Simulated Changes in Ground-Water Flow Caused by Hypothetical Pumping in Southeastern Carson City, Nevada

By Douglas K. Maurer

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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 per year (acre-ft/yr)	0.001233	Cubic hectometer per year (hm^3/yr)
Gallon per minute (gal/min)	0.06309	Liter per second (L/s)
Mile (mi)	1.609	Kilometer (km)

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 SOUTHEASTERN CARSON CITY, NEVADA

By Douglas K. Maurer

ABSTRACT

An existing ground-water model was used to simulate changes in ground-water flow caused by hypothetical pumping in an area near the southeastern part of Carson City, Nevada. A total of five hypothetical pumping patterns were used in the model simulations. The simulations assumed two pumping rates: total annual average pumpage of 1,100 gallons per minute and 1,700 gallons per minute, which were assumed constant throughout the year. Simulations of the lesser quantity of pumpage did not induce significant losses from the Carson River to the aquifer after 50 years of simulation. The simulations indicate that a maximum of 140 gallons per minute (220 acre-feet per year) of induced flow from the Carson River could occur as a result of projected total pumpage of 1,700 gallons per minute after 10 years; the induced flow could increase to 320 gallons per minute (520 acre-feet per year) after 50 years. However, river losses were projected to decrease to only 15 gallons per minute (25 acre-feet per year) after 10 years and 210 gallons per minute (340 acre-feet per year) after 50 years when the locations of the pumping centers were moved farther away from the river.

INTRODUCTION

Simulations using an existing ground-water flow model of Eagle Valley and vicinity were made by the U.S. Geological Survey in cooperation with the Carson City Department of Public Works and the Nevada State Engineer. The purpose of the simulations were to determine how much water might reasonably be pumped in the vicinity of Clear Creek, about 4 miles southeast of downtown Carson City (figure 1) without affecting flow in the creek or inducing streamflow losses from the Carson River. Pumpage was restricted to that part of the Carson Valley hydrographic area within the legal boundaries of Carson City. This area is located in the southeast corner of Carson City and is delineated by Township 14 North, Range 20 East, sections 3 and 4, the north ½ of sections 9 and 10, and the east ½ of section 5 (see plate 2). Existing water-quality data (Wateresource Consulting Engineers, Inc., and Lumos & Associates, Inc., 1986, p. 2-12, 6-5; Trexler and others, 1980, p. 51; and analyses from files of Nevada Consumer Health Protection Services) in the area of concern suggest that ground water may contain dissolved fluoride, arsenic, iron, and (or) manganese above recommended maximums for a public supply, particularly in the fine-grained deposits of the Carson River flood plain. Thus, pumpage in the model simulations was restricted to the northern part of the area of concern.

