Simulated Changes in Ground-Water Flow Caused by Hypothetical Pumping in East Carson Valley, Douglas County, Nevada

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CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to metric (International System) units by using the following factors:

Multiply	*By*	*To obtain*
Acre-foot (acre-ft)	0.001233	Cubic hectometer (hm^3)
Acre-foot per year (acre-ft/yr)	0.001233	Cubic hectometer per year (hm^3/yr)
Cubic foot per second (ft^3/s)	0.02832	Cubic meter per second (m^3/s)
Foot (ft)	0.3048	Meter (m)
Square mile (mi^2)	2.590	Square kilometer (km^2)

ALTITUDE DATUM

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), which is derived from a general adjustment of the first-order leveling networks of both the United States and Canada.

SIMULATED CHANGES IN GROUND-WATER FLOW CAUSED BY HYPOTHETICAL PUMPING IN EAST CARSON VALLEY, DOUGLAS COUNTY, NEVADA

By Douglas K. Maurer

ABSTRACT

An existing ground-water model of Carson Valley was used to simulate changes in ground-water flow on the east side of Carson Valley, Nevada, in response to hypothetical increases in ground-water pumpage. Pumpage scenarios that reflect State ground-water permits and pending applications were used in four different simulations to estimate the effect of hypothetical development on ground-water levels and storage, ground-water flow to the Carson River, and ground water consumed by evapotranspiration over a 45-year period. The four simulations were based on pumpage rates ranging from 0.13 to 6.4 cubic feet per second (92 to 4,590 acre-feet per year). Changes in ground-water flow and water levels caused by the lowest rate were minimal and at the limit of accuracy of the ground-water model. The highest pumping rate caused water-level declines as much as 15 feet, decreased ground-water storage by 27,000 acre-feet, decreased ground-water flow to the Carson River by 4.3 cubic feet per second (3,100 acre-feet per year), and reduced evapotranspiration losses by about 1,200 acre-feet per year.

INTRODUCTION

Simulations using an existing ground-water flow model of Carson Valley were made by the U.S. Geological Survey in cooperation with the Douglas County Department of Public Works and the Nevada State Engineer. Carson Valley is about 10 miles south of Carson City, Nev., and is dominated by surface-water flow of the Carson River, which is diverted throughout the entire valley by a system of ditches. Flow of the Carson River is also an important source of water for agricultural and increasing municipal use downstream from the valley. This report describes the results of simulations made to determine the effect of hypothetical ground-water pumpage scenarios on the ground-water system on the east side of the valley. The possible effects of additional pumpage include: reduction in ground-water flow to the Carson River, the decline of ground-water levels and the resulting loss of ground-water storage, and reduction in evapotranspiration by natural plants and crops.

DESCRIPTION OF GROUND-WATER FLOW MODEL

The computer program used for the simulations was written by MacDonald and Harbaugh (1984). The program is designed to simulate ground-water flow in three dimensions. Maurer (1986) describes the development, calibration, and limitations of the ground-water flow model for Carson Valley. Plate 1 shows the location of rows and columns of the model grid on the east side of the valley. The grid cells are 1 mi^2 in area and pumpage; water-level changes, ditch leakage, and evapotranspiration are averaged over each grid cell. Two layers were used in the model to simulate both the shallow water table and confined aquifers present beneath much of the valley floor. The lower layer extends east to row 6 in plate 1.

Evapotranspiration is calculated as a function of depth to water, decreasing to zero at a specified maximum root depth for vegetation. A stream-routing subroutine simulates both river and ditch flow by adding or subtracting stream gain or loss in each cell to the specified volume of flow where the rivers enter the model area and at the diversion point of each major ditch system. Losses in streamflow are simulated whenever the ground-water level in the cell beneath a river or ditch is below the water level in the river or ditch. Similarly, gains in streamflow are simulated whenever the ground-water level is above the water level in the river or ditch. The amount of gain or loss is dependent on the difference in water level between the river or ditch and ground water and on the ability for the streambed deposits to transmit water (streambed conductance).

