rio Grande.

It should be noted that this is a very simplified model of the aquifer system of the San Luis Valley. The blue clay layer separating the confined and unconfined aquifers is actually a discontinuous series of clay lenses with varying hydraulic conductivities (Powell, 1958). Second, there is extensive complex faulting in the Valley that creates pathways from the lower aquifer to the surface (Glanzman, 1989). Finally, artesian and deep wells have been in place since 1887 (Hearne and Dewey, 1988); Powell (1958) reported 61 large-capacity pumped wells completed in confined aquifers. There is likely a great deal of movement of water between the two aquifers through these wells and their surrounding bores, particularly through old and faulty casings.

Anecdotal accounts of the non-homogeneous nature of the aquifers in the Valley come from Fred Huss of the Rio Grande Water Conservation District and John Davey, consulting engineer (1994). Both have reported testing water levels in wells of equal depths only a few hundred feet apart and, under static conditions, finding water levels that vary by several feet. The general consensus is that there are indeed many levels of confined, semi-confined, perched, and unconfined aquifers in the Valley. Thus, drilling two monitoring wells only a few hundred feet apart and using identical casing depths and screened section depths does not guarantee that one is 'looking at' the same aquifer. Many wells in the San Luis Valley do in fact penetrate and draw water from more than one aquifer; so what does the water height or a water quality sample from that well actually represent in terms of information? Probably very little (Hearne and Dewey 1988). In looking at spatial trends, one is probably safest in using very shallow monitoring wells (NAWQA 1984; Eddy-Miller 1993; Durnford *et al.*, 1990) or very deep wells into the confined aquifer. At any point between, it may be very difficult to accurately comprehend the hydrogeology at a particular monitoring point.

It should be clear from these general and anecdotal experiences with the geohydrology of the Valley that any attempts to determine spatial trends in water quality must be well thought out. Simply monitoring a group of wells with 'similar' depths and screened sections may not be a very accurate way of characterizing water quality. Additionally, exact quantification of the well specifications are often unavailable (Thompson, 1993) or questionable as to the accuracy of the records (Huss, 1994). Other than very shallow or very deep wells, the nature of the hydrogeology in the strata being sampled can be complex and easily misunderstood.

B. History of Water Use in the San Luis Valley

1. Agriculture

A summary of the history of agricultural development and water use in the San Luis Valley is presented by Hearne and Dewey (1988) and is reprinted here for reference;

> "Development of irrigated agriculture in the Alamosa Basin has undergone five basic changes: (1) Extensive diversion of surface water started about 1880; (2) development of confined ground water started about 1840; (3) a shift of irrigated areas from the center of the Alamosa Basin to the west was completed by about 1910; (4) ground water withdrawals by large-capacity irrigation wells (greater than 300 gallons per minute) became significant about 1950; and (5) extensive irrigation by sprinkler systems started about 1970.
>
> The Alamosa Basin has been used for irrigated agriculture since at least the 1630's when the Spanish settlers arrived. However, prior to about 1880, irrigated acreage was small. An extensive network of canals was constructed during about 1880-90 to divert water for irrigation. By 1904, all streams entering the basin were appropriated for irrigation. Irrigation was concentrated in the central part of the Alamosa Basin northeast of Monte Vista, Colo.
>
> Water from confined aquifers in the Alamosa Basin has been used since 1887. Although the number of wells completed in confined aquifers increased, through the 1930's discharge primarily was from small-capacity flowing wells; only two large-capacity, pumped wells completed in confined aquifers were used for irrigation during 1936 (Powell, 1958).

The main concentration of irrigated areas shifted from the center of the Alamosa Basin to the western side (Powell, 1958). Crops were subirrigated by applying enough surface water to raise the level of the water table to the root zone of the growing crops. Higher water levels resulted in waterlogging in the lower areas to the east. Increased evapotranspiration from areas where the water table is near the surface resulted in alkali damage to some areas. Lands to the east were abandoned, and irrigated agriculture shifted to higher land to the west. By about 1910, agricultural areas in the center of the basin were out of production, and irrigation was concentrated on the western side of the Alamosa Basin on the Rio Grande fan.

Extensive development of ground-water resources for irrigation began about 1950 Continued artificial recharge by subirrigation, canal leakage, and flow from wells completed in confined aquifers increased the volume of water stored in the unconfined ground-water reservoir, raising water levels on the western side of the Alamosa Basin by 50 to 100 feet (Powell, 1958). This ground-water resource was developed when the supply of surface water decreased during the drought of the 1930's. However, the rate of ground-water withdrawal was small compared to the rate of withdrawal after 1950 (Emery and others, 1972). The rate of withdrawal from confined aquifers also increased; Powell (1958) reported 61 large-capacity pumped wells completed in confined aquifers.

Irrigation with sprinkler systems became common during the 1970's. The total number of sprinkler systems increased from 262 in 1973 to 1,541 in 1980 (Davis Engineering Service, Inc. 1981). Most sprinklers irrigated a quarter section (about 160 acres). The greatest density of sprinkler systems was on the Rio Grande fan north of the river: Townships 39N to 41N and Ranges 7E to 9E (pl. 1). Diversions from surface water and water withdrawn from wells in both unconfined and confined aquifers can supply water for sprinklers."

It should also be noted that along with the development of wells for agriculture, ground water is the primary source for drinking water in the Valley. While Alamosa, Monte Vista and most other communities receive their drinking water supplies from deep wells in the lower aquifer, it is estimated that more than 80 percent of the individual domestic drinking water wells are drilled in the upper aquifer (Davey, 1994).

With the increase in agriculture came an increase in the use of agricultural chemicals. High nitrate concentrations in parts of the Valley have been blamed on the heavy applications of chemical fertilizer (Emery *et al.*, 1973). One undocumented source of nitrates in the soil and ground water is the use of sheep manure, particularly around the town of Center. Around the Second World War, local residents were known to fill trailers with sheep manure and distribute it on agricultural fields (Curtis, 1994). It seems unlikely that this manure application affects ground water quality 50 years later, although it is not known how long and to what extent the practice was continued after the war.

2. Water Development

At the same time that agriculture was developing in the San Luis Valley, there had been problems since the late 19th century with Mexican government complaints that the United States was not delivering historical water supply through the Rio Grande. Much of the blame was placed on the development of water diversion and irrigation in the San Luis Valley. Eight major irrigation drains were constructed in the Valley to reclaim 90,000 acres of land that were waterlogged and the Elephant Butte Reservoir was constructed in 1916 in order to help deliver 60,000 acre feet of water per year to Mexico as required by the Treaty of 1906 (Elfrink *et al.*, 1989). Still, problems persisted.

Studies dating back to the early 1900's suggested that 60,000 acre feet of water lost to evapotranspiration in the sump area of the closed basin might be salvaged (Elfrink *et al.*, 1989). In light of these legal problems with water supply that persisted through the 1970's, the Reclamation Project Authorization Act of 1972 (PL 92-514) authorized the construction of a project "...for the principal purposes of salvaging, regulating, and furnishing water from the closed basin area of Colorado..." Water from the project would be used for: (1) assisting in meeting the delivery required by the Rio Grande Compact at the streamflow gaging station on the Rio Grande near Lobatos, Colorado, (2) maintaining two wildlife refuges in Colorado, (3) eliminating any deficit in deliveries by Colorado, and (4) irrigation or other beneficial uses in Colorado (Hearne and Dewey, 1988). This is informally known as the Closed Basin Project. It consists of a series of 170 salvage wells completed in the unconfined aquifer only, along with 82 observation wells (Elfrink *et al.*, 1989). These wells are expected to supply about 101,800 acre feet per year of ground water to the Rio Grande (Leonard and Watts, 1988). A series of pipes direct the pumped water to a conveyance channel that will deliver the water to the Rio Grande. Some water will also be diverted to the Alamosa National Wildlife Refuge and the Blanca Wildlife Habitat Area.

C. Previous Ground Water Quality Studies in the San Luis Valley

Many agencies have performed studies of the ground water quality in the San Luis Valley, including;

- Colorado Department of Health
- Colorado State University
- U.S. Geological Survey
- Agro-Engineering, Inc.

The bulk of this work has emphasized monitoring nitrate concentrations in the upper aquifer, although concentrations of other anions and cations, pesticides, and silica, as well as specific conductance and pH have also been measured. Some of the more salient conclusions from these studies as well as other monitoring programs outside the San Luis Valley are provided below;

- The key contaminant in the upper aquifer of the San Luis Valley is nitrates (Thompson, 1993; Ellis and Levings, 1994). Pesticides do not currently appear to be any more than very localized problems, and no drinking water supplies appear threatened. Other than that caused by natural processes, particularly hydrothermal, the confined aquifer is not affected by pollutants. Many parts of the Valley, particularly in the Closed Basin, do show significant concentrations of sodium and other ions from natural sources as well as evapotranspiration of irrigation water (Emery, 1973; Glanzman, 1989).
- The primary area of concern for high nitrate concentrations appears to be concentrated about or just to the south of Center, with observed levels of more than 30 mg/L as N (Edelmann and Buckles, 1984). There is some evidence that nitrate levels have been increasing, at least during a 1984 to 1992 study period (Thompson, 1993).

- Significant seasonal variation of nitrate levels do occur in shallow ground water sampling (Eddy-Miller, 1993). The BMP analysis by Eddy-Miller (1993) shows substantial variation of nitrate levels in shallow ground water wells on a weekly basis, and very large variations from one month to the next during the growing season. This suggests sampling frequency for BMPs should be at least quarterly and preferably monthly if seasonal maximums and minimums are of interest.
- Based on Spooner *et al.* (1991) BMP monitoring requires long-term monitoring (6 to 10 years) for trend determination.
- Nitrate concentrations decrease with increased sampling depth in the shallow upper aquifer. (Edelmann and Buckles, 1984).
- Nitrates introduced into the soil during a season may not show a significant impact on the ground water nitrate levels until at least the next season (Eddy-Miller, 1993). Also, nitrate levels in the applied irrigation water and in the soil are a significant source of the overall nitrogen available for leaching (or plant uptake). This must be taken into account in any study of spatial or temporal trends.
- Results from contamination vulnerability models indicate that the upper aquifer is highly susceptible to contamination (Durnford *et al.*, 1990).
- Water in the lower, confined aquifer is generally of very high quality, as it appears to be isolated from most anthropogenic sources. Sampling from wells completed in the lower aquifer show concentrations of nitrite plus nitrate at less than 1 mg/L as N (Edelmann and Buckles, 1984).

Additionally, there are only a few areas where significant demineralization results in high mineral levels, although low levels of arsenic have been detected in drinking water wells for the town of Alamosa (Davey, 1994). Due to the high quality of the water in the confined aquifer, it is an excellent source of drinking water for the Valley.

It is recommended that a long-term, regional study of nitrate levels in the San Luis Valley should be pursued (Thompson, 1993; Durnford *et al.*, 1990). The use of shallow monitoring wells and drinking water wells is recommended, with clear documentation of the placement, depth, and screening depth of the well being necessary for data that will yield useable information (Durnford *et al.*, 1990; Thompson, 1993). Also, BMP analysis should be carried out over an extended period of time, with at least two to three years of pre-BMP implementation baseline data, and an equal time period for post-BMP implementation (Spooner *et al.*, 1991). The most effective method for BMP analysis is the paired watershed or nested watershed design (Spooner *et al.*, 1991). Also, the use of ^{15}N isotope testing may be used to determine if a source of nitrates is generated by fertilizers or animal waste (McMahon *et al.*, 1993).

D. General Approaches to Monitoring System Design

1. Historical Review of Monitoring Design Development

While most previous ground water quality monitoring performed in the San Luis Valley has been driven by specific laws and/or problems, there is a separate body of knowledge developing on the topic of water quality monitoring system design. It is from this knowledge that some of the procedures used in this study have been derived. Monitoring system design "theory" tries to tie management decision-making (generally legally mandated) to monitoring system design. Over the years a number of researchers have supported "steps" that lead to a well designed water quality monitoring system. These researchers point out that if some rationale is not used to define this design of a monitoring system, the resulting data often fails to provide the desired information. It has only been in the past 30 to 40 years that any significant work has been done to develop systematic approaches to monitoring system design. The reason for this is that water quality monitoring has traditionally been a regulatory-driven field; that is, the need for a monitoring system has typically been defined by water quality law. But such laws have proliferated only in the last three decades or so; hence the field of water quality monitoring system design is a relatively new one. This legislative call for monitoring is discussed further in Chapters IV and V.

Many have contributed to the development of current thinking on the steps required to design a monitoring system. A discussion of this may be found in Ward *et al.*, 1990. Sanders *et al.*, 1979 suggested 12 steps in the design process;

1) Determine monitoring objectives and relative importance of each;

2) Express objectives in statistical terms;

3) Determine budget available for monitoring and amount allocated for each objective;

4) Define the characteristics of the area in which the monitoring is to take place;

5) Determine water quality variables to be monitored;

6) Determine sampling station locations;

7) Determine sampling frequency;

8) Compromise previous objective design results with subjective considerations;

9) Develop operating plans and procedures to implement the network design;

10) Develop data and information reporting formats and procedures;

11) Develop feedback mechanisms to fine tune the network design; and

12) Prepare a network design report.

In 1983, Sanders *et al.*, reduced the number of steps to five, but the first step still reflects the need for defining monitoring objectives: "Evaluate information expectations." Schilperoort and Groot (1983) also listed five steps; again, the first step was similar:

> "The monitoring objectives should be identified and quantified, including the definition of an effectiveness measure. This step, while being the most important step, is also a very difficult one. In general, these objectives include the estimation of the present quality state, the detection of long term trends, the detection of standards violations, and model studies."

The remaining steps proceed to qualify the design of the system on the basis of environmental, statistical, and economic limitations. In listing the tasks required for the design of a national water quality network for New Zealand, Smith *et al.* (1989) lists the first step as: "Develop the goal and objectives of the network." Ward *et al.*, 1990, state that "...the framework for design of water quality information systems begins with quantifying the information required by management and quantifying the information that the monitoring system is capable of producing." The comment is made that these two segments often are not entirely compatible.

The exact methods by which this information will be obtained are referred to as the Data Analysis Protocols (DAPs). These are discussed in Ward and Loftis (1989) and Ward *et al.* (1990) and are developed in detail by Adkins (1993). The particular topics that should be addressed in a DAP are described by Adkins as;

- Identification of information goals.
- Handling of data record attributes.
- Graphical presentation of data.
- Choice of data analysis methods.
- Interpretation of results.

- Information reporting.
- Protocol revision.

Again, the identification of information goals is the first step.

2. Defining Information Goals

From this discussion of the historical development of monitoring design, it appears generally accepted that the first step in designing a monitoring system is to clearly define the information goals of the system, tempered by the reality of what that system can actually produce. Typically, the information goals are defined by the laws that trigger the "construction" of the monitoring system; e.g. in the case of the closure of a hazardous waste site, the Resource Conservation and Recovery Act (RCRA) regulations specify where and for how long monitoring is to be performed. Alternatively, an agency may perform monitoring of a specific region for a perceived public health threat, such as contamination of ground water by pesticides. Finally, there are monitoring surveys such as the National Water Quality Assessment (NAWQA) program operated by the U.S. Geological Survey and the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP). These seek to characterize the overall water quality and sources of contamination for specific regions and the United States as a whole. The point to be made here is that the information goals are fairly well-defined in all of these programs, either by the laws requiring monitoring or by the agency that decided the monitoring was necessary.

In the case of the San Luis Valley, many different monitoring programs have collected water quality information in the past, each for specific laws with specific information goals. But the purpose of this paper is not to address a singular problem or goal; instead, it attempts to extrapolate multiple goals from the laws, regulations, and various parties concerned with the quality of the ground water in the Valley. Thus, this paper serves to inform the people of the San Luis Valley as to the legal and regulatory calls for monitoring as well how their own information needs translate into monitoring goals. This is not crisis management, and it is not water quality characterization; it is the generation of that information that the people of the Valley need in order to manage their resources, given that many laws impact on this management of the ground water. Thus, the information goals must be determined by another means, a means that does not seem to be addressed in any detail in the literature. The challenge of this research will be to define a methodology for determining those information goals.

3. The Integrated Water Quality Monitoring System

The function of a regional ground water quality monitoring system for the San Luis Valley is best given by the diagram in Figure 2.1. This is the "wheel and axle" framework for an integrated monitoring system as described by Payne and Ford (1988) and Pollack and Ford (1989). This was originally used to describe the Temporally Integrated Monitoring of Ecosystems (TIME) program developed by the U.S. Environmental Protection Agency (USEPA) for

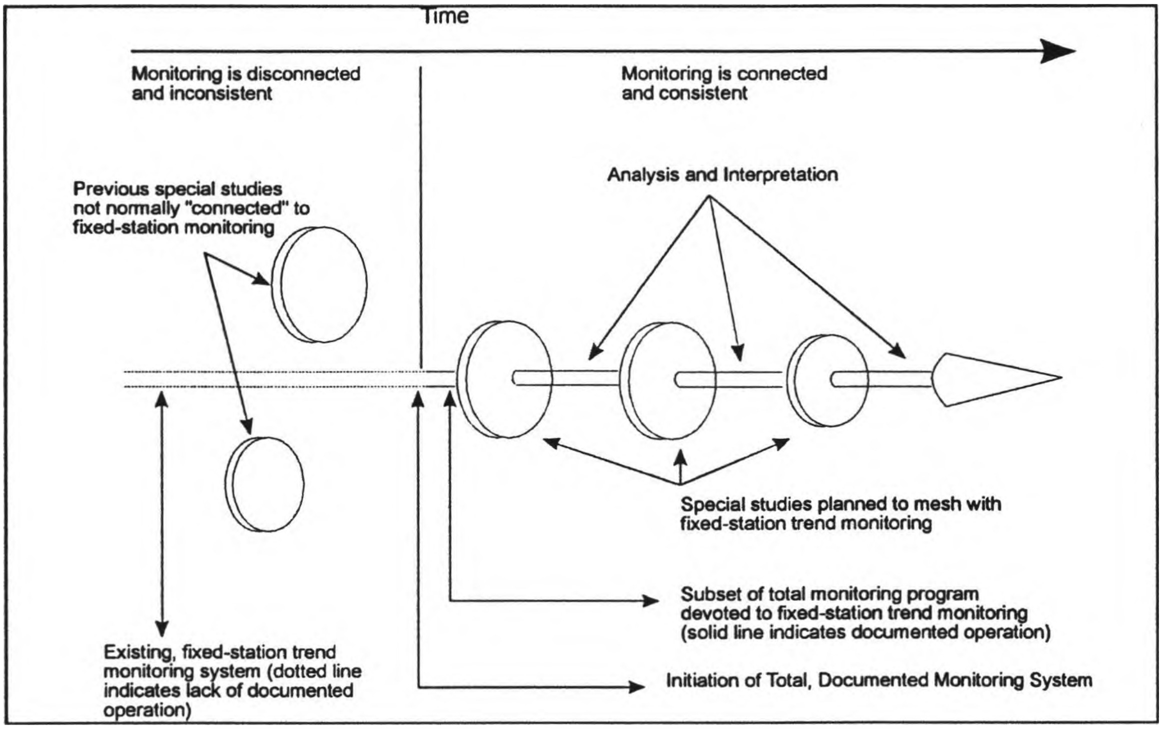

Figure 2.1. The conceptual "wheel-and-axle" design for a fully integrated water quality monitoring system (after Payne and Ford, 1988).

measuring the impacts of acid precipitation. The axle is the long-term trend monitoring part of the system, with the wheels representing special studies that are logically attached to the long-term subsystem. Special studies, in the case of an agricultural area like the San Luis Valley, would include Best Management Practices (BMP) monitoring, pesticide detection, or spatial mapping of a particular contaminant. "Attaching" these special studies to the axle means that each special study is coordinated with existing fixed sites as well as sites from previous special studies. In this way, data from one "wheel " can be correlated with another as well as the long-term "axle" sites.

The other key component to this design that holds the wheels and the axle together is analysis and interpretation of data. A monitoring goal of trend detection requires an objective form of measurement. Simple data collection cannot answer this question; the data must be analyzed through statistical methods. Specific, standardized statistical methods can be used to either measure the magnitude of the trend (estimation) or test to determine the confidence level that there is in fact a trend (hypothesis testing) (Ward *et al.*, 1990). The latter is sometimes also referred to as determining if there is a "significant" trend. The use of statistics (and related graphical analysis) is therefore the key to taking raw data and producing information that can be used to further develop the monitoring system and/or assist water quality managers in the decision-making process.

Although many separate monitoring programs have been performed in the Valley, they were not designed to "fit together" as this wheel-and-axle integrated design does. For example, data from Emery *et al.* (1973) cannot be directly compared to Edelmann and Buckles (1984) for trend determination (Ellis and Levings, 1994). That is the key difference between these previous monitoring studies and this research. By carefully designing the axle, wheels can be attached from the outset or at a later date as data is analyzed and/or information goals change.

CHAPTER III

METHODS

In order to achieve the objective of generating the Integrated Information Goals as defined in chapter one, it is necessary to examine, through the review and identification of federal, state and local laws, regulations, implementing agencies and concerned groups, the current structure of nonpoint source pollution management with respect to ground water quality in the San Luis Valley. As mentioned in Chapter II, there is no clear regulatory or popular mandate that dictates the information goals for a regional water quality monitoring system for the San Luis Valley. Additionally, the review of monitoring systems design and implementation gives little assistance in providing a methodology for determining these goals when they are not expressly given by said regulation or mandate. Therefore, a method had to be developed to determine these information goals. The steps used in this study are:

A) Through literature review and interviews of water quality managers, identify the relevant laws, regulations, and concerned parties with respect to water quality management in the San Luis Valley, including:

1) Federal legislation, especially the nonpoint source provisions of the Clean Water Act, and the Safe Drinking Water Act;

2) Colorado legislation, especially SB90-126, SB89-181 and the Water Quality Standards for Ground Water;

3) Concerns and needs of the residents and businesses in the Valley;

4) Concerns and needs of those using the water in the Valley; and

5) Any other regulations or concerns encountered during the system development.