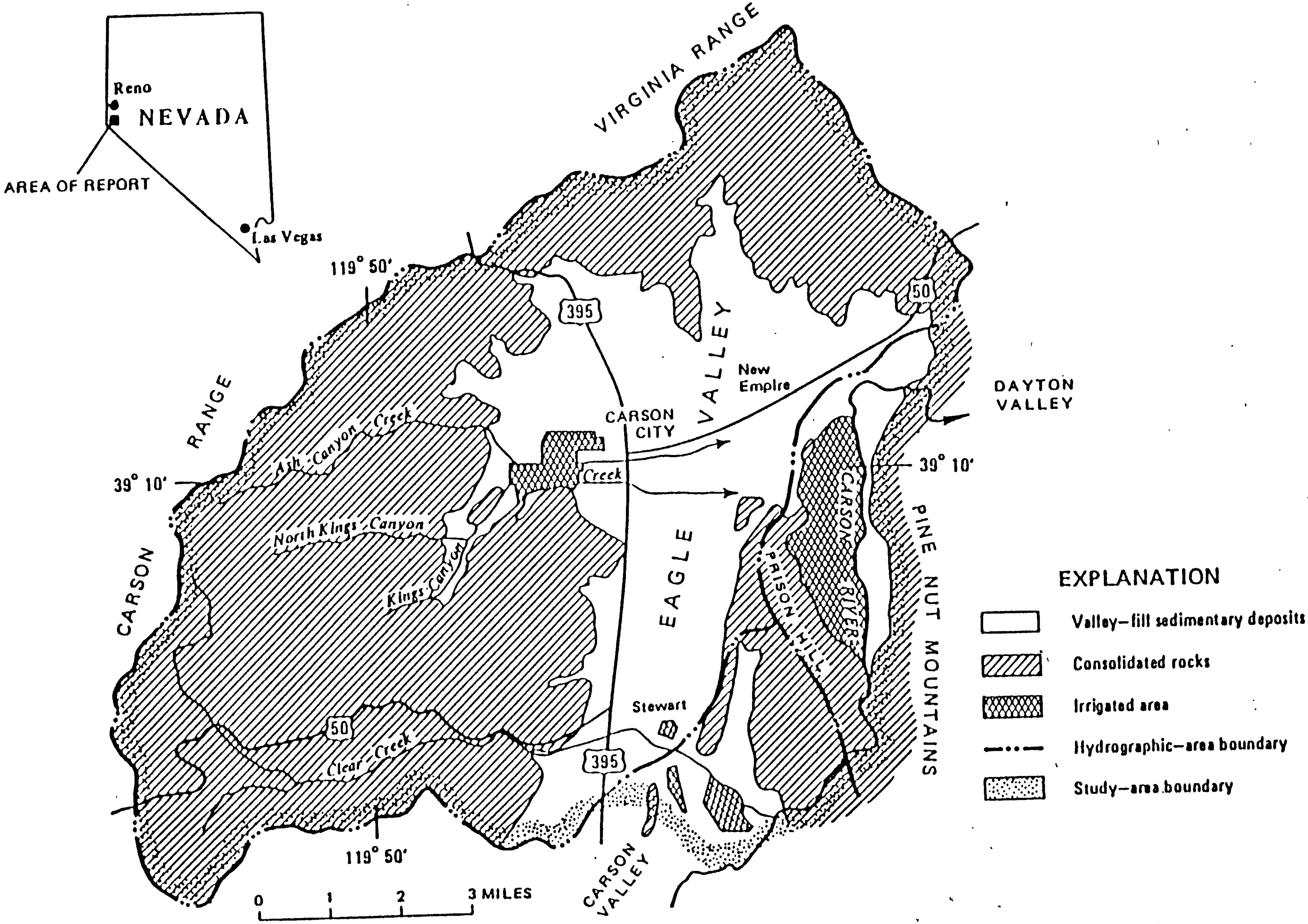

FIGURE 1.—Geographic setting, generalized geology, irrigated areas, and relation between study-area and hydrographic-area boundaries.

DESCRIPTION OF GROUND-WATER FLOW MODEL

Two existing ground-water flow models include much of the area of concern: one developed by Arteaga (1982) and another developed by Maurer (1986). The Arteaga model was used to simulate the additional pumpage as the boundaries were best suited for the simulations. An artificial impermeable boundary was used in both models to separate Eagle Valley from Carson Valley. For this reason, simulated water-level declines may be greater than what might actually be measured. The Arteaga model includes a reach of the Carson River near Clear Creek as a boundary that can simulate either discharge of ground water to the river, or recharge of surface water to the ground-water reservoir. The calibrated model by Arteaga simulated ground-water discharge from Eagle Valley to the Carson River at about 960 acre-ft/yr in the reach near Clear Creek.

The model by Arteaga does not include a function that allows leakage from Clear Creek to increase as the water-table declines. Existing water-level data in the vicinity of Clear Creek indicates that the water table lies below the bed of Clear Creek throughout most of the area. Thus, leakage from the creek to the water table may be at a maximum and would most likely not be affected by increased pumpage. If Clear Creek is connected directly with the water table with no intervening unsaturated zone, then leakage from the creek could increase if pumpage increases. The most likely location for this to happen is the last ½ mile of streambed before the creek enters the Carson River.

Plate 1 shows the distribution of model cells. The boundary between Eagle Valley and Carson Valley hydrographic areas is shown in plate 2. Node 222 was moved about 0.15 mile from the position in the original model to the southwest to correspond to the location of the South Edmonds well drilled after the original study. Comparisons of simulations before and after this change showed no effect on calculated head and ground-water discharge to the Carson River. River leakage is calculated in the model at nodes marked R, evapotranspiration is calculated at nodes marked ET and is summed over the outlined areas surrounding the nodes, and pumpage is applied at nodes marked P.

The initial water-level distribution used for the simulations was the final water-level obtained from the 1964-78 simulation by Arteaga. The average annual rates of recharge and evapotranspiration used by Arteaga were also used for all simulations. Pumping rates used for the simulations are also average annual values. If pumpage is seasonal, for example, only 6 months per year, then a pumping rate twice that shown in table 1 would produce the same model results. In the area where Clear Creek discharges into the Carson River, the estimated ground-water discharge to the Carson River from both the steady-state (1964) and transient (1964-78) simulations by Arteaga was about 960 acre-ft/yr, and ground-water discharge by evapotranspiration was simulated at about 400 acre-ft/yr.

RESULTS OF SIMULATIONS

Five hypothetical pumping scenarios were simulated with the ground-water model. The first scenario assumed total annual average pumpage was 1,100 gal/min from three wells, which included pumping from the South Edmonds well. The other four scenarios assumed total pumpage of 1,700 gal/min distributed among selected wells in an attempt to reduce the amount of streamflow induced from the Carson River. Each scenario was simulated for a 10-year and 50-year period assuming average unchanging conditions. The 50-year simulation was made in addition to the 10-year simulation to more closely determine the long-term effect of pumpage. However, in terms of the assumption of average, unchanging conditions, the 10-year simulation is probably the more realistic. At the end of the 10-year period, only 30 percent of the projected pumpage was derived from a decrease in storage, while at the end of the 50-year period, only about 5 percent of the projected pumpage was derived from storage. The results are summarized in table 1. Projected water-table declines caused by pumpage after a 10-year period for each scenario are shown on plates 2A-E.

Evapotranspiration in the vicinity where Clear Creek discharges into the Carson River (figure 1) was effectively captured by pumpage in all simulations. The projected decrease in evapotranspiration listed in table 1 in excess of 400 acre-ft/yr is the result of simulated water-level declines extending beneath areas of evapotranspiration farther to the north and west (figure 1).