The initial water-level distribution and average annual rates of recharge, evapotranspiration, river flows into the valley, and diversions for irrigation developed in steady-state model calibration by Maurer (1986, p. 51-59) were used as base conditions for the simulations discussed here. The model was run for a 45-year period to assure equilibrium conditions at the end of the simulation (Maurer, p. 83). The pumping rates used for simulations are also average annual values. If pumpage is seasonal, for example only 6 months per year, then a pumping rate twice the annual average rate shown in table 1 would produce the same model results.

RESULTS OF SIMULATIONS

Four hypothetical pumping scenarios were simulated with the model. The pumping scenarios represent state permits for ground-water withdrawal over four time periods (table 1). Pumpage from each group of permits was added to the previous scenario to determine the effect of each step of development. In all scenarios, land use in irrigated fields west of the development was not changed.

Table 2 summarizes the results of the simulations, and plates 2A through D show the resulting decline in ground-water levels. In all cases, the results of the simulation are compared to the calibrated steady-state simulation where no pumpage was applied. In the first scenario, the low pumping rate resulted in water-level changes that were less than 1 foot and decreased storage by 2,500 acre-feet for the 45-year pumping period (an average of 55 acre-ft/yr). The effect on evapotranspiration and calculated ground-water flow to the Carson River are also very slight. The low pumping rate approaches the magnitude of errors involved in mathematical rounding and calculation of storage in the model; thus, the calculated changes in flow rates for the first scenario are not mathematically meaningful.

In scenarios 2 through 4, simulated water levels decreased by at least 1 foot for most of the east side of the valley and a maximum of 15 feet in scenario 4 (plates 2B through D). Further to the west, water levels in the upper layer are maintained by leakage from the ditch system. In the lower model layer, water-levels dropped the same amount but simulated declines of up to 1 foot extend about 2 miles farther to the west than shown in plates 2A through D for the upper layer. In scenario 4, simulated storage decreased by 27,000 acre-feet after 45 years of pumping, while simulated ground-water flow to the Carson River decreased by 4.3 ft^3/s (3,100 acre-ft/yr).

All simulations assumed the water pumped was totally consumed representing "worst case" conditions. It is probable that some of the pumped water will either seep back to the ground water or enter the Carson River, thus leading to less water-level decline than calculated. Also, the values presented in table 2 and plates 2A-D are not exact predictions of future conditions because of ever changing land-use patterns and climatic conditions. Thus, the values are only indicators of possible long-term effects caused by the full use of approved permits for the withdrawal of ground-water along the east side of Carson Valley.

The maximum decrease in flow of the Carson River is estimated to be 3,100 acre-ft/yr (scenario 4). Frisbie and others (1985, p. 133) reported that the records of outflow of the Carson River from Carson Valley are good, which implies that the uncertainty in mean annual flow of about 306,000 acre-ft/yr is between 14,000 and 25,000 acre-ft/yr. Thus, even after 45 years of pumping, the reduction of Carson River outflow could probably not measured.

TABLE 1.--*Permitted pumping rates applied in model simulations*

[Abbreviations: ft^3/s, cubic feet per second; acre-ft/yr, acre-feet per year]

Scenario	Permit number	Row, column	Rate: Ft^3/s	Rate: Acre-ft/yr
1	17105	6,9	0.127	92
2	49416-49418	7,10	2.50	1,800
	49419-49421	7,11	.39	283
	49432-49433	7,12	.217	157
	Plus pumpage from scenario 1		.127	92
	Total, scenario 2 (rounded)		3.23	2,330
3	42191	8,11	0.062	45
	42193	8,11	.062	45
	43388	8,11	.062	45
	46162	7,7	.028	20
	47608	8,10	.20	145
	47609	8,11	.20	145
	49103	7,9	.017	12
	49865	7,11	.028	20
	Plus pumpage from scenario 2		3.23	2,330
	Total, scenario 3 (rounded)		3.89	2,810
4	49434-49435	7,10	2.46	1,780
	Plus pumpage from scenario 3		3.89	2,810
	Total, scenario 4 (rounded)		6.35	4,590

