# PROPOSED WORK PLAN FOR THE STUDY OF HYDROLOGIC EFFECTS OF GROUND-WATER DEVELOPMENT IN THE WET MOUNTAIN VALLEY, COLORADO

By S. G. Robson

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## CONTENTS



## ILLUSTRATIONS



## CONVERSION TABLE

| *Multiply inch-pound units* | *By* | *To obtain SI units* |
|---|---|---|
| inch (in.) | 25.40 | millimeter |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| square mile ($mi^2$) | 2.590 | square kilometer |
| gallon per minute (gal/min) | 0.0631 | liter per second |
| acre-foot per year (acre-ft/yr) | 0.001233 | cubic hectometer per year |

# PROPOSED WORK PLAN FOR THE STUDY OF HYDROLOGIC EFFECTS OF GROUND-WATER DEVELOPMENT IN THE WET MOUNTAIN VALLEY, COLORADO

By S. G. Robson

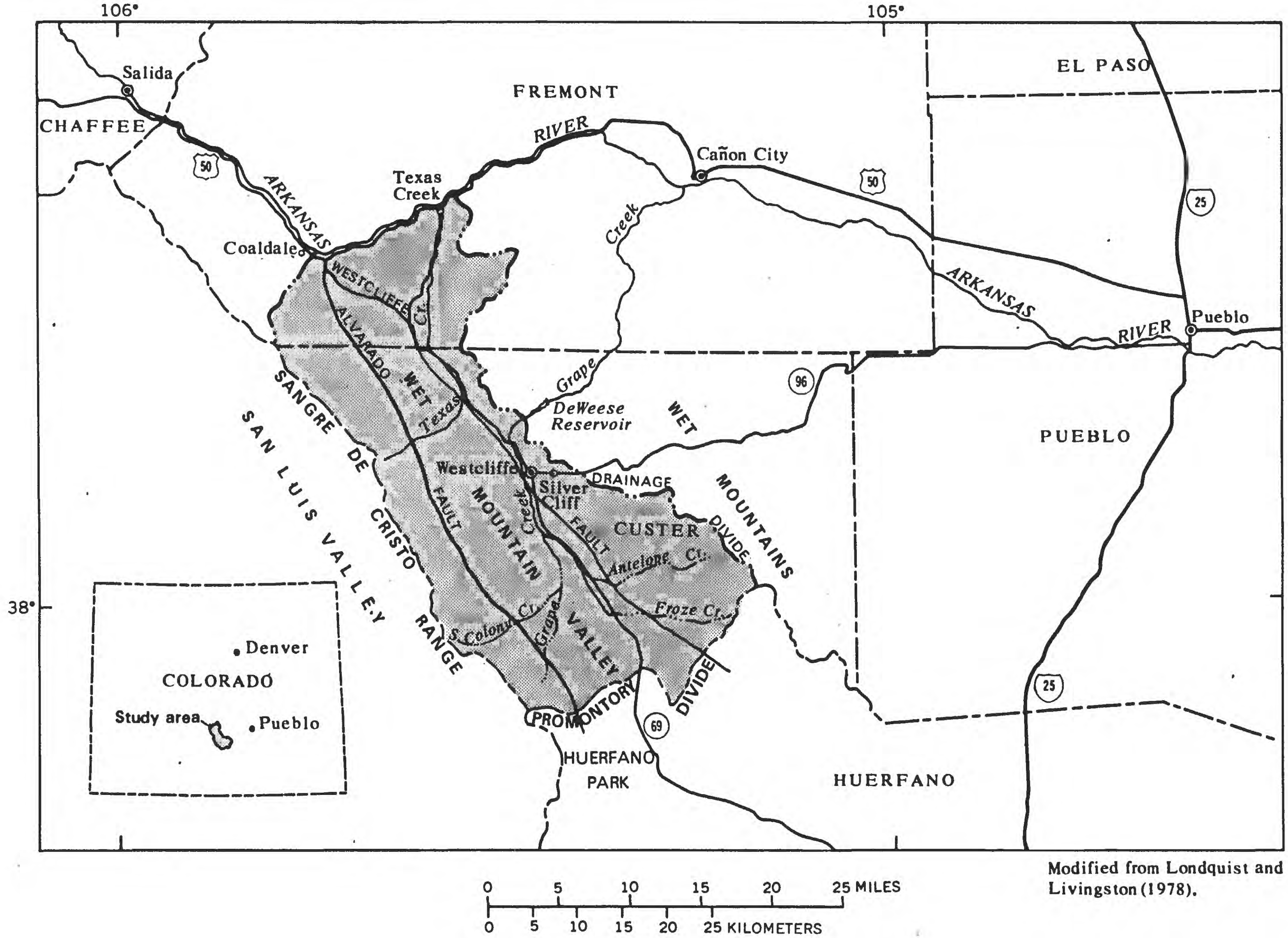
## ABSTRACT

The Wet Mountain Valley is an intermontane graben bounded by the Sangre de Cristo and Wet Mountains, located about 50 miles west of Pueblo, Colorado. Large-scale ground-water development in the valley could adversely affect existing water rights in the valley and in the downstream Arkansas River basin. A water-resource investigation has begun to provide a better understanding of the hydrologic system and to determine the extent that quantity and quality of surface and ground water in the valley might be affected by proposed development. This report presents a plan of study outlining data collection, interpretation, and analytical techniques that could be used in subsequent phases of the study to meet the project objectives.

It is proposed that additional data collection be undertaken to better define the hydrologic system in the valley and that ground-water flow modeling techniques be employed to simulate the response of the hydrologic system to ground-water development. The effects of development on water quality will be estimated on the basis of model-simulation results and additional water-quality data collected near areas of poor-quality water in the shallow water table. Data to be collected will better define the recharge-discharge characteristics (including evapotranspiration), and aquifer characteristics, geologic characteristics, and water-quality conditions in the valley-fill aquifer. Long-term monitoring can be used to indicate impacts of development by comparing measurements of predevelopment and postdevelopment hydrologic conditions.

## INTRODUCTION

The Wet Mountain Valley is located about 50 mi west of Pueblo, Colorado, between the Sangre de Cristo Mountains on the west and the Wet Mountains on the east (fig. 1). The thickly alluviated part of the valley floor between the Alvarado and Westcliffe Faults is about 35 mi long and is about 2 mi wide at the northern end near Coaldale and is about 10 mi wide at the southern end near the topographic divide with Huerfano Park. The upper 200 ft of valley-fill sediments commonly supply water to wells, but sediments thicker than 6,000 ft are thought to occur along the west side of the valley (Zohdy and others, 1971) and may have considerable water-yielding potential.




