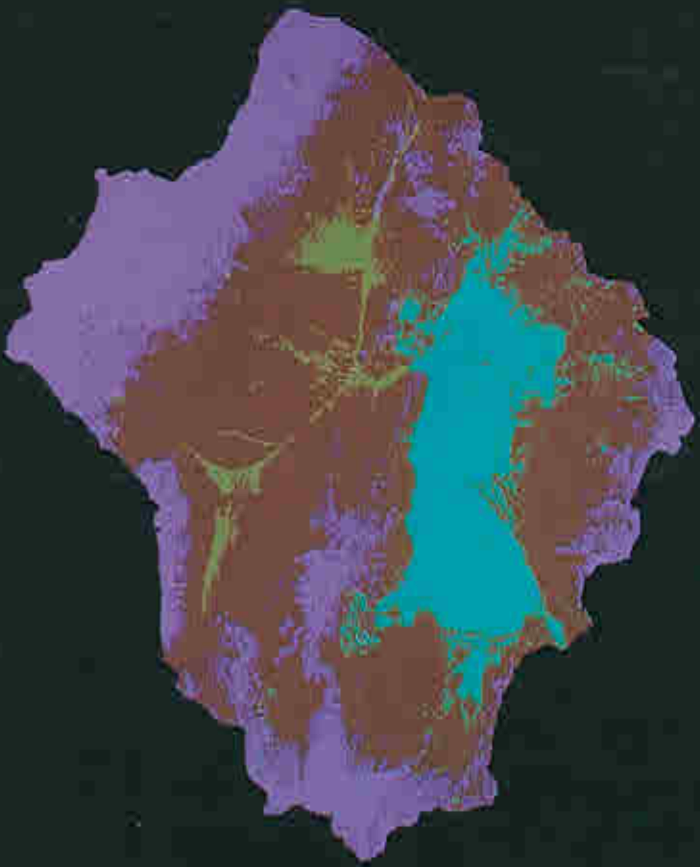

HYDROLOGY AND STEADY STATE GROUND-WATER MODEL OF COAL AND GARDEN VALLEYS, LINCOLN AND NYE COUNTIES, NEVADA

1993

Las Vegas Valley Water District

COOPERATIVE WATER PROJECT
Water for Nevada's Future
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HYDROLOGY AND STEADY STATE GROUND-WATER MODEL OF COAL AND GARDEN VALLEYS, LINCOLN AND NYE COUNTIES, NEVADA

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1993

PREFACE

This report on the water resources and development potential of Coal and Garden Valleys is one of a series of reports on hydrographic basins in southern and eastern Nevada, prepared by the Las Vegas Valley Water District as part of the District's Cooperative Water Project. Kay Brothers and James V. Tracy developed the ground-water flow model and co-authored the report. Thomas S. Buqo performed detailed evaluations of the available data and prepared selected portions of the report. David J. Donovan prepared all the report figures. Information used in performing this work was provided by the Nevada State Engineer's office, the U.S. Geological Survey, Summit Engineering, Inc., and the U.S. Air Force. Additional information and technical assistance was provided by the staff of the Research Department of the Las Vegas Valley Water District, under the direction of Terry Katzer, Director.

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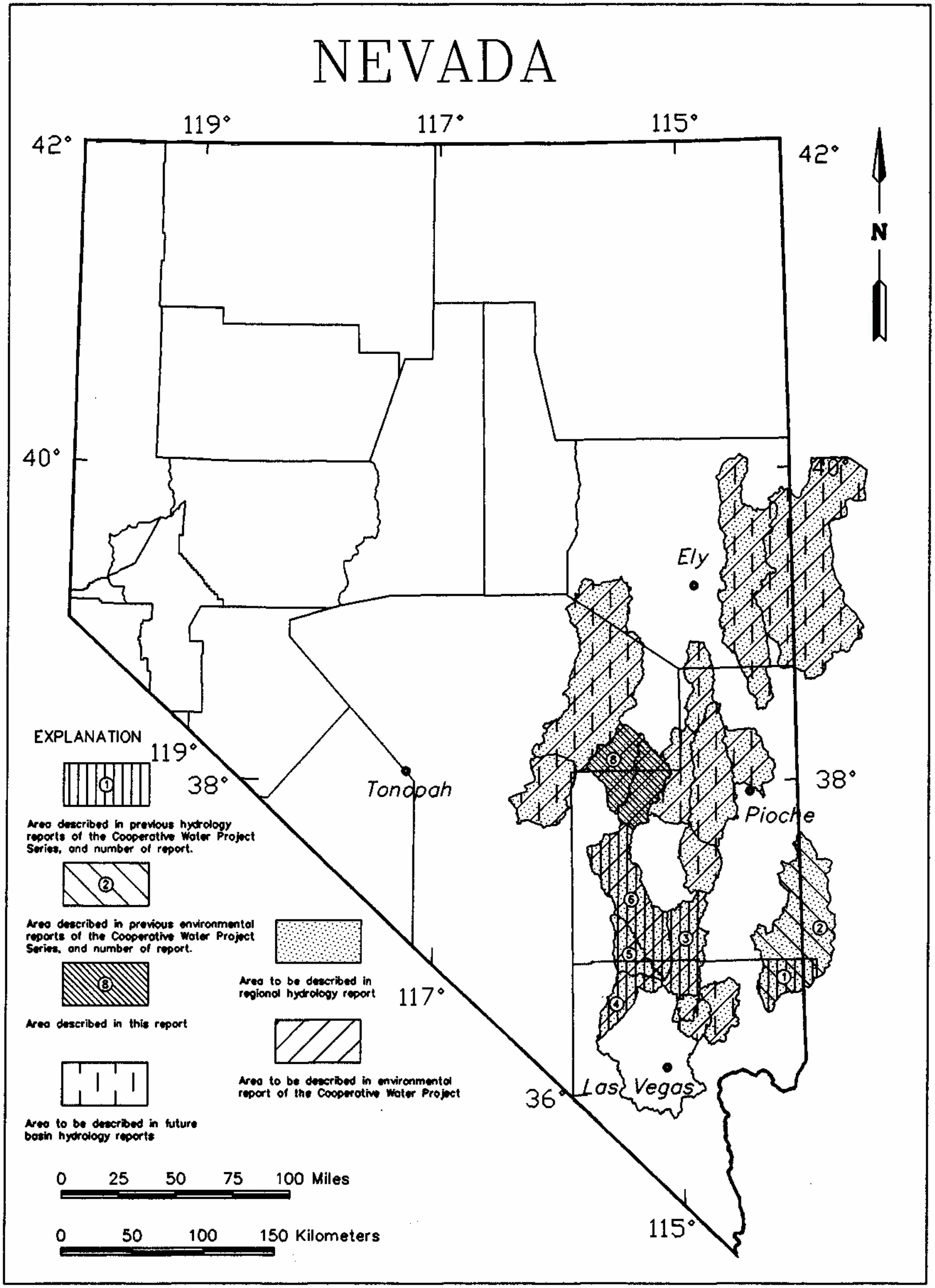


Areas described in previous reports of this series, the area described in this report and the areas to be described in future reports.

INTRODUCTION

In October 1989, the Las Vegas Valley Water District (District) filed five applications to obtain ground-water rights from Garden Valley and four applications for ground-water rights in Coal Valley, both located in Nye and Lincoln Counties, Nevada. Since the time of these water right filings, the District has conducted extensive investigations of these areas including the collection of basic hydrologic data, a water rights inventory, the synthesis of all published and agency information on the water resources of the area, and the development of conceptual and numerical models of the valleys. Because of their similar characteristics and their locations within a large regional flow system, the models developed, and this report, encompass both of the valleys. This report details the hydrologic assessments of Coal and Garden Valleys that were conducted, and the steady-state ground-water flow model developed to represent the aquifer systems of the two basins.

BACKGROUND

Coal and Garden Valleys are arid basins located about 125 miles north of Las Vegas, Nevada (Figure 1). The northern third of Coal Valley and northern half of Garden Valley are situated in Nye County and the southern portions of both basins are in Lincoln County. More than 30 production, test, and observation wells have been drilled in these valleys; data concerning these wells provides much information about the alluvial aquifer that occurs in both valleys. On the basis of the geology of the basin, the hydrogeology of neighboring basins and limited test drilling performed as part of the U.S. Air Force's MX Missile water resources program, it is known that the regional carbonate aquifer underlies Coal and Garden Valleys.

The District plans to develop the water resources of Coal and Garden Valleys through installation of a well field and distribution system that will convey the water to users in metropolitan areas of Clark County. Preliminary plans call for the drilling of water wells at nine locations; final optimized wellfield designs will be developed in subsequent phases of the development program and will be based upon detailed planning and environmental studies.

To assist its efforts in formulating final plans for developing the water resources of Coal and Garden Valleys, the District developed a numerical model of the ground-water flow regime of the valleys. A numerical model is a computer code which translates the mechanics of ground-water flow through the earth through a series of mathematical equations. By coupling the available information on the two basins (and similar valleys in Nevada) with the predictive capabilities of the model, it is possible to estimate the response of the ground water to the proposed water withdrawals by the District.

The development of a ground-water flow model for Coal and Garden Valleys serves two important purposes. First, it is a useful planning tool in developing well field designs by allowing water supply design experts to simulate the efficiency of different design alternatives; secondly, it allows planners to simulate the potential effects of the water withdrawals, if any, on neighboring water users, and the environment.

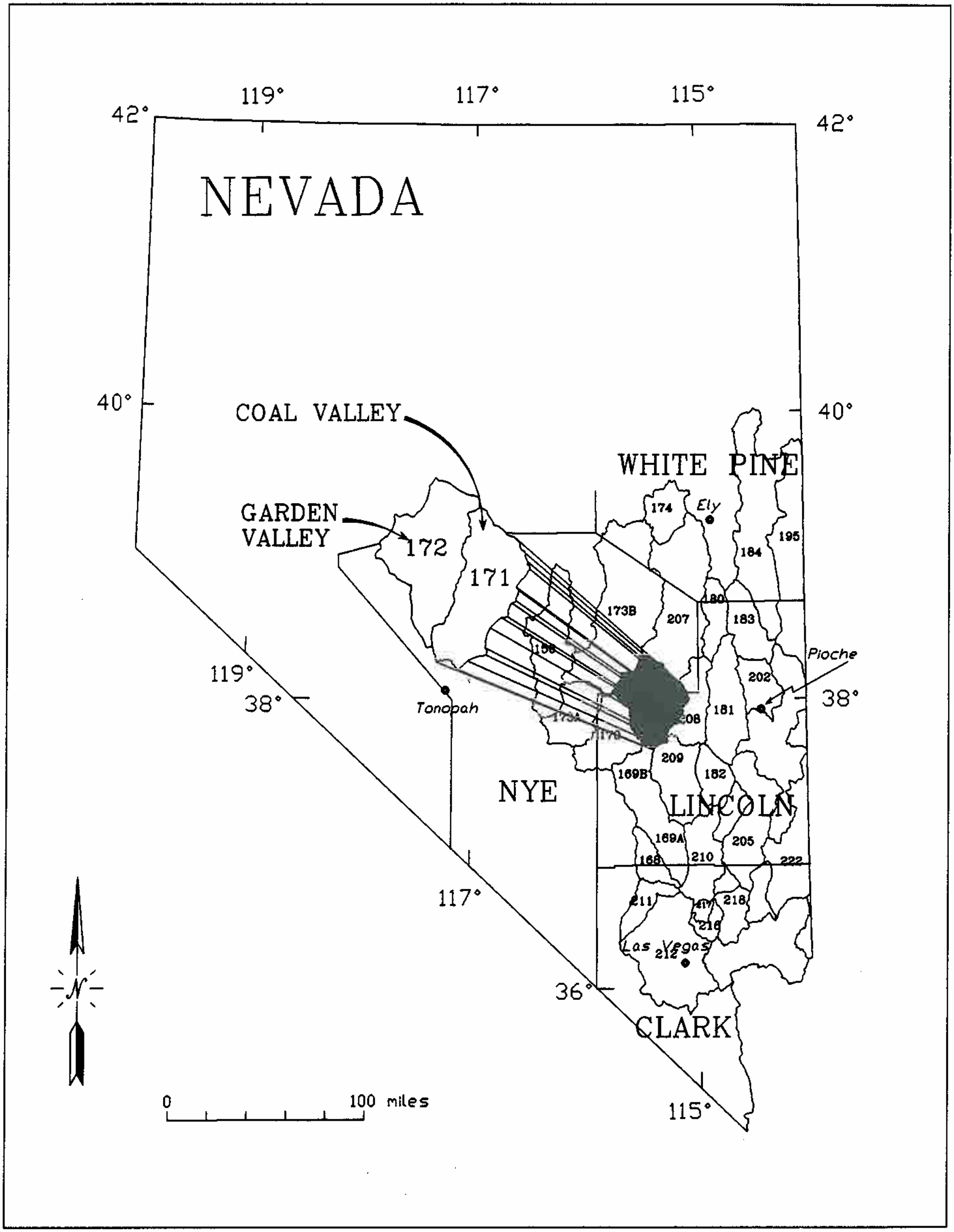


Figure 1. -- Location of the study area

Both beneficial and negative impacts may result from ground-water withdrawals from the valley-fill deposits and/or the regional carbonate aquifer in the arid basins of Nevada. The benefits derived from the application of currently unused ground-water to beneficial use is, of course, the primary positive impact. The economic impact of large-scale ground-water development programs, such as that proposed by the District, is likely to be appreciable and the project is likely to result in significant short-term and long-term economic benefits. The proposed program will require the cooperative efforts of large teams of scientists, engineers, and water planners, and the services of the water well and construction industries.

Beside the favorable economic impacts expected to result from the proposed development of ground water in Coal and Garden Valleys, negative impacts can occur. The primary negative impact of ground-water withdrawals is the lowering of ground-water levels in the vicinity of the production wells; this lowering of water levels is commonly referred to as drawdown. If the long-term drawdown near a pumping well, or a wellfield in any given valley, is significant, then the direction and rate of ground-water flow can be altered and potentially may result in:

- Increased pumping lifts and costs;
- Reductions in spring-flow rates;
- Reductions in surface-water flows; and
- Degradation of water quality.

The magnitude and significance of these impacts depends largely upon the overall hydrologic setting of the basin where the withdrawals occur. In remote, undeveloped basins with no surface water or large springs, the drawdown that will result from ground-water development may not result in significant adverse impacts within the valley. In other instances, the presence of sensitive environments in a valley may be adversely impacted as a result of the same amount of drawdown. Examples of sensitive environments in Nevada include: 1) wetland areas that provide valuable habitat for many types of wildlife; 2) surface water flows and their associated riparian habitats; 3) springs that either support wildlife or have been developed for ranching, mining, quasi-municipal, or domestic uses; and 4) areas where ground water provides the sole source of drinking water for a community.

Because many of the basins in central and southern Nevada are hydraulically linked, via the regional carbonate aquifer, the drawdown that results from the development of ground water in one valley can impact the environment of another valley. Thus, the development of a numerical model of ground-water flow to simulate the impacts of pumping must take into account the environment in peripheral valleys as well as the valley actually being modelled. The District is in the process of preparing a computer model to evaluate these potential region impacts.

There are several springs in Coal and Garden Valleys located, for the most part, in the surrounding mountains. Garden Valley is in hydraulic communication with Coal Valley which is in hydraulic communication with the White River flow system, specifically Pahroc and/or Pahranagat Valley. Withdrawing water from either of the two basins could potentially have undesirable effects on downgradient basins and any ground-water development will be monitored. About nine miles to the southeast, from southern Coal Valley, in the northern part of Pahranagat Valley, is the Key Pittman State Wildlife Management Area. This area is a sensitive wetland, and modelling the hydrogeology of Coal and Garden Valleys will aid in predicting the effects of withdrawing water upon this area.

The use of numerical methods to simulate water withdrawals in Coal and Garden Valleys provides a tool for predicting the effects that would be expected to result from proposed District development. Recently, the U.S. Geological Survey (USGS) has reported the findings of a cooperative study of the water resources potential of the carbonate aquifer conducted in cooperation with the U.S. Bureau of Reclamation, state and local agencies, including the District (Dettinger, 1989). This report recommends the effective use of computer models for predicting the site-specific effects of water withdrawals from the carbonate aquifer. The report concluded that increased confidence in such predictions can be achieved through a staged approach to development coupled with adequate monitoring and interpretation. The development of a computer model of the steady-state ground-water flow regime in Coal and Garden Valleys, performed as part of this investigation, represents one of the first steps in implementing such a staged approach.

The steady-state ground-water model, described in this report, provides a preliminary representation of the aquifer system based upon the information available at this time. As additional data becomes available through District efforts, the model of the ground-water flow regime for either or both valleys can be updated accordingly to provide a more refined representation of the hydrologic system.

PURPOSE AND SCOPE

The purpose of this project was twofold: 1) to define the hydrologic conditions of Coal and Garden Valleys, and 2) to develop a calibrated steady-state ground-water flow model of the valleys. The specific objectives of these investigations were to:

- Collect land use data in the valleys;
- Compile and review published reports and unpublished data on the basins;
- Interpret the available data and determine the characteristics of the basins; and
- Prepare a computer model to simulate steady-state ground-water flow in the basins.

To achieve these objectives, a detailed investigation of the hydrologic conditions of Coal and Garden Valleys was conducted. The scope of work included a review of all available published and unpublished data, the evaluation of the occurrence and movement of ground water and water chemistry, and the development of conceptual and steady-state numerical models of the hydrogeologic regime of the valleys. The basin characterization information and steady-state flow model discussed in this report will be used by the District to develop a transient, regional model including Coal and Garden Valleys' ground-water regime.

LOCATION AND PHYSIOGRAPHIC SETTING

Both Coal and Garden Valleys lie within the Great Basin Physiographic Region as defined by Fenneman (1931). In this section, the location of the two valleys and their general physiographic setting is shown in Figure 2 and is discussed below.

Garden Valley is located between the Grant and Quinn Canyon ranges to the northwest and west, the Golden Gate Range to the east, the Worthington Mountains on the southwest, and unnamed hills on the south. To the north, Garden Valley is separated from White River Valley by a surface water divide. Along its eastern boundary (the Golden Gate Range), Garden Valley is in direct hydraulic communication with Coal Valley via both the surface water and ground-water regimes.

Garden Valley is approximately 50 miles along its central axis, 10 miles wide, and covers 493 square miles (Scott, et al., 1971). The valley floor ranges in elevation from 6,200 feet above mean sea level (AMSL) on the alluvial fans to about 5,100 feet AMSL at Water Gap in the Golden Gate Range. The valley floor averages about 5,500 feet AMSL overall in elevation. On the north and northwest, Garden Valley is bounded by the Quinn Canyon Range and, on the southwest, by the Worthington Mountains. Troy Peak, in the Quinn Canyon Range, rises to an elevation of 11,300 feet AMSL, while the highest point in the Worthington Range, Worthington Peak, is at an elevation of almost 7,000 feet AMSL. On the east, Garden Valley is separated from Coal Valley by the lower Golden Gate Range, with several peaks above 6,600 feet AMSL. On the south, Garden Valley is separated from Sand Spring Valley (Penoyer Valley) by a topographic divide with an elevation of about 6,600 feet AMSL.

The physiography of Garden Valley is typical of other valleys in Nevada; mountains bound the valley on the east and west and alluvial fans radiate from the major mountain watersheds, forming a somewhat continuous bajada. On the valley floor, the major features are the numerous washes that drain the Quinn Canyon Range and Worthington Mountains. These washes join near the Water Gap in the northern Golden Gate Range with drainage into Coal Valley.

Coal Valley is located between the Golden Gate Range to the west, the Seaman Range to the east, and the Mount Irish and Timpahute ranges on the south. To the north, Coal Valley is separated from White River Valley by a low topographic divide. Along its western boundary (the Golden Gate Range), Garden Valley is in direct hydraulic communication with Coal Valley via both the surface water and ground-water regimes. On the southwest, Wild Horse Valley drains via Cold Springs Wash through Murphy Gap into Coal Valley. This small basin is considered part of the Coal Valley hydrographic basin.