Projected drawdown, decrease in storage, and decrease in ground-water discharge to the river is less for the first scenario than the other four simulations. In addition, the pumpage of scenario 1 did not result in significant flow being induced from the Carson River to the aquifer. In the other four scenarios, with total pumpage increased to 1,700 gal/min, pumping nodes were moved away from the river until the induced flow from the river was minimal at the end of the 10-year period. At the end of the 50-year simulation, induced river loss was decreased from scenario 2 to 5 by increasing evapotranspiration losses to the north and west.

The model does not compute evapotranspiration for the nodes along the Carson River even though it does occur. Some of the 960 acre-ft/yr computed as ground-water discharge to the river is actually discharged by evapotranspiration along the river. Thus, the actual river gain is probably less than the 960 acre-ft/yr computed in the model simulations. However, if ground-water discharge to the river is decreased by pumping, some of the actual evapotranspiration along the river will probably be supplied by induced flow from the river, which may result in a slightly greater river loss than is reported in table 1.

TABLE 1.--*Results of model simulations after 10-year and 50-year pumping periods using average annual pumping rates*[1]

[In gallons per minute (acre-feet per year) except as noted.]

	Node	Pump rate	Changes resulting from pumping[2]: Decrease in evapotranspiration[3]	Decrease in ground-water storage	Decrease in ground-water flow to river[4]	Induced river loss	Maximum aquifer drawdown (feet)
Scenario 1	222	500 (800)	425 (685)	340 (520)	350 (560)	0	29
	238	300 (480)	*575 (925)*	*45 (75)*	*460 (740)*	*0.6 (1)*	*35*
	240	300 (480)					
Rounded total		= 1,100 (1,760)					
Scenario 2	222	500 (800)	470 (760)	490 (790)	600 (960)	140 (220)	39
	238	300 (480)	*700 (1,125)*	*60 (100)*	*600 (960)*	*320 (515)*	*49*
	240	300 (480)					
	229	300 (480)					
	247	300 (480)					
Rounded total		= 1,700 (2,700)					
Scenario 3	222	800 (1,290)	480 (770)	490 (790)	600 (960)	125 (205)	40
	238	300 (480)	*710 (1,150)*	*60 (100)*	*600 (960)*	*315 (505)*	*50*
	229	300 (480)					
	247	300 (480)					
Rounded total		= 1,700 (2,700)					
Scenario 4	222	500 (800)	485 (775)	580 (890)	590 (950)	45 (75)	44
	238	300 (480)	*760 (1,220)*	*70 (110)*	*600 (960)*	*250 (405)*	*56*
	240	300 (480)					
	229	300 (480)					
	230	300 (480)					
Rounded total		= 1,700 (2,700)					
Scenario 5	222	500 (800)	510 (825)	585 (945)	580 (920)	15 (25)	48
	240	400 (640)	*790 (1,270)*	*75 (125)*	*600 (960)*	*215 (345)*	*60*
	229	400 (640)					
	230	400 (640)					
Rounded total		= 1,700 (2,700)					

[1] Values are rounded to the nearest 5 gallons per minute or acre-feet per year.

[2] Values in first line show 10-year results; italicized values in second line show 50-year results.

[3] Evapotranspiration in Clear Creek area based on steady-state simulations by Arteaga (1982) was 400 acre-ft/yr at nodes 247, 249, 250, 261, and 266 (figure 1).

[4] Ground-water outflow from Eagle Valley to the Carson River in the Clear Creek reach based on steady-state simulations by Arteaga (1982) was 960 acre-ft/yr.

Mean annual flow of the Carson River, measured 2 miles downstream from the confluence with Clear Creek, is about or 306,000 acre-ft/yr. The streamflow records were reported as good (Frisbie and others, 1985, p. 113), which implies the uncertainty of flow in the estimate is between 14,000 and 22,000 acre-ft/yr. This uncertainty is many times greater than the amount of flow induced from the river in all model simulations. Also, because of changing land-use patterns and climatic conditions, the values are not exact but rather are indications of long-term trends.

SUMMARY

A ground-water flow model was used to estimate the effect of hypothetical pumping in an area near the southeastern part of Carson City, Nev. Pumping effects on ground-water levels, evapotranspiration, and flow to and from the Carson River were estimated. In scenario 1, a pumping rate of 1,100 gal/min was applied at three nodes. This resulted in minimal amounts of aquifer drawdown and decrease in evapotranspiration, ground-water storage, and ground-water flow to the river. No surface-water flow was induced from the river to the ground-water aquifer. In scenarios 2 through 5, a withdrawal of 1,700 gal/min was simulated at nodes increasingly distant from the Carson River. In these scenarios, all ground-water flow to the river was captured; induced surface-water flow from the river toward the location of pumping was at a minimum of 25 acre-ft/yr after 10 years in scenario 5. However, after 10 years, decreases in evapotranspiration (825 acre-ft/yr), ground-water storage (945 acre-ft/yr), and aquifer drawdown (48 feet) were greatest in scenario 5.

The decreases in evapotranspiration, ground-water storage, ground-water flow to the river, and induced river loss and aquifer drawdown calculated by the simulations should not be considered exact; instead, they are indications of long-term trends. The uncertainty in the measured mean annual flow of the Carson River downstream from the simulated pumping (14,000 to 22,000 acre-ft/yr) is many times greater than the projected amount of flow induced from the river in all model simulations.