Modified from Londquist and Livingston (1978).

Figure 1.-- Location of study area.

In December 1983, the Round Mountain Water and Sanitation District applied for conditional water rights for 75 wells located throughout the valley. These wells are planned to be completed at depths from 750 to 1,000 ft below land surface and screened at depths below about 100 ft. Pumped at rates from 450 to 1,000 gal/min, the wells would yield from 20,000 to 97,000 acre-ft/yr, depending on the effects that might accrue to other vested, decreed, or conditional water rights in the Arkansas River basin. This development is envisioned to include all unappropriated water in the aquifer that is available without infringing on any existing water rights. A hydrologic study of the Wet Mountain Valley has been proposed (1) to provide a better understanding of the hydrologic system in the valley, and (2) to determine the extent that the quantity and chemical quality of both surface and ground water in the valley might be affected by proposed development. This report presents a work plan outlining data collection, interpretation, and analytical techniques that could be used in this study to meet the project objectives.

## GEOHYDROLOGY OF THE STUDY AREA

The Wet Mountain Valley is a westward-dipping intermontane graben bounded on the west by the Alvarado Fault and on the east by the Westcliffe Fault (fig. 1). Vertical displacements on the Alvarado Fault of more than 6,700 ft (Zohdy and others, 1971) have brought Pennsylvanian and Permian sandstone, conglomerate, and shale of the Sangre de Cristo Formation into lateral contact with unconsolidated valley-fill materials consisting of interlayered sand, gravel, clay, and volcanics of the Tertiary Huerfano and Santa Fe Formations. Lesser vertical displacement on the Westcliffe Fault is shown by Zohdy and others (1971) to be about 1,200 ft near the town of Westcliffe. Here the valley-fill materials are in lateral contact with Precambrian igneous and metamorphic rocks of the Wet Mountains. Quaternary alluvium covers the northern and central part of the valley and generally extends from pediments on the lower part of the Sangre de Cristo Mountains to eastward-sloping merged alluvial fans in the valley. Resulting surface-water drainage is predominantly eastward from the Sangre de Cristo Mountains to the northward-flowing reaches of Texas, Grape, Antelope, and Froze Creeks, which are located along the eastern margin of the valley (fig. 1). A surface-water and ground-water divide at the southern end of the valley separates the Wet Mountain Valley both physically and hydrologically from Huerfano Park. The convergence of the Alvarado and Westcliffe Faults at the northern end of the valley marks the northern extent of the valley-fill materials.

