STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

Carson City, Nevada

WATER RESOURCES—INFORMATION SERIES

REPORT 4

A PROPOSED TEN-YEAR COOPERATIVE WATER RESOURCES PROGRAM BETWEEN THE STATE OF NEVADA and U. S. GEOLOGICAL SURVEY

OCTOBER 1962

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DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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WATER RESOURCES - INFORMATION SERIES

REPORT IV

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A PROPOSED TEN-YEAR COOPERATIVE WATER RESOURCES PROGRAM BETWEEN THE STATE OF NEVADA and U. S. GEOLOGICAL SURVEY

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Hugh A. Shamberger

Director

October, 1962

State Department of Conservation
and Natural Resources

Office of Director
Carson City, Nevada
October 29, 1962

To His Excellency,
Grant Sawyer,
Governor of Nevada,
Carson City, Nevada.

Sir:

I am herewith submitting a proposed ten-year cooperative water-resources program between the State of Nevada and the U. S. Geological Survey. This proposal is made pursuant to your request that a state water plan be developed. This particular program would be an integrated part of such plan and is needed if we are to meet the challenge of properly developing our water resources during this period of rapid development. I have included in our budget for cooperative work with the U. S. Geological Survey an amount of money that will handle the needs for the first two years of the proposed plan.

As a further development in a proposed state water plan, the Governor's Natural Resources Committee has prepared a proposed "State Development Plan for Nevada". We are in hopes of obtaining a grant of money from the Federal Housing and Home Finance Agency to help finance the plan which has been divided into three phases. Phase I has as its objective the compilation and inventory of basic data related to our natural resources, human resources, and public facilities. The State Planning Board is the legal state entity authorized to accept such grants, and consequently Mr. William Hancock, Manager of the State Planning Board, is actively heading the program. He will look to the Governor's Natural Resources Council for assistance and advice. This proposed plan will be submitted to you for review and approval shortly as it is hoped to formally present it to the Federal Housing and Home Finance Agency in November.

Other elements of a state water plan are being developed.

I trust that the above meets with your approval.

Sincerely,

Hugh A. Shamberger
Director

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PREFACE

The need for a 10-year program for the investigation of water resources is evident from the accelerated development in the State during the past several years. Previous and recent development of Nevada's water resources has shown present and potential problems with respect to the available water resources, natural losses, effectiveness in utilization, existing or changing quality of water, conservation and management, and those of legal and administrative nature. Some of these problems can be solved by diligent effort and reasonable planning, but others will be extremely difficult and complex and will require concentrated effort even to determine satisfactory guide-lines. As development of the State continues to increase it will be necessary, more than ever, to be prepared with solutions to these problems.

For solutions to be sound, and in the best interest of conservation and development and of optimum value to Nevada, we need a carefully planned approach toward obtaining the required physical data and information on the water resources of the State. Further, we need it in time to provide adequate solutions to any of the problems identified above.

The full text of this statement briefly identifies the variety of problems that have been or may be encountered with continued development. This is followed by a statement of the long-range program, which includes brief descriptions of the several elements of this program together with short-range aspects of the program for the 1964-65 biennium. Projected costs and professional manpower requirements for the proposed program also are included.

This program has been prepared to provide for needs for water information, preparation to meet future needs, and to be operating at an appropriate level to keep current with existing needs by the end of the 10-year period. It is designed to permit reasonable flexibility in adjustment to cover changing emphasis which cannot be readily foreseen at this date.

The program is proposed as a cooperative arrangement under 50-50 percent financing with the U.S. Geological Survey in which the work will be carried out by the Geological Survey on the basis of joint planning with this Department. This arrangement is desirable because of the long experience of that organization in water-resources investigations and the fact that the resulting information is unbiased with respect to special interests in any particular development. In that sense it will aid materially in achieving fair and equitable solutions to many of the water-resources problems.

During my 27 years of work in the field of water in Nevada, I have seen much accomplished in water development, many difficulties arising from problems relating to water, and through it all the people of Nevada have shown an increasingly strong desire toward solving their mutual problems through cooperation. As

increased economic development inevitably involves more and better use of water, I am confident that providing sound and adequate information on the water resources of Nevada will be of great assistance in meeting our future responsibilities. I sincerely urge strong and sympathetic support of this long-range program of water-resources investigations.