B) Read through the laws and regulations, paying particular attention to implications for the need to know the quality of ground water.

C) Study the roles of concerned parties with respect to water quality management in the Valley.

Based on this review, information goals are defined for a monitoring design for the San Luis Valley. The procedure for defining these goals is:

A) Determine the relevance of the previously discussed laws and regulations to the San Luis Valley.

B) Synthesize information goals for each set of laws, regulations, and concerned parties, using similar language for similar information goals.

C) Combine similar information goals into new ones that encompass all the information needs previously determined.

D) Through interviews and questionnaires, ask these same agencies and parties involved in water quality management how well these goals reflect their own monitoring goals.

E) Utilize the feedback from these interviews and questionnaires to modify (if necessary) the information goals in order to incorporate the changes recommended by the various agencies.

Finally, the Integrated Information Goals are specified that are needed to support ground water quality management in the San Luis Valley:

A) Develop a framework for the Integrated Information Goals (IIGs).

B) For each of the final information goals, present specific Integrated Information Goals that address all the information needs from the laws and concerns that generated each goal.

CHAPTER IV

CURRENT GROUND WATER QUALITY MANAGEMENT STRUCTURE

A. Federal Laws and Regulations

1. Federal Authority

While reviewing the laws and regulations covering water quality and pollution control it becomes apparent that the federal government has taken the leadership role, with state and local laws largely reactive to federal legislation. Because of this, the issue of federal authority to regulate water pollution needs to be addressed. It is noted that many of these federal acts use the term "navigable waters," a reference to the commerce clause, Article 1, Sec. 8, Clause 3 of the U.S. Constitution, which grants Congress power "(t)o regulate commerce with Foreign Nations, and among the several States..." The term "navigable waters" is therefore used in the context of interstate commerce.

How, then, does this justify federal legislation controlling water quality in non-navigable streams, irrigation ditches, or ground water? In Quivira Mining Co. versus United States, 765 F.2d 126 (10th Cir. 1985), the EPA argued that a uranium mining facility should be required to hold an NPDES permit to discharge waste into a settling pond, and eventually to a reservoir. The court ruled that pollutants could migrate through underlying aquifers into non-navigable waterways and eventually reach a navigable stream, upholding the

EPA's position. Through this logic, it is apparent that federal authority to legislate surface and ground water quality controls is virtually complete.

In similar decisions, even this issue of navigability is deemed as extraneous. In United States versus Ashland Oil and Transportation Company, 504 F.2d 1317 (6th Cir. 1974), the oil company had not reported an oil spill into a non-navigable tributary of the Green River in Kentucky. The court upheld the Congress' power to control water pollution in such waters:

> "The government in this case, however, pins its argument primarily upon the wider concept that water pollution is subject to Congressional restraint because it affects commerce in innumerable ways and because it affects the health and welfare of the nation, Wickard vs. Filburn, 317 U.S. 111, 63 S. Ct. 82, 87 L. Ed. 122 (1942). The statute lends some weight to the government's argument by its many references (some of which have been quoted above) to aspects of pollution control which have no possible direct bearing on navigability. Congressional concern in the 1972 Act with the impact of pollution upon fishing for commercial purposes or upon bathing and fishing and boating for recreational purposes of interstate travelers, and for the needs of towns, cities, industries and farms for unpolluted water for both health and commerce supports this broader concept. Congress, as indicated above, intended to exercise its full constitutional powers, and we are required to give effect to that intention."

2. Overview of Federal Laws and History

The issue of maintaining "navigable waters" controlled most water quality legislation until the middle of this century. Often cited as the first federal water pollution control act, the Rivers and Harbors Act of 1899 was actually designed to prevent nuisances to navigation (Anderson *et al.*, 1990). This also was the first call for some form of water quality monitoring, although primitive. In the early 1900's, pollution control was mostly a matter of removing foul odors or debris from the waterways. The first federal standards that applied to drinking water were issued in 1914, but were only legally binding on water suppliers used by interstate carriers (Pontius, 1993). In 1948, the first federal water quality control act was signed, followed in 1956 with the Federal Water Pollution Control Act (PL 84-660), a reauthorization of the 1948 act. This was significant in that it mandated, for the first time, a water quality monitoring system. In the 1965 Federal Water Quality Act (PL 89-234), states were required to monitor water quality and set up commissions and standards. The 1972 Amendments to Federal Water Pollution Control Act (PL 92-500), or as it is now called, the Clean Water Act (CWA), stated the goal "that the discharge of pollutants into navigable waters be eliminated by 1985" (Sec. 101, 33 U.S.C., Sec. 1251). Although not specifically stated, this obviously referred to point sources of pollutants. To this end, the law established the National Pollutant Discharge Elimination System (NPDES), which defined discharge permitting; this resulted in the need for extensive discharge monitoring. Additionally, Sec. 305(b) required states to generate reports every two years describing water quality for all navigable waters within the state, effectively mandating some form of stream monitoring . Although not the exclusive thrust of the 1972 Act, end-of-the-pipe controls were the primary emphasis (Anderson *et al.*, 1990).

It should be apparent that throughout this history, most water quality law was aimed at point-source pollution and surface water quality. Section 208 of the 1972 CWA attempted to address non-point source pollution, but was largely ineffective due to erratic federal funding, lack of data, and intergovernmental conflicts at the regional level (Anderson *et al.*, 1990). Section 319, added by the Water Quality Act of 1987, was intended to remedy this problem by identifying state waters threatened by nonpoint pollution sources and using voluntary "best management practices," or BMPs, to mitigate agricultural source pollution. These BMPs are typically agricultural practices and procedures designed to mitigate the pollution of surface and ground waters by agricultural chemicals. This continues to be the basis for most nonpoint pollution prevention activity, although Section 6217 of PL101-508 augments the CWA by addressing the problems of runoff in coastal waters.

3. The 1972 Act and Section 208

As mentioned above, the 1972 Amendments to the Federal Water Pollution Control Act (PL 92-500) or, as it is now called, the Clean Water Act, represented the first federal attempt at addressing the complex problem of non-point source pollution. Section 208 of the act was written specifically to this purpose. This section utilized an aggressive timetable to move the states to compliance, as defined by the following subsections:

> "(a)(2) The Governor of each State, within sixty days after publication of the guide lines issued pursuant to paragraph (1) of this subsection, shall identify each area within the State which, as a result of urban-industrial concentrations or other factors, has substantial water quality control problems. Not later than one hundred and twenty days following such identification and after consultation with appropriate elected and other officials of local governments having jurisdiction in such areas, the Governor shall designate (A) the boundaries of each such area, and (B) a

> single representative organization, including elected officials from local governments or their designees, capable of developing effective area wide waste treatment management plans for such area. The Governor may in the same manner at any later time identify any additional area (or modify an existing area) for which he determines areawide waste treatment management to be appropriate, designate the boundaries of such area, and designate an organization capable of developing effective areawide waste treatment management plans for such area.
>
> (b) (1) (A) Not later than one year after the date of designation of any organization under subsection (a) of this section such organization shall have in operation a continuing areawide waste treatment management planning process consistent with section 201 of this Act. Plans prepared in accordance with this process shall contain alternatives for waste treatment management, and be applicable to all wastes generated within the area involved. The initial plan prepared in accordance with such process shall be certified by the Governor and submitted to the Administrator not later than two years after the planning process is in operation.

The plan referred to in subsection (b) (1) (A) is further defined in subsection (b)(2). Among these requirements are those to identify non-point sources due to various anthropogenic causes:

> "(F) a process to (i) identify, if appropriate, agriculturally and silviculturally related nonpoint sources of pollution, including return flows from irrigated agriculture, and their cumulative effects, runoff from manure disposal areas, and from land used for livestock and crop production, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources;
>
> (G) a process of (i) identify, if appropriate, mine-related sources of pollution including new, current, and abandoned surface and underground mine runoff, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources;

> (H) a process to (i) identify construction activity related sources of pollution, and (ii) set forth procedures and methods (including land use requirements) to control to the extent feasible such sources;
>
> (I) a process to (i) identify, if appropriate, salt water intrusion into rivers, lakes, and estuaries resulting from reduction of fresh water flow from any cause, including irrigation, obstruction, ground water extraction, and diversion, and (ii) set forth procedures and methods to control such intrusion to the extent feasible where such procedures and methods are otherwise a part of the waste treatment management plan;
>
> (J) a process to control the disposition of all residual waste generated in such area which could affect water quality; and
>
> (K) a process to control the disposal of pollutants on land or in subsurface excavations within such area to protect ground and surface water quality."

Further, subsection (j)(1) refers to the implementation and evaluation of Best Management Practices (BMPs).

> "The Secretary of Agriculture, with the concurrence of the Administrator, and acting through the Soil Conservation Service and such other agencies of the Department of Agriculture as the Secretary may designate, is authorized and directed to establish and administer a program to enter into contracts of not less than five years nor more than ten years with owners and operators having control of rural land for the purpose of installing and maintaining measures incorporating best management practices to control nonpoint source pollution for improved water quality in those States or areas for which the Administrator has approved a plan under subsection (b) of this section where the practices to which the contracts apply are certified by the management agency designated under subsection (c)(l) of this section to be consistent with such plans and will result in improved water quality."

BMPs are a non-technology based equivalent to the Best Available Technology (BAT) practices that the Clean Water Act used for abatement of point source discharges. However, whereas the National Pollutant Discharge Elimination System (NPDES) used mandatory BAT's for specified dischargers, the BMP regulations were strictly voluntary.

The major elements of Sec. 208, then, are the appointing of a state agency for implementation of the requirements of the act, a state plan for mitigation of non-point source pollution, and the funding of voluntary BMPs to determine the most effective ways to prevent said pollution. This would seem to be a rational and workable approach; but as described in Anderson *et al.*, 1990, this was not to be the case:

> "...The Sec. 208 mandate is a monument to systematic, rational processes. Based on a correct assessment of water quality problems, Sec. 208 proceeds relentlessly to specify logical solutions: build treatment capacity only where needed; issue NPDES permits only where water quality will be protected; use appropriate non-technology-based land use controls to curtail non-point urban, agricultural, construction, and silvicultural runoff; attack needs on a "problem-shed" basis. But the Sec. 208 program is at odds with two major premises that underlie the federal water pollution control program. First, Sec. 208 planning was delegated to regional agencies rather than to the state agencies responsible for administering the NPDES program. Second, Sec. 208 introduced a planning process at odds with the technological pollution control requirements Congress mandated to clean up the nation's waters. Hostility to the program inside EPA and a number of implementation problems weakened the Sec. 208 planning effort. These problems included the short time frame allowed for the planning process, erratic federal funding, lack of adequate data, and intergovernmental conflicts at the regional level. State water pollution control agencies objected to the delegation of authority at the regional level and ultimately convinced EPA to allow the state agencies to

> exert substantial control over the regional water quality planning process...
>
> ...Regional Sec. 208 agencies did address non-point water pollution problems, but non-point source pollution is politically difficult to remedy. Legislative authority for non-point pollution control often is either nonexistent or inadequate...
>
> ...Despite these difficulties, EPA responded to congressional criticism late in the Carter Administration by redirecting the program to non-point pollution problems. All of the Sec. 208 plans have now been approved, but the program seemed finished as both the Carter and Reagan Administrations recommended termination. Congress rescued it in 1981 with continued funding, but the program is currently moribund..."

4. The 1987 Amendments and Section 319

In response to the failure of Sec. 208, the Water Quality Act of 1987 introduced section 319. This is again described in Anderson *et al.*, 1990;

> "The Water Quality Act of 1987 mounts a new non-point source initiative. The Act establishes a national policy to control non-point sources of pollution "in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and non-point sources of pollution." H.R. Conference Report No. 1004, 99th Cong., 2d Sess. 143 (1986). Section 319 requires that states identify waters threatened by non-point sources of pollution and prepare four-year watershed-based management programs to control non-point source pollution. The 319 program is linked to neither the water quality planning programs nor the water quality standards maintenance program. Four hundred million dollars is authorized over four years for state grants to implement agricultural and urban non-point source management programs. EPA approval is subject to vigorous deadlines. The program must identify the BAT management practices that the state will adopt, including the regulatory and non-regulatory programs, and establish a schedule containing annual milestones. The Act returns to the 1960s concept of the

management conference to deal with interstate non-point source pollution."

Key elements to Sec. 319 include;

a) State Assessment Reports (subsection [a]): these include identification of "navigable waters" which require nonpoint source controls in order to meet water quality standards; identification of nonpoint sources contributing to the above non-attainment of quality standards; the processes and programs to be used to identify and carry out appropriate BMPs

b) State Management Programs (subsection [b]): identification of BMPs, programs to implement BMPs, a schedule for implementation milestones, and identification of federal assistance and funding programs

c) Grants for Implementation of Management Programs (subsection [h]): "...the Administrator shall make grants ... under this subsection to such State for the purpose of assisting the State in implementing such management program..."

d) Grants for Protecting Groundwater Quality (subsection [i][1]):

   "...the Administrator shall make grants under this subsection to such State for the purpose of assisting such State in carrying out groundwater quality protection activities which the Administrator determines will advance the State toward implementation of a comprehensive nonpoint source pollution control program. Such activities shall include, but not be limited to, research planning, groundwater assessments, demonstration programs, enforcement, technical assistance, education and

> training to protect the quality of groundwater and to prevent contamination of groundwater from nonpoint sources of pollution..."

The use of "Section 319 money" under these grants is discussed further in subsequent sections of this paper. It is this provision that has generated many different monitoring programs since the passage of this act. The difficulty has been the lack of coordination in information gathering and sharing from the various 319 projects. Each project acts autonomously from the others, with no incentive for adding its data or conclusions to a larger database (Austin, 1993). State officials attempting to put together a monitoring program, for example, may not have timely access to valuable retrospective information gathered (at some expense) by a water conservancy district. Despite the establishment of national water quality databases (e.g., STORET, WATSTORE) this remains a problem.

5. Antidegradation

In the 1987 Amendments to the Clean Water Act, Sec. 1313(d)(4)(B) presents the non-degradation policy for state streams. This policy contains three key parts:

a) Existing instream water uses; all waters must be protected from degradation that would cause them to no longer meet their current use standards

b) Existing water quality; those waters that currently exceed the standards for the use designated must be maintained at that higher level of water quality. The social and economic implications of this policy will be taken into account in allowing degradation to the minimum standards that will still maintain existing uses.

c) Outstanding national resources; high quality waters in national or state parks or other exceptional waters must be managed so as to maintain water quality.

It is apparent that this policy refers to surface water; use standards are typically defined in terms of recreation and fish habitat. However, that the law does not specifically include ground water does not preclude applying antidegradation policy to ground water either. In a subsequent section, an analysis of the Code of Colorado Regulations will indicate Colorado's approach to ground water antidegradation (5CCR 1002-8, 3.12.0 *et seq.*).

Additionally, Heineck (1989) points out that section 304(l) of the 1987 Act requires that states must develop lists of waters that have impaired water quality despite the use of appropriate discharge controls and technology. For these waters, the state is to develop "individual control strategies" to bring these waters into compliance. This strategy is to be used "in combination with existing controls on point and nonpoint sources" Sec. 304(l)(1)(D). Additional controls may be placed on point or nonpoint sources as the state sees fit. With the increasing cost of point source technology, there is the issue of "...possible collision between point sources and nonpoint sources as to where additional toxics controls should be placed." (Heineck, 1989). An increased emphasis on the hydrologic link between ground and surface water would likely tie these two waters together in an integrated policy on antidegradation and water quality standards compliance.

6. RCRA/CERCLA

A comprehensive ground water monitoring program is not specifically called for under sections 208 and 319 of the CWA. In fact, it is primarily the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) that contain language calling specifically for ground water monitoring. RCRA is often referred to as a "cradle to grave" system for handling hazardous wastes (Anderson *et al.*, 1990). It calls for monitoring of ground water at the periphery of any disposal site. Identification of any off-site contamination can trigger a CERCLA response. CERCLA, or Superfund, requires that contaminant be removed from soils and ground water both inside and outside of the offending site. Again, ground water and vadose zone monitoring are performed in the pursuit of this goal.

One of the key issues in Superfund cleanups is "How clean is clean"? Gutter (1989) discusses EPA policy on this matter. The use of MCLGs (maximum contaminant level goals) or the less stringent MCLs (maximum contaminant levels) have been borrowed from the Safe Drinking Water Act as definitions for "clean". Congress has shown preference for the more restrictive MCLGs: "(R)emedial action shall require a level or standard of control which at least attains Maximum Contaminant Level Goals established under the Safe Drinking Water Act...where such goals...are relevant and appropriate under the circumstances of the release or threatened release." 42 U.S.C. Sec. 9621(d)(2)(A). This might require clean up levels to below background in many circumstances. The difficulty of cleaning an aquifer contaminated, for example, by dense non-aqueous phase liquids means that monitoring might have to continue for a very long time.

Obviously, RCRA and CERCLA are applied to point source problems only. What should be noted here is the use of SDWA standards for the definition of clean. Again, Anderson *et al.*, 1990 points out:

> "There are no national groundwater aquifer standards. The federal Environmental Protection Agency sets only end of the tap drinking water standards. The agency has set maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs). The former take into account both health and technical feasibility; the latter are set at a level, often zero, at which there will be no harmful health effects. States have relied upon these standards to establish groundwater standards."

The implication for future controls on nonpoint source pollution into aquifers would seem to be that these same standards would be used to define management policy.

7. The Safe Drinking Water Act (SDWA)

The Safe Drinking Water Act was enacted to ensure the safety of public drinking water systems. It does this primarily by defining "maximum contaminant levels", or MCLs, for a wide variety of contaminants in drinking water. The definition of a regulated water supplier under this Act is mirrored in the Colorado Primary Drinking Water Regulations. Discussion of that definition is provided in this paper under the section dealing with the Colorado law. The primary role of the EPA in this Act has been to determine and promulgate such MCLs. Alternatively, section 1412(b)(7)(A) allows the EPA Administrator to promulgate rules requiring the use of a given treatment technique in the event that determining MCLs for a contaminant would be economically or technologically infeasible.

SDWA is an "at the tap" regulation that is primarily concerned with water quality at the point of use. There is, however, a "Sole Source Aquifer Demonstration Program" in Section 1427 which gives procedures for "...development, implementation, and assessment of demonstration programs designed to protect critical aquifer protection areas designated as sole or principal source aquifers..." Subsection (a). There is, therefore, the recognition that for ground water supplied systems aquifer protection is drinking water protection, particularly when there is no advanced treatment train utilized. Additionally, whereas streams tend to be more accessible to clean-up and somewhat self-cleaning after a spill or discharge is eliminated, aquifers can be extremely difficult to clean up. Thus, advanced treatment trains or an alternative drinking water source are almost always required, resulting in great cost to either the water supplier and users or the polluter, or both.

Due to the MCL standards, SDWA has had a significant impact on other water quality programs, such as that previously noted in the discussion of

RCRA and CERCLA. Whenever water quality standards must be established for a clean up program, streams, lakes, or aquifers, these are often referenced to or set at the MCLs. The technical feasibility of attaining MCLs (particularly difficult in cleanup actions) is usually secondary to the desire for safe drinking water, whether the water will be put to such use or not. Alternative standards would require a comparison standard, such as the EPA's 10^{-6} lifetime cancer risk for carcinogens. But what comparison standard should be used for cleaning up an aquifer that is currently used for irrigation only? Should it still be clean enough to drink 1 liter per day? Two liters per day? What about physical contact? The complexity of answering all the possible questions for all possible scenarios makes the use of MCLs a safe and conservative choice for the regulatory body involved. The primary effect of the SDWA in ground water monitoring tends to be the influence on regulations that deal specifically with ground water protection.

8. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

The Federal Insecticide, Fungicide, and Rodenticide Act, or FIFRA, is a set of licensing regulations for pesticides requiring that they not cause unreasonable damage to the environment when used according to EPA restrictions. The definition of unreasonable is dependent on the benefits of using the pesticide versus the environmental and human health risk. In spite of this, EPA views this consideration of benefits as irrelevant except in isolated and unique cases (Lewis and Berry, 1989). This is likely due to the underlying purpose of FIFRA; not to license pesticides, but to protect ground water.

Pesticides were first regulated in 1910 to prevent consumer fraud from bogus chemical constituents. In 1947, FIFRA was passed requiring the Department of Agriculture to register pesticides to ensure that proper labeling would prevent injury to those using the chemicals. In 1964, an amendment to FIFRA called for the suspension of any pesticide that created an "imminent hazard." The first cancellation of a pesticide by EPA was that of DDT, following the failure of the Secretary of Agriculture to do so when that agency administered FIFRA. In 1972, Congress amended FIFRA with the Federal Environmental Pesticide Control Act (FEPCA). This provided a detailed procedure for the registration, restricted registration, cancellation, and suspension of a pesticide license.

The relationship of FIFRA to ground water quality monitoring is seen in comments made by Lewis and Berry, 1989:

> "EPA's proposed strategy for addressing pesticides in groundwater articulates several basic principles that intends to adopt in regulating individual chemicals. EPA decided, for example, that it will adopt a differential approach, under which the degree of protection will depend upon the use of the ground water in question; EPA will give priority to protecting groundwater that is a current or potential drinking water source or that is critical to a fragile ecosystem. As the primary reference point for determining the specific goals to be achieved by prevention measures or when contamination has reached a level requiring cleanup, EPA will use maximum contaminant levels (MCLs) established under the Safe Drinking Water Act or, when not MCLs have been established, interim criteria to be established by EPA.