Coal Valley is approximately 36 miles along its central axis, 13 miles wide, and covers about 460 square miles (Scott, et al., 1971). The valley floor ranges in elevation from 6,600 feet above mean sea level (AMSL) high on the alluvial fans flanking the west slopes of the Seaman Range to about 4,950 feet AMSL in the Pleistocene lakebed in the south-central part of the

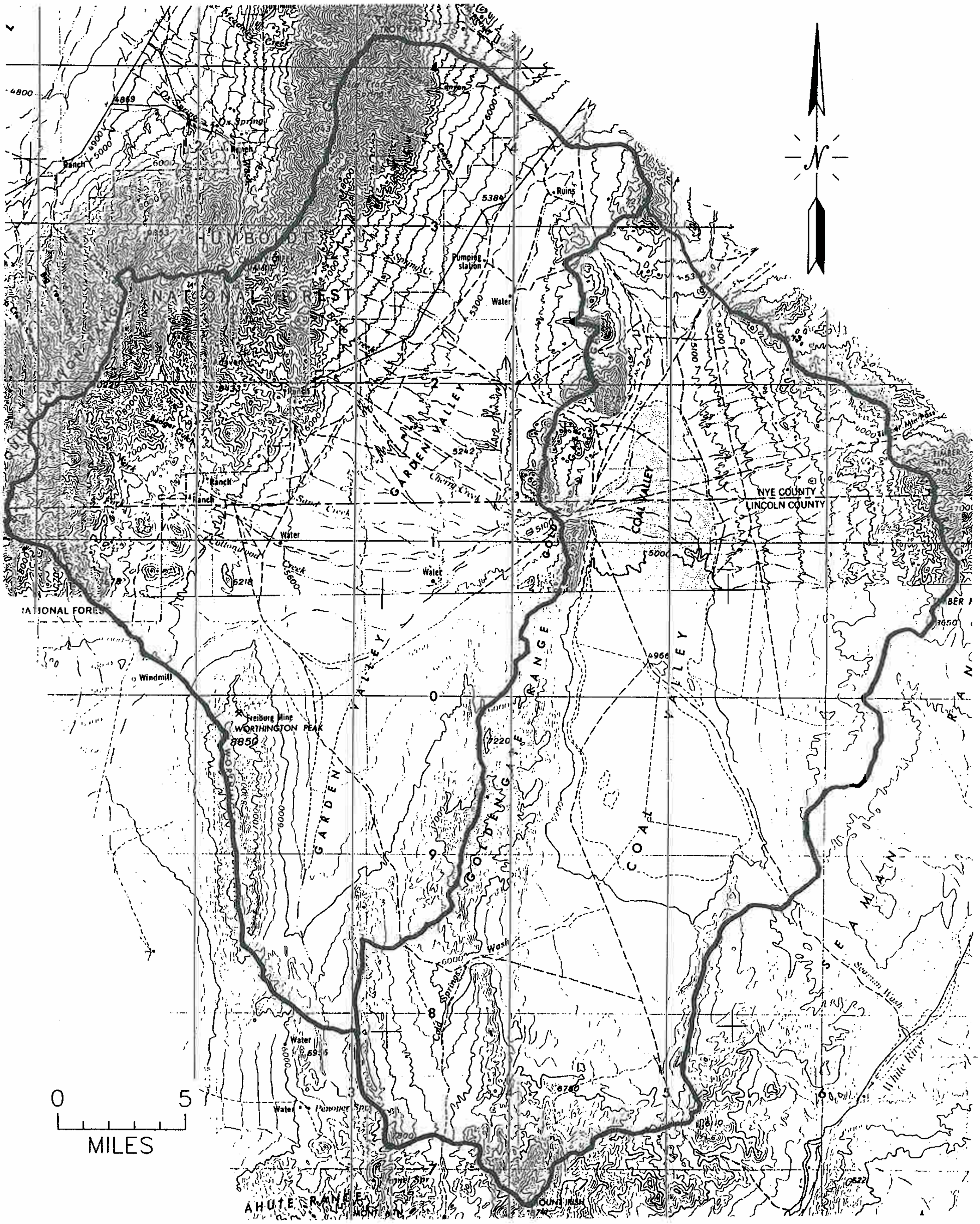


Figure 2. -- Location of Garden and Coal Valleys

valley. The valley floor averages about 5,500 feet AMSL overall in elevation. On the west, Coal Valley is bounded by the Golden Gate Range, described by Eakin (1963) as a series of mountains and saddles. On the east, Coal Valley is separated from Pahroc Valley by the Seaman Range, with several peaks above 6,600 feet AMSL. On the south, Coal Valley is bounded by the Mount Irish Range with a maximum elevation of over 8,740 at Mount Irish. On the southwest, the Timpahute Range rises to an elevation of over 7,950 feet AMSL at Monte Mountain.

The physiography of Coal Valley is similar to that of Garden Valley in that alluvial fans radiate from the major mountain watersheds, forming a somewhat continuous bajada. On the valley floor, the major features are the two dry lake beds attributed by Eakin (1963) to the shallow Pleistocene lakes.

AVAILABILITY OF DATA

Coal and Garden Valleys are located in a remote and largely unpopulated portion of Nye and Lincoln Counties, and only reconnaissance level evaluations of the water resources of the area are available. Records are available for more than 30 water wells that have been drilled in Coal and Garden Valleys. Other available information includes published reports by the Nevada Bureau of Mines and Geology, the USGS, and the Desert Research Institute. In the late 1970s and early 1980s, the two valleys were also extensively investigated by the U.S. Air Force as part of their MX Water Resources Program. As a result of these previous investigations and the development that has occurred in the valley, the hydrologic conditions have been relatively well defined. Regional data from adjacent valleys are also available to supplement the existing valley-specific data.

Well data, including water level measurements, are available for at least 28 locations in Coal and Garden Valleys. The distribution of data points in the valley, although not ideal; does provide good coverage for northern Garden Valley and southern Coal Valley. Additional data for Coal Valley is available for dry observation holes drilled during Air Force activities in Coal Valley. While these wells are dry, they do provide a minimum value for the depth to water in the valley and are, hence, of some utility in modelling the basins. The available well information is provided in Table 1. As indicated, some of these wells are thought to be duplicates however between different data bases the location or elevation is different. This is discussed in some detail under the "Steady State Simulation" section and outlined in Table 8. Appendix A provides an explanation of the well location designations used in Table 1 and throughout this report.

The valley-specific data was supplemented by regional data. Previous investigations in neighboring valleys have generated a data base of regional information which can be used to help formulate a ground-water model for Coal and Garden Valleys. These data provide specific measures or estimates of the ground-water conditions at selected points in time and values for key hydrologic parameters. Several of the wells in adjacent valleys that were drilled as part of the Air Force's MX investigations extend through the valley-fill into the underlying carbonate rocks.

Table 1.--Water level data for Coal and Garden Valleys.

Location	Land Surface Elevation	Depth to Water	Elevation of Water	Date Measured
COAL VALLEY				
1S-59E 34CB1	5125	862	4263	06/81
1S-59E 34CB2	5120	845	4275	06/81
2S-58E 11A	5700	111.7	5588	03/11/85
2S-58E 11A	5200	100.64	5099	05/08/63
2S-58E 12BB	5600	108	5492	05/80
2S-60E 5CD	5300	11	5289	11/65
3N-59E 10BD	5560	803	4757	04/81
3N-59E 10BD	5600	801.9	4798	12/11/91
GARDEN VALLEY				
1S-57E 3A1	5540	489	5051	06/80
1N-57E 20	6200	188	6012	05/80
2N-57E 22BA1	5583	430	5153	04/81
2N-57E 22BA2	5575	420	5155	04/81
2N-58E 3AA	5200	140	5060	03/81
2N-58E 14C	5150	114	5036	05/80
3N-57E 16C	6150	36.28	6114	03/20/90
3N-58E 1AD	5210	88	5122	03/81
3N-58E 1AD	5200	85.3	5115	10/80
3N-58E 1DA	5280	85.1	5195	09/04/91
3N-58E 15B1	5310	221	5089	05/80
3N-59E 18BB	5200	150.1	5050	09/04/91
4N-58E 22DB	5500	153	5347	03/81
4N-58E 23D	5350	16	5334	05/80
4N-58E 26ABA	5340	12.0	5328	03/20/90
4N-58E 33DB	5550	DRY	<5350	11/80
4N-58E 36A	5300	22.75	5277	05/80
4N-59E 5ABC	5350	50.46	5300	03/20/90
4N-59E 6DDD	5290	3.1	5287	03/20/90
4N-59E 8B	5300	10	5290	05/80

Table 1.--Water level data for Coal and Garden Valleys.

4N-59E 8BBC 4N-59E 8B1	5270 5300	3.22 12	5267 5288	03/20/90 05/80
4N-59E 30CD 4N-59E 30DC	5300 5275	62.98 65	5237 5210	03/12/85 03/81
5N-59E 31CA	5440	113.0	5327	09/04/91
5N-59E 32D	5350	59	5291	05/80
DRY AIR FORCE SHALLOW WELLS				
1N-60E 33CC	4960	>200	<4760	1/80
1S-59E 27CA	5110	>200	<4910	1/80
1S-59E 33CC	5240	>200	<5040	1/80
2N-59E 22B	5025	>250	<4775	1915
3N-59E 12AA	5080	>200	<4880	11/80
3N-59E 27AD	5040	>200	<4840	11/80

The primary source of data for Coal and Garden Valleys is a reconnaissance report authored by Eakin (1963). Investigators of the regional flow system and adjacent valleys have included Ertec Western (1981); Thomas, et al. (1986); Harrill, et al. (1988); Kirk and Campana (1988); and Dettinger (1989). The sources of recent data available for the two valleys include: 1) details on water well construction from Well Drillers Reports filed with the Nevada State Engineer Office; 2) water level, spring discharge, and water chemistry data and the results of aquifer tests from the USGS databases; and 3) the results of aquifer tests and exploratory drilling into the carbonate aquifer by the Air Force during 1980 and 1981.

Other available data included technical reports of the Nevada Department of Conservation and Natural Resources, USGS Professional Papers, Water-Supply Papers, and Open-File Reports, and cooperative reports on the regional carbonate aquifer study conducted in 1988. Characterizations of the regional setting, particularly those by Eakin (1963), Kirk and Campana (1988), and the recent publications by the USGS, provide important, and accepted regional interpretations that are also of considerable use in evaluating Coal and Garden Valleys.

Information on the status of water rights in both valleys was made available by Summit Engineering Corporation (SEC) in the form of water right abstracts which are included in Appendix B. According to SEC, these abstracts were based upon a thorough compilation and review of the public documents available from the Nevada State Engineer Office, the regulatory authority governing water rights in Nevada.

The conceptual and numerical models of Coal and Garden Valleys, discussed later in the report, were based on the available site-specific and regional data discussed in the previous paragraphs, the observations made during reconnaissance trips to the valley, and the knowledge of the overall regional ground-water setting.

METHODS

In assessing the water resources potential of Coal and Garden Valleys, and developing a steady-state numerical model of the ground-water system of the basins, only standard approaches and procedures were used. In this section, the methods and procedures that were used are identified and discussed, along with a brief introduction to the selected numerical modelling code.

Data Collection and Compilation

Primary hydrologic data (i.e., new field measurements) were performed as part of this investigation by SEA, Inc. Data from the USGS Water Resources Division's databases that included the most recent measurements available, were provided through the District along with well drillers reports, published reports, and maps. A literature search was conducted to identify and compile data from available published sources.

The locations and data sources were verified by comparing reported or entered data point locations and parameters with field observations and/or the published source of information. Spatial data sets (e.g., water levels, water chemistry, and water right locations), were plotted at uniform scales and annotated. The resulting maps were inspected for anomalous values and further verification was performed to resolve any anomalous data points.

Numerical Model Development

The model used to simulate the ground-water regime of Coal and Garden Valleys is a computer code prepared by the USGS and referred to as MODFLOW (for "Modular Three-Dimensional Finite-Difference Ground-Water Flow Model"). The USGS has prepared comprehensive documentation for this code in one of their series of manuals on techniques of water-resources investigations (McDonald and Harbaugh, 1988). An overview of the code, a discussion of the general approach used in modelling, and the specifics of the model developed for the basin are detailed in the "Ground-Water Flow Model Development" section.

GENERAL HYDROGEOLOGIC FEATURES

The development of numerical simulations of the proposed District ground-water withdrawals in Coal and Garden Valleys requires a thorough understanding of the hydrologic regime of the basin. The information that is available concerning the valley, and adjacent or similar areas, is used to develop a conceptual model of the source of water in the valley, its occurrence and flow in the subsurface, and the relationship between the valley and adjacent areas. In this section, the regional and valley-specific hydrologic conditions in both valleys are described and discussed.

REGIONAL AND BASIN HYDROGEOLOGIC FEATURES

Both Coal and Garden Valleys are situated in the Alluvial Basins Ground-Water Region as defined by Heath (1984). Individual hydrographic basins in this region are characterized by alluvial basins that are underlain by bedrock, and are separated by the bedrock outcrops in the bounding mountain ranges, or, in some instances, by lower divides in alluvial terrain.

When ground water flows from one basin to another, the basins are termed to be part of a flow system. Both the Coal and Garden hydrographic basins are located in the Colorado River Flow System as defined by Harrill, et al. (1988). This flow system comprises 35 individual hydrographic basins as shown in Figure 3; thus some part of the ground water that originates as precipitation in the upland areas of Coal and Garden Valleys may ultimately discharge out of the system at Moapa about 80 miles to the southeast. Thus, this water, after being discharged from Coal and Garden Valleys ultimately reaches the Colorado River through a pathway combining ground-water, spring, and surface-water flows.

The general patterns of interbasin flow in the White River Flow System are shown in Figure 3. The overall component of regional ground-water flow is to the south. Within individual valleys in the flow system, recharge from the bounding mountain ranges results in a local flow component that generally coincides with the topography (i.e, from the mountains toward the axis of the valleys or toward playas with downward vertical hydraulic gradients).

Coal and Garden Valleys do not appear to receive underflow from other adjacent basins. Subsurface flow from Garden Valley through the Golden Gate Range and into Coal Valley is estimated at about 8,000 acre feet per year. Subsurface discharge from Coal Valley is into southern Pahroc Valley and/or northern Pahranagat Valley, and is estimated at 10,000 acre feet per year, Eakin (1963) and Harrill et al. (1988).

LITHOLOGIC AND HYDROLOGIC FEATURES

The hydrostratigraphic units present and their ability to store and transmit ground water are important considerations in developing both conceptual and numerical models of Coal and Garden Valleys. The type, thickness and depth, and water-bearing properties of the geologic materials in the valley can be used to define the overall water resources potential. In this section, the geologic units present in Coal and Garden Valleys and their hydraulic properties are described and discussed.

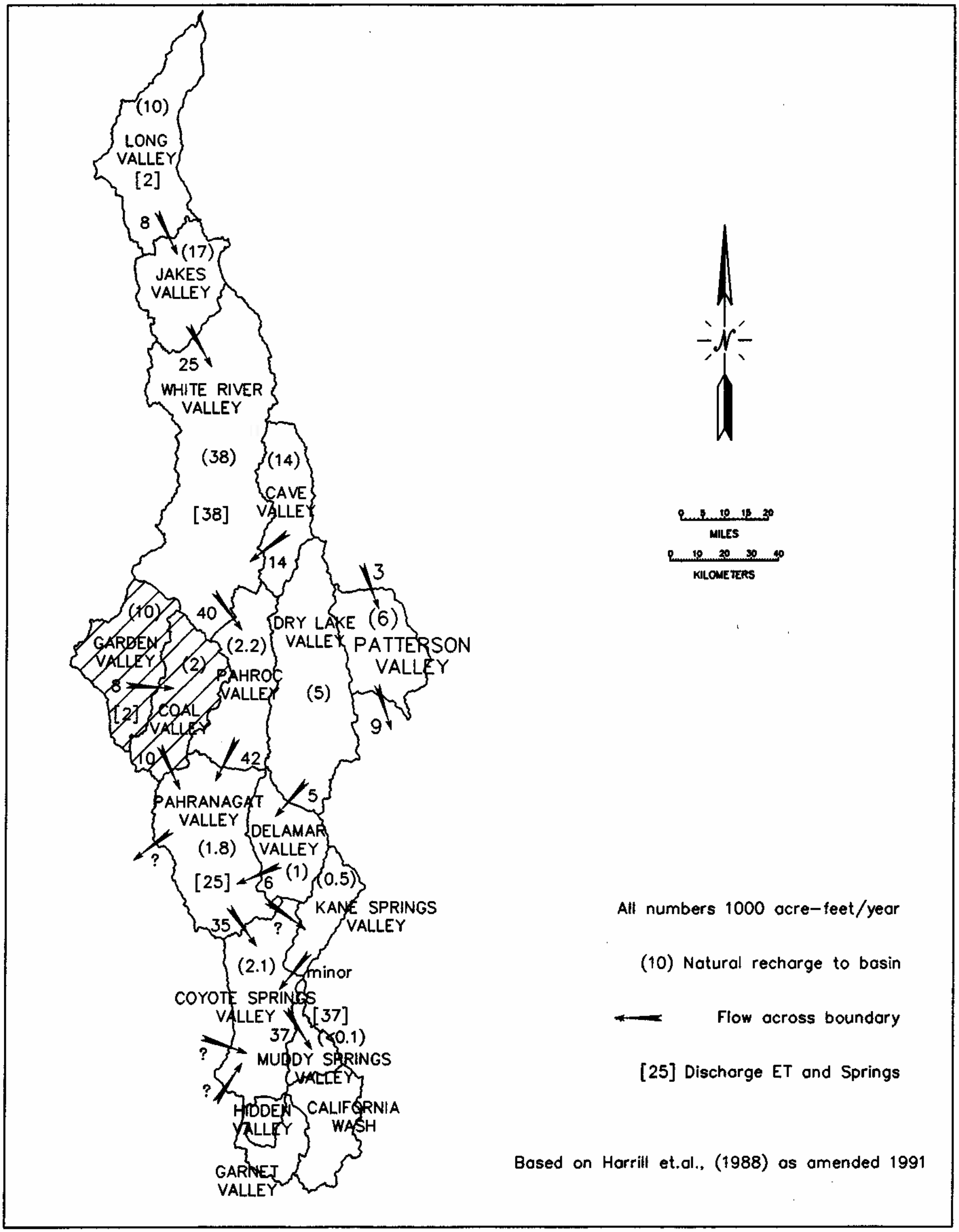


Figure 3. -- Location of Garden and Coal Valleys within the White River Flow System

Hydrostratigraphy

The stratigraphy of the Grant Range and northern Golden Gate and Seaman Ranges has been summarized by Kleinhampel and Ziony (1985) while Tschanz and Pampeyan (1970) summarize the stratigraphy of the southern part of these ranges along with the Quinn Canyon, Timpahute, and Mount Irish Ranges. The hydrostratigraphy of the area is complicated by the extensive disturbances that have occurred in the rocks present in these ranges.

The stratigraphic sequences of the mountains bounding, and separating, Coal and Garden Valleys are shown in Figure 4 along with the general distribution of rocks as presented by Kleinhampel and Ziony (1985) and Tschanz and Pampeyan (1970). The rock units mapped by these workers are categorized on Figure 4 into six discrete hydrostratigraphic units, volcanic rock, Paleozoic aquifers, Paleozoic aquitards, older lake deposits, younger lake deposits, and alluvium. To the west, Garden Valley is bounded by a thick sequence of rocks of Paleozoic age in the Grant Range, northern Quinn Canyon Range, and the Worthington Mountains. Between these two ranges are the volcanic rocks of the central and southern Quinn Canyon Range.

More than 25,000 feet of Paleozoic rocks occur in the Grant Range with the most complete section in northern Nye County according to Kleinhampel and Ziony (1985). In Garden Valley however, the predominant rocks are of Devonian or younger age and include, from youngest to oldest: 1) the Ely Limestone (aquifer); 2) the Chainman Shale (aquitard); 3) the Joana Limestone (aquifer); 4) the Pilot Shale (aquitard) 5) the Guilmette Formation, Simonson Dolomite, Sevy Dolomite, Laketown Dolomite, and the Ely Springs Dolomite (aquifer); 6) the Eureka Quartzite (aquitard); 7) the Pogonip Group and Pole Canyon Limestone and undivided cambrian shales and limestones with localized slate and marble (aquifer); and 9) the Pioche Shale and the Prospect Mountain Quartzite (aquitard).

Only the intermediate age Paleozoic sequence outcrops in the Golden Gate Range where a thick sequence of the Pilot Shale aquitard is underlain by an aquifer comprising the Guilmette Formation, Simonson Dolomite, Sevy Dolomite, and Laketown Dolomite aquifer. Presumably, the older (pre-Silurian) sequence present in the Grant Range is also present at depth.