TABLE 2.--*Results of model simulations for a 45-year pumping period*

[Abbreviations: ft^3/s, cubic feet per second; acre-ft/yr, acre-feet per year]

	Pumping rate		Decrease in evapotranspiration		Decrease in ground-water flow to river			
Scenario	Ft^3/s	Acre-ft/yr	Ft^3/s	Acre-ft/yr	Ft^3/s	Acre-ft/yr	Cumulative decrease in ground-water storage (acre-feet)	Maximum drawdown (feet)
1	0.127	92	0.02	15	0.08	60	2,500	<1
2	3.23	2,330	.80	590	2.28	1,650	15,000	8
3	3.89	2,810	1.00	720	2.62	1,900	17,000	8
4	6.35	4,590	1.65	1,200	4.27	3,080	27,000	15

SUMMARY

An existing ground-water flow model (Maurer, 1986) was used to estimate the effects of hypothetical pumping on ground-water levels, evapotranspiration, and ground-water flow to the Carson River in Carson Valley, Nev. Pumping rates simulated for a 45-year period ranged from 92 to 4,590 acre-ft/yr in four scenarios. At the lowest pumping rate, changes calculated by the model were not meaningful because of errors in mathematical rounding and calculation of storage. At the highest pumping rate, ground-water flow to the Carson River was projected to decrease by 3,100 acre-ft/yr, with a maximum of 15 feet of water-level decline. The projected water-level decline caused evapotranspiration at the end of the 45-year simulation to decrease by 1,200 acre-ft/yr and ground-water storage depletion of 27,000 acre-ft.

Because pumped water was assumed to be totally consumed, the results represent "worst case" conditions. Also, because of changing land-use patterns and climatic conditions, the projected decreases in evapotranspira-tion, ground-water storage, and ground-water flow to the Carson River should not be considered exact. The maximum decrease in ground-water flow to the Carson River (3,100 acre-ft/yr) probably could not be measured because of uncertainty in the measurement of the mean annual outflow from the Carson River to the valley (14,000 to 25,000 acre-ft/yr).

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Frisbie, H. R., La Camera, R. J., Riek, M. M., and Wood, D. B., 1985, Water resources data for Nevada, water year 1984--volume 1: U.S. Geological Survey Water-Data Report NV-84-1, 247 p.

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Maurer, D. K., 1986, Geohydrology and simulated response to ground-water pumpage in Carson Valley, a river-dominated basin in Douglas County, Nevada, and Alpine County, California: U.S. Geological Survey Water-Resources Investigations Report 86-4328, 109 p.