The Sangre de Cristo Mountains are several thousand feet higher than the Wet Mountains, receive move precipitation (Londquist and Livingston, 1978), and consequently produce the most runoff into the valley. Recharge to the valley-fill material occurs as direct infiltration of precipitation on the valley floor, or as infiltration of surface-water inflow from the surrounding mountains. The asymmetrical topography of the valley, and the larger precipitation and runoff on the west side of the valley, produce a predominantly eastward flow of water in the valley-fill aquifer. The interlayering of fine- and coarse-grained sediments in the valley-fill materials produces anisotropic conditions in the aquifer. Numerous clay and fine-grained volcanic beds serve as confining layers for water in adjacent coarse-grained sediments, and artesian conditions are common in the low-lying areas along the east side of the valley. The resulting relatively low vertical hydraulic conductivity likely produces an aquifer system in which most recharge moves laterally through the upper part of the aquifer from recharge areas to discharge areas, and only a small part of the recharge enters the deeper part of the aquifer and recharges the confined system.

The northward-trending reaches of Texas, Grape, and Antelope Creeks serve as discharge areas for the aquifer system. Evapotranspiration from the grassland soil and shallow water table along the east side of the valley is an important component of water loss from the valley. Ground-water underflow into or out of the valley is probably insignificant. Water pumped from wells primarily is used for stock or domestic purposes, and the current (1984) small rate of pumping has not significantly altered the steady-state (pristine) condition of the valley-fill aquifer.

## METHOD OF STUDY

The objective of the study of the Wet Mountain Valley is (1) to provide a better understanding of the hydrologic system in the valley; and (2) to determine to what extent the quantity and chemical quality of both surface and ground water in the valley might be affected by proposed development. Objective 1 can be met in part by updating existing information on the hydrologic system (Zohdy and others, 1971; Scott and Taylor, 1975; Londquist and Livingston, 1978) with current data. However, a better definition of the hydrologic system will be obtained as a result of knowledge gained in the construction and calibration of a ground-water flow model of the valley-fill aquifer. This work will provide a quantitative definition of the various characteristics of the hydrologic system and will illustrate the function and importance of each component of the system in the overall movement of water through the valley.

The quantitative aspects of objective 2 should be met by use of ground-water flow modeling techniques that will allow simulation of the response of the aquifer to various pumping alternatives. A finite-difference model built in a multilayer steady-state configuration will be appropriate for this simulation. Use of a variable-interval grid will allow greatest model resolution in the area of principal concern near Westcliffe. A coarser and more economical grid interval may be used in the outlying parts of the valley. This model can be calibrated (a test of its validity) by comparing model-calculated water levels with current water levels in the aquifer, which are still in near steady-state condition. However, the lack of transient conditions (significant water-level changes) in the aquifer will preclude calibration as a transient-state model. Consequently, simulation of development alternatives requiring transient-state simulation will be performed using an uncalibrated transient-state model developed from the calibrated steady-state model.

Such a modeling approach requires quantitative estimates of numerous characteristics of the hydrologic system and will produce simulation results of no better accuracy than that of the estimated characteristics. Thus, if the response of the hydrologic system to development is to be estimated accurately, the characteristics of the hydrologic system first must be measured to an appropriate level of accuracy. Because the transient-state model will not be calibrated fully, it is important to examine the response of the model to changes in the values of the hydrologic characteristics used in the model. A limited sensitivity analysis will be undertaken to demonstrate the range of model response that could be produced by the possible errors, which occur in estimating the hydrologic characteristics used in the model.