Hugh A. Shamberger
Director
Department of Conservation
and Natural Resources

October 29, 1962.

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A PROPOSED TEN-YEAR COOPERATIVE WATER RESOURCES PROGRAM BETWEEN THE STATE OF NEVADA AND THE U. S. GEOLOGICAL SURVEY

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SUMMARY OF THE LONG-RANGE PROGRAM

Accelerated use and development of water resources in Nevada during the past several years has shown present and potential problems with respect to the available water resources, natural losses, effectiveness in utilization, existing or changing quality of water, conservation and management, and those of legal and administrative nature.

The long-range program has been carefully designed to increase the rate of acquisition of water-resources data and knowledge in time to develop solutions to the various problems before they become overly critical. In that sense the early stages of the program emphasizes obtaining information to meet immediate needs, the middle period emphasizes maintaining the rate of acquisition of data and preparation to meet further needs, and the latter part of the program is designed to be at an operating level sufficient to keep current with the then existing needs.

The several categories of investigations include (1) continuing water-resources inventory, (2) reconnaissance investigations, (3) quantitative areal studies, (4) comprehensive studies, (5) specific-problem studies, (6) applied research, and (7) topic reports.

Figure 1 shows the proposed distribution of effort by category for the 10-year program and for the preceding 5 years. Figure 2 shows the projected 10-year and the preceding 5-year distribution of professional personnel and funds.

The proposed program is defined by categories to permit maintaining balance of effort throughout the 10-year period. The need for investigation in particular areas can be determined at the time of planning the successive short-range biennial programs.

INTRODUCTION

Nevada is undergoing rapid economic development at an increasing rate. All indications are that this growth will continue in the future. It is incumbent on the State to prepare for this increased development to assist in achieving soundness, orderliness, and prominence to that development. A vital factor in continued development involves the availability of water to meet the growing needs. We need to know more adequately the quantity, quality, and distribution of water that can be developed. We need to know how better to utilize our limited supplies. We need to determine improved practices of administration and regulation. These needs are required to permit optimum development of water in the best interests of the State and its people.