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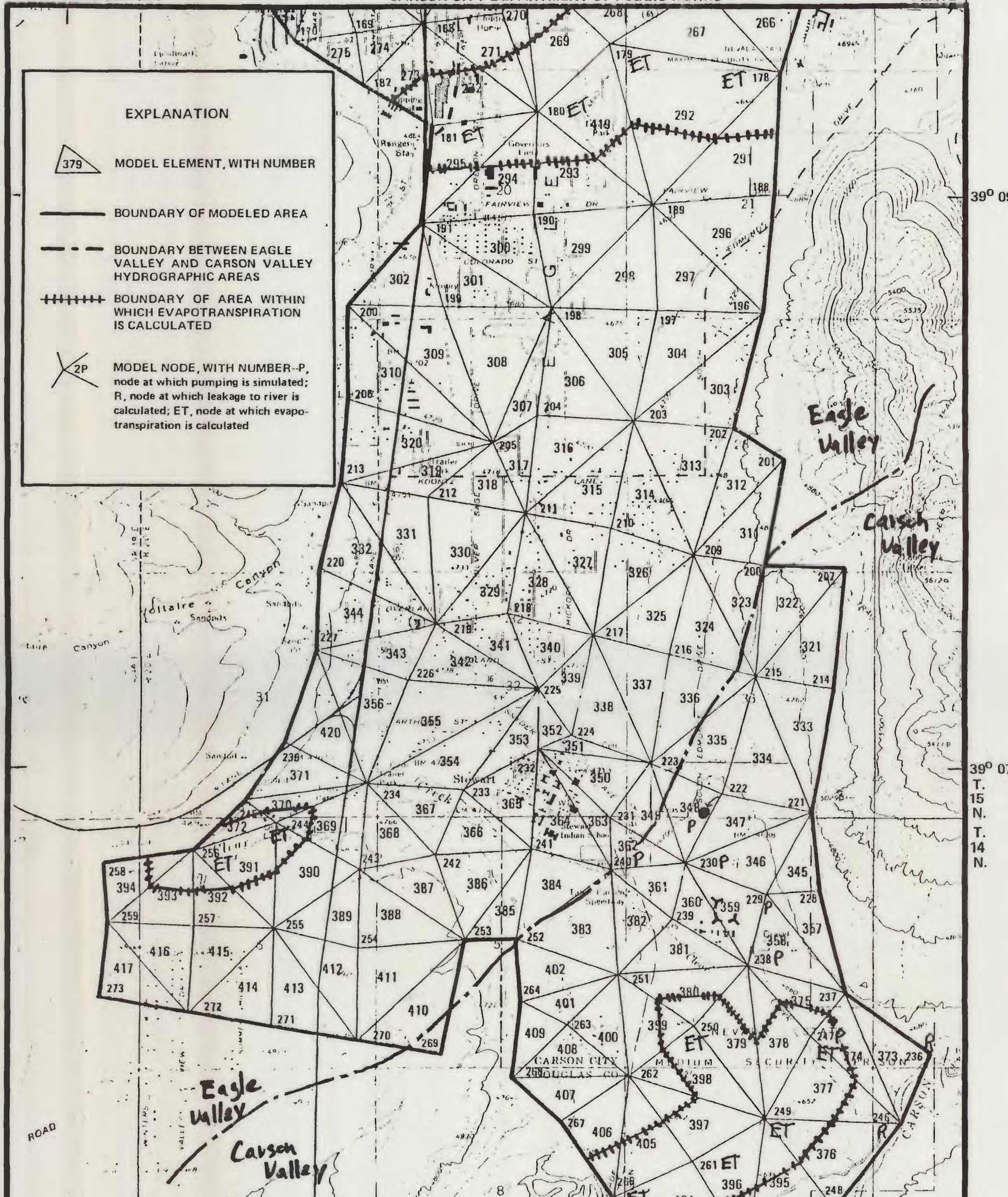
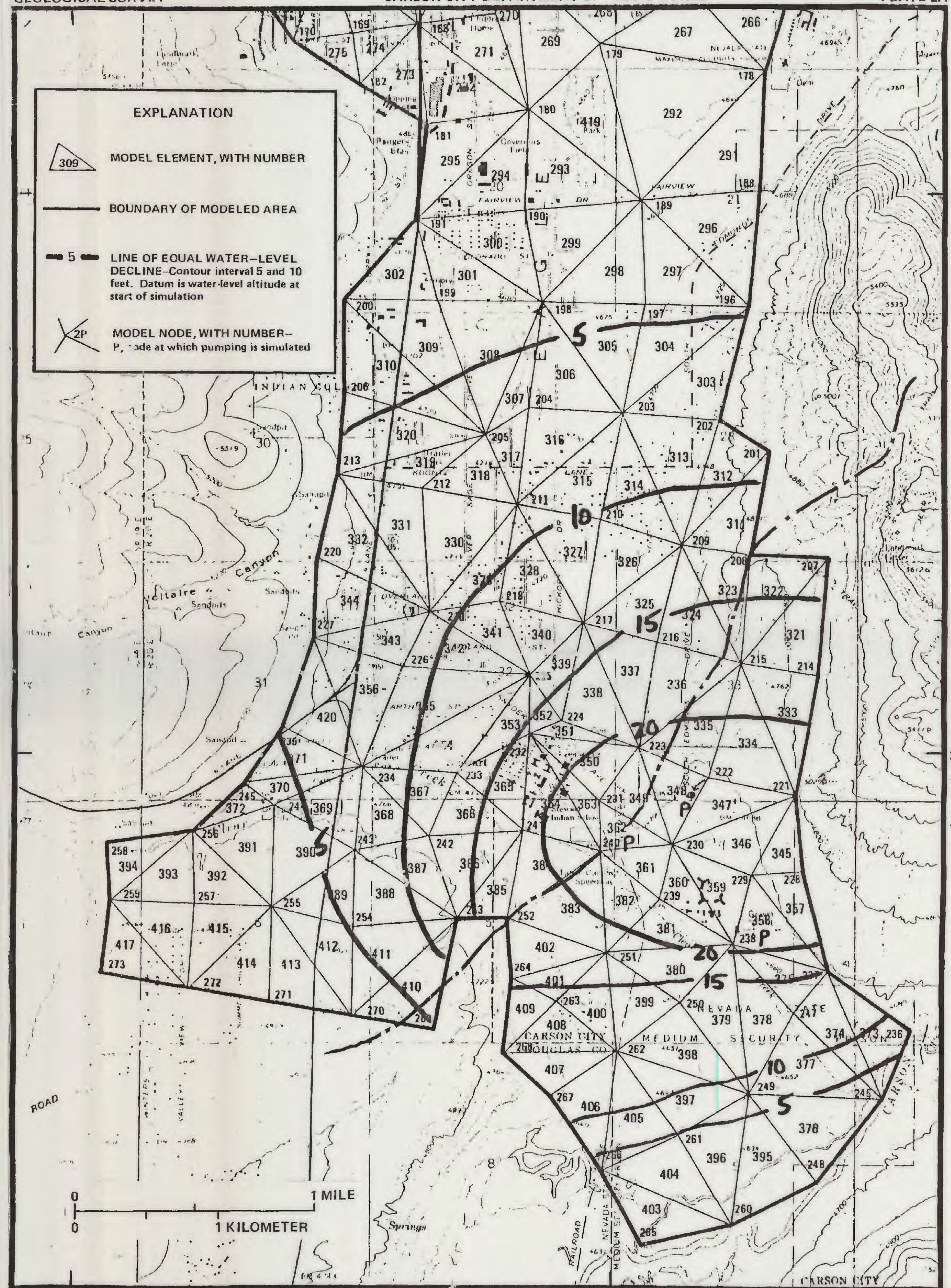
PLATE 1