The chemical-quality aspects of objective 2 can be met by first defining the existing water quality in the valley-fill aquifer and then using results of modeling to indicate the likely direction and rate of ground-water flow assuming various schemes of development. With this information, the possible migration of poor-quality water currently in the shallow part of the aquifer near Westcliffe can be studied to estimate the possible impacts on adjacent areas.

The predictive approach to objective 2 outlined previously could be supplemented by field observation of the response of the hydrologic system to development. To measure changes caused by ground-water development, background conditions need to be measured prior to development. Post-development measurements then can be compared to corresponding predevelopment measurements to indicate changes that may result from ground-water development.

## ADDITIONAL DATA REQUIREMENTS

The Wet Mountain Valley is similar to the San Luis Valley in hydrologic conditions such as recharge from mountain-front runoff, an aquifer consisting of a thick sequence of alluvial and volcanic materials, evapotranspiration of ground water from areas of shallow water table, and relatively small rates of surface-water discharge from the valley. Because of these similarities, the hydrologic system in the Wet Mountain Valley can be expected to respond to stress in a manner similar to that observed in the more developed parts of the San Luis Valley; thus, it is expected that the ratio of lateral to vertical hydraulic conductivity ($K_l/K_v$) and potential evapotranspiration salvage will be key factors in the future response of the hydrologic system in the Wet Mountain Valley. These two factors indirectly ($K_l/K_v$) or directly (salvage) affect the water levels in the shallow part of the aquifer system; it is primarily through the shallow aquifer that existing water rights could be affected by development of the deeper parts of the aquifer system. Other model parameters that must be defined prior to model construction include: (1) Recharge-discharge terms such as surface-water inflow and outflow, pumpage, direct recharge to the aquifer from precipitation, and evapotranspiration; (2) aquifer characteristics such as hydraulic conductivity, specific yield, specific storage, and saturated thickness; (3) boundary conditions such as the hydrologic effects of graben-bounding faults and the hydrologic conditions at the southern end of the valley; and (4) geologic characteristics such as the location and structure of lithologic units forming confining layers or water-yielding layers, and the depth of the aquifer system. Additional data also are needed to define the ground-water quality in the upper part of the aquifer in the area of the shallow water table, and in the deeper part of the aquifer near areas of proposed ground-water development.

The magnitude of effort required to define these data can range from a relatively quick estimate based on textbook examples to long-term, intensive, complex, and expensive data collection. The degree of effort needed should be controlled by the accuracy and sophistication required of the model and other study results. In hydrologic studies involving water-rights issues, a cost savings through reduction in collection of critical data may be more than offset by increased costs of litigation needed to resolve the resulting conflict of opinion. Therefore, the data-collection effort outlined here is an effort to properly document the important hydrologic characteristics of the valley with a minimum expenditure of time and financial resources, and is based on discussions of study needs as expressed by Clyde Young, consultant to the Round Mountain Water and Sanitation District, Robert Jesse of the Colorado State Engineers Office, and Russell Livingston of the U.S. Geological Survey.

## Recharge-Discharge Terms

Recharge to the Wet Mountain Valley occurs principally through infiltration of runoff from the Sangre de Cristo Mountains and from infiltration of precipitation on the valley floor. Work by Londquist and Livingston (1978) estimated mean annual surface inflow to the part of the alluvial valley drained by Grape Creek on the basis of 2 years of continuous stage record at 2 stations and periodic measurements at 4 other stations. These results should be updated to incorporate the 1974 to 1978 period of record now available at the two continuous-record stations and expanded to include runoff estimates for the Texas Creek drainage. Additional miscellaneous discharge measurements also could be used to supplement the updated runoff estimates to provide the best estimate of mean annual surface-water inflow to the valley. If data are insufficient to estimate mean annual runoff from some drainages, additional periodic discharge measurements could be made to supplement existing data. Operation of additional continuous-record stations may not be required to obtain adequate mean annual surface-water inflow estimates.

Mean annual surface-water outflow from the southern part of the valley is adequately measured at the continuous-record station on Grape Creek near Westcliffe (Londquist and Livingston, 1978). Operation of the gage on Texas Creek at Texas Creek has been discontinued. This gage could be reactivated and the record correlated with periodic discharge measurements to be made on Texas Creek at the boundary of the valley-fill aquifer. This will provide an estimate of mean annual outflow from the Texas Creek drainage area.