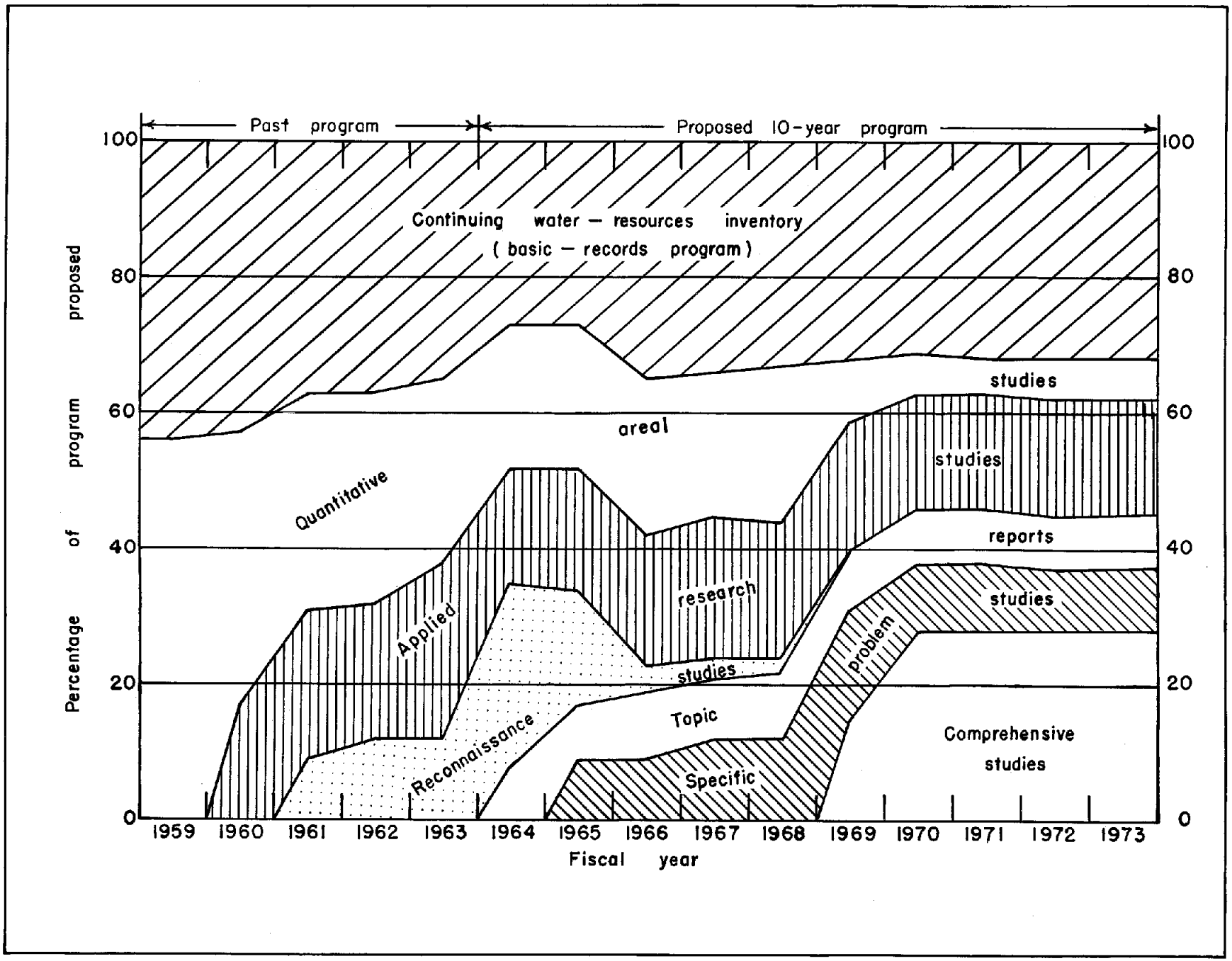

Figure 1. Distribution of effort by categories of work proposed in the long-range cooperative program