Base from U.S. Geological Survey Carson City, Genoa, Mc Tarnahan Hill, and New Empire 1:24,000, 1968, photorevised 1982

DISTRIBUTION OF FINITE–ELEMENT CELLS AND NODES USED IN MODEL, AND BOUNDARY BETWEEN EAGLE VALLEY AND CARSON VALLEY HYDROGRAPHIC AREAS, WESTERN NEVADA



Base from U.S. Geological Survey Carson City, Genoa, Mc Tarnahan Hill, and New Empire 1:24,000, 1968, photorevised 1982

DISTRIBUTION OF WATER-LEVEL DECLINES CALCULATED FROM SCENARIO 1, AFTER 10 YEARS OF HYPOTHETICAL PUMPING, EAGLE VALLEY AND CARSON VALLEY HYDROGRAPHIC AREAS, WESTERN NEVADA

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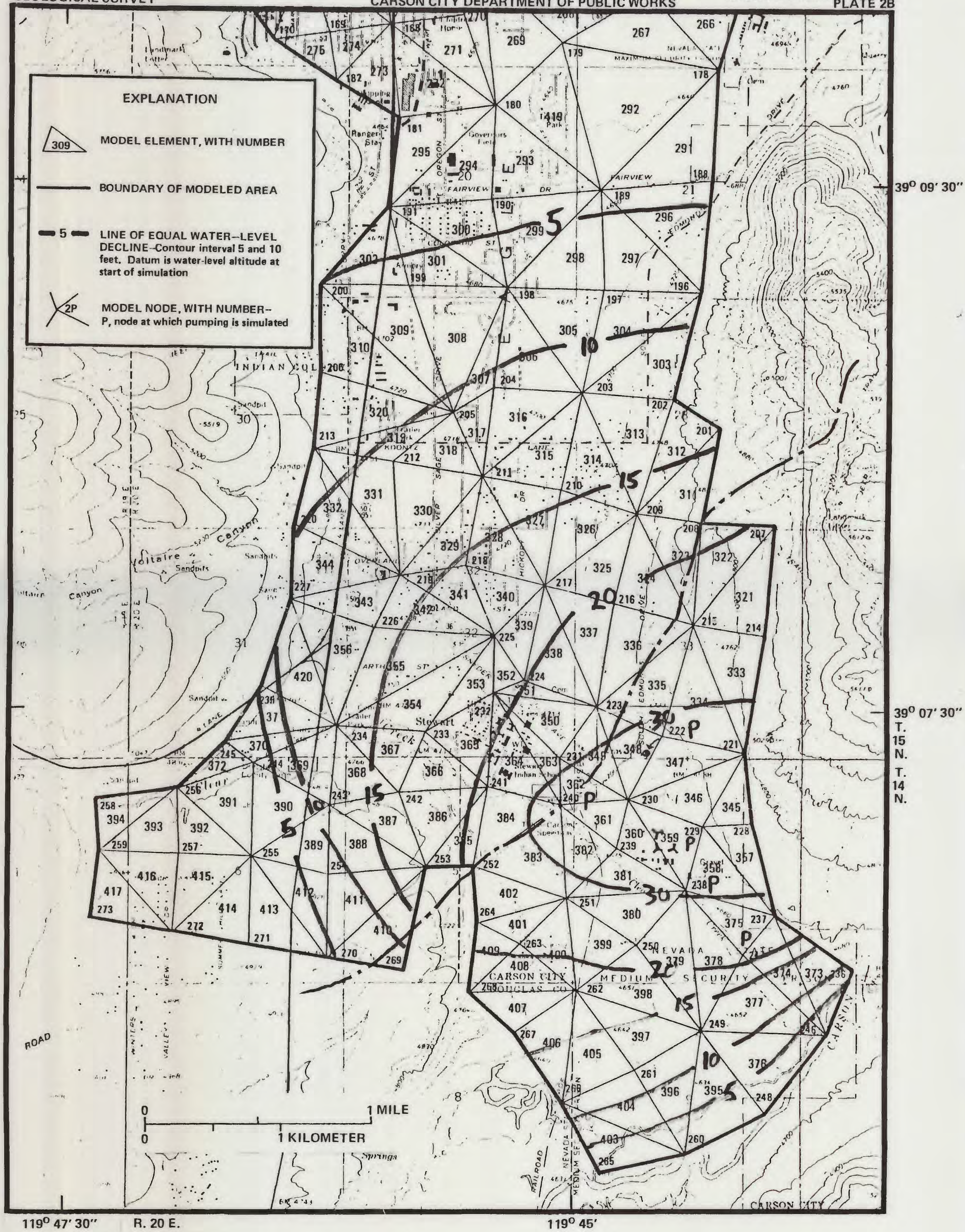
PLATE 2B



Base from U.S. Geological Survey Carson City, Genoa, Mc Tarnehan Hill, and New Empire 1:24,000, 1968, photorevised 1982

DISTRIBUTION OF WATER–LEVEL DECLINES CALCULATED FROM SCENARIO 2, AFTER 10 YEARS OF HYPOTHETICAL PUMPING, EAGLE VALLEY AND CARSON VALLEY HYDROGRAPHIC AREAS, WESTERN NEVADA

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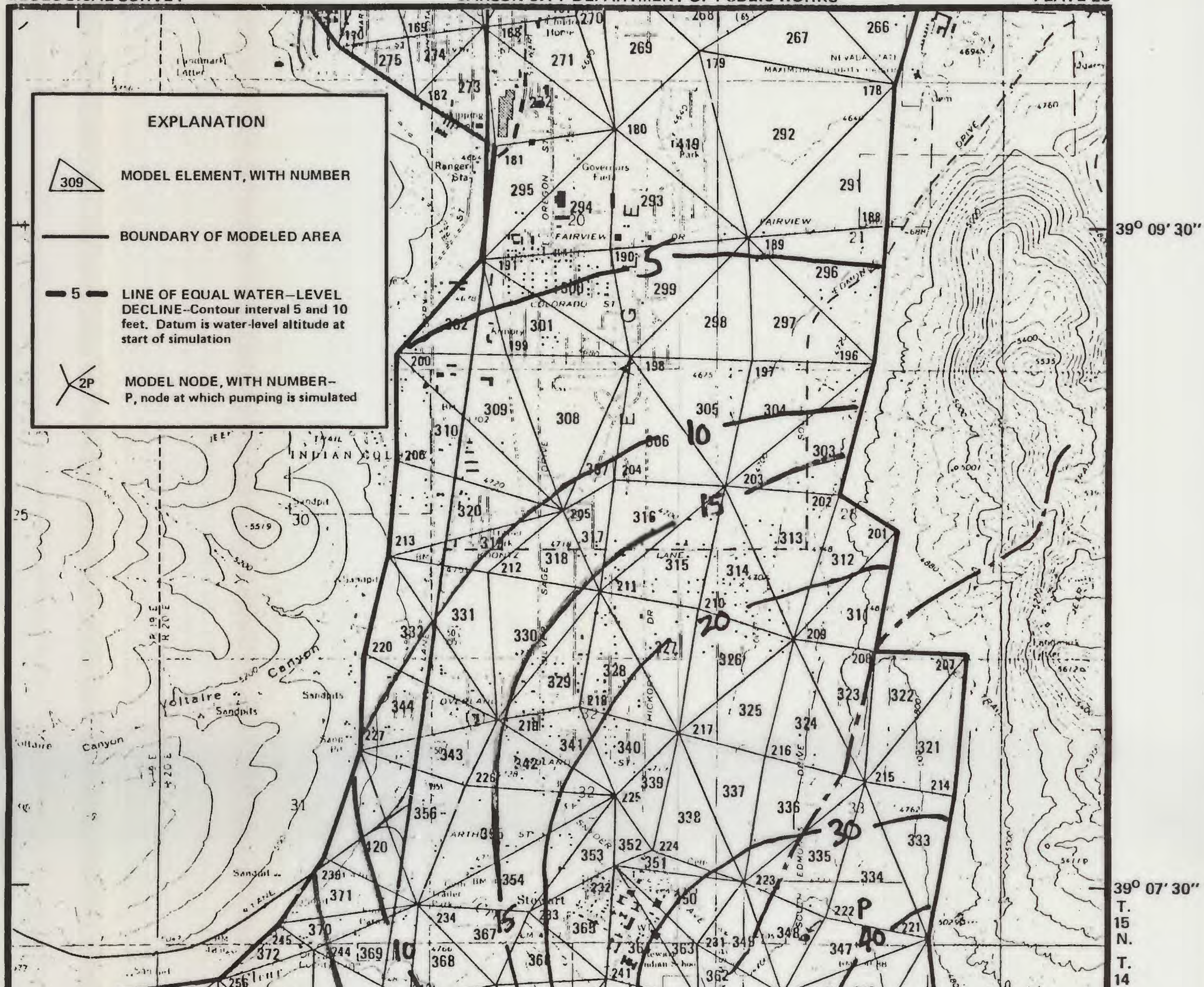