> The strategy calls for preventing contamination through a combination of uniform national measures (such as restrictions on the manner in which a product may be used), geographically variable use restrictions imposed by EPA, and "state management plan." EPA views the states as playing a critical role in providing the necessary flexibility to take unique local conditions into account and to guard against the over- or underprotection that would inevitably occur if cancellation or use restriction decisions were to be made solely on a national basis."

Thus, the actual impact a pesticide may or may not have on a given aquifer, and whether that aquifer is used for drinking water will play a role in the restrictions placed on the use of a given pesticide. State implemented BMPs, as part of the state management plan, will need to be evaluated through monitoring in order to assess the need for further pesticide restrictions. The information produced from pesticide monitoring programs should have a significant effect on how the EPA implements FIFRA and FEPCA on a regional basis. Thus, this presents the interesting relationship of monitoring to regulation under FIFRA; instead of the legislation driving the need for monitoring, it is the information produced from monitoring that will define the specific regulations.

In 1991 EPA published its "Pesticides and Ground Water Strategy," requiring that pesticides that EPA find to be a threat to ground water must be regulated under a State Management Plan (SMP). These regulations are site-specific; a pesticide used widely in soils with preferential flow paths may be regulated under that state's SMP, whereas in another state the pesticide may be used sparingly in slow draining soils and therefore no SMP regulations will be required. Once a pesticide is detected at or near the MCL or other criteria, it must be assessed for continued use. If an EPA determines that SMP regulation of a pesticide is required, its future sale and use will be restricted to those states with an SMP approved by EPA (Little, 1992). Field scale and large scale monitoring studies have been and will continue to be required by EPA to identify areas that may require SMP regulation, as well as demonstrating the effectiveness of management plans in protecting the ground water.

9. S1114 (Proposed 1994 Clean Water Act Reauthorization)

Title III of S1114 introduced by Senators Baucus and Chafee as part of the 1994 reauthorization of the Clean Water Act includes substantial language for state water quality monitoring programs. These programs are to assess state waters for biota protection and suitability for recreation, identify waters not meeting quality standards, assess the contribution of point and nonpoint sources to pollution problems, and provide for continuous monitoring (Sec. 301[b][2]). More specific regulations are to be promulgated by EPA within two years of enactment. This seems to point out an increased recognition that nonpoint source pollution is an integral part of water quality issues and cannot be dealt with as an unrelated problem.

Section 321 of the bill is entitled "Comprehensive Watershed Management." This is defined as:

(a) Identifying more fully water quality impairments and the pollutants, sources, and activities causing impairments;

(b) Integrating water protection quality efforts under this Act with other natural resource protection efforts, including Federal efforts to define and protect ecological systems (including the waters and the living resources supported by the waters);

(c) Defining long-term social, economic and natural resource objectives and the water quality necessary to attain or maintain the objectives;

(d) Increasing, through citizen participation in the watershed management process, public support for improved water quality;

(e) Identifying priority water quality problems that need immediate attention; and

(f) Identifying the most cost-effective measures to achieve the objectives of this Act.

This again points at defining all the variables and goals that are involved in water quality management. A determination of the "most cost-effective measures" may also increase scrutiny of agricultural management practices that could benefit water quality at significantly less cost than expensive treatment technologies for point sources.

In order to accomplish the above goals of Comprehensive Watershed Management, the bill calls for the establishment of a Water Quality Monitoring Council (Section 301). The purpose of this Council would be to coordinate federal and state water quality monitoring programs. Within two years of enactment, the President, with the recommendations of the Council, would submit to Congress "...a strategy for the coordinated implementation of water quality monitoring programs." According to the bill, this strategy is to:

> "review and assess the location and function of fixed monitoring stations and hydrologic study units...and describe;
>
> > the roles and responsibilities of Federal agencies;
> >
> > methods of coordination among agencies, including procedures to ensure the implementation of the strategy;
> >
> > the anticipated level of resources to be devoted to monitoring programs by each agency; and
> >
> > measures to ensure that Federal monitoring programs are responsive to the monitoring needs of States to the fullest extent practicable."

Every five years EPA is required to provide Congress with a report on conditions and trends in national water quality as well as the adequacy of funding for the programs specified. This Council would seem to address the issue of uncoordinated monitoring projects noted in the discussion of Section 319. It is apparent that water quality monitoring is to be a key component of the Clean Water Act with the adoption of S1114. What is not clear is how this will be specifically implemented.

B. State and Local Laws

With a semi-arid climate and limited water supplies, Colorado water law has historically been concerned with water rights, with the Office of the State Engineer (SEO) being responsible for their administration. Nonetheless, the recent exchanges of agricultural water shares for municipal use has resulted in conflicts with senior water appropriators over the quality of substituted water supply (Simpson, 1993). This issue addressed by the Colorado legislature in Senate Bill 89-181, in which the State Engineer's Office is given standing to raise water quality issues in addition to traditional water quantity issues in augmentation plans and exchanges (Danielson, 1992).

Senate Bill 90-126 of the Colorado legislature defines the role of the state Department of Agriculture in developing strategies to control water pollution from agricultural sources. This bill shows a significant departure from the federal Section 319 and similar nonpoint source legislation in that it contains specific criteria for the "(p)romulgation of control regulations." These controls are to be used in the event that voluntary controls are insufficient to prevent or mitigate the presence of a given agricultural chemical in the water. This act then allows the use of regulatory controls on agricultural practices as a part of water quality management in Colorado.

It should also be noted that much of Colorado law can be seen to follow the federal lead in environmental legislation and regulation. Water quality standards are typically based on the EPA-promulgated drinking water standards. By enacting this legislation, the state serves to own its water quality management, rather than allowing the EPA to decide what standards should be applied where. Thus, the legislation gives the appearance of being proactive, although one could cynically question how much of it would exist without federal prodding.

1. Colorado Ground Water Standards

The Colorado Ground Water Standards are found in the Colorado Code of Regulations 5CCR 1002-8, starting at 3.11.0. The stated purpose of these regulations is "...to establish statewide standards and a system for classifying ground water and adopting water quality standards for such classifications to protect existing and potential beneficial uses of ground waters" (3.11.2). Section 3.11.9 discusses the issue further by stating;

> "These regulations are the first step in developing a comprehensive, statewide ground water protection program. The complete program will include control regulations which will enforce the water quality standards. These additional regulations may include amending the current CDPS permit regulations and adopting activity-specific control regulations.
>
> It is not the intent of the Commission to control existing or future uses of ground water (i.e., domestic, agricultural, or industrial uses). The intent is to protect ground water quality from uncontrolled degradation and thereby protect existing and future uses of ground water."

Additionally, on May 15, 1984, the Colorado Water Quality Control Commission adopted the following statement pertaining to ground water protection:

> "The goal of the Water Quality Control Commission is to provide maximum beneficial use of ground water resources, while assuring the safety of the users by preventing or controlling those activities which have the potential to impair existing or future beneficial uses of ground water or to adversely affect the public health. The necessary program is to be instituted in a manner that is consistent with and complementary to the provisions of the Colorado Water Quality Control Act."

In light of this, the classifications used for ground water are given in 3.11.4;

a) Domestic Use Quality

b) Agricultural Use Quality

c) Surface Water Quality Protection

d) Potentially Usable Quality

e) Limited Use and Quality

Each classification is determined by a set of criteria that includes existing and potential future use of the water, overall water quality, and TDS levels (3.11.4).

The standards developed for ground water fall into four different categories; narrative standards, numeric standards, statewide standards, and site-specific radioactive materials and organic pollutant standards. The narrative standards can be generalized as stating that there will be no toxics in toxic amounts for any pollutants not listed in the accompanying tables. These are designed to protect all potential uses of the water, so they are not classification-specific. The numeric standards use the aforementioned table values in the following manner;

a) "Domestic Use—Quality"—The Human Health and Secondary Drinking Water Standards listed in Tables 1 and 2, respectively, except as specified in Section 3.11.5(B)5. Most of the Table 1 values are MCLs established by the National Primary Drinking Water Regulations. Table 2 values are the National Secondary Drinking Water Standards. These are pollutants "which may adversely affect the aesthetic quality of a drinking water such as taste, odor, color, and appearance and which thereby may deter public acceptance of and confidence in that ground water source as a drinking water supply" (3.11.9).

b) "Agricultural Use—Quality"—The Agricultural Standards listed in Table 3, except as specified in Section 3.11.5(B)5.

c) "Surface Water Quality Protection"—The standards necessary to prevent the exceedance of surface waters standards.

d) "Potentially Usable Quality" appropriate standards considering those factors listed in Section 3.11.4(B)(4)(d).

The "Limited Use and Quality" designation is defined as ground water which meets none of the criteria for the other classifications or which has been exempted under 2CCR 404-1 under the Colorado Oil and Gas Conservation Act, and therefore, no standards are set.

The statewide standards are designated for radioactive materials and organic pollutants listed in subsections 3.11.5(C)(2) and (3) and table A. The site-specific radioactive materials and organic pollutant standards may be used in lieu of the statewide standards when taking into account the classification of the ground water at the particular site, similar to the numeric standards.

In 3.11.9, the Commission states that it "...envisions that future and/or amended regulations will specify the design criteria and/or monitoring requirements necessary at the point or points of compliance. Down-gradient ground water monitoring locations may correspond to the point of compliance for the regulated activity." In 3.11.6(B), specific agencies are instructed to establish points of compliance for activities under their control (e.g., SB89-181). Subsections C and D give guidelines for points of compliance. In 3.11.11, further discussion is found on the topic of temporal and spatial criteria for sampling:

> "The intent of any permit or control regulation should be to permit sampling frequency and interpretation that adequately reflects groundwater quality variation over time. Owners and operators should have latitude in this regard provided that an acceptable minimum number of samples are taken from each well annually. At the discretion of the owner/operator a shorter sampling interval may be employed to demonstrate that an exceedence of standards is due to temporal effects. This interval should be determined after evaluating the aquifer's effective porosity, hydraulic conductivity, and hydraulic gradient (which would govern rates of flow), and the fate and transport characteristics of the potential contaminants. This additional effort should help identify seasonal trends in the data and permit evaluation of the effects of seasonal variation or slugs of contamination if present in the samples. To better characterize spatial variability, an owner/operator may wish to install and sample from multiple background and compliance wells. If sufficient data is made available through these additional efforts, the owner/operator may employ statistical procedures such as moving averages and trend analysis to reduce seasonal and temporal effects. Utilization of site-specific characterizations to statistically evaluate an exceedence of standards requires detailed knowledge of the site. For owners/operators to use these methods they should be able to identify the uppermost aquifer, and aquifers hydraulically interconnected beneath the facility property, including

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TO: Dennis Bagenstos

FROM: Robert Ward RCW

DATE: April 26, 1995

NO. OF PAGES: 4

FAX NO.: (303) 480-1020

SUBJECT: Draft Paper Outline

Dennis,

Attached is my first, very rough, shot at an outline for a paper from your thesis. I am somewhat concerned that I've written the paper in a popularized style that may not be the best approach (really depends on where we try to publish it). Also, I am not completely satisfied with the introductory approah. Some of the words later in the outline may be better used in the introduction (eg water management occurs at the local level but seems to be directed from Federal and state).

Anyway, I thought you could take a look at this and perhaps it would prompt you to hatch a brilliant idea of how to proceed! Let me know your thoughts and I will take another shot at it.

Does the outline, as organized with subtitles, fit the general organization that you had in mind? If not, let me know what you were thinking and I will work around that.

The outline did not come as easy I thought it would. This is a fascinating topic, but it is not easy to present in a more technical "paper" format.

Robert

What are we required to know about water quality?

Dennis J. Bagenstos[1] and Robert C. Ward[2]

Twenty-five years have passed since the first Earth Day. This twenty-five years has generated considerable interest and concern about the Earth's environment, including the quality of its water. Many citizens of the United States, however, do not know if their water is safer/cleaner today than it was 25 years ago. Reports continue to be published that decry a specific water quality problem while others claim we have made great progress in cleaning up our nation's waters. No firm, unbiased water quality information is available against which the public can judge claims made about impending water quality disasters or strides in improvement.

These twenty-five years have also generated a tremendous amount of legislation to remedy past pollution problems and to prevent future problems, often passed upon revelation of a specific impending water quality disaster (eg the Safe Drinking Water Act in 1974 after the Mississippi River was declared to contain cancer causing chemicals). Unfortunately, the laws passed have tended to be rather problem specific (eg drinking water, surface water pollution control, and ground water clean up).

As each law is passed, at both the Federal and state levels, invariably it contained a requirement for "monitoring" of the media or problem being addressed by the legislation. As time passed and the laws multiplied, the calls for "monitoring" began to overlap. This situation was described for Federal legal mandates for monitoring the marine environment in a report issued by the National Research Council (1990). The report noted that there are 25 separate Federal laws calling for monitoring the marine environment; sixteen of which have been enacted since 1970. Five Federal agencies were noted as being assigned the Federal monitoring responsibilities. The cost of this monitoring was estimated to be $133 million annually in 1985, with 43% of the money spent at the Federal level, 37% at the state and local level, and 18% by the private sector. This is a lot of laws, many agencies, and much money - is it effective and efficient?

How does the public know if our water laws are achieving their goals? In general, the pubic is asked to pay for the separate monitoring efforts mandated by the numerous laws without receiving much information feedback about the status and trends

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in water quality. They can obtain information about aspects of water quality pertaining to drinking water, agricultural Best Management Practices, or discharge permits; but not the general "water quality" status and trends.

The purpose of this paper is to examine the legal calls for ground water quality monitoring <u>in a local situation</u> with the intent of defining the commonality contained within separate information requests. The hope is that by carefully examining all the legal ground water quality information requests, it will be possible to identify several common types of information that could then be obtained with a more coordinated and more efficient monitoring system. In addition, it is hoped that such coordination in monitoring could also include a function to inform the public, in words they can understand, of the status and trends in the quality of the water upon which they rely for their domestic, agricultural, recreation and ecological needs.

The local perspective utilized in the paper is that of the ground water quality situation in the San Luis Valley of Colorado. The goal is to examine the Federal and state legal overlay requiring ground water quality monitoring, of some form, in the San Luis Valley. This particular perspective of legal requirements for water quality information is different from that obtained by looking at a part of the total hydrological cycle (such as the marine environment).

<u>San Luis Valley Setting</u>

<u>Review of Laws Requiring Ground Water Quality Information</u>

<u>Common Information Requests</u>

<u>Implications to Monitoring in the Valley</u>

With 38 Federal and state legal requirements for monitoring ground water quality in the San Luis Valley, it is not surprising to find Federal and state agencies taking the lead in monitoring the Valley's ground water quality. These efforts represent considerable effort and have not been coordinated in a manner that permits the public in the Valley to obtain an overview of the general ground water quality status and trends.

Furthermore, there is some confusion as to exactly who is responsible for monitoring ground "water quality" in the San Luis Valley for purposes of informing citizens. The vast majority of current efforts are funded and operated by Federal and state agencies meeting their agency missions (for example, salinity control, drinking water protection, non-point source pollution control, and resource data collection). When a local water manager, environmental group, the League of Women Voters, or citizens of the Valley want to know if the ground "water quality" conditions in the San Luis Valley are not causing human health or environmental problems in the Valley, who is responsible to informing them? Who informs the public of general ground water quality status and trends in the Valley?

A careful examination of legal requirements to monitor ground water quality in the San Luis Valley points out that the "parts" are being addressed but the "whole" is unknown. In other words, while each separate monitoring effort may justify the mission of its operating agency, the citizens of the Valley have no way of knowing if the larger ground water situation in the Valley is improving as a result of the many parts operating properly. Are the funds being used to operate the parts creating a "whole" that results in taxpayers being confident that their tax dollars are maintaining a healthy environment?

Conclusions

Water quality management occurs at the local level. Most often the structure for that management is defined, and its operation directed, by Federal and state laws. This paper uses the perspective of a local situation to examine the overlay of Federal and state laws to determine what ground water quality information the local populace is expected to produce to meet the legal mandates.

In the San Luis Valley, there are 38 Federal and state legal requirements or implications for information on the ground water quality. These requirements are being met by the responsible Federal and state agencies, but no one is responsible for integrating the information into a complete water quality "picture" for the Valley. Consequently, the citizens of the Valley have a hard time sorting through the information bits they receive from each monitoring effort to develop a level of comfort about the status and trends of their ground water quality.

References

National Research Council. 1990. Managing Troubled Waters: The Role of Marine Environmental Monitoring. Committee on a Systems Assessment of Marine Environmental Monitoring, Marine Board, Commission on Engineering and Technical Systems, National Research Council, National Academy Press, Washington, D.C.

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January 20, 1995

Dr. Robert Ward
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Dear Robert:

I apologize for not getting this to you sooner. I keep thinking I'll wait until I have a final draft of my paper to include with it, and days turn into weeks, and, well, you know.

I am working on the paper now that things have slowed a bit at work for the winter. I'll get something to you in the near future. I'm also working on a paper with Jonathon Jones on the first phase of a development of a stormwater management plan for a developing watershed with karstic geology. It contains a large volume springfield that supplies a large portion of the local water supply. We also need to make some preliminary recommendations on water quality monitoring, so you may find it interesting.

Also, I am including a paper I ran across while working on a water quality monitoring plan for a confidential client. Very relevant to my work, thought I might cite it in my paper.

I was just handed an 80-page document on hydrology I need to review and comment on yet this afternoon, so I'll cut this off. Welcome to the world of private consulting!

Very truly yours,

WASTE ENGINEERING, INC.

By:____________________
Dennis J. Bagenstos, E.I.T.
Civil Engineer

DJB
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groundwater flow direction and rate, and the basis for that identification.

In many situations it may benefit the owner/operator to install intermediate monitoring points. These monitoring points could be closer to the source or activity, or within the unsaturated zone. The monitoring points could function to alert the owner/operator to a potential contamination problem before it reaches the point of compliance."

2. Classifications and Water Quality Standards for Ground Water

The Classifications and Water Quality Standards for Ground Water are found in the Colorado Code of Regulations 5CCR 1002-8, starting at 3.12.0. The stated purpose of these regulations is:

"...to apply the framework for ground water classifications and water quality standards, as set forth in 'The Basic Standards for Ground Water 3.11.0 (5CCR 1002-8)' to specific ground waters in the state, and to adopt an interim narrative standard to protect these ground waters prior to the adoption of use classifications and numerical standards for specific areas" (3.12.2).

The Interim Narrative Standard is discussed in 3.12.5 as being applicable to all unconfined ground water in five specified areas, including the San Luis Valley Aquifer System (see Figure 4.1). This Standard is defined in 3.12.5(2)(a):

"Until such time as use, classifications and numerical standards are adopted for the ground water in this area, and subject to the provisions of subsection (b) below, ground water quality shall be maintained for each parameter at whichever of the following levels is less restrictive:

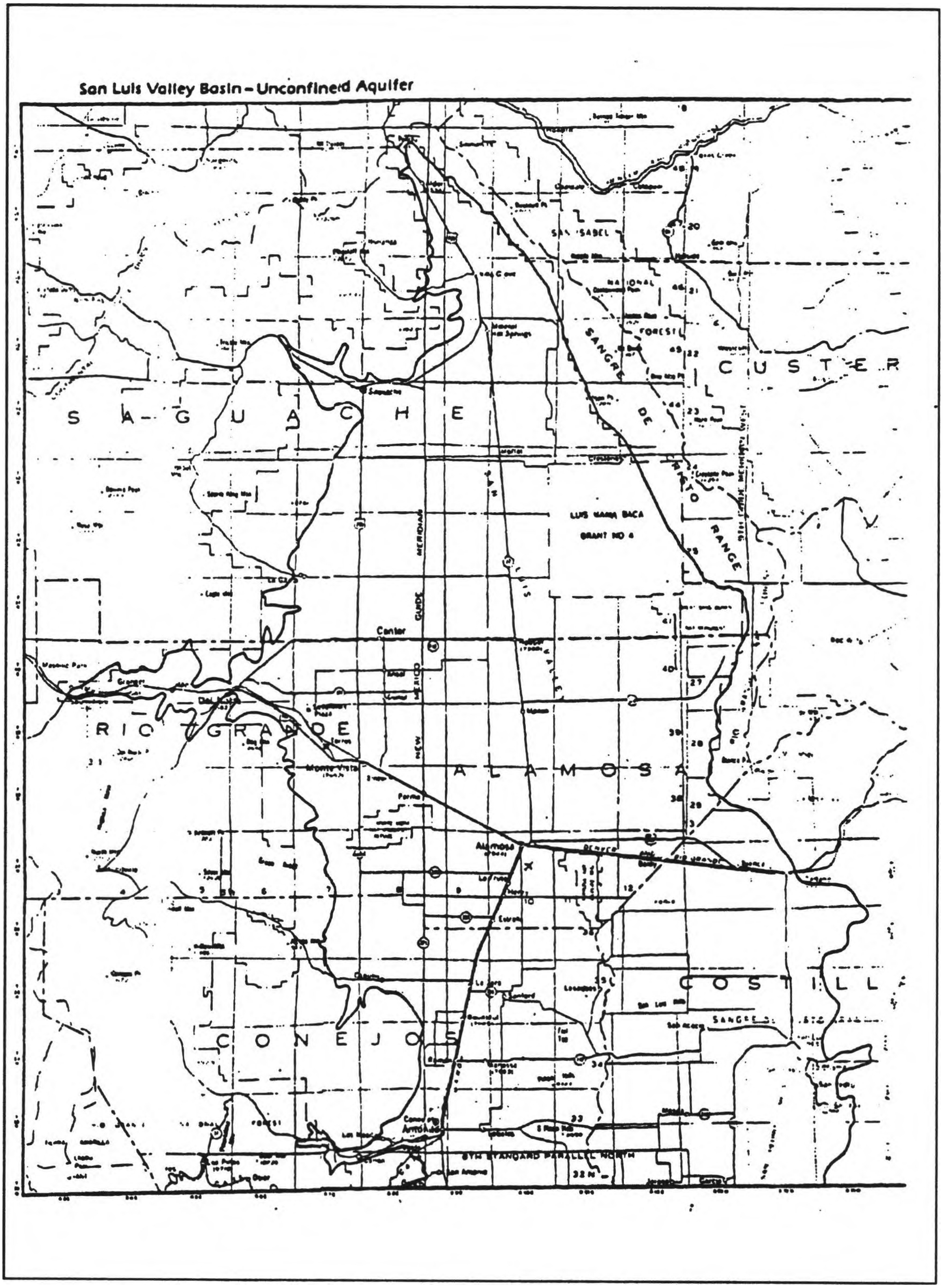

Figure 4.1. Spatial Extent of the San Luis Valley unconfined aquifer as identified by the Colorado Water Quality Control Commission (5CCR 1002-8 3.12.5).