Volcanic rocks outcrop in the central and southern Quinn Canyon Range, the Timpahute and Mount Irish Ranges, the southwestern part of the Golden Gate Range, and in the southern portion of the Seaman Range. While these rocks have largely replaced the sedimentary rocks in the Quinn Canyon Range, large blocks (4 to 50 square miles) of Paleozoic carbonate rocks are still present in the Timpahute and Mount Irish Ranges. The presence of these blocks is considered significant in that they likely allow pathways for the preferential movement of ground water in some areas.

The entire upper Paleozoic sequence is exposed to the east, in the Seaman Range. In the northern part of the range, volcanic rocks of the Shingle Pass and Needles Range formations are present along with a sequence of upper Paleozoic rocks including: 1) the Ely Limestone

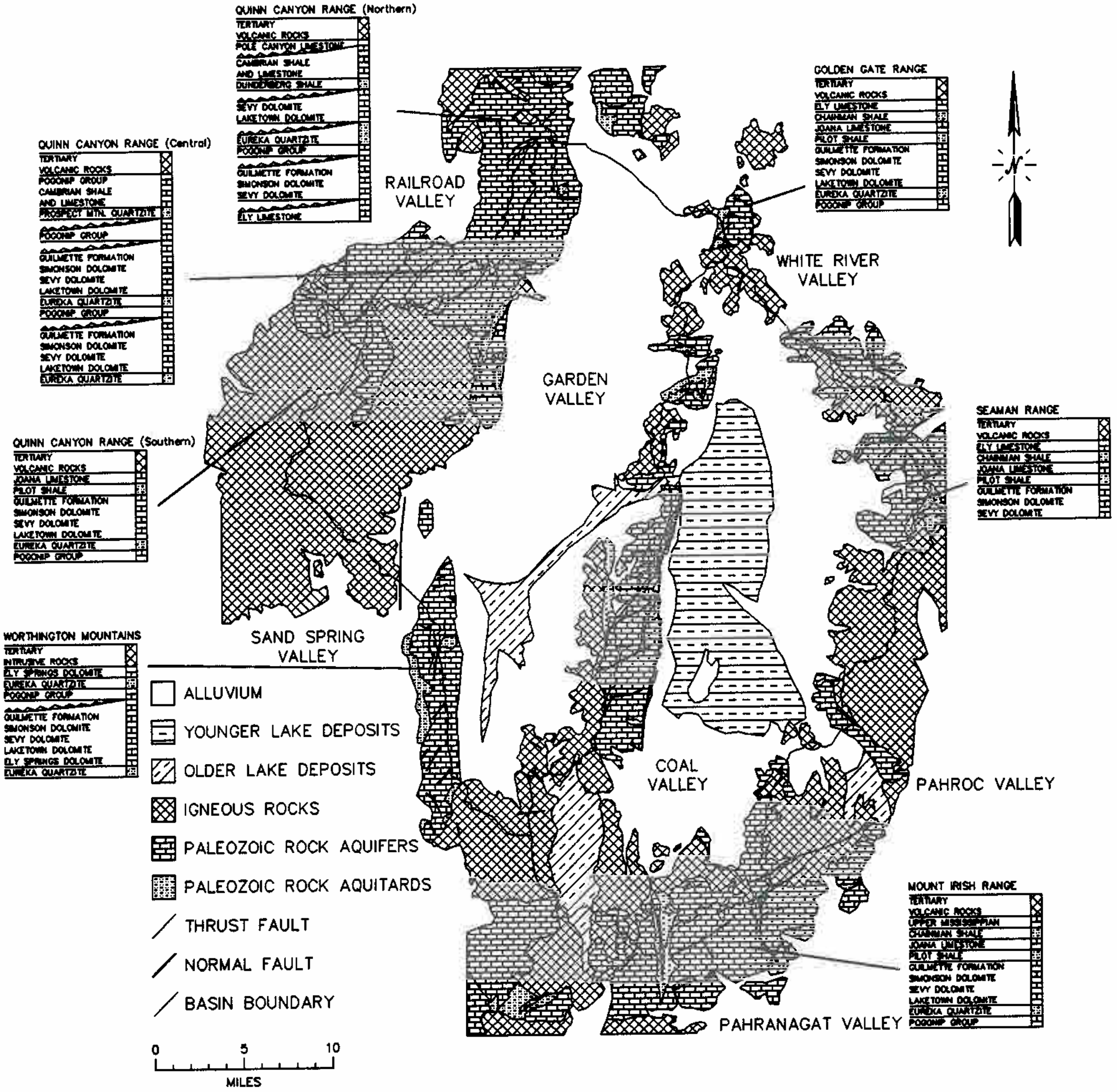


Figure 4. -- General hydrogeological map of Garden and Coal Valleys, modified from Tschanz and Pompeyan (1970) and Kleinhampl and Ziony (1984)

(aquifer); 2) the Chainman Shale (aquitard); 3) the Joana Limestone (aquifer); and 4) the Pilot Shale (aquitard) and the Guilmette formation, Simonson Dolomite, and Sevy Dolomite (aquifer). In the central part of the Seaman Range, the Ely Limestone is absent, but the other units are present and are presumably underlain by the older Paleozoic rocks present in the Grant Range. Except in the Seaman Wash area where limited exposures of Paleozoic sediments occur, volcanic rocks predominate in the southern Seaman Range.

The three major aquitards, the Chainman Shale, Pilot Shale, and Eureka Quartzite are of particular significance because of their poor water transmitting characteristics. As shown on Figure 4, one or more of these units is present in all of the mountains bounding, and separating, Coal and Garden Valleys. Where the Paleozoic sediments are nearly horizontal, they tend to impede the vertical movement of water. However, where tilted such as in the Grant, Golden Gate, and Seaman Ranges, these same units tend to impede the horizontal flow of water. As a result, flow from the Grant Range is impeded by the west tilting aquitards of the Golden Gate Range resulting in an area of shallow ground water in northern Garden Valley.

Overlying the consolidated rock on the valley floor, the alluvial fans, and along a few canyon bottoms in the mountains are unconsolidated valley-fill deposits. These deposits include alluvium typical of valleys in the Great Basin and lacustrine (lake) sediments. According to Tschanz and Pampeyan (1970), Garden Valley was the site of a Middle Pliocene to Early Pleistocene lake while Coal Valley was the location of a younger (Late Pleistocene) lake. Regardless of the age, the lakebed deposits of both valleys are of hydrologic significance in that they are typically fine-grained and not favorable aquifers.

The younger alluvium is distributed along the alluvial aprons between the mountain fronts and the lakebed deposits. Where saturated this alluvium is often a favorable aquifer except in areas of coalescing alluvial fans where the sorting is poor and near playa margins where extensive clay and/or evaporite deposits are common at depth. The grain size of these deposits decreases with distance from the source, and away from distributary channels on alluvial fans. Interbedding of fine and coarse-grained materials is common in the valley-fill deposits, which range from gravels and sand, in alluvial fans, to clay-sized material, in mudflows and playa deposits. Caliche deposits, which may impede the downward infiltration of water in the soil zone, may also be common in the valley-fill as evidenced by the extensive stands of Creosote Bush, a general indicator of well-developed calcic horizons.

Table 2 presents the available data on the hydraulic characteristics of rocks and unconsolidated sediments that are present. These parameters, and other features, are discussed for each modelled hydrostratigraphic unit in the following sections.

Table 2.--Summary of transmissivity and hydraulic conductivity values in southern Nevada.

Transmissivity (ft^2/day)

Aquifer	Minimum	Maximum	Median	Number of Samples	Reference
Valley Fill	321	4,478	1,470	7	Winograd and Thordarson (1975)
	25,920	259,200	-	2	Burbey and Prudic (1985)
Tuff/Volcanic	6.7	9,090	281	5	Winograd and Thordarson (1975)
	259	-	-	1	Burbey and Prudic (1985)
Carbonate	174	11,496	1,470	11	Winograd and Thordarson (1975)
	11	250,000	2,100	31	Unpublished USGS Data
	86	43,200	4,320	5	Burbey and Prudic (1985)

Hydraulic Conductivity (ft/day)

Aquifer	Minimum	Maximum	Median	Number of Samples	Reference
Valley Fill	0.02	140	74•	7	Plume and Carlton (1988)
Carbonate	0.01	940	5.40	38	Unpublished USGS Data
	0.02	1.53	0.18	8	Winograd and Thordarson (1975)
Clastic	0.006	0.10	0.02	4	Unpublished USGS Data

• Average value for 18 tests in 14 basins

<u>Valley-Fill Deposits</u>

Based upon the available information, the older alluvium is presumed to be similar, hydraulically, to the valley-fill sediments and, for the purposes of modelling, the older and younger valley-fill may be considered as one hydrostratigraphic unit. Eakin (1963) estimated the thickness of the valley fill to probably be "at least several hundred feet thick" however, an oil exploration well in 2N-60E 19 (in north-central Coal Valley) penetrated 2,700 feet of alluvium.

The flow of ground water through the valley-fill aquifer occurs primarily through the interstitial porosity. However, flow is controlled by the variations in the relative permeabilities of the interbedded materials. The fine-grained deposits of the lake deposits and similar alluvial materials, although not tested in Coal and Garden Valleys, can be expected to exhibit permeabilities several orders of magnitude smaller than sand and gravel. The interbedding of fine grained and coarse-grained sediments in the valley-fill deposits results in horizontal permeabilities that are considerably greater than vertical permeabilities.

On a regional basis, the transmissivity (a measure of the ability of an aquifer to transmit ground water) of the valley-fill ranges from about 321 to about 259,200 ft^2/day according to Burbey and Prudic (1985) and Winograd and Thordarson (1975). The transmissivity of the alluvium in a given valley or hydrologic setting is a function of both the permeability and the saturated thickness of the aquifer. Small values of transmissivity (less than 670 ft^2/day) generally indicate fair to poor well yield potential while high transmissivity wells (greater than 6,700 ft^2/day) may be capable of producing wells yields in the hundreds or even thousands of gallons per minute.

As with most of the undeveloped basins in Nye and Lincoln Counties, and elsewhere in Nevada, data on the transmissivity of the valley-fill aquifer in Coal and Garden Valleys is limited. Bunch and Harrill (1984) reported a transmissivity of 3,000-7,000 ft^2/day for the valley-fill aquifer in Coal Valley at (1S-59E 34CB) and, for Garden Valley, 12,000-13,000 ft^2/day at (2N/57E 22BA). For the two wells tested, the well yields ranged from 450 to 510 gallons per minute.

Regionally, the hydraulic gradient (slope of the surface of the ground water) in the valley-fill aquifer is often less than 60 ft/mi, and is usually less than 30 ft/mi (Winograd and Thordarson, 1975). Because of the distribution of wells in Coal and Garden Valleys, the calculation of gradients must be based upon widely separated wells and the inferred water surface between the wells. Based upon water level measurements taken at wells in and around Coal and Garden Valleys, the gradient is quite variable, ranging from steep (about 265 ft/mile) in southern Coal Valley to only about 1.3 ft/mi in southern and central Garden Valley. On a local basis, the gradients in the vicinity of operating water wells may also be steep.

Consolidated Rock

The carbonate aquifers present in Coal and Garden Valleys consists of thick sequences of Paleozoic limestones and dolomites separated by thinner aquitards comprising shale or quartzite. Collectively, the Paleozoic rocks present comprise the numerous individual rock units that were previously discussed, and have an overall thickness of as much as 30,000 feet. Flow through the carbonate aquifers is believed to occur primarily through fractures and solution openings, and is likely to be concentrated in areas of greater fracture frequency. Except in areas of structural or stratigraphic anomalies, the hydraulic gradient in the carbonate aquifers is likely to be small because of high transmissivity.

The movement of ground water across the contact between the valley-fill aquifer and the carbonate aquifer depends on the potentiometric heads (elevation of the water table or piezometric surface) in each aquifer. In areas where the head is higher in the valley-fill, the ground water is semi-perched and moves principally downward into the underlying carbonate, serving to recharge the regional carbonate aquifer. Where the head in the carbonate aquifer is higher than the valley-fill, ground water can enter the overlying alluvial material through upward leakage from the carbonate rocks. A well drilled in the carbonate aquifer at (3N-59E 10BD) in 1980 had a head of 4798 but there are no nearby wells in the valley-fill that allow a comparison of heads. Given that Coal and Garden Valleys are situated near source areas (the Grant and Quinn Canyon ranges), it is likely that a downward gradient is present and that recharge to the carbonate aquifer from the valley-fill aquifer is occurring.

The Paleozoic sediments underlie the alluvial deposits at depth under all of Coal and Garden Valleys but probably are separated from the valley-fill deposits by volcanic rocks in some areas. Although four discrete aquifers can be identified on the basis of the stratigraphy, the structural deformation that has occurred in the valleys has resulted in the overlapping of these aquifers. Thus for the purposes of developing a numerical model of the area, the entire Paleozoic sequence may be considered as a single aquifer.

In the nearby valleys, the transmissivity of the carbonate aquifer has been found to range from 11 to 250,000 ft^2/day (Winograd and Thordarson (1975); Burbey and Prudic (1985); and unpublished U.S. Geological Survey data), with values as high as several hundred thousand ft^2/day possible in fractured areas (Winograd, 1963; Winograd and Thordarson, 1975). Variations in structural setting, proximity to faults, mechanical rock properties, depositional environment, and aquifer thickness are the chief parameters that account for the large variations in the transmissivity of carbonates. A test well drilled by the Air Force in the carbonate aquifer has a transmissivity of only 400 ft^2/day however, much higher transmissivities are likely to be present in areas where the carbonate aquifer is more intensely fractured.

In general, it is inferred that the transmissivity of the carbonate aquifer in Coal and Garden Valleys is variable with the highest transmissivities occurring in the vicinity of major structural elements such as north-south trending normal faults and the southeast trending Seaman Pass fault. In these areas, dissolution of the carbonates results in high secondary porosities and very high transmissivities. In the relatively undisturbed areas between such structural features the transmissivities are probably appreciably lower because of the inferred lesser degree of development of secondary porosity.

The Tertiary volcanic rocks that crop out in the mountains of Coal and Garden Valleys probably represent a partial hydraulic barrier to ground-water flow. These rocks consist of tuffs and other volcanoclastic rocks that generally form aquitards.

The clastic aquitard is composed of Precambrian and Cambrian siltstones, quartzites, shales and sandstones. Ground-water potentials are likely to be greatly affected by this unit because of the low transmissivity. In fact, recharge and discharge areas are often determined by the location and orientation of this unit. Ground water will tend to flow along the dip of this barrier rather than through it. The aggregate thickness of this unit is approximately 10,000 feet; however, local thickness varies with structure. With respect to ground water in Coal and Garden Valleys, the clastic aquitard is of little significance because it is believed to occur at depths well below those considered economic for ground-water development.

Structural Features

Faulting within Coal and Garden Valleys is generally consistent with features typical of the Basin and Range Province (i.e., horst and graben structures oriented along north and northeast-trending normal faults). The Basin and Range is dominated by north-south trending fault scarps and lineaments that cut through the alluvium (Tschanz and Pampeyan, 1970). Several periods of regional tectonism have faulted, fractured, and displaced both bedrock and valley-fill materials.

Of particular note are the thrust faults that are present in the Quinn Canyon and Grant ranges and the Worthington Mountains (Figure 4). These low angle features have faulted older rocks onto the top of younger rocks. These faults are of particular significance in that they can double the thickness of the aquifers (and aquitards) that are present in the shallow subsurface.

Also of note are faults that are not north-south trending such as the Seaman Pass fault and a number of east-west trending faults in the central northern Golden Gate and Seaman ranges. Existing data do not support ground-water movement along these faults, but it may occur. Where these faults intersect north-south trending faults such as the Freiberg Fault and the Golden Gate fault (bounding the east side of the Worthington Mountains and Golden Gate Range, respectively) large scale dissolution of the carbonate aquifers may have occurred. Such intersections are generally more favorable for ground-water development than areas where faulting is absent.

Finally, a large Cretaceous-Tertiary volcanic cone forms the core of the Seaman Range. This circular cone, which is partially obscured by younger volcanics and alluvium, appears to be about 6 miles in diameter at the surface. It is unbroken by faults, possibly enlarges at depth, and may be deep-rooted. Under these circumstances it could be a very effective hydrogeological barrier between Coal and Garden Valleys and central Pahroc Valley.

WATER RESOURCES APPRAISAL

To develop a steady-state ground-water flow model that is representative of Coal and Garden Valleys's hydrologic system, it is necessary to define the magnitude of the water resources available in the basin and the basin's development history. The following sections present the available information on the surface and ground-water resources of the valley.

Figure 5 shows a conceptualization of the overall hydrologic system of Coal and Garden Valleys. Each of the major components of the water budget for the basins are discussed in detail in the following sections. It should be noted that although there are numerous wells in the two basins, detailed hydrologic studies have not been conducted. Therefore, the development of the conceptual model of the two valleys must rely, in part, upon inference based upon the data that are available and analogy to other basins in eastern and southern Nevada that share similar characteristics.

SURFACE WATER

An accurate simulation of a hydrogeologic system requires an understanding of the surface water conditions and the significance of surface water in the overall water budget for a given hydrographic basin. This section describes the general conditions of the surface water regime of Coal and Garden Valleys.

General Conditions

Surface water resources are meager in Coal and Garden Valleys and limited mainly to three streams, Cherry Creek, Pine Creek, and Cottonwood Creek which drain the eastern slopes of the Quinn Canyon Range in Garden Valley. Flows in these creeks are fed by springs, snowmelt and runoff from winter and summer rainfall events. As noted by Eakin (1963) the perennial flow in these creeks dissipates quickly on the upper reaches of the alluvial fans and seldom flow into the lower portions of Garden Valley. Runoff from the Grant and Quinn Canyon ranges is rarely large enough to generate surface water flows between Garden Valley and Coal Valley through the Water Gap in the Golden Gate Range. Coal Valley is topographically closed with no exit for surface water flow.

Flow in the washes in both valleys is ephemeral, occurring in response to the infrequent precipitation over the drainage area. No surface water measurements or estimates are available for the washes in Coal and Garden Valleys nor has the annual flow between the two valleys been established. Scott, et al. (1971) give the quantity of this flow as "some" but unknown. Eakin (1963) noted that an early attempt to impound this flow for irrigation was unsuccessful because of the infrequency of flow. The quantity of surface water discharge into Coal Valley, even during flows in response to precipitation over Garden Valley, is probably only a few tens of acre feet of water because of the short duration of such flows. Therefore, the simulation of surface water flow from Garden Valley into Coal valley is not warranted in a ground-water flow model. Similarly, because much of the flow in the creeks that drain the Quinn Canyon Range quickly reenters the ground-water system, it need not be accounted for in a numerical model.