Base from U.S. Geological Survey Carson City, Genoa, Mc Tarnahan Hill, and New Empire 1:24,000, 1968, photorevised 1982

DISTRIBUTION OF WATER-LEVEL DECLINES CALCULATED FROM SCENARIO 3, AFTER 10 YEARS OF HYPOTHETICAL PUMPING, EAGLE VALLEY AND CARSON VALLEY HYDROGRAPHIC AREAS, WESTERN NEVADA

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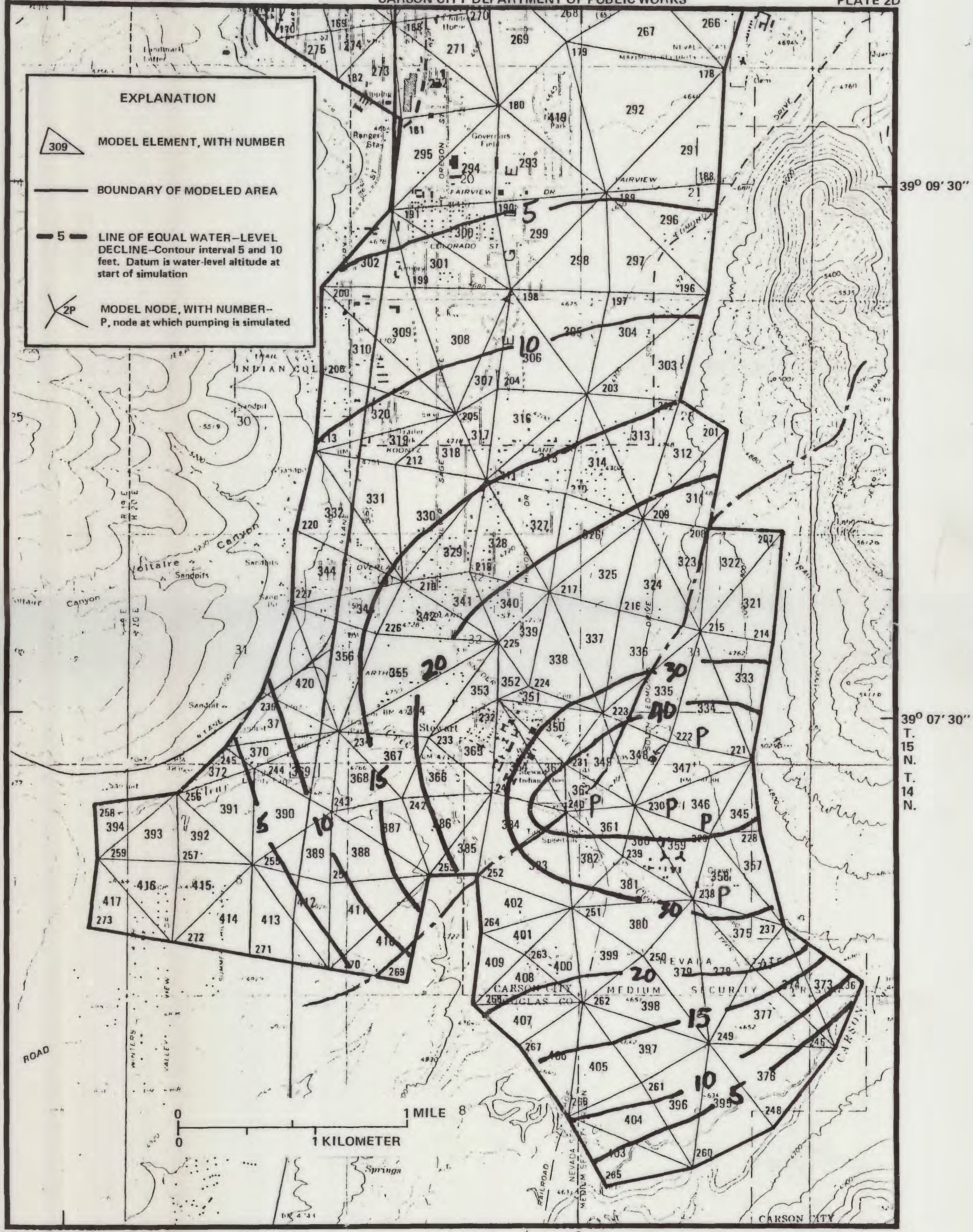
PLATE 2D