(i) Existing ambient quality as of October 30, 1991, or

(ii) that quality which meets the most stringent criteria set forth in Tables 1 through 4 of 'The Basic Standards for Ground Water'."

It is apparent then, that this is effectively an anti-degradation standard that relies on either existing water quality data or the published standards as the base criteria. In fact, Section 3.12.11(B)(1) states the purpose of the Interim Narrative Standards is to "... assure that: (1) in clean areas, quality adequate to protect all potential uses is preserved; and (2) in contaminated areas, quality is not allowed to get any worse." Much discussion is found as to the availability and usefulness of water quality data as of the October 30, 1991, date. Due to the antidegradation flavor of this regulation, the Commission has resisted the idea of subsequent permitting dates as baselines. However, the Commission notes that later data collections could be "...presumed to be representative of existing quality as of the regulation's effective date if no new or increased sources of ground water quality contamination have been initiated in the interim" 3.12.11(B)(3). In this manner, the "... potentially regulated entity can avoid application of the default standard by generating site-specific data, even subsequent to the effective date of this regulation" 3.12.11(B)(4).

The other side of such an issue is remediation. No specific remediation procedures are presently outlined in the regulations (outside of previously established RCRA or CERCLA guidelines). In fact, in 3.12.5(2)(b), the commission states:

> "This interim standard shall not be interpreted or applied as defining or limiting the potential need for remediation of contaminated ground water where remedial requirements are established under state or federal law. It is the Commission's intent that, to the maximum degree technically feasible and economically reasonable, remedial efforts should be directed at cleaning up ground water contaminated by human activities to a degree such that it is usable for all existing and potential beneficial uses; this interim narrative standard is not intended to define when such remediation is or is not feasible. Where contamination already exists, this interim standard is merely intended to assure that conditions are not allowed to deteriorate further pending remedial action. The appropriate level of clean-up to be achieved may be addressed by this Commission in a future classification and standard-setting proceeding, or by other agencies with jurisdiction over remedial actions."

This statement demonstrates that in these regulations, the Commission is not strictly defining a crisis management system such as CERCLA, but is instead emphasizing an antidegradation, or pollution control approach.

In 3.12.11(B)(5), the Commission also makes a specific statement as to the impact of these regulations on agriculture:

> "The Interim Narrative Standard recognizes that past agricultural and other human activities have adversely impacted ground water quality, and does not mandate that such impacts be remediated. Of course, the Commission hopes that in many circumstances improved quality will be achieved over time. With respect to agricultural activities, the starting point for efforts to control ground water quality impacts will be implementation of Senate Bill 90-126."

Again, the Commission appears to be emphasizing controls to prevent further deterioration of agriculture-use aquifers rather than clean-up mandates. A possible difficulty with this statement can be found in the Section 3.12.12 municipal wellhead protection regulations. These Section 3.12.12 regulations are similar in concept to the Safe Drinking Water Act Section 1427 Sole Source Aquifer Demonstration Program. Here, site-specific standards are set for 10 of Colorado's largest community ground water supplies for drinking water, including the town of Alamosa (3.12.7[4] and see Figure 4.2):

> "CITY OF ALAMOSA WELLFIELD, ALAMOSA COUNTY
>
> (a) Specified Area: All confined and unconfined ground waters within the saturated zone underlying the area as illustrated in Figure 4.
>
> (b) Classifications: The classifications of the confined and unconfined ground water in the specified area are:
>
> - Domestic Use—Quality
>
> - Agricultural Use—Quality
>
> (c) Ground Water Quality Standards: The ground water quality standards included in Tables 1-4 of the 'Basic Standards for Ground Water' 3.11.0 (5CCR 1002-8) are assigned to all confined and unconfined ground water in the specified area."

The intent is to protect drinking water supplies while protecting agricultural uses within the specified wellfield areas. There is no provision here for the substitution of existing quality as the standard, as in the case of narrative standards. If the aquifer does not meet the table standards, what remediation could be called for? What level of enforcement is the Commission likely to use? In Section 3.12.11(B)(1), the Commission states that "(t)he major issue left open by the interim standard is the determination as to what level of remediation may be appropriate in the variety of circumstances where existing quality does not meet table value standards." It is not clear how the

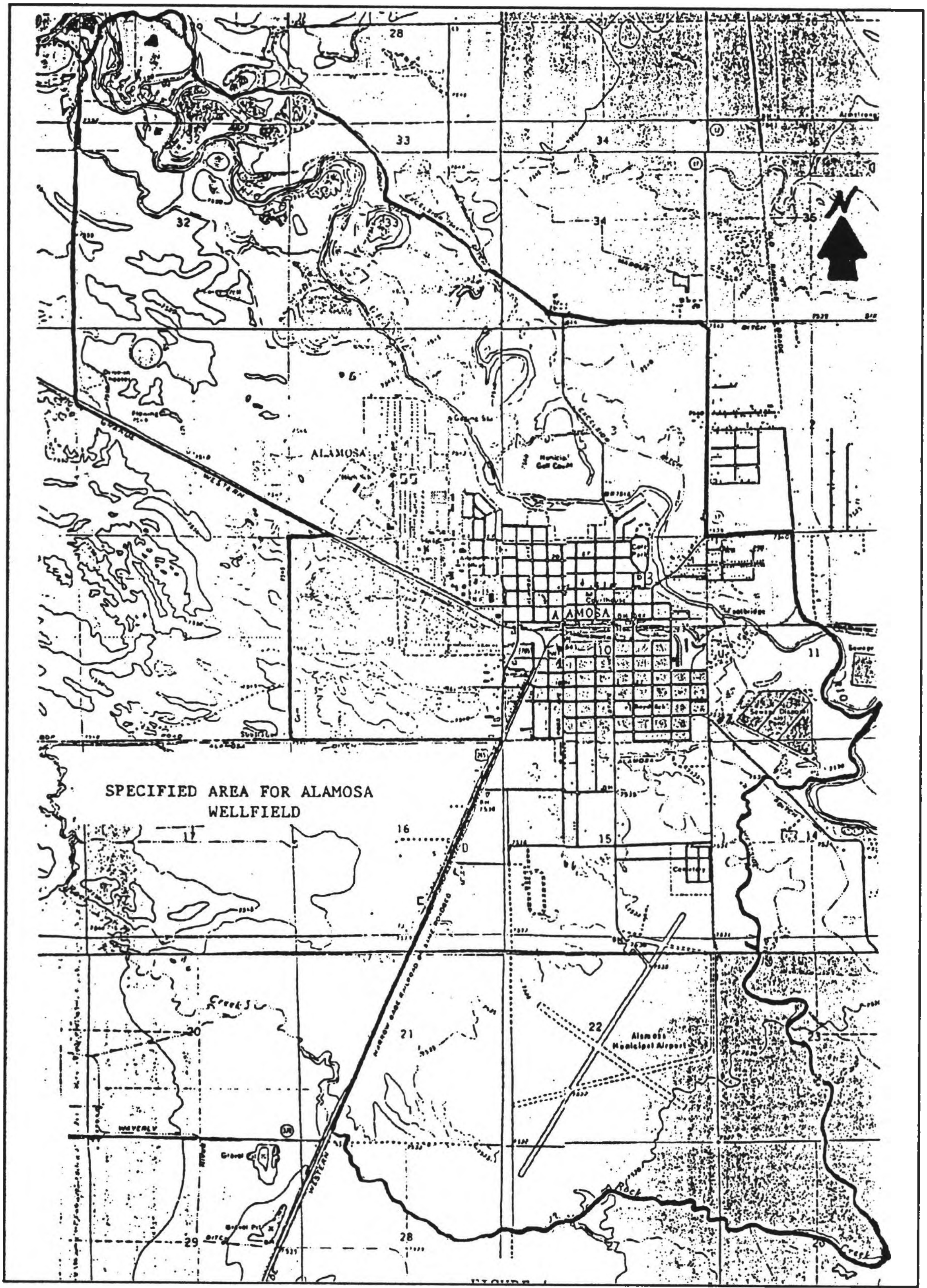

Figure 4.2. Spatial extent of the Wellhead Protection Area for Alamosa, Colorado, as defined by the Colorado Water Quality Control Division (5CCR 1002-8 3.12.7).

compliance oriented Section 3.12.12 wellhead protection regulations relate to the lack of compliance emphasis for agricultural impacts seen in Section 3.12.11(B)(5) as discussed previously.

In the case of Alamosa, the lower, confined aquifer supplies drinking water and its quality is not directly affected by agricultural activities. Despite this, the commission has included the unconfined aquifer in this wellhead protection plan. Note that both domestic and agricultural use designations have been applied to the same site; with respect to numerical standards, 3.11.5(B)(2) states that "(w)hen a ground water has a multi-use classification, the most restrictive standard for a parameter shall apply." Additionally, paragraph (c) above specifically applies the MCLs from Table 1 to the upper unconfined aquifer within the wellfield area. Thus, even though the drinking water supply for Alamosa is procured from the lower aquifer, the Commission specifies that both aquifers will be of drinking water quality. Noting the great expense that is involved in removing organic and nitrate pollution from drinking water supplies, it is certainly to the town's advantage to protect its ground water. The need to maintain ground water at drinking water standards when it is not to be used as such is a different issue and may require further discussion by the parties involved.

Upon a thorough review of these regulations, they appear somewhat vague as to their exact implementation, particularly with respect to agricultural sources of contamination. In many cases the Commission has itself noted these, making allowance for site-specific and activity-specific hearings as preference to creating very definitive and all-encompassing rules. Additionally, many of the problems caused by non-point source discharges cannot be solved by simple rulemaking, and the Commission seems to acknowledge this fact. Nonetheless, there is strong support here for monitoring ground water quality baselines and effects due to point and non-point sources. In section 3.12.11(D), the Commission comments:

> "... the Division is requested to work with other state agencies and outside entities to develop proposals for enhancing the currently available ground water quality data base. This may include better integration of data currently generated from a variety of sources, as well as proposals for funding for developing more data in the future. In addition, this effort should consider whether additional monitoring requirements should be established for activities potentially impacting ground water quality. This effort should also take into account the need for improved information for more precise delineation of wellhead protection areas."

The Commission also states that "(t)hese regulations are the first step in developing a comprehensive, statewide ground water protection program. The complete program will include control regulations which will enforce the water quality standards. These additional regulations may include amending the current CDPS permit regulations and adopting activity-specific control regulations" (Section 3.11.9 [Purpose]). The groundwork for more specific activity regulations, such as agricultural BMPs, seems to be laid in these current regulations.

3. Colorado Water Quality Control Act/SB 90-126

Senate Bill 90-126 is an amendment to the Colorado Water Quality Control Act with attached funding provisions. Several key definitions are given in section 2 of the Act as an addition to the C.R.S. in section 25-8-103:

> "(1.1) 'Agricultural management area' means a designated geographic area defined by the commissioner of agriculture that includes natural or manmade features where there is a significant risk of contamination or pollution of groundwater from agricultural activities conducted at or near the land surface.
>
> (1.2) 'Agricultural management plan' means any activity, procedure, or practice adopted as a rule by the commissioner of agriculture pursuant to article 4 of title 24, C.R.S., in consultation with the Colorado cooperative extension service and the water quality control division, to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical.
>
> (1.3) 'Best management practices' means any voluntary activity, procedure, or practice established by the department of agriculture, in consultation with the Colorado cooperative extension service and the water quality control division, to prevent or remedy the introduction of agricultural chemicals into groundwater to the extent technically and economically practical."

These definitions seem to have their basis in the language used in Section 319 of the federal Clean Water Act. The importance of these is seen in subsequent sections of the Act.

Section 3 of the Act specifically requires that the Water Quality Control Commission not require treatment techniques which may damage the water rights of agricultural nonpoint source dischargers. The Commission is directed to pursue "...incentive, grant, and cooperative programs in preference to the promulgation of control regulations... Except as provided by section 25-5-205.5, control regulations related to agricultural practices shall be promulgated only if incentive, grant, and cooperative programs are determined by the commission to be inadequate and such regulations are necessary to meet state law or the federal act." Once again, the preference for voluntary programs is emphasized, but the language does recognize the possibility of the need for control regulations.

Section 4 of the Act adds section 25-8-205.5 to the Water Quality Control Act. Subsection 1 states"

> "The general assembly hereby declares that the public policy of this state is to protect groundwater and the environment from impairment or degradation due to the improper use of agricultural chemicals while allowing for their proper and correct use, in particular, to provide for the management of agricultural chemicals to prevent, minimize, and mitigate their presence in groundwater and to provide for the education and training of agricultural chemical applicators and the general public regarding groundwater protection, agricultural chemical use, and the use of other agricultural methods."

Once again, this is fairly non-threatening language in terms of government intervention. However, subsection (3)(c) gives the Department of Agriculture authority to develop BMPs for any activity relating to the use of any agricultural chemical, while subsection (3)(d) allows him to require the use of Agricultural Management Plans (AMPs) in the event that he finds the use of BMPs to be ineffective in preventing or mitigating ground water pollution. Thus, there is specific language here that allows the state to require specific agricultural practices, although enforcement provisions are not given except for large storage, mixing and loading sites.

Provisions for monitoring require that the Colorado Department of Health Water Quality Control Division assist the Department of Agriculture in identifying agricultural management areas, determining the presence of agricultural chemicals in ground water at levels exceeding the water quality standards, and determining the susceptibility of an aquifer to contamination by any given agricultural chemical (25-8-205.5[5]). The subject of determining relative contamination risks within agricultural management areas is the subject of Paris, 1993.

If the Division finds water quality standards are exceeded, or there is a reasonable likelihood of exceedance, it must report to the Department of Agriculture (Section 25-8-205.5[6][a]). Subsection (b) authorizes the Department to promulgate rules and regulations regarding the use of any agricultural chemical involved. If further monitoring data suggests that these regulations are inadequate to control contamination, the Department of Agriculture and the Water Quality Control Division are authorized to amend said regulations to achieve compliance. Section 25-8-205.5(7)(a) allows the Water Quality Control Division to promulgate control regulations only when:

> "(I) Any occurrence has been referred to the commission pursuant to subsection (6) of this section; or
>
> (II) Incentive, grant, and cooperative programs are determined by the water quality control commission to be inadequate as set forth in section 25-8-205(5)."

Further, subsection (b) requires that "(a)ny such control regulations shall be promulgated in consultation with the commissioner of agriculture."

It should be apparent that SB90-126 is regarded by many as the driving force for water quality monitoring of agricultural non-point source pollution in Colorado. Not only is monitoring essential to implementation of the Act, but the authorization of promulgating mandatory BMPs should act as a harbinger of possible future rules and legislation. The issue of agricultural impacts on ground water is no longer an afterthought to water legislation, but a problem to be solved by whatever means necessary. The emphasis remains on voluntary compliance, but the limited success of this approach in the past indicates that mandatory regulations are a serious possibility.

4. SB 89-181

Rather than developing new laws for water quality, SB 89-181 is intended to more closely define the roles of existing agencies in water quality control; "...pursuant to C.R.S. 25-8-202(7)(d), this subsection (7) is not intended either to grant additional jurisdiction to any agency or to curtail the jurisdiction of any agency to fulfill its statutory responsibilities" (Danielson, 1992). The water quality responsibilities of the State Engineer's Office, the Oil and Gas Conservation Commission, the Mined Land Reclamation Division, and the Hazardous Material and Waste Management Division were acknowledged through this amendment to Article 8 of Title 25. These are recognized as implementing agencies as referenced in 5CCR 1002-8(3.11 and 3.12). The

Water Quality Control Commission and Division of the Colorado Department of Health retains final authority in setting standards and classifications for water quality, as well as specifying points of compliance.

Of interest to ground water quality monitoring designers are the provisions referring to the State Engineer's Office. The three categories of implementation of water quality standards and classifications by the SEO are:

a) Discharges to ground water,

b) Substitute water supply plans and

c) Plans for augmentation and exchange plans

These are discussed in Simpson, 1993, and summarized below.

The permitting and licensing of wells has always been the responsibility of the State Engineer's Office. Where faulty or outdated well construction causes a potential or actual ground water contamination problem, the SEO may order the well properly abandoned. The point of compliance is placed at the periphery of the disturbed material around the borehole. In the case of artificial ground water recharge sites, the SEO has placed the point of compliance at the boundary of the recharge pit. In this case, it is the responsibility of the SEO to insure that this substitute supply meets the needs of senior appropriators as well as any standards set by the Water Quality Control Commission.

In the case of substituted water supplies, the SEO may require that the substituted water meet the water quality standards for the senior appropriator. The SEO will determine which standards to apply based on the senior appropriator's use of the water; e.g., agricultural standards for agricultural uses, or drinking water standards for municipal water supplies. Since the identity of the senior appropriator may change seasonally, this must also be considered.

As in the previous situation, the SEO may raise water quality issues where augmentation and exchange plans may result in senior appropriators receiving water that is of inadequate quality for their use. The SEO would have standing in the Water Court as any other public water-user to oppose applications for augmentation plans. This may include a statement of opposition, a protest to referee's ruling, or a motion to intervene. In light of budgetary considerations, the SEO typically will not raise water quality issues when other water users already oppose the plan.

In Simpson, 1993, the State Engineer summarizes his approach to SB 89-181 with this statement:

> "Staff at the State Engineer's Office will continue to participate in various forums where water quality and quantity issues can be considered... Stringent regulations may not always be the most effective and economically feasible long term solutions. Solutions based on Best Management Practices and public education may work better to bring about the desired change."

5. Colorado Primary Drinking Water Regulations

The regulations covering drinking water supplies in Colorado closely mimic the federal Safe Drinking Water Act. These regulations are promulgated by the State Board of Health under Part 1 of Title 25, C.R.S. The key aspect of these regulations is in the definition of those water supply systems that are affected. Section 1.1.2(1) states that these rules do not apply to a public water system that:

(a) Consists only of distribution and storage facilities and does not have any collection and treatment facilities and,

(b) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(c) Does not sell water to any person and,

(d) Is not a carrier which conveys passengers in interstate commerce.

A community water system is defined as one serving 25 year-round residents or at least 15 service connections used by year-round residents (Section 1.2.2[5]). Affected systems would include a city water supply, a private well supply to a mobile home park with 15 or more sites, or a vendor of containerized water. A domestic well for a farm or household would not be regulated.

Drinking water regulations such as these are "at the tap" regulations, meaning that the point of compliance is at the point of use. In the case of "CT", or residual disinfectant concentrations, the point of compliance would be the first customer in the distribution system. Obviously, this does not require monitoring of ground or surface water quality per se, but such quality will be almost completely correlated to the tap water quality in the case of untreated well supply systems. Furthermore, the need for expensive treatment facilities in the case of nitrate or organic chemical contamination makes it economically expedient for a supplier to monitor and regulate such conditions. Additionally, the municipality may require local best management practices for agricultural activities in order to protect its ground or surface water supply. Again, in the case of the San Luis Valley, most of the major water supply systems in the valley use water from the deep confined aquifer that is unaffected by agricultural effects. This is not typically the case in the San Luis Valley with domestic water supplies for private dwellings. There is also the occasional gas station or private business with its own well on site. Separate health regulations for restaurants require their water supply conform to drinking water standards. These may be enforced by the county health department or the state health department in the absence of a local department.

6. Colorado Ground Water Management Act

The Colorado Ground Water Management Act is primarily concerned with the permitting and proper installation and maintenance of wells. In Section 37-90-102, the Legislative Declaration states that:

> " (1) It is declared that the traditional policy of the state of Colorado, requiring the water resources of this state to be devoted to beneficial use in reasonable amounts through appropriation, is affirmed with respect to the designated ground waters of this state... All designated ground waters in this state are therefore declared to be subject to appropriation in the manner defined in this article.
>
> (2) The general assembly finds and declares that the allocation of nontributary ground water pursuant to statute is based upon the best available evidence at this time... The doctrine of prior appropriation shall not apply to nontributary ground water. To continue the development of nontributary ground water resources consonant with conservation shall be the policy of this state. Such water shall be allocated as provided in this article upon the basis of ownership of the overlying land. This policy is a reasonable exercise of the general assembly's plenary power over this resource."

It should also be noted that section 37-90-110 specifies the powers of the State Engineer in administration of this Act. The SEO's primary role is the permitting and inspection of wells to enforce "...compliance with any regulation, control, or order established by the ground water commission as provided for under the provisions of this article" (Sec. 37-90-110[f]). In order to further clarify this role, SB 89-181 clarified the SEO's involvement in ground water extraction and recharge activities with associated water quality issues, classifying the SEO as an "implementing agency" for the Water Quality Control Commission. Thus, this Act concerns itself with traditional water quantity and proper well construction regulations as opposed to SB89-181 which emphasizes the SEO's standing to raise water quality issues.