Additional data are needed to define the distribution of mean annual precipitation because this source is shown by Londquist and Livingston (1978) to constitute 75 percent of the water entering the valley. Because the valley is a closed ground-water basin with minimal discharge as ground-water underflow, water entering the valley from surface inflow and precipitation can only leave the valley by surface outflow and evapotranspiration. If the principal inflow (precipitation) is carefully determined, the difference between total inflow and surface outflow will provide an estimate of mean annual evapotranspiration for the valley as a whole, assuming no major changes in the amount of ground water in storage.

Long-term precipitation data are available from U.S. Weather Bureau stations at Coaldale and Westcliffe, but data are lacking for the remaining area of the valley. Therefore, additional recording and nonrecording precipitation gages could be installed at 10 to 15 locations on the valley floor and operated for at least 2 years. Recording rain gages will provide records of annual rain and snow accumulation and will be used to correlate nonrecording gage data that accurately record only rainfall. An acceptable correlation should be possible because about 75 percent of the mean annual precipitation occurs as rainfall between April 1 and October 31. Records from the new gages then can be correlated with those from the long-term stations at Westcliffe and Coaldale to estimate the areal distribution of mean annual precipitation in the valley.

The mean annual rate of evapotranspiration for the valley is the sum of various rates of evapotranspiration from different types and densities of vegetation located in areas having different depths to ground water. These individual rates must be quantified for the model to properly simulate how much water lost to evapotranspiration might be salvaged if ground-water levels decline. If the proposed development causes water levels in the aquifer to decline in areas that presently have water at a shallow depth, the rate of evapotranspiration discharge from these areas likely will decrease, and water that formerly was lost to the atmosphere will be available for other beneficial use. For example, if a 10-percent reduction in evapotranspiration were possible, more than 18,000 acre-ft/yr of water would be salvaged for other use (Londquist and Livingston, 1978). Thus, a principal part of the data-collection work is directed to defining the present distribution of evapotranspiration rates in the valley, and the way these rates can be expected to change in response to declining water levels. Although the proposed ground-water development in the valley will be designed to have minimum impact on the water level in the shallow aquifer or on surface-water rights or existing land use and vegetation, it is important that the model be built to simulate properly the mechanism by which these impacts could occur. This will allow testing of various development proposals to determine their relative impacts on shallow and deep water supplies.

Data collection required to model evapotranspiration salvage correctly will require mapping of vegetation type and density, and depth to the water table in the upper part of the valley-fill aquifer. Pan-evaporation data collected at a central point in the valley would indicate the rate of evaporation for open water surfaces. The pan-evaporation data also may be approximately equal to the potential evapotranspiration of moist grassland soil as indicated by Pruitt and Lourence (1968). Evapotranspiration determinations can be made using an energy-budget technique (Linsley and others, 1982, p. 160) that requires monitoring of net radiation, soil heat flux (temperature differential at 2 and 4 in. depth), and vapor-pressure gradient (temperature and humidity at 0.5 and 5 ft above the land surface). Equipment requirements can be minimized by repeatedly operating some of the instruments for brief periods (perhaps 24 to 48 hours) at each of several monitoring sites in the valley rather than fully equipping each site. Because differences in evapotranspiration from various soil covers and depths to water are important, the number of monitoring sites will be determined by vegetation and depth to water mapping; perhaps as few as 3 to 5 sites would be sufficient.

Although the aquifer system is in near steady-state condition, pumpage data need to be collected to provide definition of current conditions and to serve as a basis for future pumpage estimates that may be required as part of model simulation of development. Efforts also need to be made to locate and measure discharge from springs and flowing wells. Location, well depth, and water-quality data should be collected to aid in assigning the discharge to a particular geologic unit. This is particularly important near Westcliffe where development of the confined aquifer could reduce discharge from springs or flowing wells supplied from the deep parts of the aquifer. If such flow exists, its reduction could directly affect existing water rights in the area.