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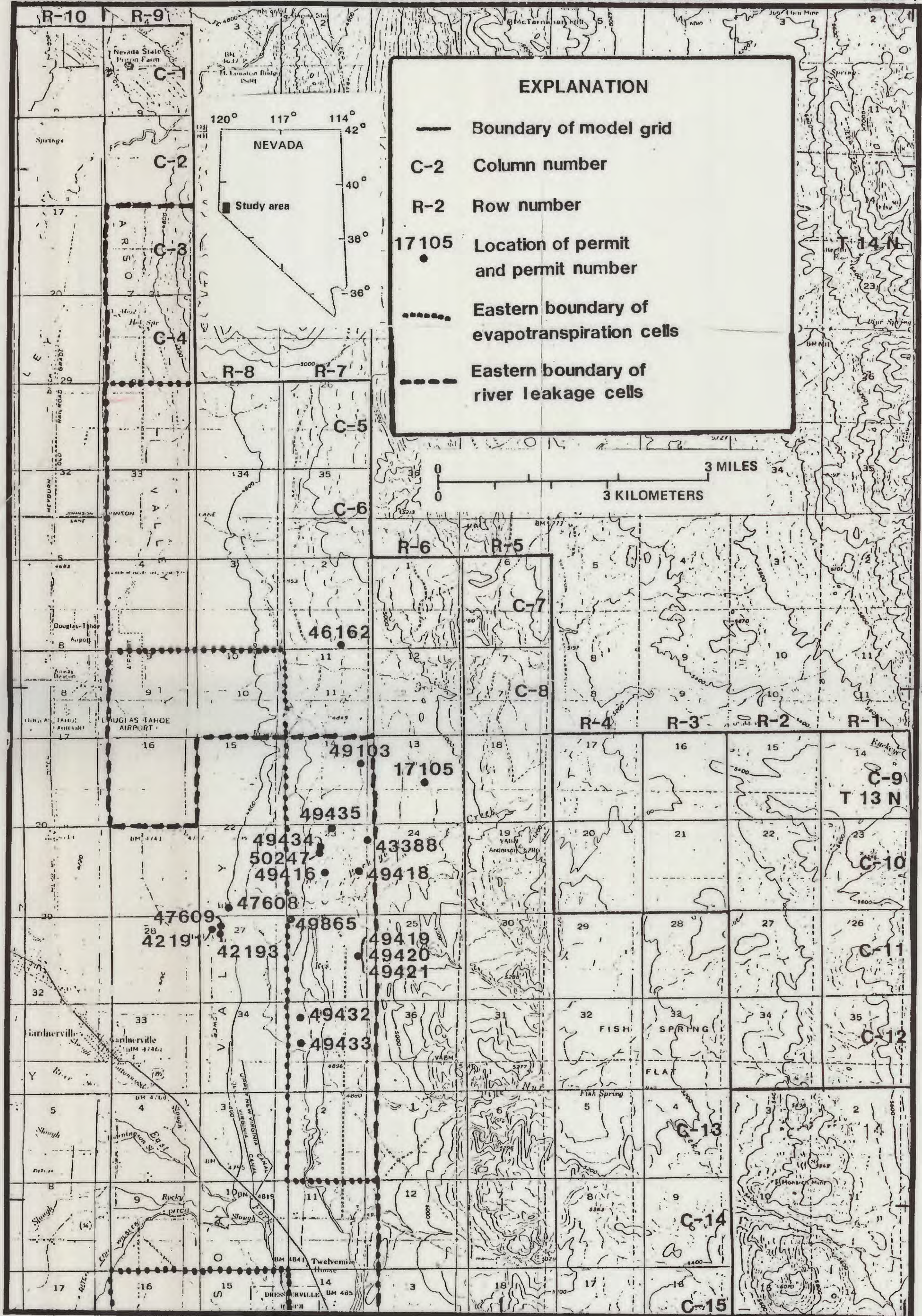
PLATE 1



Base from U.S. Geological Survey Carson City, Dayton, Freel Peak, 1956, and Mt. Siegal, 1957

LOCATION OF ROWS AND CELLS IN MODEL GRID, BOUNDARY OF CELLS WHERE EVAPOTRANSPIRATION AND DITCH LEAKAGE ARE SIMULATED, AND DISTRIBUTION OF PERMITS FOR GROUND-WATER WITHDRAWAL ON EAST SIDE OF CARSON VALLEY, DOUGLAS COUNTY, NEVADA