C. Implementing Agencies and Concerned Parties

1. Environmental Protection Agency

The EPA is called upon as an enforcement agency and a regulatory and rule making body in most federal laws concerned with the environment and related human health issues. Relevant regulatory roles in non-point source groundwater monitoring come chiefly from the Clean Water Act:

a) Section 305(b): The so-called Section 305(b) reports are to be written by the state on a biannual basis, describing the state's water quality and an analysis of those factors which affect the water quality.

b) Section 208: This initial approach to managing non-point source pollution problems resulted in the establishment of "Section 208" agencies which were to monitor the effect of said pollution as well as corrective BMPs.

c) Section 319: The use of "Section 319" grants has provided numerous independent agencies to set up monitoring programs similar to the Section 208 agencies.

Other key regulatory roles come from the Safe Drinking Water Act, the Federal Insecticide, Fungicide, and Rodenticide Act, the Resource Conservation and Recovery Act, and the Comprehensive Environmental Recovery and Compensation Liability Act.

2. Colorado Department of Health

The Colorado Department of Health, or CDH, acts primarily as an implementing agency for water quality monitoring efforts through its Water Quality Control Division. Responsibilities with respect to nonpoint source monitoring include;

a) Responsibility for developing the Nonpoint Assessment Report and Management Program under Section 319 of the CWA and acts as the contracting agency for funds disbursed under Section 319. The Division also maintains the statewide manual for best management practices.

b) It is the administering agency for the Colorado Water Quality Control Act and is the key agent for application of the Colorado Ground Water Standards and Classifications (5CCR 1002-8 3.11 and 3.12).

c) Responsibility for the Section 305(b) reports mandated by the CWA.

d) In conjunction with the Department of Agriculture and the Cooperative Extension, the Division is responsible for defining Agricultural Management Areas (AMAs), BMPs, and conducting monitoring under Senate Bill 90-126,

3. Colorado State Engineer's Office

Traditionally, the State Engineer's Office (SEO) has been involved with well permits, construction and design approval, maintenance, and abandonment procedures. However, SB 89-181 has redefined the SEO's involvement with water quality issues as they relate to these topics. As an implementing agency, the SEO is required to implement the water quality classifications and standards adopted by the Water Quality Control Commission.

4. Department of Agriculture

Senate Bill 90-126 calls for the Department of Agriculture to promulgate rules and regulations for bulk storage facilities for agricultural chemicals, as well as identify agricultural management areas and provide for monitoring of agricultural areas within these areas. The purpose of the monitoring is to examine the need for and effectiveness of BMPs in these areas, and, if needed, promulgate mandatory BMPs to mitigate pollution of the ground water. Such rules and regulations are to be made with the agreement of the Water Quality Control Commission.

5. The Water Quality Control Commission

In Colorado, the Water Quality Control Commission acts in a manner similar to the EPA at the federal level. This is a rule-making and policy-making agency, responsible for writing the regulations covering water quality found in the Colorado Code of Regulations. As such, it tends to maintain a level of veto power over the other implementing agencies mentioned above. Any regional monitoring program must be evaluated in terms of fitting the goals and priorities set by the Commission.

6. Local Health and Welfare Departments

County health departments are typically involved with the permitting of water and waste water systems, as well as monitoring local businesses which sell food and drink to the public. If a local department does not exist, these tasks are given to the Colorado Department of Health (Anderson, 1993).

These departments are often concerned with ground water quality as a measure of drinking water quality. Even in those areas where public drinking water supplies may be entirely stream or reservoir fed, there are always private drinking, irrigation, or stock watering wells that could be affected. These departments are concerned with protecting the public health in its entirety, so as well as being regulatory agencies they act as providers for the public welfare in a non-regulatory role as well.

7. Cooperative Extension

The Cooperative Extension is involved with the development of BMPs and the definitions of Agricultural Management Areas (AMAs) as a function of SB90-126. Additionally, the Act calls for training and educational activities related to these BMPs (Section 25-8-205.5[4]). Although this work is to be done under the Department of Agriculture, the Extension also is working closely with the CDH Water Quality Control Division in development of the monitoring required to evaluate these BMPs (Waskom, 1993).

8. U.S. Geological Survey Water Resources Division / National Water Quality Assessment Program (NAWQA)

NAWQA is described as a national design with flexible local implementation (Dennehy, 1993). The program is broken up into two elements: regional watershed-based study units, and a national synthesis. The approach used in each study unit consists of three steps;

a) Retrospective Analysis

b) Study Unit Investigation

c) Regional Synoptic Studies

By examining a variety of environmental and anthropogenic factors, the NAWQA project aims to develop a better understanding of the effects of these factors on water quality. One such study unit is located in the Rio Grande basin and includes the San Luis Valley. Monitoring was initiated there in the summer of 1993.

9. Local Residents

In areas such as the San Luis Valley, agriculture is the primary economic and social base. Farmers are typically fiercely independent businessmen with many years of hands-on experience in managing an enterprise that requires huge capital investments and has substantial risk attached. As a result, they tend to be wary of government officials telling them how to manage their productivity. Many have been involved, however, in the implementation of BMPs at the request of the Cooperative Extension. These BMPs often offer an economic advantage to the farmer as well as an environmental one. Additionally, these individuals are often very concerned with preserving water quality, as they well understand the importance of water in the San Luis Valley.

The issue of mandatory BMPs is, as one might guess, very controversial. In a discussion of the proposed 1994 Clean Water Act, Roger Bill Mitchell, a Monte Vista farmer and president of the Colorado Farm Bureau says "(i)f BMPs aren't voluntary and profitable, farmers will not adopt them readily" (Wyant, 1993). Yet, the probability of mandatory BMPs seems great. Mitchell continues:

> "There will undoubtedly be mandatory best management practices that the federal agencies will impose in Colorado."

A monitoring program impacts these farming areas in two ways. First, it evaluates the need for BMPs or other actions needed to mitigate water pollution problems. As mentioned previously, the farmers are interested in environmental protection, but there must be clear evidence of what the problem is. Secondly, monitoring can evaluate the effectiveness of BMPs that have been put in place. Of course, monitoring may demonstrate the ineffectiveness of a BMP as well as possible benefits. The key here is in getting the "right" answer from monitoring; results that are truly representative of the actual effect of the management practice on water quality. Again, the purpose of water quality monitoring is to provide the accurate information needed by water quality managers.

10. Rio Grande Water Conservation District

The function of Water Conservation Districts in Colorado is primarily one of preserving water quantity, not quality. However, it is increasingly clear that these two concepts are becoming inextricably linked. Furthermore, demands for minimum flows and protection of habitat on the part of the Division of Wildlife, various agencies of the Department of the Interior and USDA and others have also threatened to redefine the nature of water rights in Colorado. As a result of this and the threat of further government intrusion into water management, these agencies have become more interested in water quality monitoring. Section 319 grants have been used for short-term studies to determine baseline water quality. Additionally, these districts want a better understanding of who is contributing what to water quality problems. Just as with CERCLA actions, whoever has the best information indicating that someone else may be responsible for a pollution problem can benefit greatly in litigation.

The Rio Grande Water Conservation District (RGWCD) was formed in 1967 by the Colorado General Assembly. This was done in response to the litigation of 1966 involving the states of Texas, New Mexico and Colorado, as residents of the San Luis Valley wanted a valley-wide conservation district to represent them in litigation and assist in water problems (Radosevich and Rutz, 1979). The district is in charge of determining water policy and coordinating various water projects within the Valley, as well as working with and making recommendations to the Colorado Water Conservation Board.

When American Water Development, Inc. (AWDI) petitioned the state for the withdrawal of up to 200,000 acre-feet of water per year from the lower, confined aquifer in the San Luis Valley, the RGWCD was the primary legal representative of those who opposed the permitting. Given the previous discussion on the quality and quantity of ground water available in the Valley, it is unlikely that the AWDI petition will be the last that the Valley encounters from those who would extract water from the Valley for sale to municipalities. Thus, the RGWCD will likely have an ongoing role in increasing understanding of the hydrology of the ground water in the Valley in order to have a greater scientific basis for the discussion and possible protest of such petitions. Since, as previously discussed, water quality is an arguable issue in water transfers, this is a viable approach.

The potential use of water quality issues to control water quantity in the San Luis Valley is one reason that the RGWCD may become more involved in water quality monitoring. Also, many farmers in the Valley have expressed concern about the presence of nitrates in their domestic water supplies. In response to this the district has considered a monitoring program for nitrates in domestic wells as an additional service to their customers. It is clear that, just as with the SEO, an organization that was initially formed around water quantity issues is now becoming interested in water quality as well.

D. Conclusions

The laws and regulations covering nonpoint source water quality monitoring are scattered about in a variety of federal and local laws and regulations. Additionally, the call for monitoring is often found by "reading between the lines", or interpreting the law to see where monitoring will be necessary. Where monitoring is called for, there is often little specific information as to what the information expectations are for that monitoring. Finally, many non-regulatory interests in monitoring result from an increased need for understanding of water quality for documentation or research purposes. As a result, defining information goals from these laws, regulations, and implementing agencies and concerned parties becomes somewhat subjective in their development. However, by subsequently presenting these synthesized goals to the various parties involved in water quality management in the San Luis Valley, it may be possible to develop some consensus as to how well these goals reflect the managers' information needs. The importance of consensus in defining monitoring goals is discussed in Ward *et al.*, 1990 and Adkins, 1993; unless the laws provide specific information needs, a consensus of opinion by the information users typically defines the "correct" statement of information goals.

CHAPTER V

EXTRAPOLATION AND SYNTHESIS OF MONITORING GOALS FOR THE SAN LUIS VALLEY

Upon review of the laws and regulations relevant to ground water monitoring in the San Luis Valley, a set of information goals can be produced which form the basis for the monitoring system design. To do this, specific information needs must be extrapolated from each law, regulation, and interested party. Due to ambiguity within these laws as to their implementation in monitoring, this is not a simple task. The needs of interested parties, e.g. environmental groups, are also often uncertain. For this reason, once the information needs for each law, regulation, and concerned party are determined, they will be coalesced into a smaller number of information goals designed to encompass all the information needs previously determined. These will be presented to the various agencies and individuals involved in water quality management in the San Luis Valley for their comments and revisions. From this, a final set of information goals is to be written that will have a high level of consensus from those involved in water quality management.

A. Legal and Regulatory Goals

1. Federal

a. Section 319 of the 1987 Clean Water Act

In stating the requirements for the State Assessment reports required under Section 319, the subsection (a)(1) calls for identification of;

> ..those navigable waters within the State which...cannot reasonably be expected to attain or maintain applicable water quality standards...
>
> ...nonpoint sources which add significant pollution to each portion of the navigable waters identified...
>
> ...the process...for identifying best management practices and measures to control each category and subcategory of nonpoint sources...

These three requirements are repeated in similar language under the State Management Programs definitions (subsection [b][2]). These can be used as the basis for the informational goals for water quality monitoring under Section 319. Although the first two requirements appear to deal specifically with surface water, this language could be interpreted as an attempt to reaffirm the federal government's authority to regulate non-point source pollution under the commerce clause. It would seem prudent that by the same reasoning found in Quivira Mining Company versus the United States, ground water should be seen as part of this language. Therefore, a restatement of these goals in terms more specific to ground water quality monitoring may be made, and is certainly necessary to the purposes of this research. The following are offered:

1) Determine regional baseline ground water quality in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.

2) Identify point and nonpoint sources of pollutants in areas defined in (1).

3) Determine the effectiveness of Best Management Practices instituted as a function of this Act.

One might reasonably ask for a definition of the "appropriate water quality standards" referred to in the first goal. As noted previously, although there are no federal ground water quality standards, the state of Colorado has established such standards. Discussion of this issue is tabled until the relevant regulations are analyzed in that section.

b. The Safe Drinking Water Act (SDWA)

As mentioned in the previous chapter, the Safe Drinking Water Act does not call for any monitoring of ambient water quality, as it is an "end of the tap" regulation. In the case where an aquifer is the primary source of drinking water to a region or municipality, the Sole Source Aquifer Demonstration Program could be used to assist in protection of such ground water. Since this is also an assessment program for ground water management plans and practices with respect to both point and non-point source contamination, water quality monitoring would be needed as part of that assessment procedure. Specific informational goals would be very similar to those outlined under Section 319.

In the specific case of the San Luis Valley, the upper aquifer that is subject to contamination from anthropogenic sources is not a primary drinking water source as defined by the Sole Source Aquifer Demonstration Program. Thus, this program under SDWA would not be applicable. There are, however, a number of private, domestic use wells in the valley that provide drinking water. Again, the issue raised with respect to the upper aquifer is "how clean is clean?" Should the goal of a ground water management plan for the San Luis Valley be the attainment of drinking water standards for the entire aquifer? Or should the goal be to identify those "taps" which do not meet SDWA standards and replace them with a water supply that does meet the standards? What of a "middle of the road" standard that could make safe the occasional drinking of the ground water without placing an extraordinary burden on agricultural practices in the Valley? Colorado law provides some regulatory answers to these issues, and these are discussed in a later section of this chapter.

c. FIFRA and Pesticide Regulations

The key issue in the EPA's program to protect ground water from pesticides is that of selective regulation. "State management plans offer a more moderate option of regulating pesticide use compared to the 'meat axe' approach of simply cancelling products," according to Jim Roelofs of EPA's Office of Pesticide Programs (Little, 1992). As an example, despite its acute toxicity and widespread detection in ground water, aldicarb registration was not cancelled despite the virtual suspension of use of ethylene dibromide in 1983 and dibromochloropropane in 1979. This was due to monitoring that demonstrated that its presence in ground water was limited to specific uses in specific use areas. (Lorber *et al.*, 1990) Yet, according to Barrett *et al.*, 1993, interpretation of monitoring data collected by EPA's Office of Pesticide Programs (OPP) from various state agencies, universities, and chemical companies is difficult. The paper states that this is due, in part, to the following problems:

1. The data are not representative of all usage areas. Many agricultural areas have not been sampled, whereas other areas have been sampled intensively.
2. The occurrence of pesticides in ground water is determined by the interaction of many complex factors (hydrogeologic, well structure, and meteorological). Quite often information is not collected on the construction and characteristics of individual wells, characterization of the soil, local hydrogeology of the aquifer, land use, and pesticide use near the well.
3. Temporal and spatial variability of pesticide residues are generally unknown. Typically, single samples are taken from isolated wells.
4. Sampling is often in atypical situations such as excessively well-drained soils, highly-developed karst regions, aquifers only a few meters in depth, or near agricultural chemical storage facilities or other potentially potent sources, which produces data that are difficult to apply to more typical situations.

5. Overall assessments of the impact of particular pesticides is complicated by the lack of a statistical design that incorporates pesticide use information and has a clearly defined target population. Studies frequently lack a design that would allow human exposure assessments to be made from ground-water residue data that are collected (e.g., potable water may not be sampled for some studies).
6. The origins of many of the detections (e.g., point source vs. leaching from field use) have not been identified or thoroughly investigated by those conducting the studies.
7. The reliability (both quantitatively and qualitatively) of much of the data is questionable because reports of pesticide detections in ground water samples have not been supported by rigorous quality assurance and quality control procedures.

Additional problems raised by Barrett *et al.* (1993) include pesticide metabolites. The toxicities of the sulfoxide and sulfone metabolites of aldicarb are similar to that of the parent compound. Therefore, even though aldicarb is not seen in the ground water, the metabolites are seen much more frequently and are just as toxic. Contamination pathways must also be taken into account in monitoring. Leaching of pesticides to the ground water may be caused by back-siphoning into a well during mixing or chemigation, improper pesticide disposal or accidental spills (particularly around poorly grouted or damaged wells), equipment rinsate, excess applications and registered field applications.

As mentioned above, lack of information on which pathway is suspected can result in erroneous conclusions leading to inappropriate regulations. Accurate, complete monitoring information is therefore as important to the pesticide user (to avoid excessively strict regulations) as it is to the general public's concerns about water quality.

Past monitoring efforts include the National Alachlor Well Water Survey (NAWWS) and the National Survey of Pesticides in Drinking Water Wells, also known as the National Pesticide Survey (NPS). The assumption made in both surveys was that there is a greater probability of detections in areas of higher pesticide use and areas with greater hydrogeologic vulnerability. Wells are then selected to represent different strata or domains based on these factors. The design allowed the studies to relate detections to specific indices of hydrogeologic vulnerability, use, water table conditions, and well depth. Future use of large scale monitoring studies will be influenced by the analyses of the NPS and NAWWS. They will likely become more focused on identifying the hydrogeologic, well characteristic, and land\pesticide factors associated with the occurrence of the pesticide in ground water (Barrett *et al.*, 1993).

The effect of this information on monitoring in the San Luis Valley is several fold. First, both large-scale, valley-wide monitoring can be used to assess the extent and possible trends in pesticide contamination of the ground water, as well as field-scale monitoring to study pathways and effects of hydrogeologic conditions. Much of this work has already been done by Durnford *et al.* (1990) and the USGS (Ellis and Levings, 1994). The second concern is to address those problems discussed in Barrett *et al.* (1993), as listed at the beginning of this section. These would likely be done with field-scale monitoring designs, including sampling soil and soil-pore water at various depths. Again, this was addressed in Ellerbroek, 1993. The difficulty with putting together specific monitoring goals for pesticide assessment is the cost of such a program; lab tests for pesticides tend to be very expensive as compared to tests for nitrates, specific conductivity, and pH (Ellis and Levings, 1994).

In terms of a regional water quality monitoring system, the use of a tiered approach might be appropriate. Intensive, short term, field-scale studies could be used to better understand the process of pesticide transport into the ground water. Long term studies could be used for trend analysis, thereby requiring only a few representative sites and less frequent sampling. Such long term studies could provide the basis for intensive short term study site selection. This approach is based on the "wheel-and-axle" monitoring design framework discussed in Chapter II, where the long-term sites represent the axle and short-term studies the wheels. Specific goals for short term monitoring should include:

1) Identify point and nonpoint sources of pesticides in ground water.
2) Identify specific circumstances and hydrogeologic conditions that contribute to pesticides entering the ground water.
3) Determine the effectiveness of Best Management Practices that may be instituted under the State Management Plan to control pesticide contamination of the ground water.

For the long term studies;

1) Determine baseline pesticide levels in representative sites.

2) Identify trends in pesticide levels.

3) Determine the long term effectiveness of Best Management Practices that may be instituted under the State Management Plan to control pesticide contamination of the ground water.

d. S1114 (Proposed 1994 Clean Water Act Reauthorization)

The non-specific language and the fact that S1114 does not necessarily represent the final form of the 1994 Clean Water Act Reauthorization makes it difficult to propose specific monitoring goals based on this law. Certainly, there is language in this bill as to the need for "ecological" monitoring, or monitoring variables that indicate not only the potential health and welfare of humans within a specified area, but also indigenous wildlife. This would seem to apply more directly to surface water quality and riparian habitat than ground water. However, in those areas where aquifers are hydraulically connected to streams or lakes, the selection of water quality variables studied for ground water should be evaluated in terms of ecological monitoring as well.

As noted in the previous discussion of S1114, there will likely be increased emphasis on nonpoint source pollution. The potential for mandatory BMPs has been noted, and this increases the need for a comprehensive and effective monitoring plan that reflects what is actually happening to ground water quality as these BMPs are utilized. This does not create any new goals that have not already been discussed; it merely strengthens the argument supporting them. Using S1114 as an indicator of future legislation, it appears that evaluating the contribution and abatement of nonpoint source pollution to the nation's water quality problems will be increasing in importance as a national goal for the next few years.

2. State and Local

a. 5CCR 1002-8 Sections 3.11 and 3.12

Those sections pertaining to ground water in the Colorado Code of Regulations bring up an issue not heretofore discussed in the federal laws: antidegradation. Traditionally the topic of surface water monitoring, this presents a new set of monitoring goals. Baseline data is required not only to establish trends, but compliance as well. Since the 1956 Federal Water Pollution Control Act states have been gathering information on surface water quality, yet there has been no such nationwide call for baseline data on ground water. Additionally, a new level of importance as to the accuracy of the data emerges: under the concept of antidegradation, new industries or activities may be restricted based on their potential to degrade existing water quality past a compliance point. What that existing water quality is becomes a politically and economically important and volatile issue.

The decision must also be made as to the temporal and spatial resolution of the monitoring data; i.e., can one simply take a single reading from the geographic center of an aquifer and proclaim that to be the quality of water for the entire aquifer? One would assume this to be inappropriate, but how specific must resolution be? From previous monitoring data, it is apparent in the San Luis Valley that there is a great deal of spatial and seasonal variation in nitrate levels (Thompson, 1993; Eddy-Miller, 1993). The spatial variation of quality in ground water due to point and nonpoint sources and natural stressors has a strong analogy in air quality. Is it more appropriate to designate certain zones as "non-compliance zones" or "compliance zones" such as is done in the Clean Air Act (1990)? Procedural issues such as these will have a direct effect on the design of a monitoring system.

Another key issue in these regulations is that of wellhead protection areas for municipalities whose primary water supply is ground water. This mimics the intimation made by Congress in the Safe Drinking Water Act Sole Source Aquifer Demonstration Program that more emphasis is needed in pollution prevention as opposed to remediation. This is a strict compliance measure, emphasizing Drinking Water MCLs and secondary standards as enforcement criteria. Since in the case of the town of Alamosa both aquifers are specified under these regulations, both will need to be monitored. It would be reasonable, however, to expect that the greatest emphasis would be placed on the lower aquifer that actually represents the town's drinking water supply.