119° 47′ 30″ R. 20 E. 119° 45′

Base from U.S. Geological Survey Carson City, Genoa, Mc Tarnahan Hill, and New Empire 1:24,000, 1968, photorevised 1982

DISTRIBUTION OF WATER-LEVEL DECLINES CALCULATED FROM SCENARIO 4, AFTER 10 YEARS OF HYPOTHETICAL PUMPING, EAGLE VALLEY AND CARSON VALLEY HYDROGRAPHIC AREAS, WESTERN NEVADA

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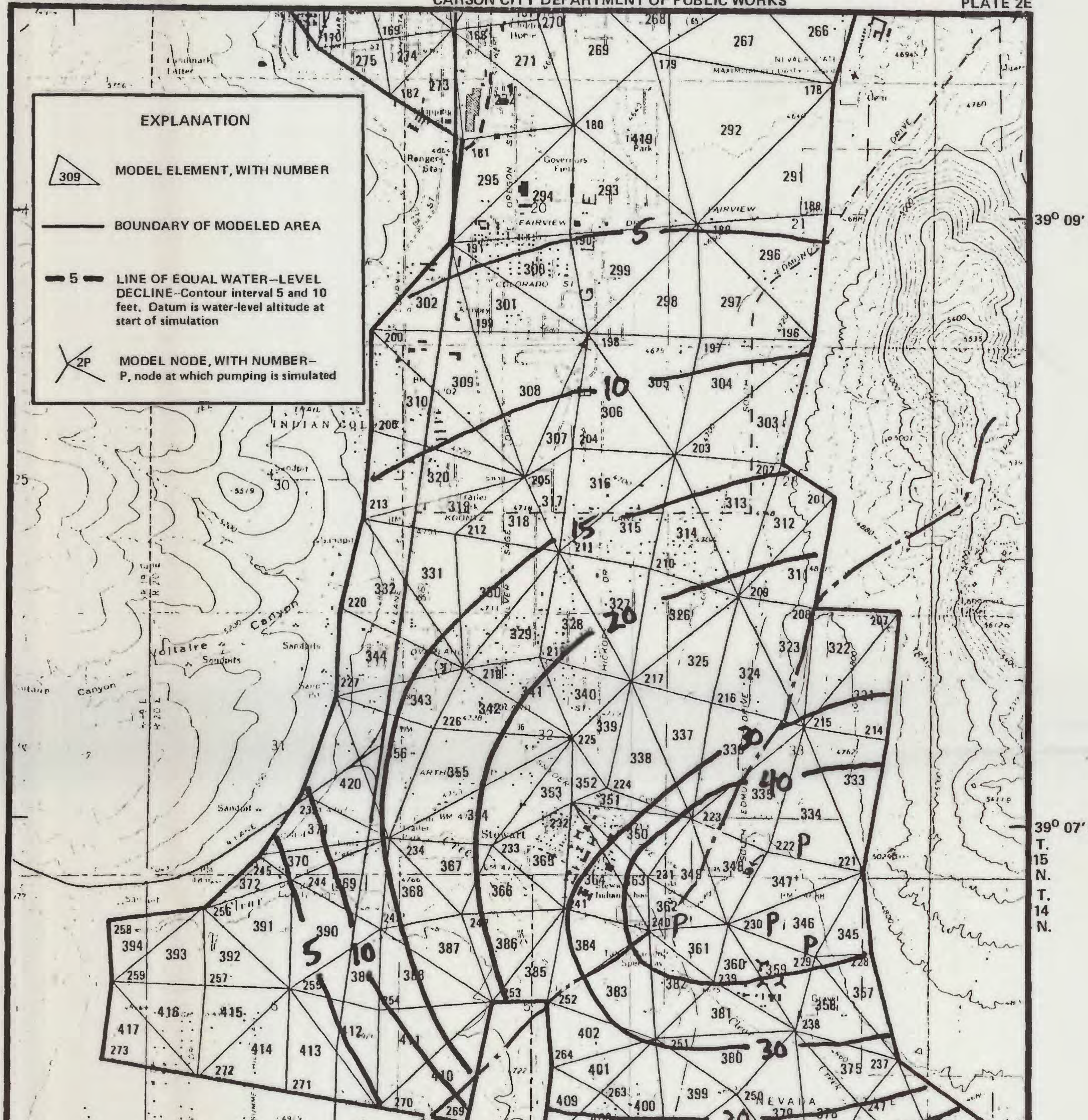
PLATE 2E



Base from U.S. Geological Survey Carson City, Genoa, Mc Tarnahan Hill, and New Empire 1:24,000, 1968, photorevised 1982

DISTRIBUTION OF WATER-LEVEL DECLINES CALCULATED FROM SCENARIO 5, AFTER 10 YEARS OF HYPOTHETICAL PUMPING, EAGLE VALLEY AND CARSON VALLEY HYDROGRAPHIC AREAS, WESTERN NEVADA