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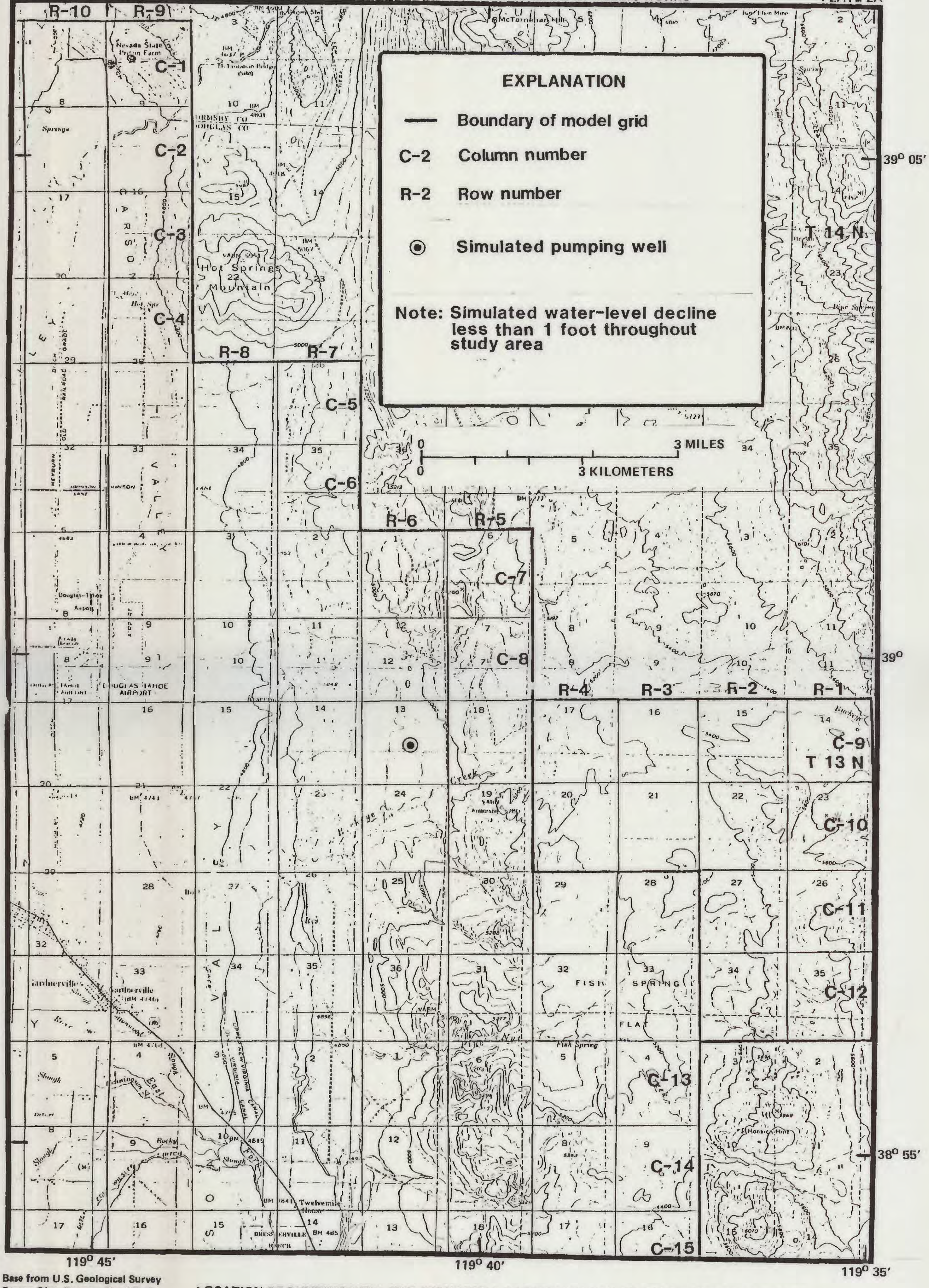
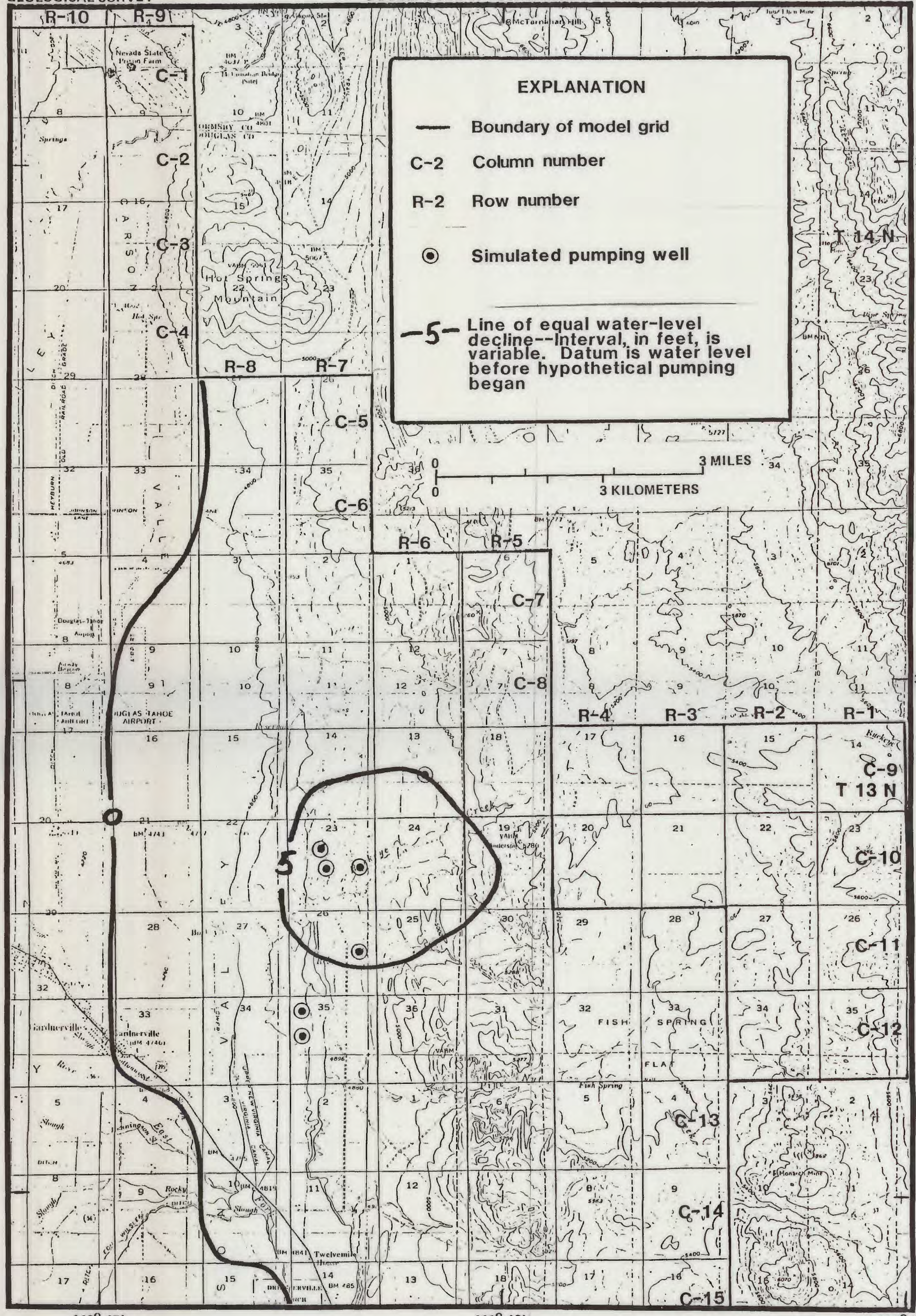