A third issue in this set of regulations is the aquifer basins specified in 3.12.5(1). These are the areas of compliance specified by the Commission under the antidegradation rules. In the case of the San Luis Valley aquifer system, this delineation is consistent with previous hydrogeologic discussions of the Valley, so it would seem appropriate to use this as the definition of the area to be studied for the purposes of this research.

Two separate sets of monitoring goals are proposed to meet the requirements of these regulations; those for antidegradation and those for wellhead protection:

Antidegradation:

1) Determine the baseline ground water quality in the San Luis Valley unconfined aquifer described in 3.12.5(1) and shown in Figure 4.1 .
2) Compare this water quality with the interim narrative standards, the numerical standards, and the statewide standards in order to establish antidegradation criteria.
3) Determine trends in that water quality.
4) Identify those sources of pollution which threaten compliance for these areas.

Wellhead Protection:

1) Determine if the ground water in the specified municipal wellhead protection area under 3.12.7(4) is in compliance with the specific water quality standards set by the Commission.
2) Determine trends in that water quality.
3) Identify those sources of pollution which threaten compliance for these areas.

b. Colorado Water Quality Control Act / SB 90-126

SB 90-126 gives specific language as to the power of the Department of Agriculture to promulgate BMPs. What is less specific is how monitoring of water quality will be used to trigger such rulemaking. There are three key definitions in this Act; Agricultural Management Areas (AMAs), Agricultural Management Plans (AMPs), and Best Management Practices (BMPs). BMPs are well-understood from previous discussion; and an AMP is essentially a BMP made mandatory by the Department of Agriculture. The definition of an AMA is somewhat less specific. The emphasis seems to be on geohydrologic features that make an area susceptible to contamination from agricultural activities, and not on whether or not water quality problems actually exist. The presence of agricultural activities, a shallow aquifer and permeable soils (such as in the San Luis Valley) would therefore seem to be enough to define an area as an AMA. Some areas within the AMA may have water quality problems, while others do not; however, this does not enter into the definition given. As such, it would seem that the study area discussed in the previous section is appropriate for monitoring requirements under SB89-126 as well.

Since this Act is similar in approach to the federal Section 319 program, a comparison of monitoring goals is appropriate. Section 319 goals were stated as:

1) Determine regional baseline ground water quality in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.

2) Identify point and nonpoint sources of pollutants in areas defined in (1).

3) Determine the effectiveness of Best Management Practices instituted as a function of this Act.

Modification of these goals to fit SB89-126 should include:

1) Determine baseline ground water quality in the area of the upper aquifer as defined in 5CCR 1002-8 3.12.5(1) in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.

2) Identify point and nonpoint sources of pollutants in areas defined in (1).

3) Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality

4) Determine whether voluntary BMPs will be adequate to meet the water quality standards established by the Water Quality Control Commission under 5CCR 1002-8 3.11 and 3.12.

c. SB 89-181

As discussed previously, SB90-181 is not a call for monitoring, but a clear definition of what agencies will be responsible as implementing agencies under various laws and regulations governing water quality. Despite this, the Act is a reminder that the State Engineer's Office concerns itself with agricultural operations in the permitting and maintenance of wells. Since numerous wells in the San Luis Valley penetrate more than one aquifer, the hazard of cross-contaminating multiple aquifers exists. This could happen through the hydraulic connection of the two aquifers through the well borehole, seepage of chemicals from above ground down through the casing, or backflow of chemigation water. Due to the large volume of the lower aquifer and its depth and hydraulic head, any serious contamination is unlikely. However, it is quite likely that there is contamination of the upper aquifer from surface spills during mixing or application of chemicals near the wellhead. If this occurs near a domestic supply well that pumps from the upper aquifer, a localized "plume" of chemical-laden water could enter the drinking supply. For these reasons, periodic inspection and examination of agricultural wells and backflow valves along with public education are necessary.

d. Colorado Primary Drinking Water Regulations

It can be argued that the bottom line reasoning for most ground water monitoring systems is the protection of human health, typically in terms of using the ground water for drinking water. Yet the federal and state drinking water regulations do not directly address this topic. Geared more toward promulgating MCLs for finished water from water suppliers, other regulations are assumed to protect the source water. In the case of many ground water supplies, however, there is little or no treatment of the source water. This argues for the use of MCLs in ground water standards, and that is what is seen in the Colorado ground water standards, as well as the federal RCRA and

CERCLA regulations. In this study, however, it is the upper aquifer that is at greatest risk of contamination, and this aquifer is not widely used by commercial or municipal water suppliers for drinking water. It is, however, used by many domestic wells that fall outside the regulatory scope of the Colorado Primary Drinking Water Regulations.

The issue here is not completely a regulatory one. Rather, there is concern about the health and welfare of the many people who are constantly exposed to the health risk of using water that is not required to meet drinking water standards (Curtis, 1994). Specific monitoring goals for the Colorado Primary Drinking Water Regulations are limited to:

1. Monitor finished water from water suppliers that fall into the jurisdiction of the Colorado Primary Drinking Water Regulations, checking for compliance with drinking water Maximum Contaminant Levels (MCLs) as established by the EPA and adopted by the Colorado Water Quality Control Commission.

It is important to note that such monitoring is an existing and ongoing procedure for water suppliers in the Valley.

e. Colorado Ground Water Management Act

As the Colorado Ground Water Management Act is primarily concerned with water quantity and not quality, it would seem out of place in a discussion of water quality monitoring. However, there is a separate issue that bears discussion. This Act describes the State Engineer's duties in the permitting of ground water extraction and recharge activities. In the recent past, American Water Development, Inc. (AWDI) petitioned the state for the withdrawal of up to 200,000 acre-feet of water per year from the lower, confined aquifer in the San Luis Valley (Laughlin, 1992). Issues brought up by ground water users in the Valley included lowering of the piezometric surface in the confined aquifer, possible effects on the upper aquifer, hydrogeologic impacts including the stability of the Sand Dunes formations, and others. If there is significant hydraulic connection between the two aquifers (Emery *et al.*, 1973; Edelmann and Buckles, 1984; Glanzman, 1989), could lowering of the piezometric surface in the lower aquifer cause a drainage of water from the upper to the lower aquifer? Although this is an obvious water quantity (prior appropriation) issue, there is a water quality side to this as well. Changes in the vertical depth of the vadose zone and hydraulic gradient could result, changing the leaching and flow characteristics of agrichemicals applied at the ground surface (Edelmann and Buckles, 1984). Seasonal changes in pumping rates of the lower aquifer might modify seasonal characteristics of water quality and depth in the upper aquifer.

There are two points to be made from this discussion. First, the possibility of such a scenario could be a factor in the granting of permits by the SEO to undertake such a large scale water transfer. If a monitoring program could provide information in order to prove or disprove such a possibility, this would be valuable evidence in the granting or disallowance of permits for such transfers. Since this chapter is dedicated to producing potential monitoring goals without respect to the feasibility of said goals, this one is stated here. The other issue would be an "after the fact" one: if such a transfer were approved and initiated, one would want to know how this might have changed water quality and water tables from previous years. With this in mind, the following monitoring goals are offered:

1) Using appropriate mathematical models and field data, determine the effect on water quantity and quality in the upper aquifer based on large scale water withdrawals from the lower aquifer.
2) Establish baseline trends in water quality and quantity at representative sites for comparison to data collected after initiation of large scale water withdrawals from the lower aquifer.

As a final comment, during the fight between AWDI and the Rio Grande Water Conservation District (representing many other anti-AWDI groups in the Valley), Diana Laughlin of Colorado State University conducted research on the sociological aspects of this conflict (1992). As part of her research, she surveyed groups involved in the struggle as to their attitudes toward the other "actors" in the Valley. When questioned about which organizations they consulted with most often, both opponents and supporters of the water withdrawals ranked the SEO very high: first among opponents, third among supporters, both out of 17 organizations (Laughlin, 1992). Ranking organizations by legitimacy (or believability), the SEO ranked in the middle by both groups, with the leaders of each group's position predictably occupying the highest ranks. From this study, it appears that the SEO is perceived as being a valuable resource for objective information by both opponents and advocates of this issue. From a political standpoint, this puts the SEO in a strong position to assist in answering many of the questions discussed. Research conducted by one of the politically active groups is inevitably discounted by the other as motivated by bias. This should be considered when creating a management infrastructure for the actual implementation of these monitoring goals.

B. Implementing Agencies and Interested Parties Goals

1. EPA and Congress

From the aggressive call for a federal Water Quality Monitoring Council and coordinated monitoring programs in S1114, it may be inferred that Congressional members are demanding better water quality information. The issue may again be primarily one of existing monitoring programs which are "data rich, but information poor" (Ward *et al.*, 1986). Thus, Congress's appetite for better information will only be satisfied with well-defined and documented monitoring programs. Additionally, Congress has continued to emphasize enforcement of more stringent drinking water standards (Pontius, 1993). Based on this, the information that Congress needs to enable it to make decisions about water law could be summarized as;

- What are the trends in water quality as a function of implementation of laws and regulations designed to improve said quality?
- Are the nation's waters in compliance with EPA promulgated pollutant limits?

- Are the nation's drinking water supplies in compliance with EPA promulgated MCLs and MCLGs?
- What anthropogenic activities have strong positive or negative impacts on water quality?

These information needs are expressed by Congress by enacting the laws discussed in this paper to get the answers they need. Yet, from S1114, Congress is apparently not satisfied with the results of these laws in terms of information gathering. Data has been collected according to the letter of the law, but the needed information has not been, or cannot be, extracted from this data. Monitoring regulations speak in terms of the **data** that must be produced, an easily quantifiable and verifiable goal. But, as discussed in Ward *et al.* (1990), this is an unreliable approach to producing **information** such as that listed above. With respect to ground water monitoring for nonpoint source pollution, the following information goals are offered based on the information requirements listed above:

1) Determine overall trends in ground water quality.
2) Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.
3) Determine regional baseline ground water quality in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.

4) Determine the effectiveness of water suppliers in providing drinking water in compliance with Maximum Contaminant Levels (MCLs) as established by the EPA.

5) Determine the impact of point and nonpoint sources of pollutants on ground water quality.

Acting as a regulatory agency for the United States, EPA has developed its own procedures and priorities in environmental protection in general and water quality monitoring in particular. According to Phil Johnson, Water Quality Regional Coordinator for Region VIII, there are several issues EPA considers for any proposed monitoring program;

1) Is the system designed for monitoring for;
   a) Compliance with water quality criteria?
   b) Current water quality status?
   c) Water quality trends?
   d) BMP effectiveness?
2) Do the design parameters meet these goals?
3) Is the design appropriate, considering all possible constraints (e.g. physical, financial, sociological)?

Additionally, all programs must have a Quality Assurance/Quality Control (QA/QC) Plan and use Standard Operating Procedures in data collection (Johnson, 1993).

4) Determine the effectiveness of water suppliers in providing drinking water in compliance with Maximum Contaminant Levels (MCLs) as established by the EPA.

5) Determine the impact of point and nonpoint sources of pollutants on ground water quality.

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3) Is the design appropriate, considering all possible constraints (e.g. physical, financial, sociological)?

Additionally, all programs must have a Quality Assurance/Quality Control (QA/QC) Plan and use Standard Operating Procedures in data collection (Johnson, 1993).

Along with these procedural goals, EPA emphasizes certain concepts in environmental regulation. These are sometimes reduced to "buzzwords", such as:

1) "Watershed Approach": Monitoring and BMP implementation should be done on a watershed by watershed basis; watershed demarcation is dependent on the scale of the program and hydrologic, geologic and biologic characteristics.
2) "Prevention": A shift away from the RCRA/CERCLA concept of the 80's which emphasized nation-wide approaches to large scale cleanup of contaminated sites, to programs designed to prevent future environmental contamination.
3) "Top-down Management": Again, typical of the 80's, in which large scale environmental problems were handled by the EPA, and the states were seen as implementors of the EPA's regulations. In the 90's, this has been replaced with an emphasis on regional and local management, consistent with the Watershed Approach.

These comments do not easily lend themselves to producing specific monitoring goals; but they do show what elements or concepts the EPA believes must be incorporated into monitoring designs. As the monitoring goals discussed here are developed into actual design protocols, these remarks serve as benchmarks to ensure the EPA's consensus as to the validity of those protocols.

2. Colorado Water Quality Control Commission

The primary tool for the Water Quality Control Commission (WQCC) to express its concerns is through the Colorado Code of Regulations (CCR). These have been previously discussed and examined for relevant water quality monitoring goals. Along with specific regulatory information, the CCR contains commentary and Statements of Purpose from the WQCC that explains much of its decision- and rule-making process. These are discussed in the previous chapter and need no further clarification here. However, it should be noticed that in several places in the 5CCR 1002-8, starting at 3.11.0, there is emphasis placed on the protection of existing uses of ground water. This is different from the goal expressed in the Clean Water Act "...to restore and maintain the chemical, physical and biological integrity of the Nation's waters" Sec. 101, 33 U.S.C. Sec. 1251. Thus, since Congress is seeking to "restore and maintain" the nation's waters, emphasis has traditionally been placed on compliance monitoring. The Colorado Water Quality Control Commission's goal in ground water management leads to comprehensive baseline monitoring first, then trend and compliance monitoring.

In section 3.11.9 of the Colorado Ground Water Standards, it is noted that "...the Commission should assume — at the least — a coordinating role in assuring consistent protection of ground water quality. By promulgating a definition of the various uses of ground water and the numerical maximum chemical concentrations necessary to protect those uses, the Commission is establishing a common denominator such that ground waters will be classified and protected." This is a reasonable and desirable approach. However, the question remains as to who is coordinating the monitoring. Certainly, the Colorado Department of Health is the primary implementing agency through its Water Quality Control Division, but there are many other monitoring programs funded through Section 319 and other programs that are implemented by various agencies. Is the information generated by these reports available to the Commission for its decision-making and rule-making processes? Are abandoned monitoring wells used by now defunct monitoring programs (such as Section 208) available for new research, along with the previously collected data? Typically, this is not the case (Austin, 1993). In examining various strategies for implementation of a regional ground water monitoring plan for the San Luis Valley, this issue needs to be considered.

3. Colorado Water Quality Control Division

The duties and responsibilities of the Colorado Department of Health Water Quality Control Division were discussed in the previous chapter. As an implementing agency, WQCD is intended to take on the goals of the WQCC as its own. However, there are some mechanical questions that the Division may have in addition to its general goals;

a) What is an Agricultural Management Area (AMA) (ref. SB90-126)? Should it necessarily be the same as an aquifer basin as defined in the CCR? If differing hydrogeologic characteristics require that one part of an AMA uses different Best Management Practices

(BMPs) than another, should two AMAs be designated instead of one?

b) What water quality variables should be measured in a monitoring program? Frequent monitoring for pesticides would be very expensive (Ellis and Levings, 1994).

c) What statistical techniques should be used to define spatial and/or temporal trends, or to characterize baseline water quality?

d) How will BMPs and Agricultural Management Plans (AMPs) be evaluated? If a longer time frame is needed to detect trends due to BMPs, how long can the Division wait before reporting on the effectiveness of a given BMP? What level of certainty is required?

The Division has attempted to answer some of these questions by proposing a strategy called the Long Range Sampling Plan shown in Table 5.1 (Austin, 1993). Compare this plan with the goals described under the Colorado Ground Water Standards and SB90-126.

Colorado Ground Water Standards:

Antidegradation:

1) Determine the baseline ground water quality in the San Luis Valley unconfined aquifer described in 3.12.5(1) and shown in Figure 4.1.

2) Compare this water quality with the interim narrative standards, the numerical standards and the statewide standards in order to establish antidegradation criteria.

Table 5.1. Long range sampling plan for the agricultural chemicals program (Austin, 1993).

Short Term: (1 - 5 years)

Regional Baseline surveys

1) Major aquifers underlying an area of irrigated agriculture

South Platte Alluvial Aquifer system
Arkansas Alluvial Aquifer system
San Luis Valley unconfined aquifer
High Plains Ogallala aquifer
Uncompahgre - Lower Colorado Alluvial Aquifer system

2) Major aquifers underlying urban areas

Denver Basin aquifer system
Fountain Creek
Cache la Poudre

Mid Term: (3 - 7 years)

Begin follow-up surveys in those areas where base line survey suggest agricultural chemicals have impacted ground water

1) Increase sampling density to better define area of impact

2) Establish trend if any

3) Incorporate other water quality data into analysis

Begin planning for permanent monitoring network

Long Term: (5 years +)

Installing a permanent monitoring network

1) Low density control wells around the state

2) Medium density monitoring wells in areas of concern

3) High density monitoring wells within any designated AMA

3) Determine trends in that water quality.

4) Identify those sources of pollution which threaten compliance for these areas.

Wellhead Protection;

1) Determine if the ground water in the specified municipal wellhead protection area under 3.12.7(4) is in compliance with the specific water quality standards set by the Commission.

2) Determine trends in that water quality.

3) Identify those sources of pollution which threaten compliance for these areas.

Agricultural Management (SB90-126):

1) Determine baseline ground water quality in the area of the upper aquifer as defined in 5CCR 1002-8 3.12.5(1) in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.

2) Identify point and nonpoint sources of pollutants in areas defined in (1).

3) Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.

4) Determine whether voluntary BMPs will be adequate to meet the water quality standards established by the Water Quality Control Commission under 5CCR 1002-8 3.11 and 3.12.

The Division's use of baseline, follow-up, and long-term monitoring programs seem to closely pattern the goals described for these regulations. Nonetheless, there is no specific language in the Division's plan for the evaluation of BMPs other than the use of high density monitoring in designated AMAs. This statement indicates that the Division expects that data from its baseline and follow-up surveys will give the information needed to set up the monitoring of AMAs. Thus, the Division seems to be addressing those goals previously discussed as well as providing the answers to more mundane technical questions posed here.

4. Department of Agriculture

In looking at the Department of Agriculture, it might be argued that there is a built-in conflict in their monitoring goals. From SB90-126, the Department is tasked with determining what areas may need Agricultural Management Plans (AMPs) and promulgating said plans. Yet, to be blunt, the Department is generally viewed as an advocate for agriculture, not a policeman. Politically, this may be an uneasy position. From a monitoring standpoint, however, the goal is distinct. For the Department to make valid, supportable decisions they must have valid, supportable information. Data analysis protocols must be stated from the start (Ward *et al.*, 1990; Adkins, 1993) so as to avoid the appearance of politically motivated modifications. Clear, documented reports will assist the Department in validating their position in whatever decision needs to be made. It is this need that is the basis for the discussion of monitoring system design in Ward *et al.*, 1990; Adkins, 1993; Sanders *et al.*, 1983; and others. This is ultimately the point of water quality monitoring: producing information that can be utilized by water quality managers in the decision-making process in such a way that those decisions can be clearly documented.

5. Cooperative Extension

The Cooperative Extension's interest in water quality monitoring concerns the evaluation of BMPs developed by that agency. Other measurement procedures, such as mass-balance models and plant sampling, can give information on the amount of nitrogen available for leaching. These are good indicators of potential contamination and have been used in BMP evaluation in the San Luis Valley (Eddy-Miller, 1993). Shallow soil samples can also be used to find nitrates and pesticides that are available for leaching. These do not directly correlate to ground water contamination, however, due to chemical reactions, soil types, hydrological factors, and other variables. It is reasonable to assume that the effectiveness of a BMP to reduce ground water contamination will be judged primarily on trends detected in ground water quality. This may seem simplistic, but it reinforces a previously stated monitoring goal:

1) Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.

6. State Engineer's Office

Through SB89-181, the State Engineer's Office has a clear mandate to consider water quality issues as well as water quantity issues. However, the key areas of interest to the SEO are water substitution and augmentation or exchange plans and well permitting. Other than monitoring wells that are contaminated due to faulty construction, backflow equipment, or operation, the only relevant issue would be the large scale pumping of the lower aquifer as described in a previous section. Thus, other than this one issue, it is unlikely that a coordinated regional ground water monitoring design for the San Luis Valley would include specific monitoring goals from the SEO. As discussed previously, however, this does not in any way preempt the SEO from participating in a monitoring program.

7. Local Residents and Businessmen

The impact of ground water quality laws and issues on the local residents of the Valley is profound. This is an area that is defined by its economic reliance on agriculture. With an average yearly rainfall of approximately 7 inches, the agriculture (as well as the drinking water supply) is in turn almost wholly dependent on ground water. Because ground water is so essential to agriculture in the Valley, the laws and regulations discussed in this paper also impact heavily on its residents. In an interview with "Colorado Rancher and Farmer," Paul Genho, chairman of the Private Lands and Environmental Management Committee for the National Cattlemen's

Association, comments that "Water quality monitoring plans" create concerns about a "pollution cop" at the edge of every farm field. He feels that, due to the nature of agricultural production practices, targeting to specific sources is almost impossible (Wyant, 1993). The validity of both of these statements is arguable, but it is the level of concern that is of importance. Not only do these issues need to be addressed in a regional ground water quality monitoring program as monitoring goals, but it is essential to obtaining cooperation of the residents and businessmen there. The key questions that must be answered for those who depend on the ground water in the Valley are:

1) Is there a dependable supply of ground water for agriculture that, for the present and the foreseeable future, will:
    a) Meet water quality requirements for agricultural use, as well as any other standards mandated by government entities;
    b) Be available without the use of excessively expensive deep wells and high pumping heads;
    c) Be safe for human consumption; and
    d) Not require extraordinary or expensive management practices that will cause harm to the water rights or the profitability of those who use the ground water.
2) Is there a dependable supply of ground water for drinking water use that, for the present and the foreseeable future, will:
    a) Meet drinking water standards as set by the Colorado Division of Health and the Colorado Water Quality Control Commission, and

not require expensive treatment processes to achieve those standards;

b) Be available without the need of high pumping heads; and

c) Not require extraordinary or expensive management practices that will cause harm to the water rights or the profitability of those who use the ground water.