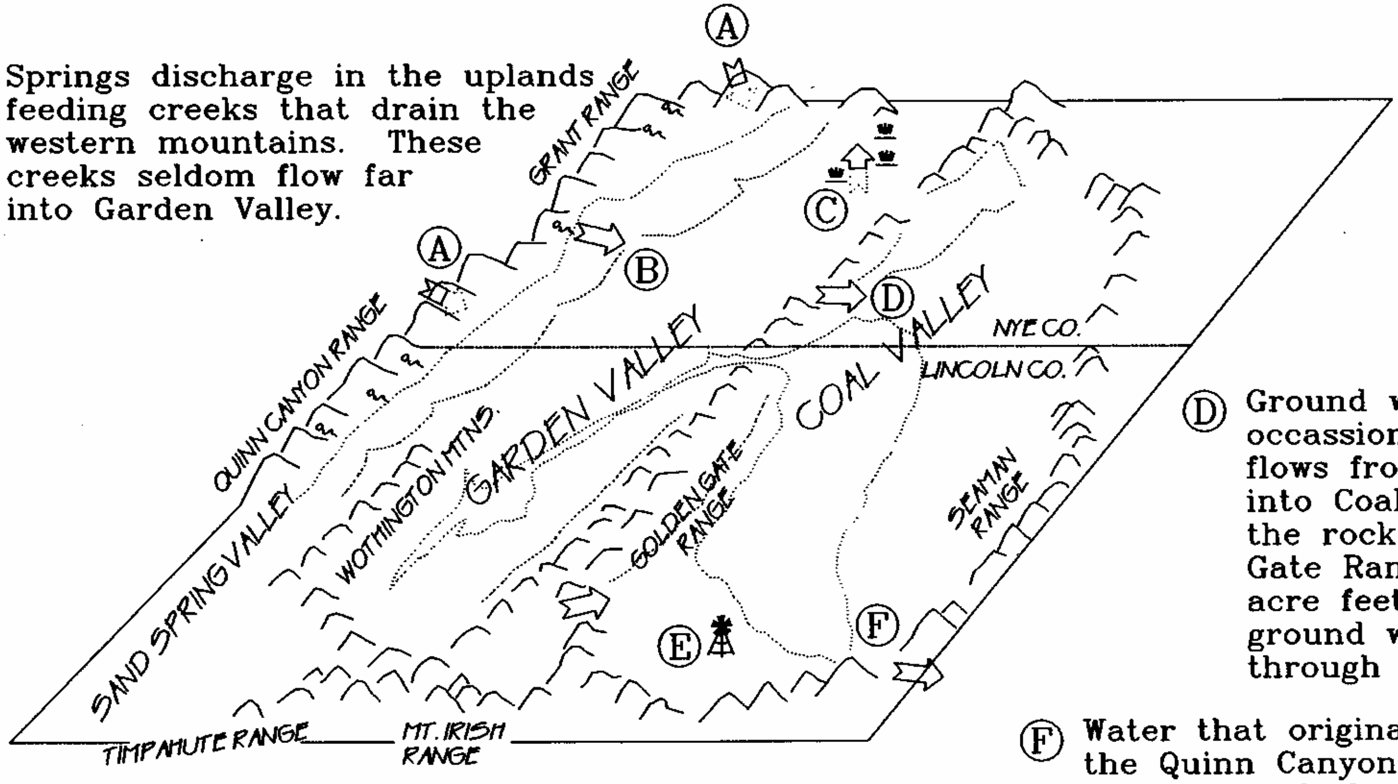
Available Records

Surface water records are limited for Coal and Garden Valleys. Eakin (1963) estimated that the combined flow in Cherry, Pine, and Cottonwood creeks was "as much as 2 cubic feet per second (cfs) in some years". Estimates made in June, 1980 for these three creeks totalled a little more

Ⓐ Ground water in Garden and Coal Valleys originates as precipitation in the mountain areas. A total of 12,000 acre feet of recharge occurs each year.

Ⓒ Shallow ground water is present only in northern Garden Valley. In this area about 1,500 acre feet of water are lost to evapotranspiration each year.

Ⓑ Springs discharge in the uplands feeding creeks that drain the western mountains. These creeks seldom flow far into Garden Valley.



Ⓓ Ground water and, occassionally surface water flows from Garden Valley into Coal Valley through the rocks of the Golden Gate Range. About 8,000 acre feet per year, of ground water, flows easterly through this range.

Ⓔ Ground–water withdrawls in Garden and Coal Valleys are limited, totaling less than 500 acre feet per year. Secondary recharge of this water is probably not significant.

Ⓕ Water that originates as rainfall on the Quinn Canyon and Grant Ranges flows through Garden Valley, then Coal Valley and ultimately, into Pahranagat Valley. Most of this discharge is through the carbonate aquifer and totals about 10,000 acre feet per year.

Figure 5. –– Conceptual model of the hydrology of Garden and Coal Valleys.

than 6 cfs. However, a low flow (0.1 cfs) was observed at the Water Gap between Coal and Garden Valleys at the same time suggesting that the estimates were made following a period of increased runoff from either precipitation or snowmelt, or both.

Runoff

The total quantity of runoff from the mountains bounding Coal and Garden Valleys is not known, but Scott, et al. (1971) estimated the combined amount of runoff for Coal and Garden Valleys to be 8,700 acre feet per year of which 8,300 acre feet per year is in Garden Valley. Heavy runoff events may result in short-duration flows along reaches of washes in the center of each valley; however, most runoff infiltrates along the upper portions of the alluvial fans, directly into open fractures in the consolidated rock areas, or into the coarse streambed deposits of the channels that drain the area. Much of this water also is transpired by vegetation or simply evaporates. That portion of the precipitation over the basin that does not runoff, but infiltrates through the unsaturated zone to recharge the aquifers, must be accounted for in the model. However, this recharge is accounted within the model independently and does not require the simulation of rainfall (and snowfall) and runoff.

GROUND WATER

It is necessary to understand the conditions and characteristics of the ground water in Coal and Garden Valleys to develop an accurate numerical simulation. This section discusses the ground water occurrence, source, movement, chemical quality, and budget for Coal and Garden Valleys.

Occurrence

Ground water occurs in Garden Valley at depths ranging from less than 10 feet below land surface in northern part of the valley to almost 500 feet in the southern part of the valley. Ground water is deeper in Coal valley, ranging from 100 feet below land surface in the northern part of the valley to more than 800 feet in the southern part of the valley. A well located in Coal Valley at (2S-60E 5CD) has a reported depth to water of only 11 feet however, this well is located in an area of the Seaman Range where the water may be perched.

Figure 6 shows the regional potentiometric surfaces for Coal and Garden Valleys based upon the water level data for the valley and vicinity, and an evaluation of potentiometric data for the White River flow system as a whole. The potentiometric surface shown is believed to represent a reasonably accurate conceptual picture of the water underlying the two basins.

As shown, the elevation of the water table ranges from about 6,000 feet AMSL, along the northwestern part of Garden Valley, to less than 4,300 feet AMSL in southern Coal Valley. A significant ground-water mound occurs in the Grant and Quinn Canyon Ranges reflecting the higher precipitation that occurs over these mountains. In the valley floor areas the potentiometric surface ranges from about 5,300 to 5100 feet AMSL in Garden Valley and from about 4750 to less than 4260 feet AMSL in Coal Valley.

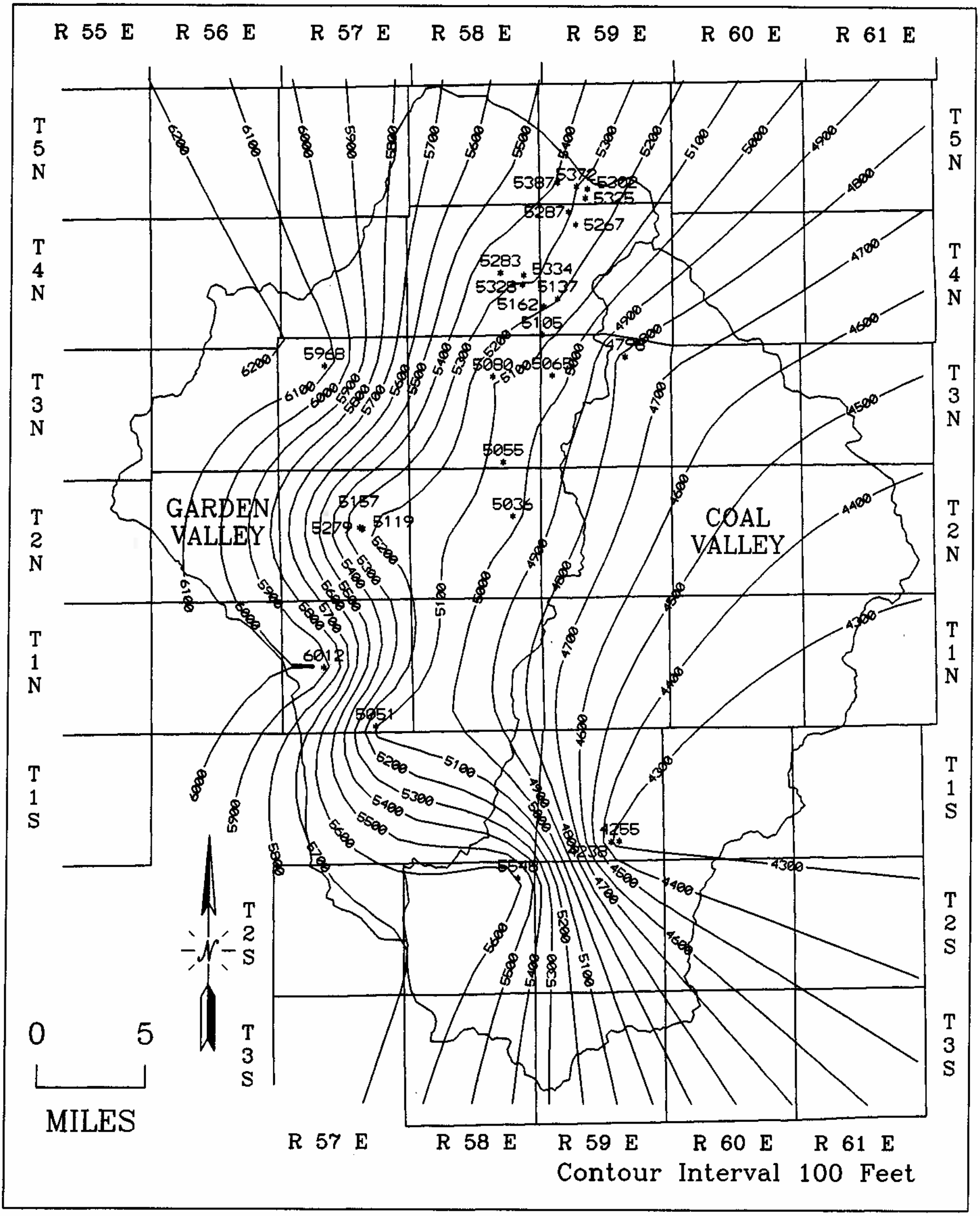


Figure 6. -- Contour map of actual water levels in Garden and Coal Valleys.

Data are generally lacking on the variations in water levels in the two basins. The U.S. Geological Survey maintains monitoring stations at a well in Garden Valley at (4N-58E 36A) and in Coal Valley at (3N-59E 10BD). Water level fluctuations in these wells have been less than ten feet. Considering the available data and the low level of development of the valley, it is reasonable to assume that the water levels in Coal and Garden Valleys have remained stable over at least the last 20 years, responding primarily to fluctuations of precipitation related ground-water recharge.

Head elevation data for the carbonate aquifer is only available for the carbonate well in Coal Valley at (3N-59E 10BD). The most recent (December, 1991) elevation of the water in this well was 4,798 feet AMSL, significantly higher than the regional carbonate spring at Hiko which occurs at an elevation of 3,875 feet AMSL.

Source

The source of ground water within Coal and Garden Valleys is primarily from recharge of precipitation over the Quinn Canyon and Grant ranges. Lesser amounts of recharge are derived from the eastern and southern bounding mountain ranges. There is no surface or subsurface flow into Garden Valley from neighboring basins. Surficial and subsurface flow into Coal Valley, as discussed previously, is limited to that contributed from Garden Valley.

Movement

In general, ground water flows eastward from the Quinn Canyon and Grant ranges toward Coal Valley. Ground-water flow seems to be primarily controlled by the location of the source areas high in the surrounding mountains and the stratigraphy and structure of the consolidated rock units. In the southern portion of Garden Valley, flow is from the south in the upland areas to the north toward the valley floor areas and then to the east through the carbonate aquifers of the Golden Gate Range. Ground water discharges from Coal Valley into southern Pahroc Valley and/or Pahranagat Valley via the fractured carbonate aquifers.

Chemical Water Quality

The chemical quality of the ground water in Nevada depends on its location. The chemical concentration in recharge areas is normally very low; however, the ground water comes into contact with soluble rock materials for long periods of time as it moves towards discharge areas where the chemical concentration is higher. The solubility, volume, distribution of rock materials, time of water contact with the rocks, temperature, and pressure in the ground-water system are factors that determine the extent to which the chemical constituents from the rock materials will be dissolved.

Limited water chemistry data are available for Coal and Garden Valleys. Selected water quality data from Bunch and Harrill (1984) are listed in Table 3. Figure 7 shows the location and selected EC and temperature values for these same sites in Coal and Garden Valleys.

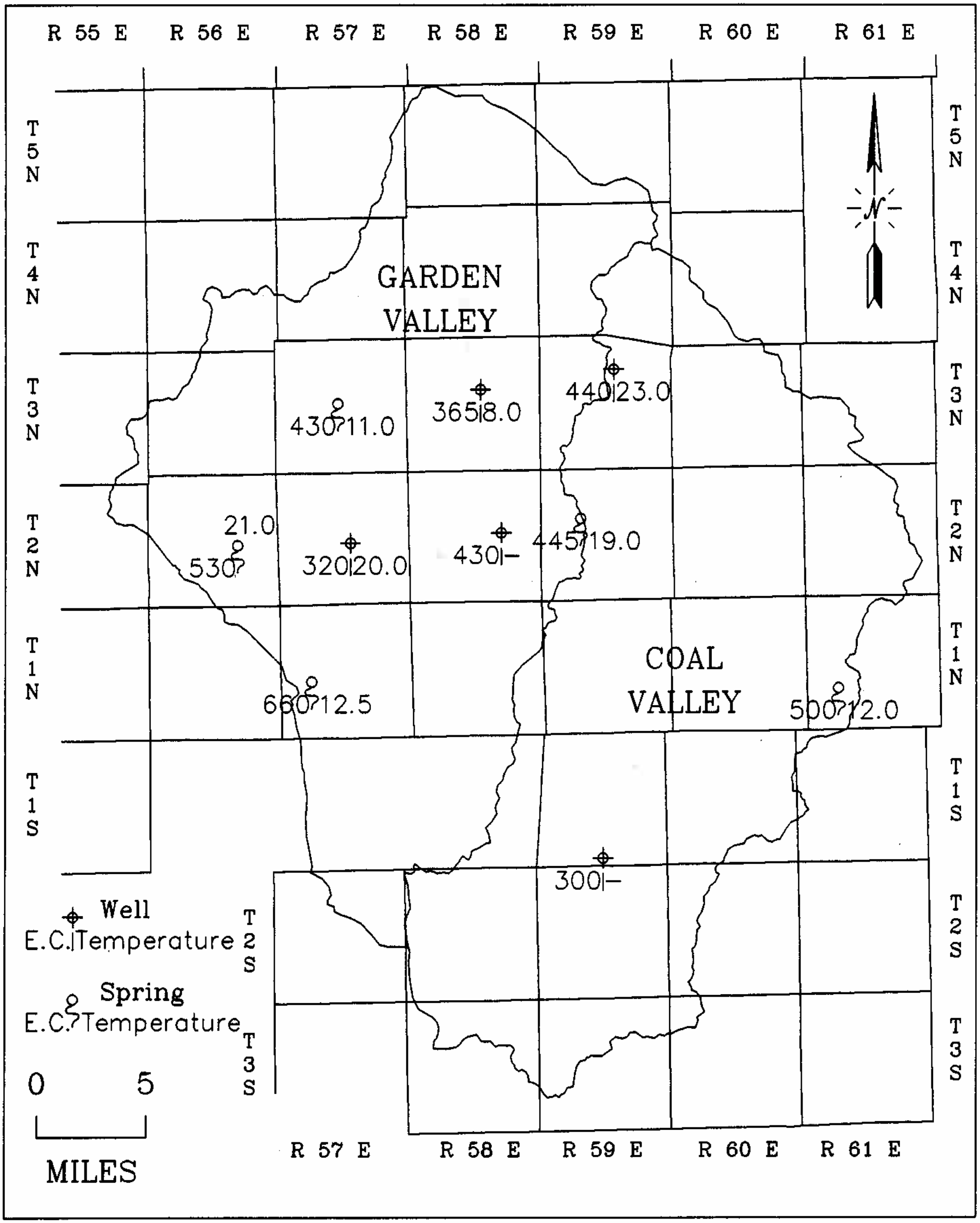


Figure 7. -- Well and spring water chemistry in Garden and Coal Valleys.

Table 3.--Selected water quality data for Coal and Garden Valley.

Location	Source	Date	Temp. C	EC umhos/cm	pH units	Ca [	Na	SO4 mg/L	Cl	K	HCO$_3$]
COAL VALLEY											
3N 59E 10BD1	Well\1835[a]	9-80	23.0	440	8.1	64	6	18	7.3	1.9	255
1N 61E 29CA	Spring	6-80	12.0	500	6.7	82	23	26	14	2.0	303
1S 59E 34CB2	Well\1315[a]	6-81		300	7.9	16	47	26	11	6.3	136
GARDEN VALLEY											
3N 57E 16D	Spring	6-80	11.0	430	6.7	67	17	21	10	3.4	327
3N 58E 15B1	Well\260[a]	6-80	8.0	365	7.1	34	10	15	6.1	4.1	249
2N 56E 23B	Spring	6-80	21.0	530	7.1						
2N 57E 22BA2	Well\1065[a]	11-80	20.0	320[b]		38	24	24	10	1.7	180
2N 58E 14C	Well	6-80		430	7.4	44	22	28	8.5	2.0	205
2N 59E 17A	Spring	6-80	19.0	445	8.4	40	15	21	7.1	2.6	273
1N 57E 20	Spring	6-80	12.5	660	7.0	100	30	55	15	3.0	386

[a] well depth below land surface; in feet.
[b] calculated from total desolved solids.

Ground-Water Budget

A ground-water budget consists of a complete accounting of all components of inflow and outflow for a hydrographic basin. The results of any model developed to simulate flow in a basin are dependent upon the accuracy of the budget. Table 4 summarizes the water budgets for Coal and Garden Valleys. The following sections present the current estimates for recharge and discharge for Coal and Garden Valleys.

Table 4.--Ground-water budget for Coal and Garden Valleys.

		Published Value Acre-feet/year (rounded)
RECHARGE		
Precipitation (Recharge)		12,000
Subsurface Inflow		0
Secondary Recharge		0
	TOTAL	12,000
DISCHARGE		
Evapotranspiration		1,500
Pumpage*		400
Outflow		10,000
	TOTAL	11,900

Source: Eakin (1963), Scott et al. (1971), Summit Engineering Corp.
* not included in steady state model

Estimated Average Annual Recharge

Recharge to a basin usually consists of several components: precipitation, subsurface inflow, and secondary recharge. Estimates for these elements for Coal and Garden Valleys are provided in the following sections.

Precipitation

The source of recharge to the hydrologic system of Coal and Garden Valleys is the infiltration of precipitation over the basin. No meteorological stations are located in Coal and Garden Valleys and the characterization of precipitation over the area is inferred from recording stations located in adjacent valleys. The total precipitation over Coal and Garden Valleys is estimated at 400,000 acre-feet per year (Scott, et al., 1971) of which 230,000 acre-feet per year fall over Garden Valley and 170,000 acre-feet per year fall over Coal Valley. The volume of recharge derived from precipitation is reported by these same authors to be about 12,000 acre-feet per year, or about 3 percent of the precipitation.

The infiltration of precipitation does not occur evenly over a large area. Rather, as determined by Eakin et al. (1951) and Quiring (1965), the distribution of precipitation, and hence, infiltration and recharge, in the desert valleys of Nevada, is primarily a function of elevation and latitude. Thus, for the purposes of developing a ground-water flow model of Coal and Garden Valleys, recharge totalling about 12,000 acre-feet per year may be distributed according to the zones summarized in Table 5.

Table 5.--Recharge distribution zones for Coal and Garden Valleys (Eakin, 1963).

ELEVATION Feet Above Sea Level	PRECIPITATION Inches/Year	APPROX. AREA Acres	PRECIPITATION Acre-feet/year	RECHARGE RATE Percentage	RECHARGE FLUX acre-feet/year (rounded)
>9,000	>20	5,000	8,750	25	2,200
8,000-9,000	15-20	15,400	22,500	15	3,400
7,000-8,000	12-15	41,700	46,700	7	3,200
6,000-7,000	8-12	146,000	121,200	3	3,600
<6,000	<8	399,000		0	0.0

Subsurface Inflow

There is no inflow of ground water to Coal and Garden Valleys from upgradient basins. As noted previously, there is subsurface flow from Garden Valley into Coal Valley, estimated at about 8,000 acre-feet per year by Harrill et al. 1988.

limit for economic well drilling), then the total recoverable ground-water storage in Coal and Garden Valleys is estimated to be approximately 12 million acre-feet. However, the upper 100 feet of the rock aquifer probably contains about 600,000 acre-feet of recoverable ground-water.

INVENTORY OF WATER RIGHTS, PUMPAGE, AND LAND USE

An estimate of ground-water usage in a basin can be obtained from present water rights, pumpage, and application of pumped water to crops and other uses. These factors are examined in the following sections.