## Aquifer Characteristics

Hydraulic conductivity of the volcanic and sedimentary materials of the valley is a critical model parameter and is poorly defined by existing data. Aquifer tests using multiple piezometers installed at varied depths around the pumped well provide a means of determining both lateral ($K_l$) and vertical ($K_v$) hydraulic conductivity. The ratio $K_l/K_v$ is critical because it affects the vertical distribution of head in the multilayer aquifer and thus will determine how pumping from the deep parts of the aquifer might affect heads in the shallow parts of the aquifer. This information also will have direct bearing on the State's determination of "tributary" or "nontributary" status of the deeper parts of the valley-fill aquifer. Several aquifer tests likely would be required to define properly the lateral and vertical variations in hydraulic conductivity across the valley. Drilling of several deep wells may be required because there are few existing deep wells in the valley suitable for such testing. Any deep wells drilled in the area of artesian conditions along the east side of the valley will likely have static water levels many feet above land surface. Artesian conditions are known to exist in wells less than 100 ft deep in this area and higher head can be expected at greater depth. Casing in any deep wells drilled in this area should be solidly cemented to the well bore to prevent washout caused by the large water pressure that may be encountered at depth. If piezometers are installed to monitor aquifer tests, they also could be used to determine specific yield of the water-table aquifer through use of soil-moisture profiling before and during an aquifer test. Specific yield can be calculated from the difference in water content of the saturated aquifer and the drained cone of depression as measured with a neutron soil-moisture probe. Specific storage of the confined parts of the aquifer may be defined by aquifer-test results, or could be estimated from laboratory measurement of the physical characteristics of core samples of the aquifer materials. Thickness of water-yielding materials probably can be adequately estimated for the upper 200 to 300 ft of aquifer from drillers logs of existing wells. Logs of a few wells that are 300 to 1,200 ft deep describe lithology in this depth interval; beyond this depth no information is available to directly estimate lithologic thickness. Such information would need to be provided by drilling deep aquifer-test wells.

## Boundary Conditions

Boundary conditions are relatively well known in the Wet Mountain Valley. The normal faults forming the northeast and west boundaries of the graben have moderate to large vertical displacement and likely form nearly impermeable boundaries of the aquifer system. A ground-water divide is present at the southern end of the valley near the topographic divide with Huerfano Park. This boundary can be adequately simulated by use of a constant-head model boundary located several miles southeast of the topographic divide.

## Geologic Characteristics

The physical characteristics, thickness, and lateral extent of buried volcanic materials might have a significant effect on the hydrology of the aquifer. The lithology and structure of the volcanic and sedimentary materials that have filled the graben are reasonably well defined in outcrops and in the upper 300 ft of the subsurface through use of drillers logs and geophysical logs of water wells. However, in areas without wells and at depths below about 1,000 ft, little is known of the geology. Surface geophysics appears to be the most economically feasible technique for defining the thickness and lateral extent of these units. The need for this work will be determined by the results of aquifer testing. If these tests indicate that the volcanic materials have hydrologic characteristics similar to the surrounding sedimentary materials, then the two units can be treated as one and definition of the extent of the volcanic materials will be unnecessary. However, if the volcanic materials are found to form important confining layers (or permeable layers), then geophysical investigation likely will be required.

The total thickness of the valley-fill materials in the graben is poorly known. If surface-geophysics techniques are used, estimates of the total depth of the valley probably can be obtained. It does not seem necessary to employ surface geophysics solely for the purpose of defining the depth of the valley, because this information likely will not have a significant effect on the results of model simulation. Available data from airborne gravity or magnetic surveys might be used to estimate the depth of the valley fill by assuming that density and magnetic properties of the geologic materials are similar to those recorded in the San Luis Valley. However, without ground-truth information in the form of wells drilled to the base of the valley fill, results of this work are approximate. Geophysical data collected along the east side of the valley by mining companies might be another source of data; however, the usefulness and availability of these data are unknown.