Base from U.S. Geological Survey
Carson City, Dayton, Freel Peak,
1956, and Mt. Siegal, 1957

LOCATION OF PUMPING WELL FOR SCENARIO 1, CARSON VALLEY, DOUGLAS COUNTY, NEVADA



Base from U.S. Geological Survey Carson City, Dayton, Freel Peak, 1956, and Mt. Siegal, 1957

DISTRIBUTION OF WATER-LEVEL DECLINE IN UPPER MODEL LAYER SIMULATED IN SCENARIO 2, CARSON VALLEY, DOUGLAS COUNTY, NEVADA

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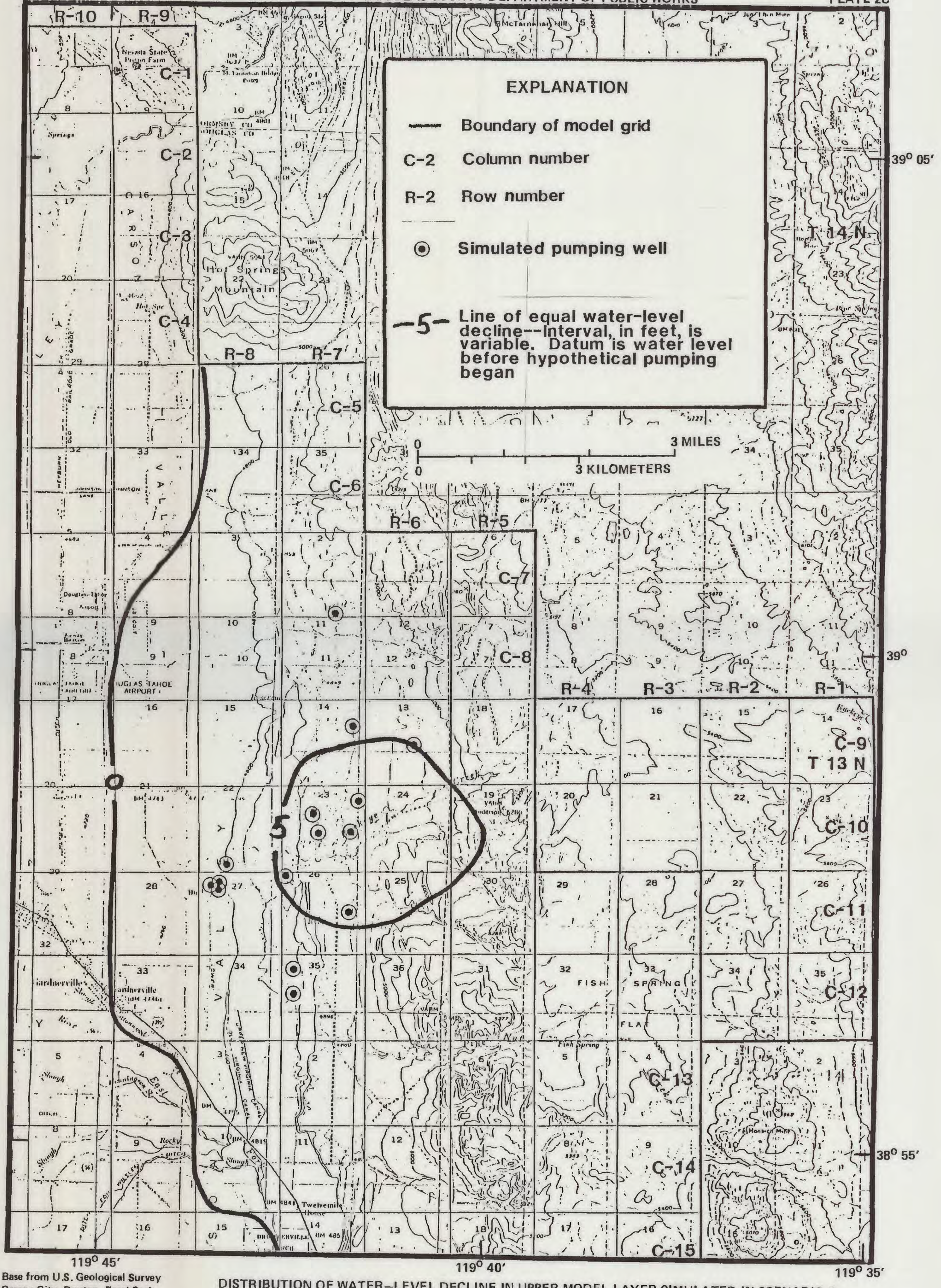
PLATE 2C



Base from U.S. Geological Survey
Carson City, Dayton, Freel Peak,
1956, and Mt. Siegal, 1957