PRESENT DEVELOPMENT

The level of development of water resources in a basin can be illustrated by the water right allocations and the current ground-water pumpage within that basin. In Coal and Garden Valleys, little ground water has been pumped historically, and little is presently being used. The Nevada State Engineer has however allocated several water-right permits in the basin and applications have been made for additional appropriations that are senior to the District's applications.

Water Right Status

Based on information supplied by SEC contained in Appendix B, the State Engineer has allocated a total of 8 water-right permits in Coal and Garden Valleys for both surface and ground water. The permitted water rights and applications are shown on Table 6 . Desert Land Entry (DLE) applications total 5,760 acre-feet per year (4,320 consumptive use), but were not included in Table 6.

Table 6.--Water rights in Coal and Garden Valleys[1] (acre-feet/year consumptive use).

	Surface		Underground	
	Permits	Applications	Permits	Applications
COAL	56	0	49	0
GARDEN	1608	15	305	0

[1] Excluding Desert Land Entries

Pumpage

Data on actual water use in Coal and Garden Valleys are not available. It is assumed that the total pumping is less than 500 acre-feet per year, therefore it is insignificant and was not included.

Land Use

Most of the land in Coal and Garden Valleys is public-domain land administered by the Bureau of Land Management. Some areas are used for livestock range and there is a small area of irrigated pasture near Adaven.

FUTURE DEVELOPMENT

Plans for future development of Coal and Garden Valley are unknown. Most of the water right applications senior to the District's applications are DLE's for agricultural use of which historically very few are developed.

MODEL DEVELOPMENT

MODFLOW is a three dimensional ground-water flow model that simulates ground-water movement through gridded layered cell blocks by solving a series of finite difference equations. These equations preserve the quantity of ground water in the modelled area. For any further detail regarding the flow model, the MODFLOW documentation (McDonald and Harbaugh, 1988) should be consulted.

The first step in developing a ground-water flow model is the formulation of a conceptual hydrogeologic model of the area to be mathematically represented. This conceptual model is based upon the available hydrologic data, inferences based on observations of similar hydrologic settings, and assumed conditions or expected ranges of conditions for parameters that have not been measured or are not readily estimated for the subject hydrologic basin.

The first step in the mathematical representation of the conceptual model is the development of a grid system covering the hydrologic basin. The grid system can be either single or multiple layers with each cell in the model being identified by grid row, column, and layer designation. Usually the grid size and number of layers are chosen based on the amount of available hydrologic data for the particular basin. Each cell is given a number of parameters (i.e. transmissivity, storage (in transient scenarios), conductive characteristics for spring flow, recharge where appropriate, and rates of evapotranspiration when the water levels are within a set distance from land surface) which control water flow through the model. The District made the decision to make all the grids for the individual ground-water flow models one mile by one mile and each model two layers, one to represent the alluvial system and the other the consolidated bedrock. In some valleys there were not enough data to warrant this scale; however, preparation of the model on this scale will provide a framework for future data entry resulting in model refinement.

APPROACH AND ASSUMPTIONS

The approach taken in all the individual basin models was to produce a steady state model which replicated as closely as possible the hydrologic basin budget as defined by the USGS while attempting to match existing ground-water levels. The most important "constant" becomes the amount of water entering the system or the recharge. Eakin (1963) established the hydrologic budgets for both Coal and Garden Valleys. Since these valleys are hydrologically connected the decision was made to produce one steady state ground-water model simulating both hydrologic budgets.

A square mile grid, 48 rows by 39 columns as shown in Figure 8, consisting of two layers was constructed to simulated ground-water flow in Coal and Garden Valleys. Both the upper alluvial and the lower consolidated rock layer were modelled as confined units. Parameter selection (i.e. transmissivity and vertical leakance) was keyed to rock type. Figures 9 and 10 show the lithology distribution for each layer, specifying alluvium, carbonate, and "other" consolidated rocks which are primarily volcanics.

PARAMETER ESTIMATES

Recharge and Discharge

Eakin (1963) estimates the recharge, based on the method described by Eakin et al. (1951), to Coal and Garden Valleys to be 12,000 acre-feet per year, 10,000 in Garden and 2000 in Coal. Eakin also estimated the total discharge from evapotranspiration and wells to be between 1500 and 2000 acre-feet per year all occurring in northern Garden Valley. A recent assessment of land use and water rights permits in these valleys confirmed that well pumpage (mostly domestic in Garden Valley) is minor and the primary estimate of discharge is still valid, due to mainly evapotranspiration and pumpage in Garden Valley. Thus, by difference, about 10,000 acre-feet exits the two valley systems as ground-water outflow.

Primary Recharge

Primary recharge in Coal and Garden Valleys is limited to the infiltration of precipitation into the ground-water system occurring in the higher elevations. Garden Valley receives the majority of the recharge to this area because of the higher elevations of the Grant and Quinn Canyon Ranges bordering the west side of the valley.

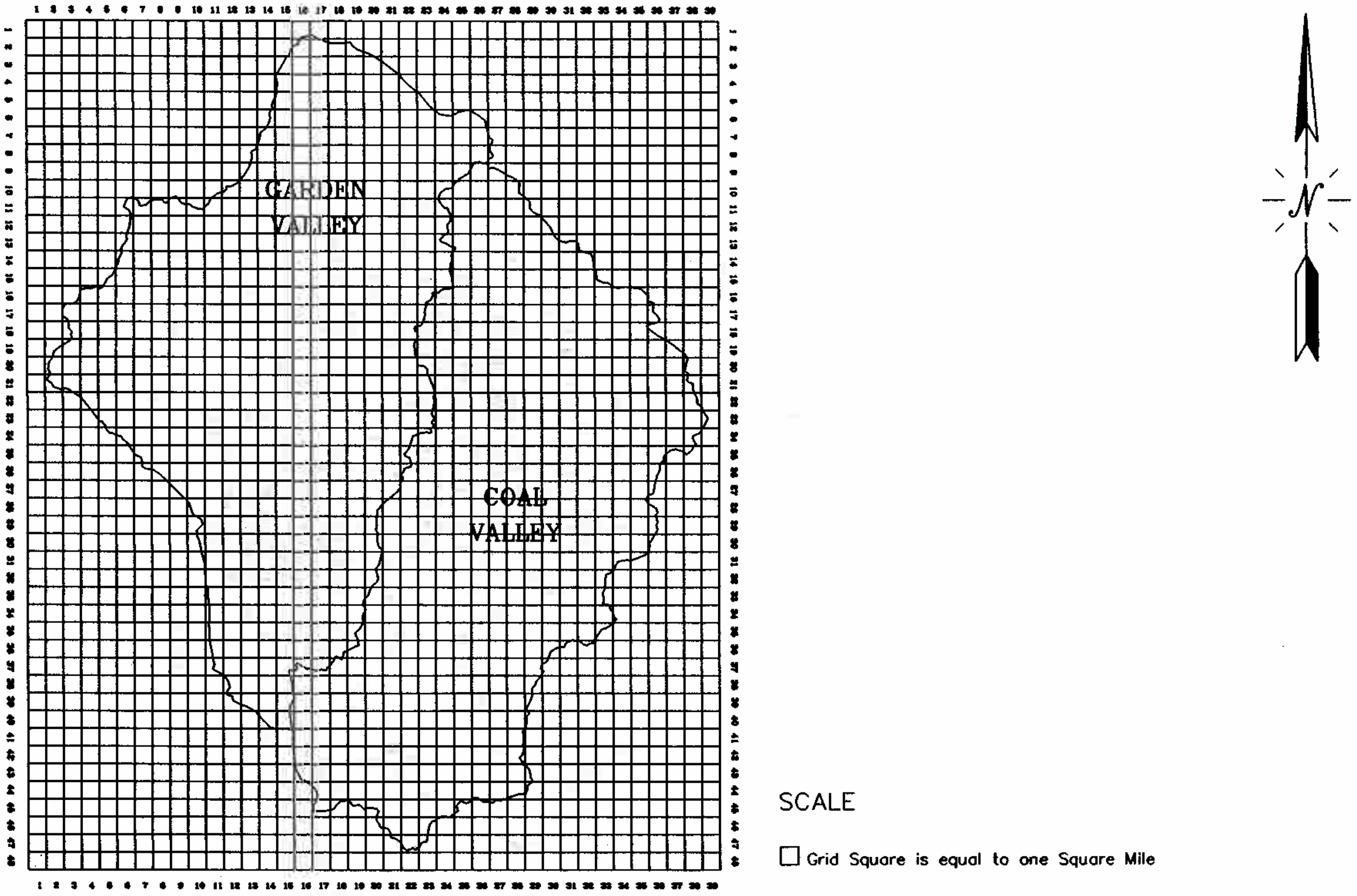


Figure 8. -- Numerical model grid, Garden and Coal Valleys.

Digital elevation data was used to computer generate and distribute recharge within the model grid based on the Eakin method (Eakin et al., 1951) with the factors listed for Coal and Garden Valleys in the report by Eakin (1963) and listed in Table 5. Digital elevations were obtained for the whole Cooperative Water Project (CWP) area from the USGS, which are based on the 1:250,000 scale Army Map Series (AMS) maps. These files contain an elevation every 90 meters and a subset of every 10th elevation (or an elevation every 900 meters) was compiled for model calculations over the project area. Dr. James Tracy developed a program to calculate recharge based on all elevations found within a grid cell using the Eakin factors (precipitation and percentage infiltrating the ground-water system) listed in the various USGS reconnaissance reports. The product of the program is a matrix corresponding to the grid which specifies recharge rates for each cell.

Figure 11 is a spatial representation of the recharge distribution used in the Coal and Garden model. Based on this method, the recharge for Coal and Garden was calculated to be about 1700 and 9600 acre-feet per year respectively. This value is only six percent less than the 12,000 acre-feet per year estimated by Eakin (1963).

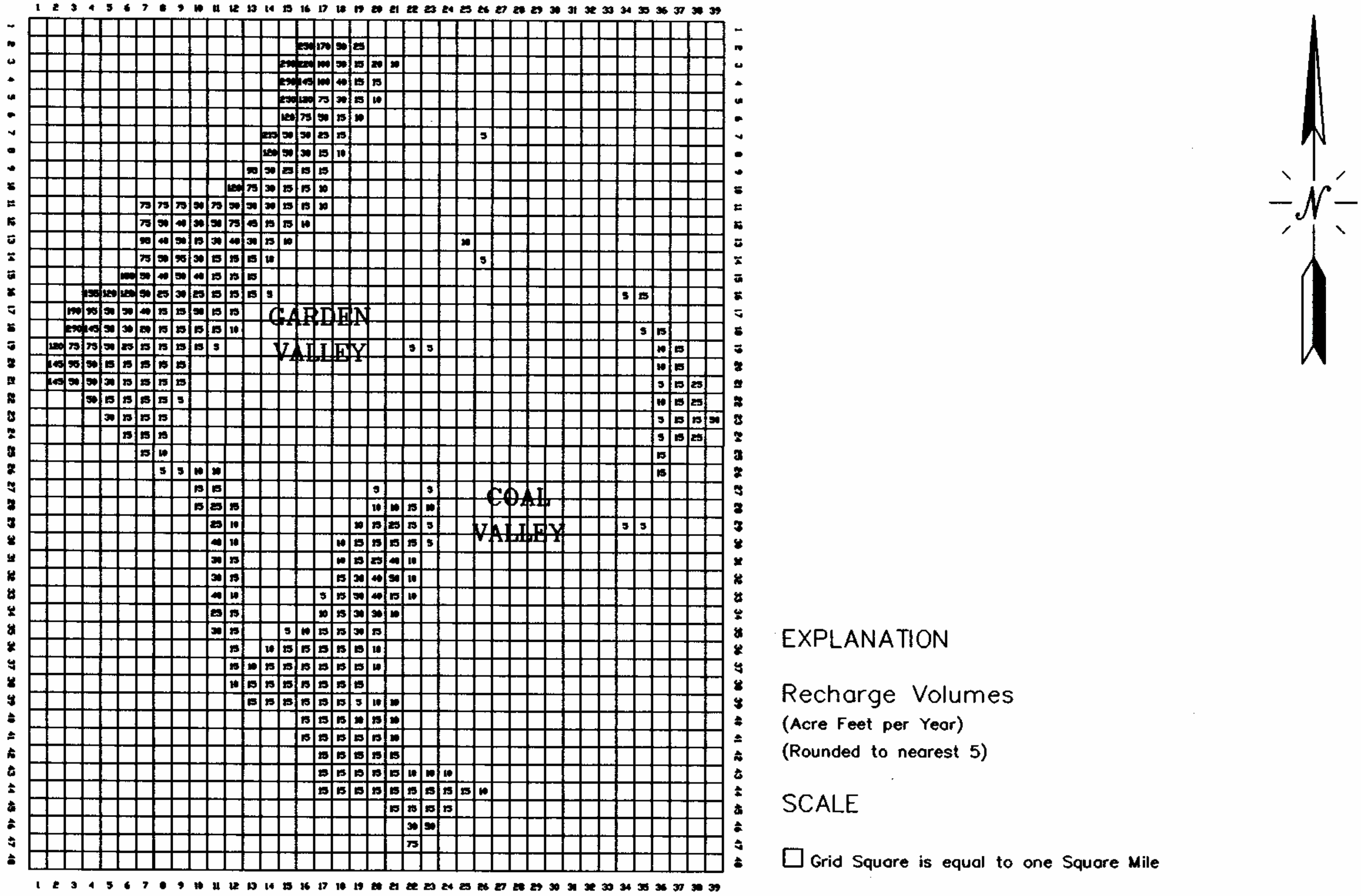
Secondary Recharge

Secondary recharge is due to infiltration of water from anthropogenic uses such as irrigation or septic disposal systems. Because there is little irrigation and very few domestic wells in this area, secondary recharge was not considered in the model.

Discharge

As stated above, the discharge from these valleys is estimated by Eakin (1963) to be between 1500 and 2000 acre-feet per year, all occurring in the northern part of Garden Valley and about 10,000 acre-feet per year of ground water flows out of the two valley system. The MODFLOW evapotranspiration function was used to estimate ET. As input the extinction depth (the depth of the ground-water surface below land surface at which ET ceases) is specified as well as the maximum ET rate (which occurs when the water surface reaches land surface). Of course the elevation of the land surface has to be specified. Again the digital elevations were used to computer generate a matrix corresponding to each cell which specifies the minimum elevation occurring in that grid cell.

The model used an extinction depth of 50 feet and the maximum evapotranspiration rate of one foot per year. Shallower extinction depths were tried; however, 50 feet was needed to arrive at a discharge comparable to the Eakin (1963) estimate and match existing water levels. The ET rate of one foot per year was thought reasonable since the USGS reconnaissance report (Van Denburgh and Rush, 1974) for neighboring Railroad Valley used rates from 0.4 ft. per year for saltgrass with phreatophytes moderately to densely scattered to 1.5 feet per year for meadow-grass and other wet area phreatophytes. Figure 12 shows the depth to water and area in which ET is occurring in Garden Valley. The model calculates the ET in Garden Valley to be 1380 acre-feet per year. The simulated evapotranspiration value compares well with the 1500 acre-feet per year estimated by Eakin (1963).



EXPLANATION

Recharge Volumes
(Acre Feet per Year)
(Rounded to nearest 5)

SCALE

☐ Grid Square is equal to one Square Mile

Figure 11. -- Model recharge volumes, Garden and Coal Valleys.

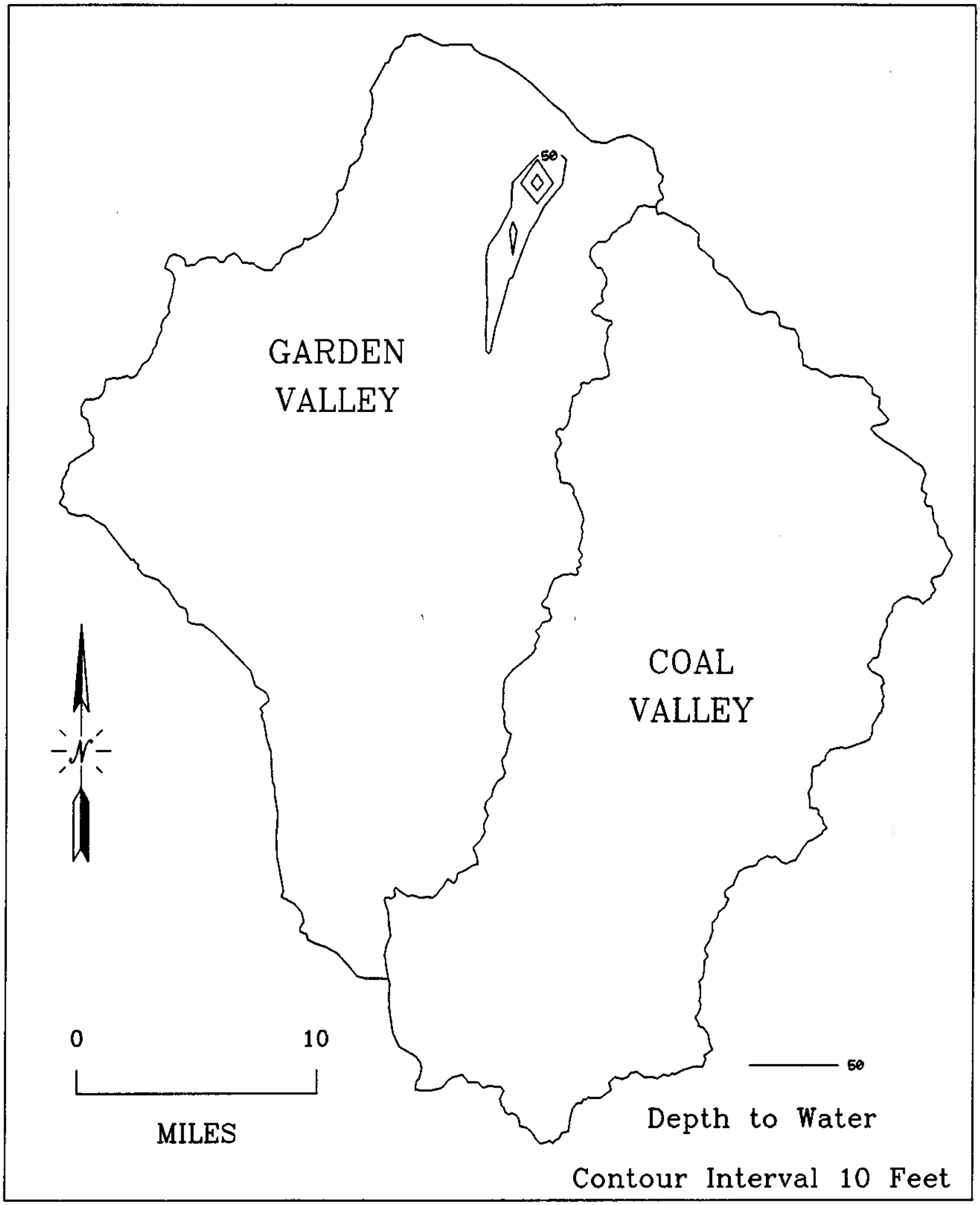


Figure 12. -- Location of evapotranspiration in Garden and Coal Valleys.

Hydraulic Characteristics

The hydraulic characteristics govern how the water introduced by recharge moves through the modelled area to the areas of discharge. For a steady state simulation the important hydraulic characteristics are transmissivity, boundary conditions (conductances) and, since this is a two layer model, vertical leakance. These parameters are discussed below:

Boundary Conditions

In essence, each individual basin was modelled as a "free body" tied to general head boundaries outside the existing basin boundary. The water levels specified for the general head boundaries were based on Thomas et al. (1986) for each layer. Conductances were established to simulate the USGS estimates for inflow and outflow in each layer, as well as match existing water levels. The USGS does not estimate any inflow into Garden Valley from another hydrologic basin; however, Eakin (1963) and Harrill et. al., (1988) estimate that 8000 acre-feet per year flows from Garden (10,000 acre-feet per year recharge less 2000 ET) to Coal. This inflow is added to the 2000 acre-feet per year recharge in Coal Valley, then the 10,000 acre-feet per year is estimated to flow out of Coal Valley generally south eastward, primarily through the consolidated carbonate rocks into Pahroc and/or Pahranagat Valley.