## Water-Quality Information

Evapotranspiration is the largest means of water loss from the valley, constituting about 89 percent of the total discharge (Londquist and Livingston, 1978). The largest rate of evapotranspiration likely occurs in an area of about 50 $mi^2$ in the central part of the valley where depth to ground water is less than 10 ft. Sparse water-quality data indicate larger dissolved-solids concentrations in shallow wells in this area than in other parts of the valley. The dissolved minerals left behind in the soil and in shallow ground water by the evapotranspiration process are not readily flushed from this area because of the low hydraulic gradient and a convergent ground-water flow field in the local aquifer. If development of the aquifer causes a decline in water level in this shallow zone or causes a change in direction of ground-water flow, the poorer-quality water could move into other parts of the aquifer and cause water-quality degradation. The lateral and vertical extent, and dissolved-solids concentration, of this shallow zone of poorer quality water is not adequately defined by existing data. Installation of about 20 shallow wells (5-10 ft deep) would allow water samples to be collected about twice a year for at least 2 years. Initial water-quality analyses should include major anion and cation determinations on a few of these samples, and on a few samples from other wells in the valley. These results and existing data can then be used to develop correlations between specific conductance and dissolved-solids concentration and other dissolved constituents. With these correlations defined, succeeding samples from the shallow observation wells would only require determination of specific conductance, thus greatly reducing the number of expensive analyses. Results of this work can be combined with model and other results to indicate the probable impact of development on the water quality in the aquifer.

Water-quality data also could be collected as part of the aquifer testing of the deep aquifer. Standard complete and trace-metal analyses on these samples would be needed to provide a first determination of water quality at these depths.

## LONG-TERM MONITORING REQUIREMENTS

The predictive capabilities of the model provide a means of examining possible future hydrologic changes caused by ground-water development; however, these predictions are not a substitute for onsite measurement of changes. Because development of additional water resources in the Wet Mountain Valley has the potential of adversely affecting existing water rights, it is important to monitor the hydrologic system before, during, and after development to determine (1) if existing water rights are being affected, and (2) the magnitude of any impacts should they occur. Existing water rights might be affected as a result of water-level declines in either the deep or shallow parts of the aquifer. Declines in the deep part of the aquifer could reduce discharge from springs or flowing wells yielding water from these deeper zones. Monitoring should be directed toward periodically measuring discharge from these sources of surface-water base flow to detect any decrease in spring flow or well discharge caused by head decline in the deep aquifer. Periodic measurement of water levels in nearby wells also would be needed. Water-level declines in the shallow part of the aquifer could cause: (1) A reduction in evapotranspiration, (2) a reduction in discharge from the shallow aquifer to stream base flow, and (3) induced recharge of surface water into the shallow aquifer. The latter two conditions tend to reduce surface-water flow out of the valley. This reduction can be detected by the gage on Grape Creek at Westcliffe. However, other factors may cause a reduction in observed outflow, and identification of specific causes may not be possible without continuous records on at least one inflow stream (possibly South Colony Creek). The monitoring of surface inflow and outflow coupled with monitoring of ground-water levels in both shallow and deep wells, primarily in the area of Westcliffe, should allow determination of the hydrologic effects of ground-water development. This monitoring could begin during this study and would need to continue beyond the time of development of the deep aquifers.

## SCHEDULE OF WORK ACTIVITIES

The relative timing of various work activities needed to conduct the study is determined by the order of need for each type of data, the length of time required to collect the data, and the needs and interests of agencies cooperating in the study. These requirements indicate a 5-year study period with the following order of work activities.

I. First year.
   A. Begin test drilling and aquifer testing.
   B. Set up precipitation-monitoring network and begin data collection.
   C. Install evaporation pan and begin data collection.
   D. Reactivate Texas Creek gage and one stream-gaging station to monitor inflow to valley.
   E. Set up long-term monitoring network and begin collecting data.

II. Second year.
   A. Complete test drilling and aquifer testing.
   B. Begin surface geophysics if need is established by drilling and aquifer test results.
   C. Continue data collection from precipitation-, pan-evaporation, streamflow-, and long-term monitoring network.
   D. Begin data collection from evapotranspiration-monitoring sites.
   E. Install shallow observation wells and begin collection of water-quality data.

III. Third year.
   A. Continue data collection from precipitation, pan-evaporation, streamflow-, and evapotranspiration-monitoring sites, and from long-term monitoring network and shallow wells used to monitor water quality.
   B. Begin reduction and interpretation of data and definition of model parameters.
   C. Begin construction and calibration of model.

IV. Fourth year.
   A. Suspend data collection from precipitation, pan-evaporation, streamflow-, and evapotranspiration-monitoring sites and suspend water-quality monitoring in shallow wells.
   B. Complete model construction and calibration.
   C. Perform model simulations.
   D. Conduct sensitivity analyses.
   E. Begin final report preparation.

V. Fifth year.
   A. Complete final report.
   B. Continue long-term monitoring.

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