Generally, the first set of goals is applied to the unconfined, and more contaminated aquifer while the second set applies to the lower, less vulnerable aquifer. Yet, due to the previously discussed wellhead protection provisions of the Colorado Ground Water Standards and the concerns of individuals whose drinking water supply is provided by the upper aquifer, there is concern for the need for safe drinking water in the upper aquifer as well.

An additional concern is that of large scale regional withdrawals of ground water from the lower aquifer for export to the Colorado Front Range or elsewhere. This raises concerns of increased pumping heads, and environmental and water quality impacts. The nature of these possible impacts are such that the agricultural base of the Valley could be seriously damaged. Additionally, the land itself is of little value without water to irrigate it. This issue, and the response of the residents in the Valley is the subject of Laughlin (1992).

In discussing the concerns that need to be translated into monitoring goals, the phrase "for those who depend on the ground water in the Valley" was used. It should be apparent that all the residents of the Valley are dependent on the quality and quantity of the ground water in direct and/or indirect ways. Translating these concerns into monitoring goals provides a set of criteria similar to what has already been discussed:

1) Determine the baseline ground water quality and water table in the San Luis Valley unconfined aquifer.

2) Determine the baseline ground water quality and piezometric head in the San Luis Valley confined aquifer, especially at the wellheads for drinking water supplies.

3) Compare this water quality with the appropriate interim narrative standards, numerical standards, and the statewide standards.

3) Determine trends in that water quality.

4) Identify those sources of pollution which threaten compliance for these areas.

5) Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.

6) Determine whether voluntary BMPs will be adequate to meet the water quality standards established by the Water Quality Control Commission under 5CCR 1002-8 3.11 and 3.12.

7) Using appropriate mathematical models and field data, determine the effect on water quantity and quality in the upper aquifer based on large scale water withdrawals from the lower aquifer.

8) Establish baseline trends in water quality and quantity at representative sites for comparison to data collected after initiation of large scale water withdrawals from the lower aquifer.

8. Rio Grande Water Conservation District

As discussed previously, the Rio Grande Water Conservation District (RGWCD) acts as a representative for the residents of the San Luis Valley in water supply issues. The growing connection between water quality and quantity, however, has caused the district to consider water quality monitoring as well (Curtis, 1994). Certainly, if the district is a legal representative of the Valley residents and a coordinator for water issues and projects in the Valley, the water quality goals listed for the Valley residents will also be of interest to the district. Additionally, as a legal representative of the Valley residents, the district is politically and legally well-placed to assist in the coordination of water quality monitoring in the Valley. It should be noted, however, that the district has historically been involved with water quantity issues; thus, looking at water quality information needs may require some shifting of priorities in funding and effort.

C. Synthesis of Goals

1. Summary of Defined Goals

In designing a ground water quality monitoring system for the San Luis Valley, the above defined goals need to be addressed. The obvious difficulty is in the number and diversity of goals. At issue is whether or not a new set of goals can be defined that will incorporate all 38 of the previously defined ones. It is advantageous to first list all the goals and what laws, regulations, agencies, or groups act as the origin for each goal:

A. Section 319 of the Clean Water Act.

1. Determine regional baseline ground water quality in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.
2. Identify point and nonpoint sources of pollutants in areas defined in (1).
3. Determine the effectiveness of Best Management Practices instituted as a function of this Act.

B. FIFRA and Pesticide Regulations.

1. Identify point and nonpoint sources of pesticides in ground water
2. Identify specific circumstances and hydrogeologic conditions that contribute to pesticides entering the ground water.
3. Determine the effectiveness of Best Management Practices that may be instituted under the State Management Plan to control pesticide contamination of the ground water.

For the long term studies;

1. Determine baseline pesticide levels in representative sites.
2. Identify trends in pesticide levels.

3. Determine the long term effectiveness of Best Management Practices that may be instituted under the State Management Plan to control pesticide contamination of the ground water.

C. 5CCR 1002-8 Sections 3.11 and 3.12; Colorado Water Quality Control Division (WQCD).

Antidegradation:

1. Determine the baseline ground water quality in the San Luis Valley unconfined aquifer described in 3.12.5(1) and shown in Figure 4.1.
2. Compare this water quality with the interim narrative standards, the numerical standards, and the statewide standards in order to establish antidegradation criteria.
3. Determine trends in that water quality.
4. Identify those sources of pollution which threaten compliance for these areas.

Wellhead Protection:

1. Determine if the ground water in the specified municipal wellhead protection area under 3.12.7(4) is in compliance with the specific water quality standards set by the Commission.
2. Determine trends in that water quality.
3. Identify those sources of pollution which threaten compliance for these areas.

D. Colorado Water Quality Control Act / SB 90-126.

1. Determine baseline ground water quality in the area of the upper aquifer as defined in 5CCR 1002-8 3.12.5(1) in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.

2. Identify point and nonpoint sources of pollutants in areas defined in (1).

3. Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.

4 Determine whether voluntary BMPs will be adequate to meet the water quality standards established by the Water Quality Control Commission under 5CCR 1002-8 3.11 and 3.12.

E. Colorado Primary Drinking Water Regulations.

1. Monitor finished water from water suppliers that fall into the jurisdiction of the Colorado Primary Drinking Water Regulations, checking for compliance with drinking water Maximum Contaminant Levels (MCLs) as established by the EPA and adopted by the Colorado Water Quality Control Commission.

F. Colorado Ground Water Management Act.

1. Using appropriate mathematical models and field data, determine the effect on water quantity and quality in the upper aquifer based on large scale water withdrawals from the lower aquifer.

2. Establish baseline trends in water quality and quantity at representative sites for comparison to data collected after initiation of large scale water withdrawals from the lower aquifer.

G. EPA and Congress.

1. Determine overall trends in ground water quality.
2. Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.
3. Determine regional baseline ground water quality in order to identify areas which are, or are at risk of becoming, out of compliance with appropriate water quality standards.
4. Determine the effectiveness of water suppliers in providing drinking water in compliance with Maximum Contaminant Levels (MCLs) as established by the EPA.
5. Determine the impact of point and nonpoint sources of pollutants on ground water quality.

H. Cooperative Extension.

1. Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality

I. Local Residents and Businessmen.

1. Determine the baseline ground water quality and water table in the San Luis Valley unconfined aquifer.

2. Determine the baseline ground water quality and piezometric head in the San Luis Valley confined aquifer, especially at the wellheads for drinking water supplies.
3. Compare this water quality with the appropriate interim narrative standards, numerical standards, and the statewide standards.
4. Determine trends in that water quality.
5. Identify those sources of pollution which threaten compliance for these areas.
6. Determine the effectiveness of Best Management Practices instituted to slow degradation of or improve ground water quality.
7. Determine whether voluntary BMPs will be adequate to meet the water quality standards established by the Water Quality Control Commission under 5CCR 1002-8 3.11 and 3.12.
8. Using appropriate mathematical models and field data, determine the effect on water quantity and quality in the upper aquifer based on large scale water withdrawals from the lower aquifer.
9. Establish baseline trends in water quality and quantity at representative sites for comparison to data collected after initiation of large scale water withdrawals from the lower aquifer.

2. Synthesis of new goals

In the process of listing the above summary, it is immediately apparent that many of the listed goals are similar or identical. There are several reasons for this. First, many of the state laws are mirroring federal requirements; the state regulations are part of the state's management plan as decreed from the federal level. Second is the author's prejudice; in most of these goals there is no clear statement of a monitoring requirement from the laws, so a goal must be subjectively interpreted based on the role monitoring serves in that law. In many cases, the role of monitoring in one law is similar to the next, so the same goal is defined for both. By looking at similar goals and placing them in categories, a new set of goals can be defined that incorporate the previous goals into one. The product of this synthesis is presented below:

a. Baseline Conditions

i. Determine baseline ground water quality for the unconfined aquifer as described in 3.12.5(1) and shown in Figure 4.1, monitoring for those contaminants listed in the tables in 5CCR 1002-8 3.11 and 3.12 that are suspected of existing within the aquifer, based on land uses and chemical uses. These should include representative sites for the future monitoring of BMPs.

ii. Determine baseline ground water quality for the confined aquifer, monitoring for those contaminants listed in the tables in 5CCR 1002-8 3.11 and 3.12 that are suspected of existing within the aquifer, based on previous monitoring data, and concentrating on those areas that are near drinking water wellheads. Sampling water from water providers as defined by the Colorado Primary

Drinking Water Regulations should be included for compliance monitoring with drinking water standards.

b. Source Impacts

Determine possible source of point and nonpoint contamination of the upper and lower aquifers, particularly those sources that threaten compliance in wells as determined from the baseline monitoring.

c. Water Table/Piezometric Head Levels

Measure the height of the water level in the well at all baseline monitoring sites.

d. Trend Detection

Considering hydrogeologic and land use factors, use representative sites from (1) to determine regional trends in water quality and water levels for both aquifers.

e. BMP Analysis

Using representative sites from (1), determine the effectiveness of voluntary Best Management Practices instituted to slow degradation of or improve ground water quality, and determine if these BMPs will be adequate to meet the water quality and antidegradation standards set by the Water Quality Control Commission. under 5CCR 1002-8 3.11 and 3.12.

f. Analysis of Water Quality Effects due to Water Transfers

Using appropriate mathematical models and field data, determine the effect on water quantity and quality in the upper aquifer based on large scale water withdrawals from the lower aquifer.

CHAPTER VI.

REFINEMENT OF GOALS

A. Questionnaire and Interviews

In Ward *et al.*, 1990, emphasis is placed on the need for all parties to agree on the information expectations from the monitoring program. Reference is made to a National Academy of Sciences report from 1977 in which problems with water quality monitoring systems often involve the designer of the system determining the information to be produced, instead of the information users (Ward *et al.*, 1990). In the case of the San Luis Valley, the determination of the monitoring goals for each of the laws and groups studied is not a clear and unambiguous task; feedback is needed to verify the validity of these goals. To this end, a questionnaire was provided to those involved with water quality management in the San Luis Valley. The response to this questionnaire, in combination with informal interviews, were used to refine the previously defined information goals.

It should be noted that this questionnaire was not intended to be a statistically valid survey of opinion. As discussed above, the definition of water quality information goals is done by consensus of those who need the information, not popular vote. Therefore, information goals need to have 100% approval by those requesting the information. Obviously, this is not likely to happen, but it does indicate the importance and difficulty of defining information goals for a monitoring system. By soliciting and incorporating input from as many parties as possible, there is a much greater chance that the information goals will be accepted and supported by those to be involved with the funding and operation of the system (Ward *et al.*, 1990).

The actual questionnaire is shown in the appendix. This was distributed by hand and through the mail to numerous parties, including;

1) Colorado Department of Health Water Quality Control Division
2) Colorado State Engineer's Office
3) Residents of the San Luis Valley
4) Professionals from the San Luis Valley who are involved with ground water production and use in the Valley
5) The United States Geological Survey
6) The Environmental Protection Agency (Region VIII)
7) The Cooperative Extension

Additionally, a letter to the editor was placed in the *Valley Courier*, an Alamosa-based daily paper. Specific names of those who received questionnaires have been excluded from this report as several respondents requested anonymity. This is in order to prevent identification of these individuals through reverse extrapolation of the names of those included in this report. Finally, several individuals were queried personally or by phone. Generally, response was highest from those individuals in government agencies. Informal response from

Valley residents was good, but formal replies to the questionnaire were minimal in number.

B. Questionnaire Results

Although there were some differences in emphasis and perception in terms of the need for specific monitoring goals, there seemed to be a general consensus as to the information goals that should be pursued. Even those groups that might not see themselves as "co-advocates" indeed do seem to have similar goals and approaches. A summary of these is given here:

1) Every regulatory agency responding indicated a medium to strong desire to cooperate with other agencies and interested parties in collecting and sharing data and finding a way to generate an all-inclusive database for water quality monitoring. This included agencies operating on the state and local levels.

2) The greatest interest was in baseline conditions, trend detection, and BMP analysis. Interestingly, there was more emphasis on BMP analysis by those respondents in the Valley than from state or other agencies.

3) The primary water quality variable of interest was nitrates (and nitrites). It was noted that previous studies showed that pesticide contamination is not a significant water quality problem in the Valley.

4) The least interest was in source monitoring. Respondents felt that the primary sources of nitrate contamination were well-defined; general agricultural practices, backflow from chemigation, and bulk loading facilities.

5) Several respondents directly involved with SB90-126 strongly emphasized that they saw their roles as non-regulatory; that their function was to assist in the detection of agricultural needs and potential problems and promote good stewardship of the water resources involved.

6) The two agencies mentioned most often as possible central coordinators for a regional monitoring plan were San Luis Valley Resource Conservation and Development, Inc. and the San Luis Valley Water Quality Demonstration Project. Both are currently involved in coordinating water quality monitoring from several sources.

7) The only disagreement that was noted as to the laws, agencies, and regulations that were considered in the development of these goals was that the regulatory emphasis was excessive, as mentioned previously. Indeed, as noted in this paper, there is very little in the way of enforcement or penalties written into these laws and regulations.

C. Modifications to Goals

Based on the responses to the questionnaires and personal interviews, the following modifications were made to the specific monitoring goals:

1. Baseline conditions

Baseline monitoring of the unconfined aquifer is unquestionably a top priority for both trend detection and BMP analysis, both of which were reinforced as primary goals by the surveys. Baseline data for the confined aquifer may not be as critical, since it is not currently showing impact from anthropogenic sources. The spatial and temporal frequency of monitoring in the upper aquifer should be considerably greater than in the lower.

2. Source impacts

The results of the survey indicate that source monitoring is a low priority for water quality managers in the San Luis Valley. The primary sources of nitrates are known, and past sources are seen as irrelevant to the task of managing current practices. It may be of interest to perform a one-time ^{15}N isotope test in some wells about Center, but only if funds are not to be diverted from more important goals. Land use and management should, however, be related to water quality parameters as suggested by respondents as well as Spooner *et al.* (1991).

3. Water table levels

This goal received little comment, except that it should be a part of any water quality variable monitoring program. It is acceptable by default due to the relative ease in including it in a monitoring program in which other variables are already being measured. Although the RGWCD is already performing this task on certain wells, it should also be included in any wells used for water quality sampling.

4. Trend Detection

Numerous respondents mentioned trend detection as a primary goal. However, it was also noted that trend detection is a long-term goal, whether for BMPs or general water quality management analysis. Also, the variable of primary interest is nitrate concentration.

5. BMP Analysis

Although there seems to be some minor disagreement as to how BMP analysis is to be part of an overall monitoring plan, there is general agreement that this is a key goal. It might be worth noting that the key here is BMP analysis, not promulgation; several respondents were adamant about this point. None of the regulatory agency respondents felt that they were developing and monitoring BMPs for possible regulatory action.

6. Analysis of Water Quality Effects due to Water Transfers

No comment was received on this goal. This is surprising given the level of controversy and conflict that arose when AWDI attempted to perform just such a withdrawal. It is likely that through the compilation of water table and other simple water quality variables that Glanzman (1989) studied, such an analysis might be performed at a later time. However, at the present time it would seem that there is too little interest on the part of water quality managers in the San Luis Valley to include this as a current goal.

D. Alternatives for Implementation

On the basis of these questionnaires and interviews, there are a number of alternatives to implementation of the regional ground water quality monitoring plan for the San Luis Valley. Virtually every agency or interested party responding was interested in cooperative efforts. Yet, every agency must understand its role in the master plan. This can only be done when clear and specific monitoring goals are defined (Ward *et al.*, 1990); and that is the point of this paper.

First, who are the water quality managers of the San Luis Valley? By default, it is the people of the San Luis Valley who are the primary water quality managers; they are the most immediately affected by the Valley's water quality, and it is almost exclusively their activities that impact on that water quality. Unfortunately, as the limited response to this questionnaire has demonstrated, they have not always taken a very active role in this task. Therefore, other agencies such as the USEPA, USGS, Colorado Department of Health, CSU, Cooperative Extension, and the Department of Agriculture appear to be the water quality managers simply because of their activities. This may be interpreted by local residents as "outsiders" telling them how to manage agriculture and water resources; yet several respondents from government agencies emphasized that this is exactly what they do not want to do. It is possible that this paradox can be resolved through the integration of all these agencies and local residents in the operation of a ground water quality monitoring system.

In order to implement this regional plan, a single group or agency could be utilized to coordinate the activities and provide a communication link for all the parties involved. Based on the results of the surveys done by Laughlin (1992) and its existing infrastructure, the Rio Grande Water Conservation District has several advantages as a choice for a coordinating agency. It has the legal authority and the trust of Valley residents that position it as a primary water quality management agency. Local monitoring groups would be likely to use the RGWCD as a depository for data. If data were collected by the RGWCD, either it or CDH could enter it into a computerized database. The key is that all data collectors could interact with this single coordinating agency. Since the RGWCD has a strong reputation with the agricultural community and no one has expressed an aversion to dealing with the district, it would be a good first choice to examine in this needed leadership role.

There are certainly other options for a central coordinating agency. Other groups in the Valley that were mentioned in the questionnaire include SLV Resource Conservation and Development, Inc. and the SLV Water Quality Demonstration Project. Since these groups are also involved in monitoring efforts in the Valley, they should also be considered as primary water quality managers. Again, the SLVWQDP has developed a level of acceptance by Valley residents. On the other side of the issue, the CDH Water Quality Control Division (WQCD) has the legal authority and mandate to perform regional ground water quality monitoring in the Valley. Also, the acceptance of the State Engineer's Office (SEO) by the Valley residents and water managers was documented by Laughlin (1992). Although not typically involved in water quality monitoring of this scale, the SEO has expressed increased interest in water quality issues. Finally, the USGS has experience in monitoring and has a number of well-designed shallow monitoring wells in the upper aquifer. Again, there seems to be a contrast in approach; the legalistic versus the practical, and top-down vs. localized management.

If one agency acts as a coordinator for water quality monitoring in the Valley (with advice and guidance from a committee of representative interests), this agency must be capable of a long-term commitment: essentially permanent. Also, if one is to use the EPA's philosophy of integrated watershed management combined with localized environmental management, the long-term residents and water users of the Valley must be the ones to take control of water quality management there. Section 319 money may be available for use by a local group (as is already the case), but it should be part of a long-term master plan. Bringing all these groups together to try to clarify the future of monitoring in the Valley would seem to be the next logical step.

CHAPTER VII.

INTEGRATED INFORMATION GOALS FOR THE SAN LUIS VALLEY

A. Format for Integrated Information Goals

After determining what goals must be satisfied by the monitoring system, specific details must be added to insure that the monitoring addresses all the information needs from the laws and concerns that generated each of the Integrated Information Goals. The items to be specified in each Integrated Information Goal are:

1) Basis for Goal

The specific law, regulation, agency, or group requiring this information is to be named, along with the specific goal(s) from each that are being addressed. Although all these individual goals are combined into the synthesized goal, siting considerations, the variables to be measured, and frequency of measurements for each specific goal may differ.

2) Siting Considerations

General guidelines for site selections are based on the individual information goals and the retrospective analysis from previous monitoring of the Valley.

3) Examples of Variables to be Measured/Frequency of Measurement

The variables to be measured depend largely on regulatory requirements such as Tables 1-4 of the Colorado Classifications and Water Quality Standards for Ground Water. Additionally, detailed analysis of previous monitoring studies will determine what contaminants have been detected in the past. Specific goals such as monitoring the effectiveness of a BMP to reduce nitrates in the ground water will also define the variable(s) of interest.

Frequency of measurements will be based on analysis of previously collected data where such data exists; otherwise, rule-of-thumb practices must suffice. It is important to note that statistics cannot be applied to nonexistent data; if it is later determined that more frequent collection is required, previously collected data may be useless for trend analysis (McBride and Loftis, 1991).

B. Integrated Information Goals for the San Luis Valley

The development of Integrated Information Goals for the San Luis Valley is dependent on the establishment of clear, concise monitoring goals. That is the primary purpose of this thesis. The final step of developing Data Analysis Protocols (DAPs) like those specified by Adkins (1993) cannot be completed until a regional water quality monitoring plan is organized around the agencies and parties who will be involved. The specific goals to be pursued and the budget available will determine the final DAPs' structure. Once the actual infrastructure is established, these DAPs can be defined. The Integrated Information goals are general outlines of options based on the extrapolation of individual information goals from each law and concern discussed in this paper. More detailed study of the hydrogeologic nature of the Valley will be necessary to confirm and make more specific the suggestions presented herein. A summary of this information is provided in table 7.1, with detailed descriptions of the Integrated Information Goals given below.

Baseline Conditions—Unconfined Aquifer

Determine baseline ground water quality for the unconfined aquifer as described in 3.12.5(1) and shown in figure 4.1, monitoring for those contaminants listed in the tables in 5CCR 1002-8 3.11 and 3.12 that are suspected of existing within the aquifer, based on land uses and chemical uses. These should include representative sites for the future monitoring of BMPs.

The critical issue in this goal is choosing representative sites. There are two types of sites in the upper aquifer; one for long term regional trend detection and the other for BMP evaluation.

Table 7.1. Summary of Integrated Information Goals.