Figures 13 and 14 show the location of the general head boundaries and the conductances used in each layer. Note that very low conductances were used essentially simulating "no flow" boundaries in Garden Valley and northern Coal Valley, with the higher conductance values related to aquifer transmissivities, in southern Coal Valley, especially in layer two, where water is thought to flow from Coal Valley to Pahroc and/or Pahranagat Valley. Using these boundary conditions the simulated flow across the southeast Coal Valley boundary is about 1000 acre-feet per year in the upper system and about 8900 acre-feet per year in the lower consolidated rock layer.

Transmissivity

Transmissivity values were assigned based on rock type. For the Coal and Garden model there are three different rock type designations; alluvial fill, consolidated carbonate rocks, and consolidated volcanic rocks as shown in Figures 9 and 10 for layers one and two, respectively. As part of the MX Missile siting investigation (Bunch and Harrill, 1984) aquifer tests were conducted in both Coal and Garden Valleys. In Garden Valley transmissivity values in the alluvium are listed as 3200, 12000, 12000, and 13,000 ft^2 per day with a value of 400 ft^2 per day in consolidated carbonates. In Coal Valley transmissivity values in the alluvium are listed as 3200, 3700 and 7000 ft^2 per day.

Originally the transmissivity values of 5000, 1000 and 250 ft^2 per day were assigned to alluvium, carbonate, and volcanic rock types, respectively. These transmissivity values proved to be too high, not allowing simulated water levels to rise near the observed levels and therefore

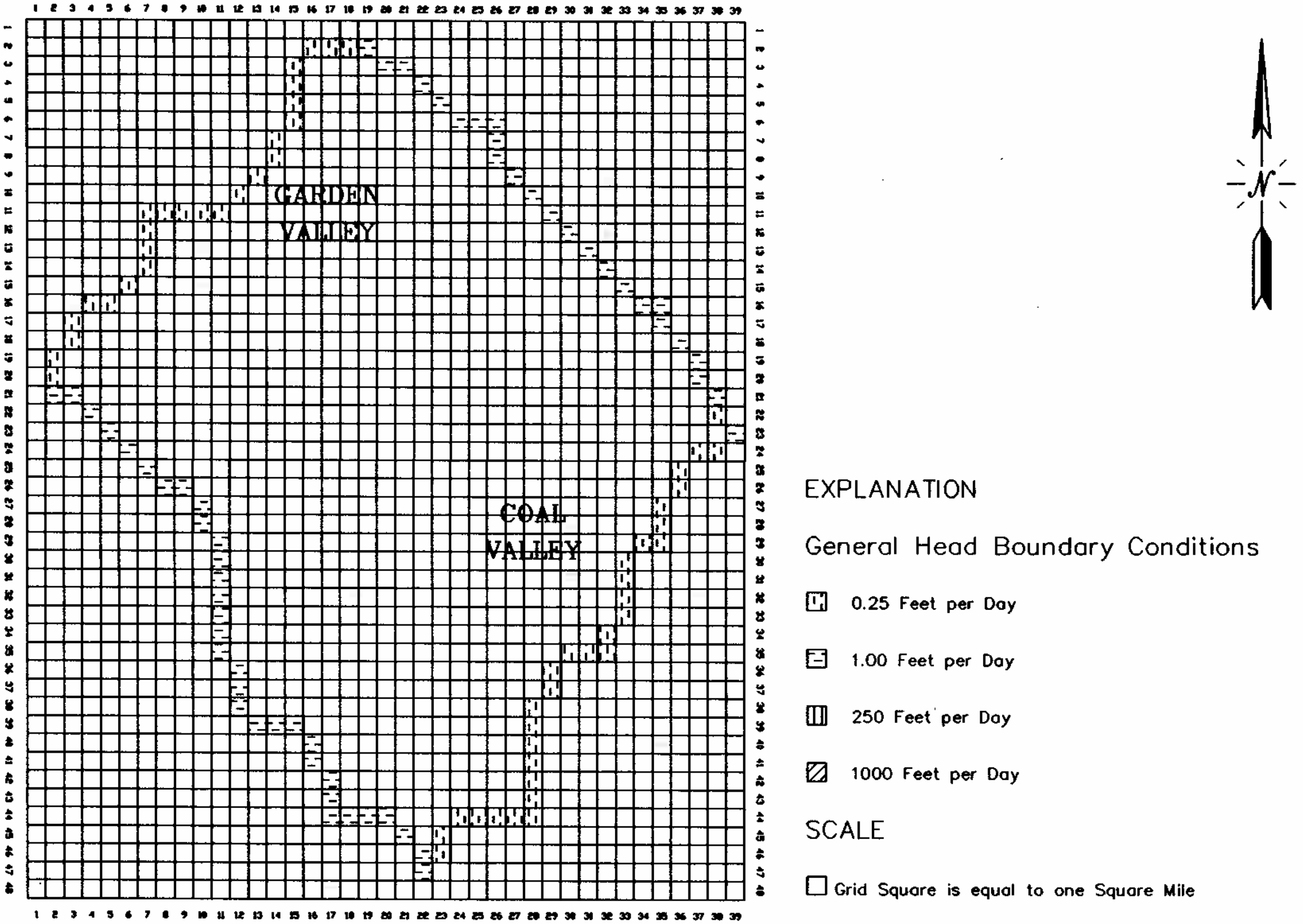


Figure 13. -- General head boundary of upper layer, Garden and Coal Valleys.

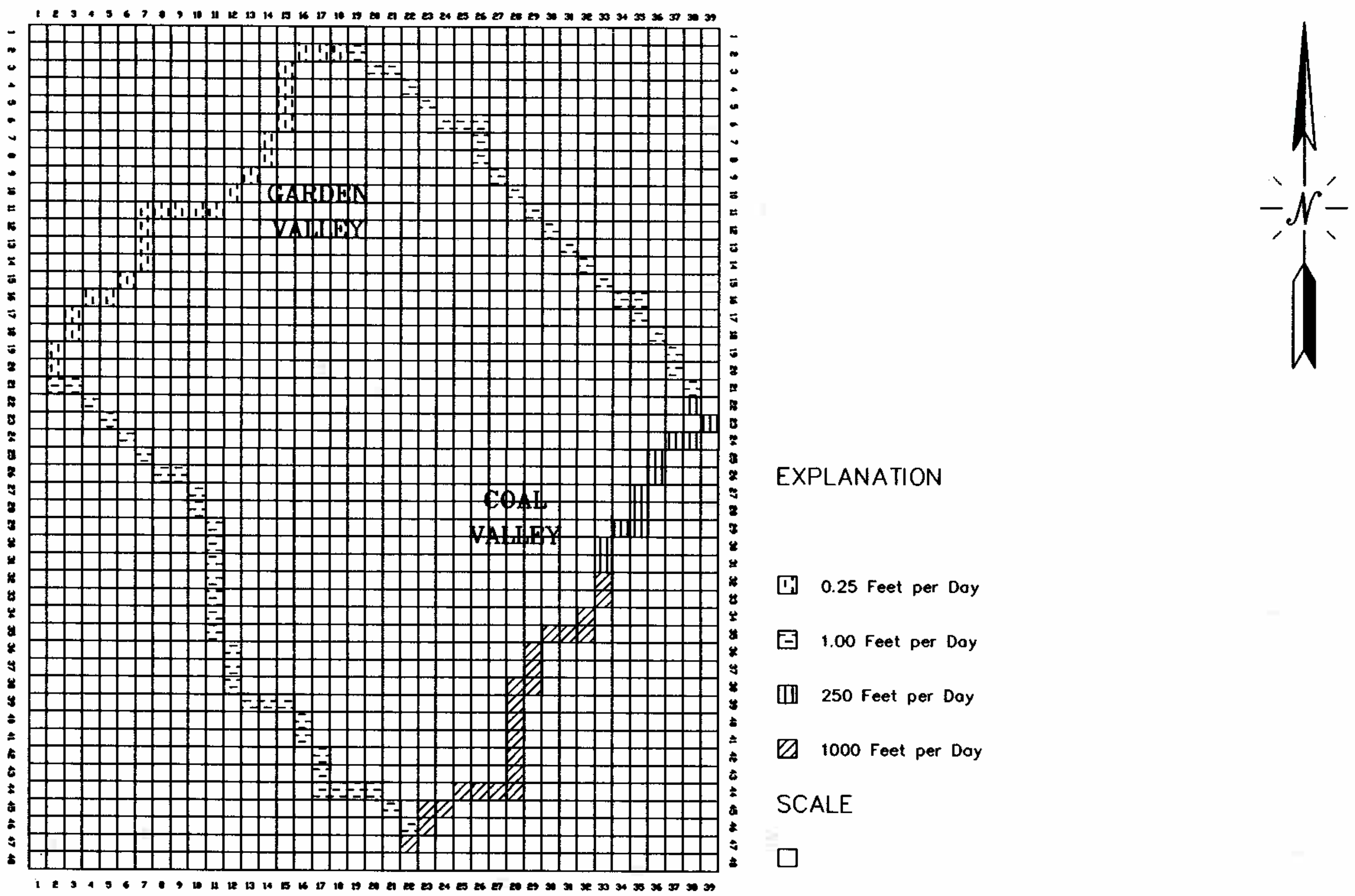


Figure 14. -- General head boundary of lower layer, Garden and Coal Valleys.

not resulting is any ET. After calibration, the final transmissivity values of 500, 400, and 100 ft^2/day for alluvial fill, carbonate bedrock, and volcanic bedrock, respectively, were used. The distribution of these values correspond to the rock type assigned to each cell, as shown in Figures 9 and 10.

The transmissivity values required to achieve model calibration are well below the median values for valley-fill deposits and carbonate aquifers (see Table 2). However, the occurrence of lakebed deposits in both of the valleys suggests that low values of transmissivity for the valley-fill deposits may be appropriate. That the modelled transmissivity value for the valley-fill is below values resulting from aquifer testing, is probably largely a function of the test well locations i.e., in areas of predominantly alluvial materials rather than lake deposits.

Although the modelled transmissivity for the carbonate aquifer is well below the median for this type of aquifer, the value agrees with the single aquifer test in Garden Valley. It is considered likely that this low transmissivity is indicative of the overall aquifer but, in areas where extensive fracturing and secondary dissolution has occurred, the transmissivity of the carbonate aquifer may be appreciably higher.

For transient modelling of the effects of water withdrawals, a sensitive parameter in the model is transmissivity. These low modelled values will result in transient simulations that will probably tend to overestimate the drawdown of water levels. The resulting simulations will thus be conservative, and given the available data base and uncertainties, such an approach is considered appropriate.

The majority of the wells in this area are located in the northern part of Garden Valley. These wells have historically been low producers (Eakin, 1963) which supports the lower transmissivity values. The calibration and the match to existing water levels is discussed in detail under the section entitled "Steady State Simulation".

Vertical Leakance

The vertical leakance value establishes the connection between the upper and lower model layers. Initially a value of 3×10^{-4} ft. per day was used, which simulates the layers as well connected. This value was too high to allow the simulated water levels to rise sufficiently in the upper layer to result in any ET and it also resulted in the majority of the water exiting Coal Valley from the upper layer.

During calibration it was necessary to develop separate vertical leakance values for Coal and Garden Valleys and final values of 5.0×10^{-8} and 7.5×10^{-6} ft. per day were used, respectively. The lower value was necessary for Garden Valley to allow water levels to rise sufficiently to result in ET. The value of 7.5×10^{-6} seemed to provide the best simulation of the outflow from the upper and lower layers in southern Coal Valley and still come reasonably close to the water levels in southern Coal Valley and the regional water levels found in Thomas et al. (1986). This is discussed in more detail under the section "Steady State Simulation".

There is geologic evidence that also supports different leakance values for the two basins. As discussed previously, older (Middle Pliocene to Early Pleistocene) lake deposits are present in Garden Valley while Coal Valley has younger (Late Pleistocene) deposits. The older deposits may be expected to exhibit lower permeabilities and hence, vertical leakances.

STEADY STATE SIMULATION

The potentiometric surfaces for the upper and lower layers resulting from the steady state simulation for Coal and Garden Valleys are shown in Figures 15 and 16 with the actual water levels imposed. The actual water level measurements and resulting contours representing the upper potentiometric surface are shown in Figure 6. There is one well completed in consolidated rock in Coal Valley and the location and depth to water is shown on Figure 16 the model simulated potentiometric surface.

Upper Layer

Table 7 shows all the water level data used for calibration for Coal and Garden Valleys model. In addition to the water level information, is the date the measurement was taken, the method used to take the measurement, the depth of the well if known, and the land surface elevation as found in the USGS data base. Many of these land surface elevations were probably interpolated from a 1:250,000 scale topography map. All the elevations were checked by the District on the more recent 1:100,000 or 1:24,000 scale maps, and for those where a difference was found the new interpolated land surface elevation is listed. The potentiometric surface is calculated for each elevation and both are listed in the table as well as the difference of the actual and model simulated water level for both sets of values. Also included are the data found in Bunch and Harrill (1984) generated as part of the MX Missile siting investigation. These data points are designated as MX and include the site location, land surface elevation, the depth of the well when known, and the depth to water.

The water levels shown in Figure 6 and Figure 15 are water levels calculated from the USGS data base using the District interpolated land surface elevations and the MX data for wells that are not duplicated in the USGS data base. The contours shown in Figure 6 are generated from gridding actual water level measurements. The contours shown in Figure 15 are model generated with actual water level measurements shown.

Five of the water level measurements in the USGS data base were deleted as indicated on the table. Based on the well depths and the location it was determined that these wells were probably duplicates, and either the most recent measurement or the entry with the land surface elevation most closely relating to the location was chosen. Wells thought to be duplicates from the various data bases are grouped together.

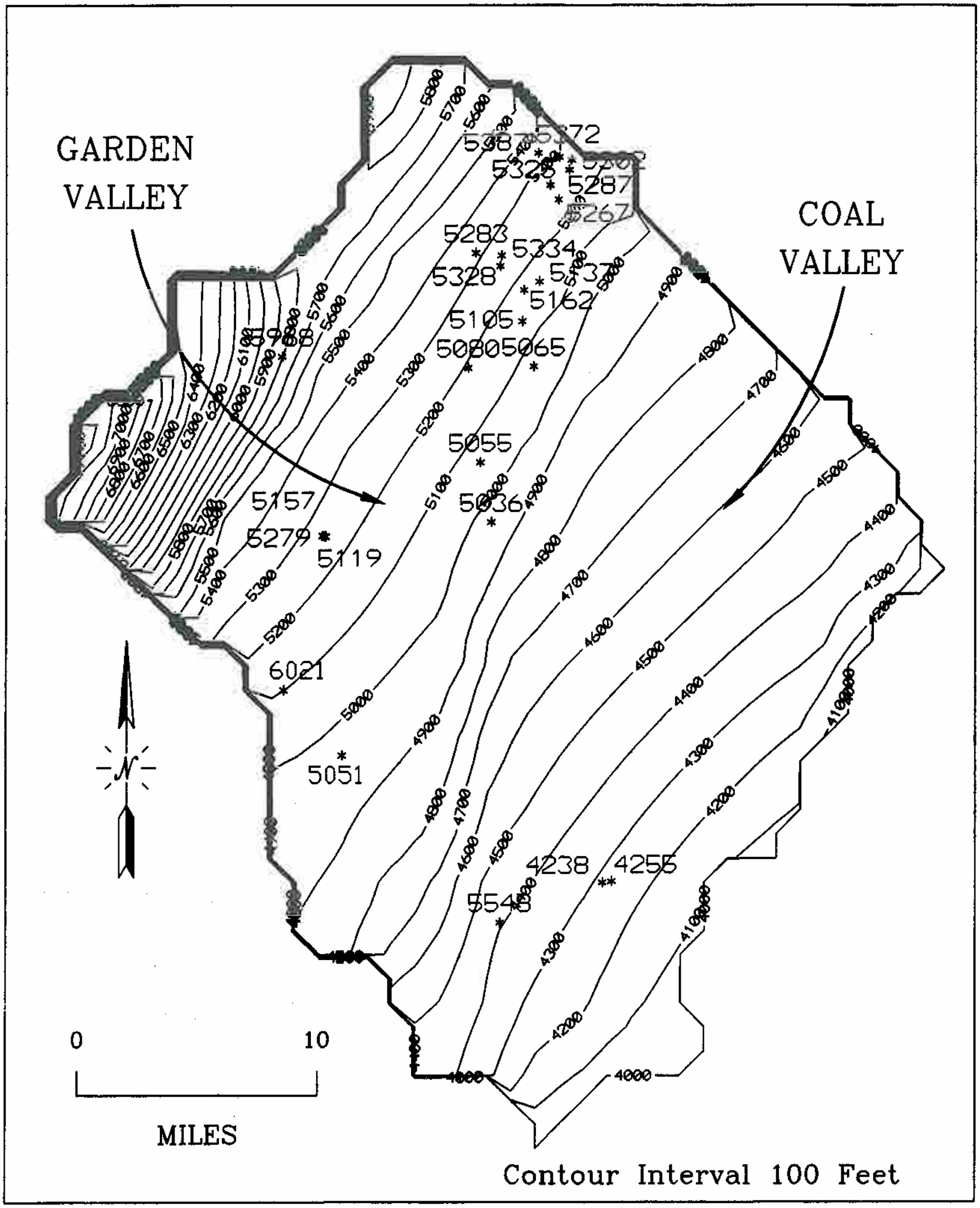


Figure 15 -- Simulated water levels (upper layer) in Garden and Coal Valleys

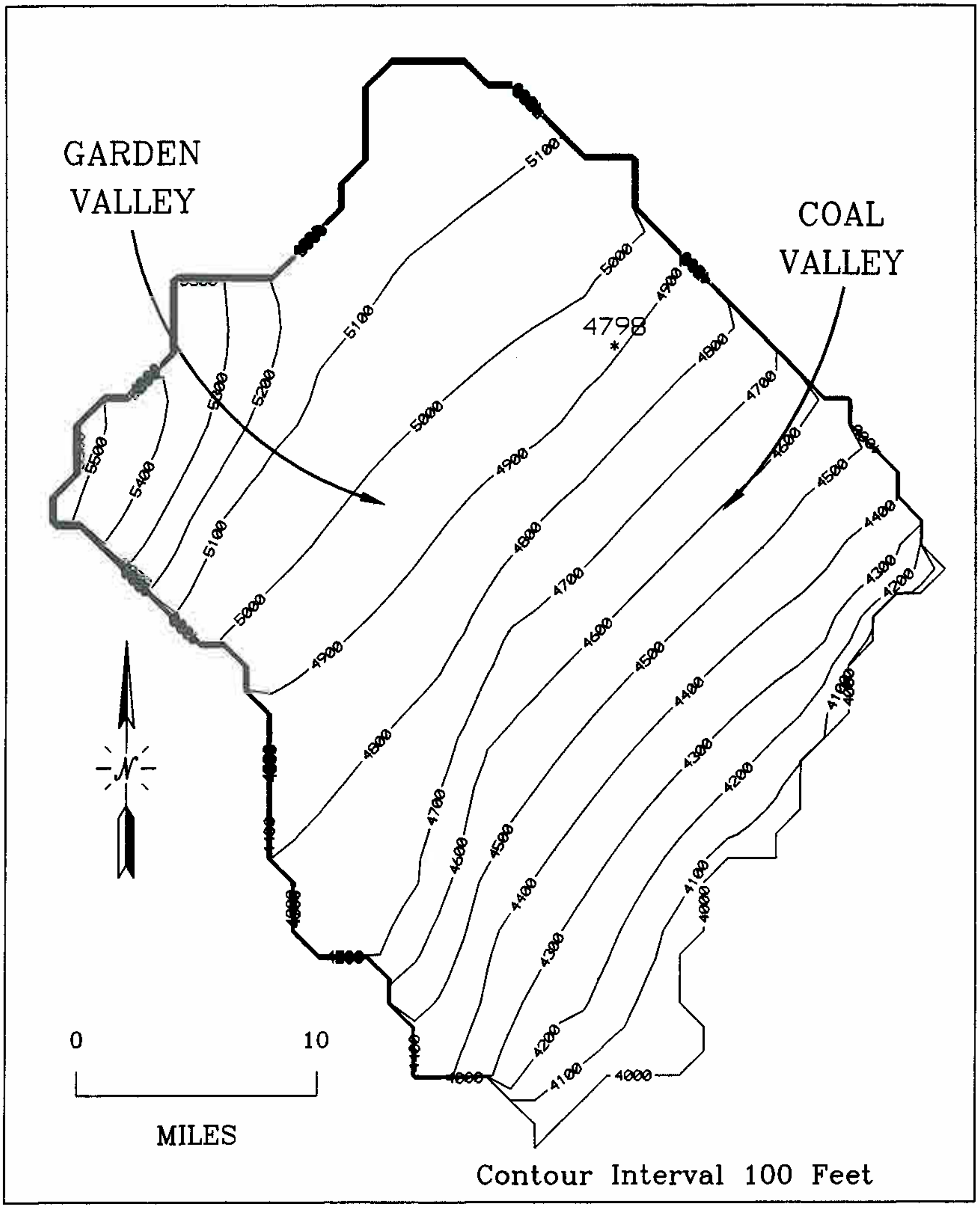


Figure 16. -- Simulated water levels (lower layer) in Garden and Coal Valleys

Table 7.--Actual vs. simulated ground-water elevations.