DISTRIBUTION OF WATER-LEVEL DECLINE IN UPPER MODEL LAYER SIMULATED IN SCENARIO 3,
CARSON VALLEY, DOUGLAS COUNTY, NEVADA

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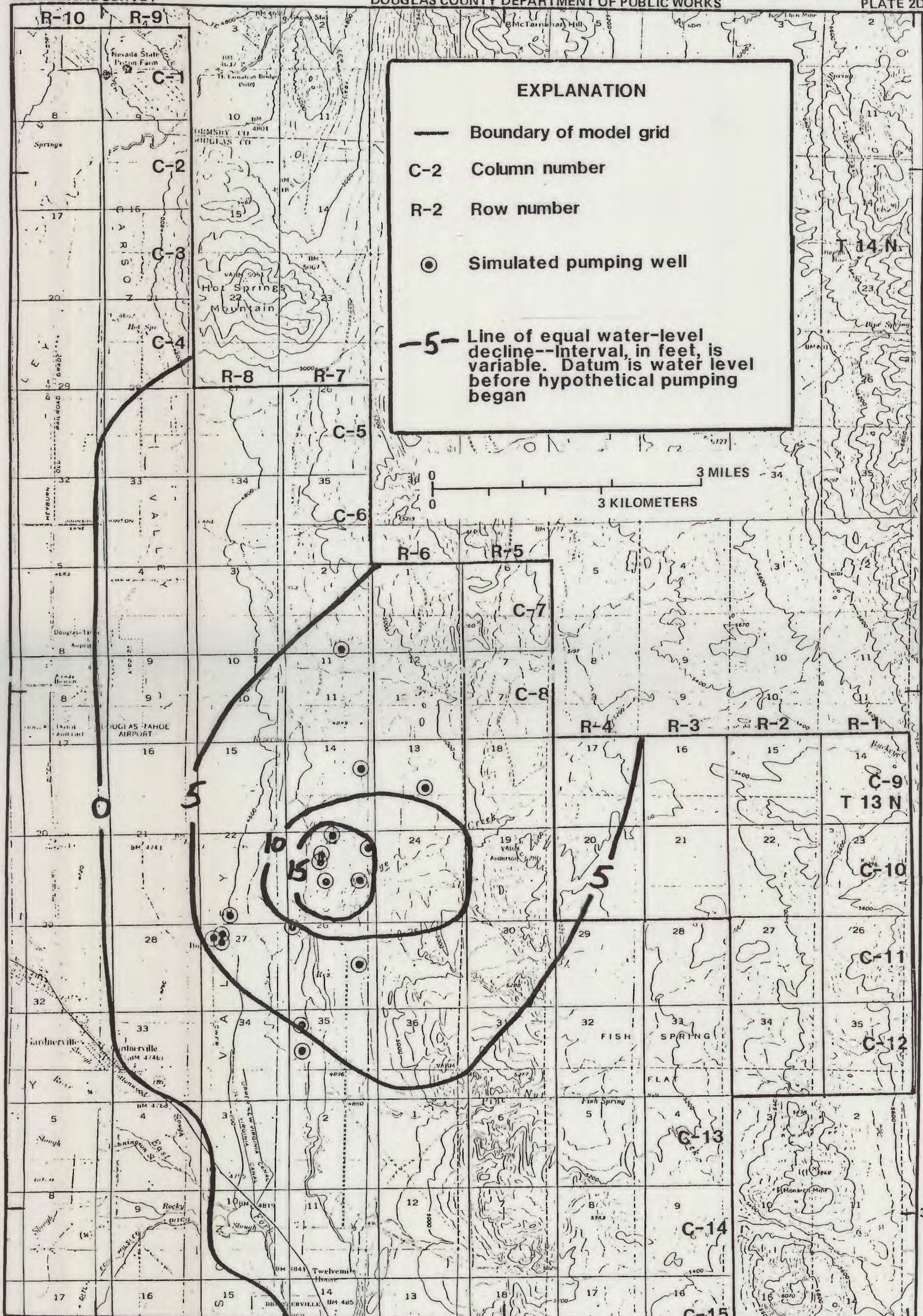
PLATE 2D



Base from U.S. Geological Survey Carson City, Dayton, Freel Peak, 1956, and Mt. Siegal, 1957

DISTRIBUTION OF WATER-LEVEL DECLINE IN UPPER MODEL LAYER SIMULATED IN SCENARIO 4, CARSON VALLEY, DOUGLAS COUNTY, NEVADA