INTEGRATED INFORMATION GOAL	SOURCE OF GOAL	EXAMPLES OF VARIABLES TO BE MEASURED/FREQUENCY OF MEASUREMENTS
BASELINE CONDITIONS Determine baseline ground water quality for the unconfined aquifer	REGIONAL TREND DETECTION SITES SECTION 319 (1) FIFRA (Long term 1) WQCD (Antidegradation 1,2; Wellhead Protection 1) SB90-126 (1) EPA/CONGRESS (3) LOCAL RESIDENTS (1,3)	•Variables should include pH, nitrates, and specific conductivity. •Sampling frequency should be at least quarterly for one year to establish a baseline that accommodates seasonality; monthly sampling will give a better representation of maximum and minimum nitrate concentrations.
	BMP EVALUATION SECTION 319 (2,3) FIFRA (Short term 1,3; Long term 3) SB90-126 (2,3,4) EPA/CONGRESS (2,5) COOPERATIVE EXTENSION (1) LOCAL RESIDENTS (5,6,7)	•Initial samples should include any contaminants that are to be mitigated through the use of BMPs. This will almost always include nitrates. •Sampling frequency should be no less than quarterly for as long as three years before BMP implementation; monthly sampling will give a better representation of seasonal maximum and minimum values for nitrates.

Table 7.1. Summary of Integrated Information Goals (cont.).

BASELINE CONDITIONS Determine baseline ground water quality for the confined aquifer	SECTION 319 (1) WQCD (Antidegradation 2; Wellhead Protection 1) EPA/CONGRESS (3,4) LOCAL RESIDENTS (2,3)	•Any contaminants previously found at "significant" levels in drinking water at the well site; variables should include pH, specific conductivity, and nitrates. •Frequency of sampling can be determined by analysis of existing databases from municipal water suppliers.
SOURCE IMPACTS	SECTION 319 (2) FIFRA (Short term 1,2) WQCD (Antidegradation 4; Wellhead Protection 3) SB90-126 (2) EPA/CONGRESS (5) LOCAL RESIDENTS (5)	•Nitrates, pH, specific conductivity, and other variables determined from baseline monitoring; Possible ^{15}N isotope testing in suspect areas. •Frequencies should be determined as discussed under baseline monitoring
WATER TABLE / PIEZOMETRIC HEAD LEVELS	COLORADO GROUND WATER MANAGEMENT ACT (1,2) LOCAL RESIDENTS (1,2,7,8)	•Measure the height of the water surface in the well or, if artesian, the total head before pumping •Frequency of monitoring will be determined by the frequency with which the well is visited for monitoring of other water quality variables.

Table 7.1. Summary of Integrated Information Goals (cont.).

TREND DETECTION	FIFRA (Long term 2) WQCD (Antidegradation 3; Wellhead Protection 2) SB90-126 (2) EPA/CONGRESS (1,5) LOCAL RESIDENTS (4,9)	•Variables to be measured should be determined from retrospective analysis of previous studies as well as analysis of the data from baseline monitoring •Frequency of sampling can be determined from the statistical analysis of baseline monitoring data.
BMP ANALYSIS	SECTION 319 (2,3) FIFRA (Short term 1,2,3; Long term 3) SB90-126 (3,4) EPA/CONGRESS (2,5) COOPERATIVE EXTENSION (1) LOCAL RESIDENTS (5,6,7)	•Any contaminants that are to be mitigated through the use of BMPs •Sampling frequency should be at least quarterly and preferably monthly. The BMP and the sampling must continue for at least two to three years for significant trends in water quality to be seen

Regional Trend Detection Sites

1) Basis for Goal

   a) SECTION 319 (1)

   b) SB90-126 (1)

   c) FIFRA (Long term 1)

   d) EPA/Congress (3)

   e) Local Residents (1,3)

   f) WQCD (Antidegradation 1,2; Wellhead Protection 1)

2) Siting Considerations

   a) Avoid unique sites:

      Near chemical storage or transfer facilities.

      Near ditches or dry runs; and

      In or near irrigation wells where chemical spillage or preferential pathways through damaged or missing borehole grouting can produce locally high pollutant levels.

   b) Avoid unique hydrogeology, other than that which would indicate the areal effect of a particular hydrogeological characteristic that might enhance or inhibit contamination.

   c) Use data collected from previous studies to increase sampling density in those areas suspected to have higher areal concentration gradients.

d) Include sampling from the wellhead protection area included in 5CCR 1002-8 3.12.7(4).

e) Include the use of existing study sites, such as those in use by NAWQA.

f) Emphasize sampling of domestic wells that supply drinking water from the upper aquifer in order to examine possible immediate health effects.

3) Examples of Variables to be Measured/Frequency of Measurements

a) Variables should include pH, nitrates, and specific conductivity.

b) Frequency of sampling should be at least quarterly for one year to establish a baseline that accommodates seasonality (Loftis and Ward, 1980). Monthly sampling will give a better representation of maximum and minimum nitrate concentrations.

BMP Evaluation

1) Basis for Goal

a) Section 319 (2,3)

b) EPA/Congress (2,5)

c) FIFRA (Short term 1,3; Long term 3)

d) Local Residents (5,6,7)

e) SB90-126 (2,3,4)

f) Cooperative Extension (1)

2) Siting Considerations

a) Due to the need for significant pre-BMP implementation data records (Spooner *et al.*, 1991), BMP sites should be determined and monitored for two to three seasons before a BMP is implemented. Therefore, even if BMPs are not currently planned, a pre-selection of sites and location of monitoring wells is extremely advantageous to BMP analysis. It is understood that this requires some "crystal ball" forecasting, but the use of a local coordinating agency may be of benefit in this task.

b) When possible, use paired watershed designs in implementing BMPs and siting BMP monitoring wells (Spooner *et al.*, 1991).

c) Avoid unique sites, as specified above

3) Examples of Variables to be Measured/Frequency of Measurements

a) Initial samples should include any contaminants that are to be mitigated through the use of BMPs. This will almost always be nitrates (and nitrites). If the effect on a contaminant not specifically addressed by the BMP is unknown, that contaminant could also be included for study of the BMP's peripheral effects (e.g., alkalinity, chloride, sodium).

b) Sampling frequency should be at least quarterly for as long as three years before BMP implementation; monthly sampling will give a better representation of maximum and minimum nitrate concentrations.

Baseline Conditions—Confined Aquifer

Determine baseline ground water quality for the confined aquifer, monitoring for those contaminants listed in the tables in 5CCR 1002-8 3.11 and 3.12 that are suspected of existing within the aquifer, based on previous monitoring data, and concentrating on those areas that are near drinking water wellheads. Sampling water from water providers as defined by the Colorado Primary Drinking Water Regulations should be included for compliance monitoring with drinking water standards.

1) Basis for Goal
   a) Section 319 (1)
   b) EPA/Congress (3,4)
   c) Local Residents (2,3)
   d) WQCD (Antidegradation 2; Wellhead Protection 1)

2) Siting Considerations

a) Avoid unique hydrogeology, other than that which would indicate the areal effect of a particular hydrogeological characteristic that might enhance or inhibit contamination.

b) Use data collected from previous studies to increase sampling density in those areas suspected to have higher areal concentration gradients.

c) Include sampling from the wellhead protection area included in 5CCR 1002-8 3.12.7(4).

d) Since municipal water suppliers who use ground water already have an established infrastructure and database on water quality from their wells, these should be utilized and incorporated into the database.

3) Examples of Variables to be Measured/Frequency of Measurements

a) Variables should be selected from any contaminants previously found at "significant" levels in drinking water at the well site or in nearby wells; the definition of significant being related to the drinking water standards for that variable. Suggested variables include pH, specific conductivity, and nitrates.

b) Frequency of sampling can be determined by statistical analysis of existing databases from municipal water suppliers. The use of statistical analysis should be specified in the Data Analysis Protocols.

Source Impacts

Determine possible sources of point and nonpoint contamination of the upper and lower aquifers, particularly those sources that threaten compliance in wells as determined from the baseline monitoring.

1) Basis for Goal
   a) SECTION 319 (2)
   b) FIFRA (Short term 1,2)
   c) SB90-126 (2)
   d) EPA/Congress (5)
   e) WQCD (Antidegradation 4; Wellhead Protection 3)
   f) Local Residents (5)

2) Siting Considerations
   a) Use those sites chosen in Baseline Monitoring for both the lower and upper aquifers.
   b) Include sampling from the wellhead protection area included in 5CCR 1002-8 3.12.7(4).

3) Examples of Variables to be Measured/Frequency of Measurements

   a) Nitrates, pH, specific conductivity, and other variables determined from baseline monitoring (both aquifers), and possible ^{15}N isotope testing for the upper aquifer for detection of nitrate sources, particularly near Center or those areas where non-agrichemical sources of nitrates are suspected.

   b) Monitoring frequencies should be determined as discussed under baseline monitoring

Water Table/Piezometric Head Levels

Measure the height of the water level in the well at all baseline monitoring sites.

1) Basis for Goal

   a) COLORADO GROUND WATER MANAGEMENT ACT (1,2)

   b) Local Residents (1,2,7,8)

2) Siting Considerations

   Those sites chosen in Baseline Monitoring for both the lower and upper aquifers are convenient choices for water table/piezometric head monitoring. However, it is important to note that unless the water height in the well represents only one aquifer, the data will be virtually useless.

This is likely a common situation in the Valley, where wells are screened through more than one aquifer, or the well provides a flow path between two aquifers. (Hearne and Dewey, 1988) Trends in water height for a well cannot be used in modeling if that height represents some unknown combination of heads in two or more aquifers. No understanding of the ground water hydrology will be gained. Thus, wells will need to be selected based on reliable knowledge of the ability of that well to represent the head from only one aquifer.

3) Examples of Variables to be Measured/Frequency of Measurements

   a) Measure the height of the water surface in the well or, if artesian, the total head before pumping

   b) Frequency of monitoring will be determined by the frequency with which the well is visited for monitoring of other water quality variables.

Trend Detection

Considering hydrogeologic and land use factors, use representative sites from (1) to determine regional trends in water quality and water levels for both aquifers.

1) Basis for Goal

   a) FIFRA (Long term 2)

   b) SB90-126 (2)

   c) EPA/Congress (1,5)

   d) Local Residents (4,9)

   e) WQCD (Antidegradation 3; Wellhead Protection 2)

2) Siting Considerations

   a) Sample sites should be chosen from those sites chosen in Baseline Monitoring for both the lower and upper aquifers. The location and number of sites should be based on the statistical methods used.

   b) Include sampling from the wellhead protection area included in 5CCR 1002-8 3.12.7(4).

3) Examples of Variables to be Measured/Frequency of Measurements

   a) Water quality variables to be measured should be determined from retrospective analysis of previous studies as well as analysis of the data from baseline monitoring. Specific conductance and nitrate levels will probably be of greatest interest due to the continuous impact of agriculture on those variables. Pesticide testing may be performed every two years in representative sites in those areas where pesticides are heavily used, since there presently appears to be little effect on water quality from them. If a trend is seen, particularly in a given area, more aggressive testing for pesticides may be appropriate. Other variables to be considered are those listed in the tables in 5CCR 1002-8 3.11 and 3.12.

b) Frequency of sampling can be determined from the baseline monitoring analysis as described under goal 1a for the upper aquifer and analysis of municipal water supplier databases as described under goal 1b for the lower aquifer. Generally, one would expect quarterly monitoring for the upper aquifer (Loftis and Ward, 1980) would be adequate, but the shallowness of the aquifer may require more frequent sampling (Eddy-Miller, 1993). The lower aquifer is not as likely to show seasonal trends due to the aquifer's size and surface isolation (Spooner *et al.*, 1991), so an annual or semi-annual sampling frequency may be adequate.

BMP Analysis

Using representative sites from (1), determine the effectiveness of voluntary Best Management Practices instituted to slow degradation of or improve ground water quality, and determine if these BMPs will be adequate to meet the water quality and antidegradation standards set by the Water Quality Control Commission under 5CCR 1002-8 3.11 and 3.12.

1) Basis for Goal

   a) SECTION 319 (2,3)

   b) SB90-126 (3,4)

   c) FIFRA (Short term 1,2,3; Long term 3)

   d) EPA/Congress (2,5)

   e) Cooperative Extension (1)

   f) Local Residents (5,6,7)

2) Siting Considerations

   Use those sites originally defined in the baseline monitoring for BMPs. It should be apparent that as BMPs are instituted in other fields, these sites will be added accordingly, but the need for baseline data is still essential to effective BMP analysis.

3) Examples of Variables to be Measured/Frequency of Measurements

   a) Variables to be sampled should include any contaminants that are to be mitigated through the use of BMPs. This will almost always be nitrates (and nitrites). If the effect on a contaminant not specifically addressed by the BMP is unknown, that contaminant could also be included for study of the BMP's peripheral effects (e.g., alkalinity, chloride, sodium).

   b) Sampling frequency should be at least quarterly and preferably monthly. The BMP and the sampling must continue for at least two to three years and preferably longer for significant trends in water quality to be seen and determined as statistically significant (Spooner *et al.*, 1991, Eddy-Miller, 1993).

Analysis of Water Quality Effects due to Water Transfers

Due to the questionnaire results, this is removed from the list of monitoring goals.

CHAPTER VIII.

CONCLUSIONS

A. Summary

The purpose of this research was to define monitoring goals relevant to ground water quality monitoring in the San Luis Valley. A legal and regulatory review was performed, along with an evaluation of the key agencies and interested parties in order to determine what monitoring information was required by each of these. The numerous individual goals derived from this study were then synthesized down into six information goals. These were refined by asking those involved in water quality management to determine the usefulness and validity of these goals in their work. A set of Integrated Information Goals was developed that included specific details to insure that the monitoring would address each of the laws and concerns that generated these goals. Suggestions for a management structure to carry out the coordination of such a regional monitoring system were also made, based on existing agencies' involvement in water quality issues in the Valley.

B. Sources of Monitoring Goals

The laws and regulations which are relevant to ground water quality monitoring in the San Luis Valley do not typically present clear information goals. As a result, extrapolating these goals tends to be a subjective process, often paying as much attention to legal statements of purpose and objectives as the actual legislation. Additionally, the laws covering nonpoint source pollution of ground water are not enforcement and rulemaking in nature as are the point source laws. Therefore, the emphasis is on voluntary compliance; there are no deadlines or enforcement provisions such as those found in point source pollution regulations or the Clean Air Act of 1990. As an example, laws may force pesticides to be manufactured such that they are more "environmentally friendly," but actual field use practices such as BMPs are not currently legally enforced. There are laws such as Colorado SB-126 which discuss the promulgation of mandatory BMPs, but no agency appears eager to consider such an action. Synthesizing monitoring goals from these laws is therefore a somewhat subjective task.

The other complicating issue is in identifying the information needs of the water quality managers in the San Luis Valley. Specifically, who are these managers? Ultimately, every resident of the Valley is dependent on the ground water in some way: physically, for drinking, irrigation, or stock watering use; economically, since without ground water most agriculture (the Valley's economic base) in this intermontane valley desert would be impossible; socially, as the lack or loss of agriculture would likely produce much the same result as the loss of mining in other ghost towns in Colorado. Yet the residents of the Valley have not taken the most active role in water quality management. Thus, the appropriate government agencies perform their legally mandated monitoring and evaluation activities in the Valley, which may give residents the perception that "outsiders" control water quality management in the Valley. As a result, monitoring goals for the most important group of water quality managers, the people of the Valley, are difficult to establish.

Finally, the hydrogeology of the San Luis Valley is complex and not fully understood. There are numerous non-contiguous aquifers of unconfined, perched, semi-confined, and confined types, and a discontinuous series of clay or volcanic layers separating them. Faults create vertical hydraulic pipelines. As a result, the information produced from regional ground water quality monitoring must be carefully interpreted.

C. Monitoring Goals for the San Luis Valley

Based on the research discussed, a set of monitoring goals was developed for a regional ground water quality monitoring system for the San Luis Valley. This set of goals was provided to various agencies and parties who could be considered part of the water quality management structure for the Valley. Through interviews and questionnaire responses, the goals were modified to reflect the stated information needs of the respondents. The final set of monitoring goals is as follows:

1. Baseline Conditions

a. Determine baseline ground water quality for the unconfined aquifer as described in 3.12.5(1) and shown in Figure 4.1, monitoring for those contaminants listed in the tables in 5CCR 1002-8 3.11 and 3.12 that are suspected of existing within the aquifer, based on land uses and chemical uses. The two types of sites to be established should include regional trend detection sites and BMP evaluation sites.

b. Determine baseline ground water quality for the confined aquifer, monitoring for those contaminants listed in the tables in 5CCR 1002-8 3.11 and 3.12 that are suspected of existing within the aquifer, based on previous monitoring data, and concentrating on those areas that are near drinking water wellheads. Sampling water from water providers as defined by the Colorado Primary Drinking Water Regulations should be included for compliance monitoring with drinking water standards.

2. Source Impacts

Determine possible sources of point and nonpoint contamination of the upper and lower aquifers, particularly those sources that threaten compliance in wells as determined from the baseline monitoring.

3. Water Table/Piezometric Head Levels

Measure the height of the water level in the well at all baseline monitoring sites.

4. Trend Detection

Considering hydrogeologic and land use factors, use representative sites from (1) to determine regional trends in water quality and water levels for both aquifers.

5. BMP Analysis

Using representative sites from (1), determine the effectiveness of voluntary Best Management Practices instituted to slow degradation of or improve ground water quality, and determine if these BMPs will be adequate to meet the water quality and antidegradation standards set by the Water Quality Control Commission. under 5CCR 1002-8 3.11 and 3.12.

Based on these goals, a set of Integrated Information Goals (IIGs) was developed (see the summary in Table 7.1). Each IIG includes:

a) Basis for goal: the specific law(s), regulation(s) or party or parties from which the monitoring goal was derived and is designed to address.

b) Siting considerations: general rules for siting of monitoring wells.

c) Suggestions for variables to be measured: guidelines and specific suggestions for the determination of what variables are to be measured and at what frequency.

D. Recommendations for Further Work

The next step in the development of a regional ground water quality monitoring system for the San Luis Valley is to establish an infrastructure for the management of the system. From the results of this research, it would seem that the first priority is to develop the interest and involvement of agencies already in the Valley, such as the Rio Grande Water Conservation District, the San Luis Valley Water Quality Demonstration Project and the San Luis Valley Resource Conservation and Development, Inc. These are more likely than outside agencies to have a greater level of acceptance on the part of farmers in the Valley, increasing the probability of cooperation and success. Such a group, given an appropriate level of long-term commitment, could act to coordinate and even compile data from various monitoring sources. Reporting of information to the various water quality managers could be done by the individual agencies, by this central coordinating agency, or both. In any case, it would be preferable that resources from outside agencies be available to assist in this process.

Once an infrastructure is established, specific monitoring goals may be discussed. Not all the goals developed here may be implemented at once. The results of this research show that baseline data, trend detection and BMP analysis (in that general order) are the top priorities among the water quality managers responding. Due to the need for two to three years of pre-BMP implementation data (Spooner *et al.*, 1991), it would be advantageous to establish these sites as soon as possible even if BMPs are not currently ready for testing.

Finally, once the infrastructure and monitoring goals are established, the Integrated Information Goals given in this paper may be further developed into

Data Analysis Protocols. A final document should be prepared in which Data Analysis Protocols (with sampling protocols) are specified (Adkins, 1993; Ward *et al.*, 1990). The purpose of this document is to ensure consistency of data collection and analysis in order to effectively evaluate trends and relationships in water quality despite changes in personnel, data record attributes, and environmental factors. Documentation should also include provisions for the revision of the Data Analysis Protocols and the factors which would trigger such revisions (Adkins, 1993).

Although the goal of analyzing water quality effects due to water transfers was removed from the final list, it is one that the residents of the Valley may want to consider. By establishing what information is needed to perform such an analysis, the appropriate variables can be included in baseline and trend detection sampling protocols for later use in modeling. In the case of a future dispute over a large-scale export of ground water from the Valley (e.g., AWDI) this could supply definitive information as to such a proposal's effect on ground water quality and quantity, as well as its economic and social effects on the people of the Valley. Failure to consider this possibility now may result in an inability for the Valley's residents to control the management of their ground water in the future.

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APPENDIX: INFORMATION GOALS QUESTIONNAIRE

EVALUATION OF PROPOSED MONITORING GOALS

1) Optional!! My Name ______________________________

2) Optional!! Agency/Group Name______________________________

3) How would you like your comments handled?
I don't wish to provide any identification________
Keep my comments anonymous, although I have provided my name for possible clarification in writing your report____________
Use my agency's name only, keep me anonymous_______
Feel free to use my name and the name of my agency/group__________

4) Are there any laws, regulations, agencies, etc. that you feel were overlooked in generating these information goals? (If possible, please include references, names, phone numbers, etc.)

____
____
____

5) Which of the synthesized goals do you see as representative of the interests of your agency or group?

____
____
____

6) Do you have any comments, changes, additions, criticisms to make for the specific discussion of the laws, regs, etc. specific to your area of interest?

____
____
____

7) Do you have any comments, changes, criticisms to make for the goals specific to your area of interest?

____
____
____

8) Do you have any comments, changes, criticisms to make for the goals not specific to your areas of interest or to the synthesis of goals?

____
____
____

9) Future research at Colorado State University will include a more detailed design of a monitoring system for the Valley. Upon which information goals do you feel this design should concentrate its efforts?

10) One of the possibilities in implementing this 'master plan' for monitoring in the Valley is to combine agency efforts where there are similar goals. Are you aware of such cooperative efforts presently in effect? Do you see any possibility of your group or agency working in such a cooperative effort? Please be as specific as possible.

11) As mentioned previously, it is not the intent of our research to critique past monitoring efforts or the lack thereof. However, we would like to get your objective and editorial comments on what elements of ground water quality monitoring you have found critical, lacking, underdeveloped, or otherwise worthy of discussion from your experience in the field. These comments may be as general or specific as you like.

12) You may find that many of the questions here are addressed in previous works by yourself or others. Any inclusions of such materials or references thereto would be appreciated, either in lieu or in addition to comments in the questionnaire.

13) Additional comments, please