Model Row/Column	Hydrologic Site No.			Well Depth Ft.BLS	Elevation of Well Head GS^1 in ft	Elevation of Well Head LV^2 in ft	Elevation of Well Head MX	Water Level Meas. Date	Water Level Meas. Ft. BLS^3	Water Level Elevation GS^1	Water Level Elevation LV^2	Water Level Elevation MX	Water Level Model Simul.	Water Level Differences GS	Water Level Differences LV	Water Level Differences MX
COAL VALLEY																
	171	N03 E59 10BD	1^4		5600			19911212	801.9 T	4798	4798		4917	+119	+119	
14/25	MX	N03 E59 10BD	1^4	1835			5560	198104	803			4757				+160
	171	S01 E59 34CB	1	1340	5100			19810608	845 R	4255	4255		4278	+23	+23	
36/25	MX	S01 E59 34CB	1	1445			5125	198106	862			4263				+15
	171	S01 E59 34CB	2	1450	5100			19810608	862 R	4238	4238		4278	+40	+40	
36/25	MX	S01 E59 34CB	2	1315			5120	198106	845			4275				+3
	171	S02 E58 11A	1^5	188	5700	5640		19850311	111.70 S	5588	5548		4431	-1157	-1157	
	171	S02 E58 11A	1^5	188	5200	?		19630508	100.64 M	Deleted						
38/20	MX	S02 E58 12BB	^{5}	188			5600	198005	108			5584				-1153
GARDEN VALLEY																
31/13	MX	N01 E57 03A1		620			5540	198006	489			5051	4983			-68
29/11	MX	N01 E57 20	^{5}				6200	198005	188			6012	5076			-936
22/13	MX	N02 E57 22BA	1	1099			5583	198104	430			5153	5257			+104
	172	N02 E57 22BA	2	1030	5400	5550		19801212	431.00 R	4969	5119		5257	+288	+138	
22/13	MX	N02 E57 22BA	2	1065			5575	198104	420			5155				+102
22/13	172	N02 E57 22BBC	1	1010	5550	5575		19900320	417.8 T	5132	5157		5257	+125	+100	
22/13	172	N02 E57 22BBC	3	300	5550	5575		19900320	295.9 T	5254	5279		5257	+3	-22	
	172	N02 E58 03AA	1	200	5200			198010	145.00 R	5055	5055		5035	-20	-20	
19/19	MX	N02 E58 03AA		200			5200	198103	140			5060				-25
22/20	MX	N02 E58 14C					5150	198005	114			5036	4948			-92
	172	N03 E57 16C	1	92.0	6200	6000		19630509	32.10	Deleted						
15/11	172	N03 E57 16CBD	1^5	92	6150	6000		19900320	36.28 S	6114	5968		5830	-284	-138	
	MX	N03 E57 16C	^{5}	92			6200	198005	19			6181				-351
	172	N03 E58 01AD	1	100	5200	5190		198010	85.30 R	5115	5105		5153	+38	+48	
13/21	MX	N03 E58 01AD		100			5210	198103	88			5122				+31
	172	N03 E58 01DA	1	100	5280	5200		19910904	85.1 T	Deleted						
	172	N03 E58 15B	1	260	5300	5315		19600120	235.00 R	5065	5080		5192	+127	+112	
15/19	MX	N03 E58 15B	1	260			5310	198005	221			5089				+103

Table 7.--Actual vs. simulated ground-water elevations (continued).

Model Row/Column	Hydrologic Site No.	Well Depth Ft.BLS	Elevation of Well Head GS[1] in ft	Elevation of Well Head LV[2] in ft	Elevation of Well Head MX	Water Level Meas. Date	Water Level Meas. Ft. BLS[3]	Water Level Elevation GS[1]	Water Level Elevation LV[2]	Water Level Elevation MX	Water Level Elevation Model Simul.	Water Level Differences GS	Water Level Differences LV	Water Level Differences MX
15/22	172 N03 E59 18BB 1	200	5200	5215		19910904	150.14 S	5050	5065		5057	+7	-8	
	MX N03 E59 18BB	200			5230	198103	153			5077				-20
10/19	MX N04 E58 22DB	100			5500	198103	153			5347	5347			+0
10/20	MX N04 E58 23D				5350	198005	16			5334	5283			-51
11/20	172 N04 E58 26ABA 1	20	5340			19900320	12.0 T	5328	5328		5251	-77	-77	
12/21	172 N04 E58 36A 1	27	5300	5185		19911212	22.75 S	5277	5162		5181	-96	+19	
	MX N04 E58 36A 1				5230	198005	25			5204				-23
7/23	172 N04 E59 05ABC 1		5350	5375		19900320	50.46 S	5300	5325		5244	-56	-81	
8/22	172 N04 E59 06D 1	200	5200	?		19630509	8.80	Deleted						
	MX N04 E59 06D	200			5300	198005	9			5291				-41
	172 N04 E59 06DDD 1		5290			19900320	3.10 S	5287	5287		5250	-37	-37	
8/22	MX N04 E59 08B	80			5300	198005	10			5290				
8/22	172 N04 E59 08BCC 1	14	5270			19900320	3.22 S	5267	5267		5250	-17	-17	
	MX N04 E59 08B 1				5300	198005	12			5288				-38
12/22	172 N04 E59 30CD 1	100	5300	5200		19850312	62.98 S	5237	5137		5140	-97	+3	
	172 N04 E59 30DC 1	100	5300	5250		198010	86.00 R	Deleted						
	MX N04 E59 30DC	100			5275	198103	65			5210				-70
6/22	172 N05 E59 31CAA 1	200	5440	5500		19910904	113.0 T	5327	5387		5327	+0	-60	
	MX N05 E59 31CA	200			5520		111			5409				-82
6/22	172 N05 E59 32C 1		5300	5380		19480227	8.01 S	5292	5372		5327	+35	-45	
7/23	172 N05 E59 32D 1		5200	5360		19630509	57.70	5142	5302		5244	+102	-58	
	MX N05 E59 32D				5350	198005	59			5291				-47

1 Based on elevations found in USGS data base
2 Based on elevations interpolated by District from 1:100,000 or 1:24,000 USGS topography maps; no number indicator use of USGS data
3 Measurement method: T=electric tape; S=steel tape; R=reported; M=measurement made equipment unknown.
4 Well completed in consolidated rock
5 Not included in calibration, see text discussion

Of the remaining wells three were not considered in the calibration. The well located in southern Coal Valley in S02 E58 11A is located in a narrow gap between volcanic consolidated rock outcroppings south of the Golden Gate range. The high water level is probably representative of a very low transmissivity and a localized or perched flow system. Also wells located in Garden Valley in N01 E57 20 and N03 E57 16C are shallow wells completed near consolidated bedrock and are probably representative of a very localized perched flow system. All three of these wells have markedly higher water levels than other observed water levels and those simulated by the model.

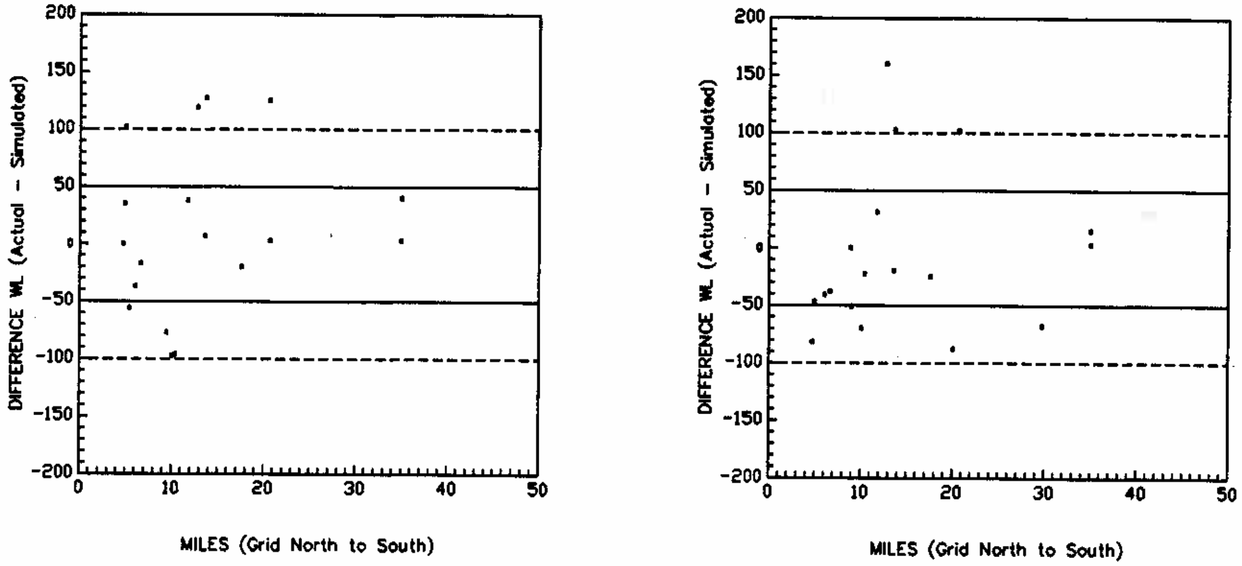
Also there are three wells located in Garden Valley in N02 E57 22B completed at depths of 1030, 1010, and 300 feet with corresponding water levels of 431, 412, and 296 below land surface. The depth to water of 296 is probably the most representative of the three of the upper system in this area and is the closest to the model simulated water level for this node; however, all three points are considered in the calibration discussion.

Figure 17 graphically illustrates the difference between the actual water levels and the model simulated levels. A graph is shown for the actual water levels calculated from the land surface elevations found in the USGS data base and those calculated from the elevation interpolated by the District. Also a graph is included for the MX data points. For the water levels based on the USGS elevations 10 (53%) of the simulated values are within 50 feet of the observed, 4 (21%) are between 50 and 100 feet and 5(26%) are over 100 feet. For the water levels based on District interpolated elevations 11 (58%) of the simulated values are within 50 feet of the observed, 5 (26%) are between 50 and 100 feet, and 3 (16%) are over 100 feet. For the MX data, 10 (55%) are within 50 feet of the observed, 5 (28%) are between 50 and 100 feet, and 3 (17%) are over 100 feet. For each case the number of values greater than the simulated values about equals the number of values less than the simulated values. Fifty feet is considered to be the "margin of error" inherent in the process due to the accuracy of interpretation of the land surface elevation from topography maps.

Lower Layer

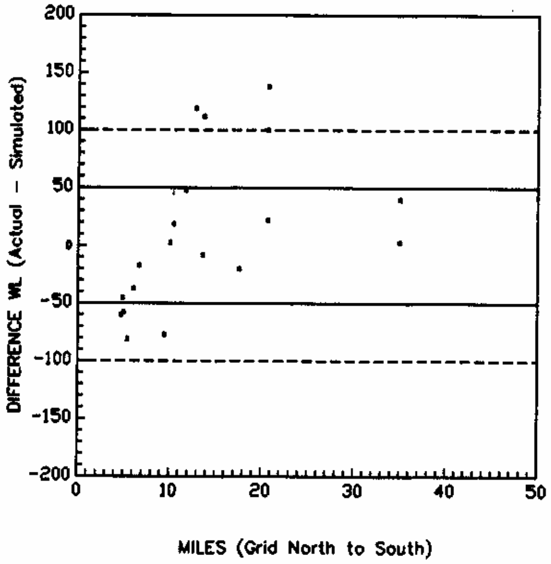
The potentiometric surface generated by the model for the lower layer is shown in Figure 16. As mentioned above, there is only one well completed in the consolidated rocks as indicated in Table 7. This well is included on the graphs shown in Figure 17 but of course compared to the simulated water level for layer two of the model. Based on regional water levels, Thomas et al. (1986) estimate the potentiometric surface in the lower layer to be about 5400 feet at the upper end of Garden Valley and about 4000 feet at the lower end of Coal Valley. The simulated values closely match Thomas et al. (1986).

Eakin (1963) estimates that about all the water exiting Coal Valley is leaving through the consolidated carbonate rocks. In order to keep water levels high enough in Garden Valley to simulate ET and match actual water levels, then transfer water from the upper to lower layer in Coal, two vertical leakance values were used as discussed above. It appears that some structure in the Golden Gate Range is responsible for dropping the water table based on the



Water Level Calibrated with U.S.G.S. Data

Water Level Calibrated with M.X. Data



Water Level Calibrated with L.V.V.W.D. Land Surface Elevation

Figure 17. -- Model calibration plots for Garden and Coal Valleys

difference in water levels found on either side of the range. The higher vertical leakance value in Coal successfully drops the water as seen by the match of the simulated water levels with the actual levels in southern Coal. However, the simulated water level for the one well located in Coal Valley (N03 E59 10BD) near the Golden Gate Range is about 117 feet higher than the actual water level indicating the water drops dramatically across this range. However, since the contours match those shown in Thomas et al. (1986) for the consolidated system in this area and the budget is comparable to the USGS budget, the model is considered to be calibrated for the lower layer. Table 8 compares the budget found in Eakin (1963) with the model generated budget.

Table 8.--Comparison of model budget (Eakin, 1963) all values ac.ft./yr.

		USGS	Steady State Model (rounded)
RECHARGE:	Garden	10000	9600
	Coal	2000	1700
ET:	Garden	1500-2000	1400
	Coal	0	0
FLOW:	Garden	8000	8200
	From Coal	10000	9900 (8900 lower)

SUMMARY

As stated above, the goal of the steady state model was to duplicate as closely as possible the budget established by the USGS listed above, and match existing water levels. Although there were aquifer test data for Coal and Garden Valleys there were insufficient data to vary cell by cell transmissivity values, therefore transmissivity values were keyed to rock type. The model "constant" becomes water entering the model as estimated by the USGS. There is no estimate of flow by the USGS entering Garden Valley other than recharge and no water entering Coal Valley other than recharge and flow from Garden Valley. The transmissivities, boundary conditions, and vertical leakance values described above provided a good match to the established USGS budget and to existing water level data.

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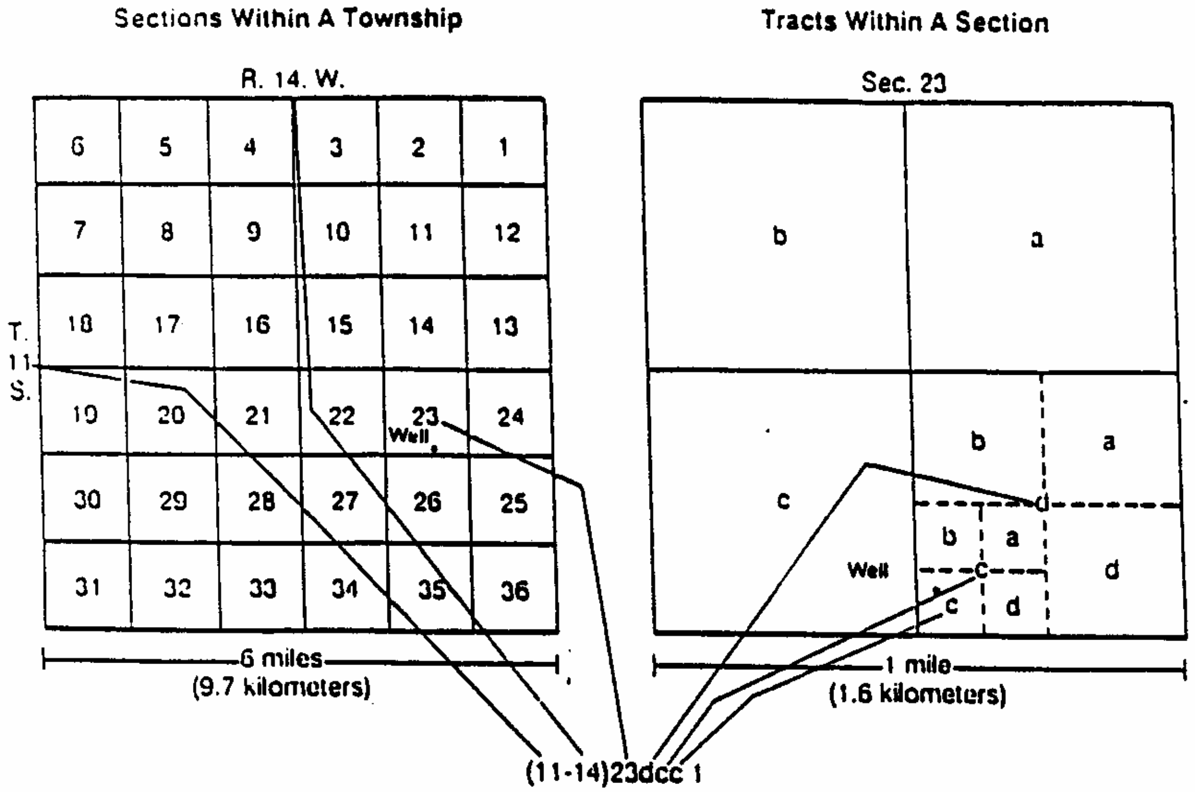
APPENDIX A

LOCATION DESIGNATION



Well and spring locations are designated with respect to the Mount Diablo baseline and meridian as shown diagrammatically above. The first number within the parentheses represents the township south of the baseline and the second number represents the range east of the meridian. The section number follows along with the section 1/4, section 1/16th, and section 1/64th. The letter designations a, b, c, and d refer to the northeast, northwest, southwest, and southeast, respectively. If more than one well occurs within the same 1/64th section, a numerical identifier is added to the end of the designation. Thus (28-63) 27aba1 represents the first well of record in the northeast quarter-section of the northwest quarter-section of the northeast quarter-section of Township 28 South, Range 63 East, Section 27.

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WATER BASIN 171
COAL VALLEY
PERMITS AND APPLICATIONS

APPLICATION/ PERMIT	CERTIFICATE/ PROOF	DATE OF PRIORITY	POINT OF DIVERSION 1/4 1/4	SECTION	TOWNSHIP	RANGE	DIVERSION RATE	CONSUMPTION AC.FT./YR.	ALLOCATED DUTY AC.FT./YR	USE	ACAD BLOCK	PLACE OF USE	NOTES
1266		01/01/69	NE SE	14	1S	60E	0.0500	2.24	2.24	STOCK & DOMESTIC	SURF_OTN	NE SE S14 T1S R60E	PERMIT 01266 - "0" PREFIX NOT ALLOWED IN DATA BASE
1509		01/01/91	NE SE	12	3S	58E	0.1000	1.12	1.12	STOCKWATER	SURF_OTN	NE SE S12 T3S R58E	PERMIT 01509
1540	NONE	01/01/75	SE NW	13	1N	59E	0.1000	1.12	1.12	STOCKWATER	SURF_OTN	SE NW S13 T1N R59E	PERMIT 01540
1544		01/01/75	SE SE	18	3N	60E	0.1000	2.24	2.24	STOCKWATER	SURF_OTN	SE SE S18 T3N R60E	PERMIT 01544
1605		01/01/99	NE SE	1	3S	58E	0.0250	0.56	0.56	STOCKWATER	SURF_OTN	NE SE S1 T3S R58E	PERMIT 01605
1606		01/01/00	SW SE	1	3S	58E	0.0250	0.56	0.56	STOCKWATER	SURF_OTN	SW SE S1 T3S R58E	PERMIT 01606
4665	1576	11/01/17	SE SE	30	1N	61E	0.0016	1.12	1.12	STOCKWATER	SURF_OTN	SE SE S30 T1N R61E	
4859	529	01/22/18	NW NE	7	1N	59E	0.0250	22.40	22.40	STOCKWATER	SURF_OTN	NW NE S7 T1N R59E	
7344	1284	04/26/25	NW NW	36	1N	60E	0.0150	11.20	11.20	STOCKWATER	SURF_OTN	NW NW S36 T1N R60E	
7915	2438	10/20/26	NE NE	3	1N	61E	0.0010	0.60	0.60	STOCKWATER	SURF_OTN	NE NE S3 T1N R61E	
46737	12283	03/16/83	NW SW	10	3N	59E	0.0350	29.12	29.12	STOCKWATER	WELL_OTN	SECS 1-3, N1/2 N1/2 SECS 10-12 T2N R58E, SECS 1,2, 4-6, N12/ S3, N1/2 NE S7, N1/2 N1/2 SECS 8,9,11,12 T2N R59E, CONTINUED IN NOTES	SECS 1-3,10-15,22-27,34-35, T3N R58E, ALL OF T3N R59E & T4N R59E, SECS 3-10,15-22,27-34 T3N R60E, SECS 1,2,10-15,22-27,34-36, T4N R58E
52775		12/13/88	NW NW	36	1N	60E	0.1000	4.48	4.48	STOCKWATER	SURF_OTN	NW NW S36 T1N R60E	
53956		10/17/89	NE NW	36	3N	60E	6.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53957		10/17/89	SW SE	14	2S	59E	6.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53958		10/17/89	SE NW	10	3N	60E	10.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53959		10/17/89	SE SW	6	3S	60E	10.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
54215		12/06/89	SE SW	12	1S	59E	0.0000	9.00	9.00	STOCKWATER	SURF_OTN	SE SW, SW SE S12, NW NE,NE NW S13, T1S R59E	PRIORITY DATE LATER THAN LVVWD APPLICATIONS
54216		12/06/89	NW NW	17	1S	60E	0.0100	20.16	20.16	STOCKWATER	WELL_OTN	NW NW S17 T1S R60E	PRIORITY DATE LATER THAN LVVWD APPLICATIONS
*** Total ***								105.92	105.92				

APPENDIX B

WATER BASIN 172
GARDEN VALLEY
PERMITS AND APPLICATIONS

APPLICATION/ PERMIT/PROOF	CERTIFICATE	DATE OF PRIORITY	POINT OF DIVERSION 1/4 1/4	SECTION	TOWNSHIP	RANGE	DIVERSION RATE	CONSUMPTION AC.FT./YR.	ALLOCATED DUTY AC.FT./YR	USE	ACAD BLOCK	PLACE OF USE	NOTES
1150		01/31/04	SW SW	35	4N	57E	0.0000	32.70	43.60	IRRIGATION	SURF_PE	S1/2 SW S35 T4N R57E	PERMIT 01150. "0" PREFIX IGNORED BY DATA BASE
1152		01/01/72	SE SW	8	3N	57E	0.0000	132.40	176.53	IRRIGATION, DOMESTIC, & STOCK	SURF_PE	W1/2 S16, E1/2, NW1/4 S17, T3N R57E	PERMIT 01152. #1 OF 3 PTS. OF DIVERSION
1152		01/01/72	NW NE	8	3N	57E	0.0000	0.00	0.00	IRRIGATION, DOMESTIC, & STOCK	SURF_PE	W1/2 S16, E1/2, NW1/4 S17 T3N R57E	PERMIT 01152. #2 OF 3 PTS. OF DIVERSION. SAME POU.
1152		01/01/72	SE NE	8	3N	57E	0.0000	0.00	0.00	IRRIGATION, DOMESTIC & STOCK	SURF_PE	W1/2 S16, E1/2, NW1/4 S17 T3N R57E	PERMIT 01152. #3 OF 3 PTS. OF DIVERSION. SAME POU
1153		01/01/81	NW SE	16	3N	57E	0.0000	48.20	64.27	IRRIGATION	SURF_PE	SE1/4 S16, SW1/4 S15 T3N R57E	PERMIT 01153.
1154		01/01/86	SW SW	15	3N	57E	0.0000	22.50	30.00	IRRIGATION, DOMESTIC & STOCKWA	SURF_PE	S1/2 S15 T3N R57E	PERMIT 01154
1155		01/31/02	SE SW	36	3N	56E	0.0000	0.00	0.00	IRRIGATION	SURF_PE	PTNS. S1 T2N R56E, S6,S7 T2N R57E, S36 T3N R56E	PERMIT 01155. #2 OF PTS. OF DIVERSION. SAME POU
1155		01/31/02	NW SE	6	2N	57E	0.0000	0.00	0.00	IRRIGATION	SURF_PE	PTNS. S1 T2N R56E, S6, S7 T2N R57E, S36 T3N R56E	PERMIT 01155. #4 OF 4 PTS. OF DIVERSION. SAME POU.
1155		01/31/02	SW NE	1	2N	56E	0.0000	0.00	0.00	IRRIGATION	SURF_PE	PTNNS. S1 T2N R56E, S6, S7 T2N R57E, S36 T3N R56E	PERMIT 01155. #3 OF 4 PTS. OF DIVERSION. SAME POU
1155		01/31/02	NE SW	36	3N	56E	0.0000	165.00	220.00	IRRIGATION	SURF_PE	PTNS. S1 T2N R56E, S6, S7 T2N R57E, S36 T3N R56E	PERMIT 01155. #1 OF 4 PTS. OF DIVERSION. SAME POU
1156		01/01/92	SE NW	3	2N	56E	0.0000	12.04	16.05	IRRIGATION	SURF_PE	PTN S3 T2N R56E	PERMIT 01156
1539		01/01/78	NE SW	2	1N	58E	0.0670	0.11	0.11	STOCKWATER	SURF_OTN	NE SW S2 T1N R58E	PERMIT 01539
1541		01/01/75	NW NE	7	2N	57E	0.1000	4.48	4.48	STOCKWATER	SURF_OTN	NW NE S7 T2N R57E	PERMIT 01541
1542		01/01/73	NE NE	28	3N	57E	0.1000	22.40	22.40	STOCKWATER	SURF_OTN	NE NE S28 T3N R57E	
1543		01/01/73		14	3N	57E	0.5000	22.40	22.40	STOCKWATER	SURF_OTN	SW SE S14, SW NE S24, SE SE S18 T3N R57E	PERMIT 01543. #1 OF 2 PTS. OF DIV. SAME POU
1543		01/01/73		24	3N	57E	0.0000	0.00	0.00	STOCKWATER	SURF_OTN	SW SE S14	PERMIT 01543. #2 OF 2 PTS. OF DIVERSION. SAME POU
1703		06/01/10	SE SE	3	2N	56E	0.5220	156.50	208.67	IRRIGATION & DOMESTIC	SURF_PE	52 AC. IN S1,11,12 T2N R56E	

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WATER BASIN 172
GARDEN VALLEY
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APPLICATION/ PERMIT/PROOF	CERTIFICATE	DATE OF PRIORITY	POINT OF DIVERSION 1/4 1/4	SECTION	TOWNSHIP	RANGE	DIVERSION RATE	CONSUMPTION AC.FT./YR.	ALLOCATED DUTY AC.FT./YR	USE	ACAD BLOCK	PLACE OF USE	NOTES
2715		05/16/13	SE SW	8	3N	57E	0.1950	58.68	78.24	IRRIGATION	SURF_PE	NE NW, NW NE, W1/2 NE, SE NE, S17, SE NE, SW NW, NW SW, S16, T3N R57E	
2911		03/16/14	SE NW	31	4N	59E	0.0060	4.49	4.49	STOCKWATER & DOMESTIC	WELL_OTN	SE NW S31 T4N R59E	
2912		03/16/14	SE NW	23	4N	58E	0.0060	4.49	4.49	STOCKWATER	WELL_OTN	SE NW S23 T4N R58E	
4563		08/24/17	SE SW	36	3N	56E	0.1470	33.03	44.04	IRRIGATION	SURF_PE	NW NE, SWNE, SE NE, S1 T1N R56E	
4635		10/13/17	SW NW	14	3N	57E	0.2900	105.90	141.20	IRRIGATION & DOMESTIC	SURF_PE	NW SE,SW NE, NE SW,SE NW, S14 T3N R57E	
4799		12/22/17	NE SW	16	3N	57E	0.0730	1.66	2.21	IRRIGATION	SURF_PE	S1/4? S16 T3N R57E	
4857		01/22/18	SE NE	24	1N	57E	0.0150	11.20	11.20	STOCKWATER	SURF_OTN	SE NE S24 T1N R57E	
4858		01/22/18		0	1N	57E	0.0250	24.64	24.64	STOCKWATER	SURF_OTN	UNKNOWN	PT. OF DIVERSION NOT SPECIFIED
4860		01/22/18	NE NW	3	1N	56E	0.0250	22.40	22.40	STOCKWATER & DOMESTIC	SURF_OTN	NE NW S3 T1N R56E	
4865		01/24/18	SE SW	16	1S	58E	0.0250	33.60	33.60	STOCKWATER	SURF_OTN	SE SW S16 T1S R58E	
5786		10/01/19	NE SW	36	3N	57E	0.1700	49.99	66.67	IRRIGATION	SURF_PE	NE SW S36 T3N R57E	
6047		04/03/20	SW NW	14	3N	57E	0.9760	22.40	22.40	STOCKWATER	SURF_OTN	NE SE S8 T3N R58E	
6679		05/19/22	SW SE	21	2N	57E	0.0190	13.44	13.44	STOCKWATER	SURF_OTN	SE NW S10 T1N R57E	
7252		11/21/24	NE SW	7	2N	57E	0.0060	4.48	4.48	STOCKWATER	SURF_OTN	NE SW S7 T2N R57E	SAME PT. OF DIVERSION AS 10467
8379		11/09/27	SE NW	19	2N	57E	0.0030	2.24	2.24	STOCKWATER	SURF_OTN	SE SE S29 NE NE S32 T2N R57E	
8380		11/09/27	NW SE	20	1N	57E	0.0130	9.63	9.63	STOCKWATER	WELL_OTN	NW SE S20 T1N R57E	
8490		03/29/28	SE SE	31	5N	59E	0.0030	0.22	0.22	STOCKWATER	WELL_OTN	SE SE S31 T5N R59E	
9592		05/31/32	SW SW	8	3N	57E	0.0000	0.00	0.00	IRRIGATION & DOMESTIC	SURF_PE	NW SW, SW SW SE SW S8, NE NW S17 T3N R57E	#1 OF 2 PTS. OF DIVERSION. SAME PLACE OF USE IRRIGATED
9592		05/31/32	NE SE	7	3N	57E	0.1000	27.00	36.00	IRRIGATION & DOMESTIC	SURF_PE	NW SW, SW SW, SE SW, S8, NE NW S17 T3N R57E	#2 OF 2 PTS. OF DIVERSION. SAME PLACE OF USE IRRIGATED
9820		12/04/34	NW SE	7	2N	57E	0.0250	180.90	180.90	DOMESTIC	SURF_OTN	NW SE S7 T2N R57E	
9843		09/08/19	SE SW	5	2N	57E	0.1780	64.50	86.00	IRRIGATION & DOMESTIC	SURF_PE	SW NE, NW SE S7 T2N R57E	

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WATER BASIN 172
GARDEN VALLEY
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APPLICATION/ PERMIT/PROOF	CERTIFICATE	DATE OF PRIORITY	POINT OF DIVERSION 1/4 1/4	SECTION	TOWNSHIP	RANGE	DIVERSION RATE	CONSUMPTION AC.FT./YR.	ALLOCATED DUTY AC.FT./YR	USE	ACAD BLOCK	PLACE OF USE	NOTES
9922		12/18/35	SW SW	10	2S	57E	0.0030	7.28	7.28	STOCKWATER & DOMESTIC	WELL_OTH	SW SW S10 T2S R57E	
10167		09/13/37	SE SE	11	2N	56E	1.0000	318.00	424.00	IRRIGATION	SURF_PE	NE SW, SE NW, SW NW, NW NW, S13 T2N R56E	
10467		01/29/40	NE SW	7	2N	57E	0.0090	6.72	6.72	STOCKWATER	SURF_OTH	NW NE S21 T2N R57E	
11047		01/11/44	NW NW	2	1S	57E	0.0220	33.60	33.60	STOCKWATER	WELL_OTH	NW NW S2 T1S R57E	
11374		09/17/45	NW NW	23	2N	56E	0.0030	2.24	2.24	STOCKWATER	SURF_OTH	NW NW S23 T2N R56E	
18644		03/11/60	NW SW	16	3N	57E	2.0000	245.40	327.20	IRRIGATION	WELL_PE	NW SW, SW SW, NE SW, SE SW, SW SE, SE SE, S16, SW SW, SE SW S15 T3N R57E	
24420		03/26/68	SW SE	6	1S	57E	0.0090	6.72	6.72	STOCKWATER	SURF_OTH	NW SW S12 T1S R56E	
32513		06/30/77	NW NE	26	4N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NE1/4 S26 T4N R58E	
32514		06/30/77	NW NW	24	4N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NW1/4 S24 T4N R58E	
32516		06/30/77	NW NW	25	4N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NW1/4 S25 T4N R58E	
33012		08/03/77	SW NW	1	2N	56E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NW1/4 S1 T2N R56E	
33306		08/23/77	NW SW	1	2N	56E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	SW1/4 S1 T2N R56E	
34558		11/03/77	NW NE	23	4N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NE1/4 S23 T4N R58E	
36783		02/14/79	NW NW	14	2N	58E	5.4000	960.00	1280.00	IRRIGATION & DOMESTIC	SURF_DLE	W1/2 S14 T2N R58E	
37229		03/27/79	NW SE	30	3N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NW SE, SE SE S30, NW NW, SE NW S32 T3N R58E	
37230		03/27/79	NW SE	32	3N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	SE1/4 S32 T3N R58E	

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WATER BASIN 172
GARDEN VALLEY
PERMITS AND APPLICATIONS

APPLICATION/ PERMIT	CERTIFICATE PROOF	DATE OF PRIORITY	POINT OF DIVERSION 1/4 1/4	SECTION	TOWNSHIP	RANGE	DIVERSION RATE	CONSUMPTION AC.FT./YR.	ALLOCATED DUTY AC.FT./YR	USE	ACAD BLOCK	PLACE OF USE	NOTES
38232		05/24/79	SE SW	15	3N	57E	0.0450	15.00	20.00	IRRIATION & DOMESTIC	SURF_PP	SW SE, SE SW S15 T3N R57E	
38595		07/18/79	NW NW	30	3N	58E	2.7000	480.00	640.00	IRRIGATION & DOMESTIC	WELL_DLE	NW NW, SE NW, NW SE, SE SE S30 T3N R58E	
53960		10/17/89	NW NE	30	1S	58E	6.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53961		10/17/89	NW SE	24	3N	58E	6.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53962		10/17/89	NE SE	31	5N	59E	6.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53963		10/17/89	NW SE	24	2S	57E	10.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
53964		10/17/89	SE SW	22	5N	58E	10.0000	0.00	0.00	MUNICIPAL & DOMESTIC	WELL_LVP		
*** Total ***								7208.58	9464.76				

APPENDIX C

APPENDIX C

APPENDIX C

STEADY STATE MODEL SENSITIVITY

A steady state simulation is a simulation in which recharge and pumping rates are held constant with no change in ground-water storage, so that model-predicted ground-water levels are representative of long-term stabilized ground-water conditions in the natural environment. Therefore, the steady-state simulation will agree with historic measured water levels if appropriate hydraulic parameters are used in the simulation model. Model hydraulic parameters are adjusted until the steady-state simulation closely approximates the historical ground-water levels. The adjusted parameters must be reasonable. Both the number of differing and discernable values and the range of these values must be consistent with the occurrence of strata which possess these properties and the estimated range, or variabilities of these properties, based on field observations and testing of these properties of the strata.

The primary purpose of the steady-state simulations is to calibrate the model. Transmissivity can be calibrated if sufficient water level elevations are known. This was done as a part of the present study. Calibration of Coal and Garden Valleys ground-water model was accomplished using several constraints that were identified in the Model Calibration section of this report.

The calibration of the model was carried out so that the total quantity of ground-water flow was held fixed to the estimates made in Eakin (1963) and Harrill (1988). Therefore, the transmissivities of the modelled units, the leakance between these units, and the conductances used in the general head boundary conditions that connect the modelled area to the White River ground-water flow system are constrained so that only these quantities of water are available.

The calibration of the model was also carried out so that observed ground-water levels and the gradient or changes between these levels within the modelled area were also matched as well as possible with little subjective changes in the model parameters. All of the initial parameters of the model were set at the initial estimates for the hydrogeologic strata that comprised the aquifer units. All of the outflow from the modelled area occurs through the White River flow system; therefore, the properties, or parameters, related to the mechanisms of flow are constrained by the estimated rate of flow. In particular, the ground-water outflow from the modelled area occurs almost exclusively through the lower carbonate aquifer from Coal Valley to Pahroc and/or Pahranagat Valley so that the transmissivities and general head conductances relevant to this unit must result in the flow of this quantity of water under the known ground-water gradient.

The ground-water levels in the wells shown in Table 7 of the report were used during the calibration. The ground-water levels, resulting from the calibration are shown in Figures 15 and 16, together with the observed ground-water levels.

Model Parameter Sensitivities

Sensitivity simulations were done to determine the effects of each parameter on the ground-water levels and flows. These parameters are the transmissivities (L1T1, L2T1, etc.) and leakances (TK1, TK2). The sensitivities were performed about the calibrated values of the model and represent the linearized change in water level elevation that would occur with a change in the specific parameter value. The model rows and columns for the observation wells are listed below in Table 1 as well as designated in Table 7 in the report with each individual well for correlation. The sensitivities represent the estimated change in ground-water level at the wells with a 100 percent increase in the calibrated values that have been previously reported in the Model Calibration section of this report. The results of these sensitivity simulations are discussed briefly.

Table 1.--Results of Sensitivity Runs, variations in feet

Row / Column	Model Simulated W/L	Δ [2]	L1T1 [1]	L1T2	L1T3	L2T1	L2T2	TK1	TK2
layer 1									
6 22	5327	-45	-1	-2	-21	0	-5	-2	0
7 23	5244	-58	-2	-1	+5	-1	-14	+1	0
8 22	5250	-17	-3	-1	0	-1	-9	0	-1
10 19	5347	0	-1	0	-60	-3	-29	-9	0
10 20	5283	-51	-1	-1	-24	-1	-17	-3	0
11 20	5251	-77	-1	-1	-16	-1	-27	-1	0
12 21	5181	+19	-5	-6	+3	-4	-49	+2	-1
12 22	5140	+3	-8	-8	+20	-6	-59	+6	-1
13 21	5153	+48	-5	-9	+6	-6	-62	-2	-1
15 11	5830	-138 [3]	-129	-59	-118	-27	-94	-80	-1
15 19	5192	+112	-5	-12	-27	-10	-74	-9	-1
15 22	5057	-8	-10	-21	+32	-11	-86	+7	-2
19 19	5035	-20	-10	-24	-8	-17	-91	-10	-1
22 13	5257	-22	-9	-32	-78	-25	-97	-36	-1
22 20	4948	-92	-15	-35	+22	-19	-96	-5	-2
29 11	5076	-936 [3]	-44	-15	-20	-33	-95	-21	-1
31 13	4983	-68	-60	-11	+15	-36	-93	-14	-2
36 25	4278	+23	+1	+2	+37	-8	-44	+4	-6
38 20	4431	-1157 [3]	-3	0	+24	-17	-70	+6	-3
layer 2									
14 25	4917	+119	0	-12	+48	-15	-120	+23	+4

1) Variable - Layer 1, Transmissivity 1
2) Difference between model simulated water level and actual water level using land surface elevation interpolated by District or MX values
3) Actual water levels thought to be in localized perched systems

Analyses of the sensitivity simulations resulted in several general observations and estimated model properties. The majority of the wells are located in Garden valley in the alluvium.

However, the transmissivity of the alluvial, valley-fill aquifer produced less significant changes in ground-water levels and flows over the modelled area than did similar changes in the lower, carbonate aquifer transmissivities. The transmissivity of the carbonate unit was based on an actual aquifer test performed as part of the Air Force MX siting activity in Garden Valley and was constrained by the estimated outflow and the ground-water gradient across the modelled area. The alluvial aquifer transmissivity was constrained by the high water levels found in northern Garden Valley which results in a steepened ground-water gradient and in some evapotranspiration in a very localized area. Changes in the volcanic aquifer and upper layer carbonate aquifer transmissivities and the leakances between the layers did not produce significant changes in the majority of the ground-water levels.