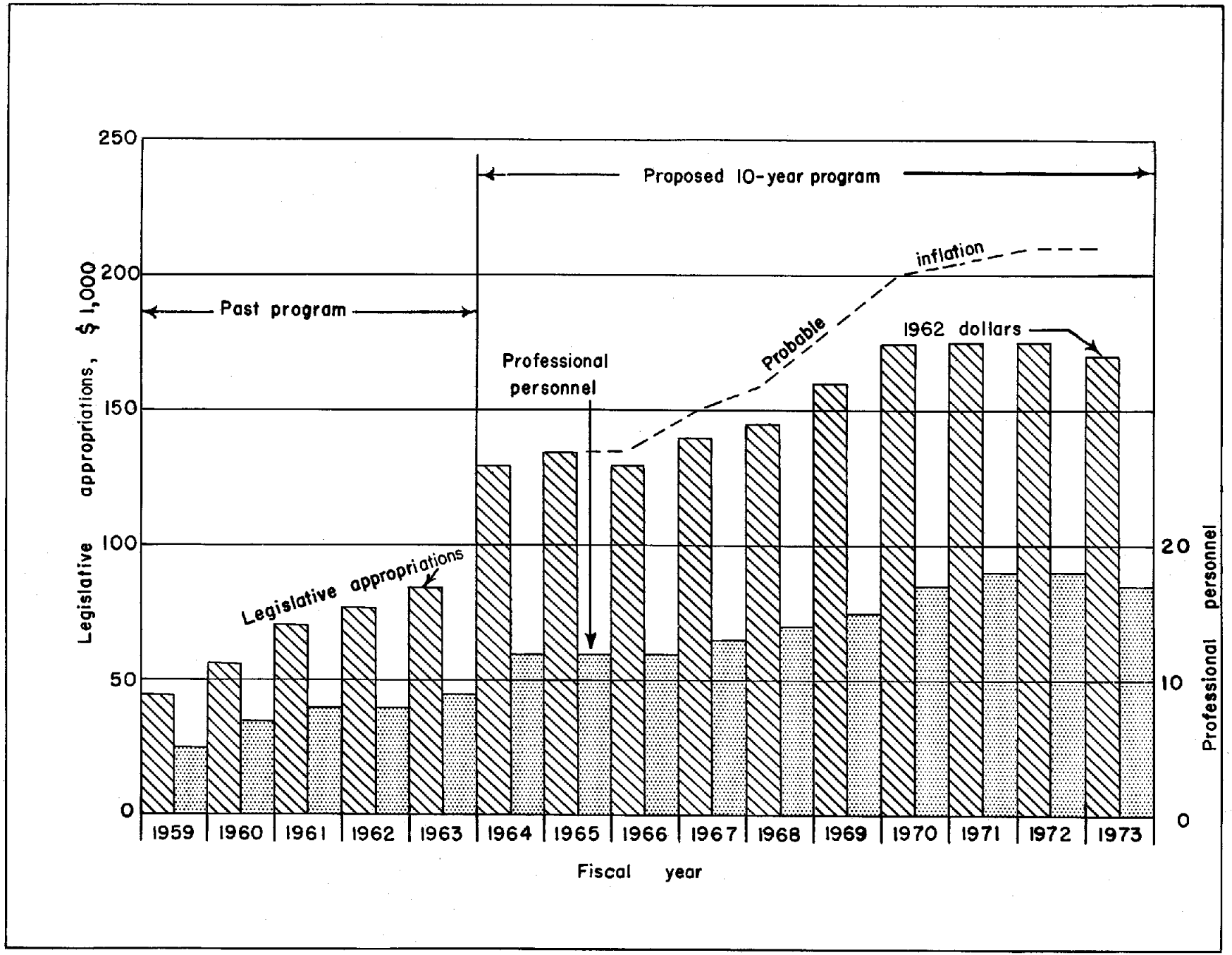

Figure 2. Estimated cost of the long-range cooperative program

The present 10-year program proposed in this statement is focused upon the aspect of adequate determination of the quantity, quality, and distribution of our water resources, as this knowledge is requisite in the final development of the other aspects. The other aspects are presently being considered and statements will be prepared in due time.

The Water-Supply Situation

In view of the rapidly changing technology in the field of water resources and our inability to foresee precisely the water needs and areas that may be developed within the State of Nevada in the distant future, it seems reasonable to limit this long-range program to the 10-year period beginning July 1963. It also seems reasonable to presume that the next 10 years may well be a critical period in water development and need for water information, as the population and industrial growth continue at a rapid rate. Some agencies have forecast that the population of Nevada will double in the next 10 years. The attendant need for water information as problems arise has been expressed at both National and State levels.

The President of the United States, in transmitting the "Report by the Presidential Advisory Committee on Water Resources Policy", to Congress has stated in part:

> A sound water policy must look toward an adequate supply of water for our people, prevent waste, reduce water pollution to its lowest practicable level, provide means for the best and most effective distribution of water, improve navigation, and take steps to check the destructive forces of water which destroy land, property, and life. There are many different problems in different areas. It is neither practicable nor desirable to have only Federal responsibility. There is no single "national" water problem.
>
> 1. Basic data.--That the present program of basic data collection (such as rainfall, stream flows, and hydrology) be accelerated, and be programed and carried out on a more consistent and definite basis (sec. 1).
>
> 2. Planning.--That planning for water resources and related developments be conducted on a cooperative basis with representatives of all Federal, State, and local agencies involved; and that this joint participation be continuous from the beginning in order that plans and projects developed assure the best and most effective use and control of water to meet both the current and long-range needs of the people of a region, State, or locality, and of the Nation as a whole (sec. 2.)"

The "Senate Select Committee on National Water Resources" has prepared 32 committee prints describing all aspects of water from basic facts to research. It is apparent that most of the prints are concerned with water problems and

needs, such as future needs, flood control, management needs, evapotranspiration reduction, weather modification, water-quality management, saline-water conversion, effects of nuclear energy, and reuse of water.

In Committee Print No. 3 the six major National water problems are described: Distribution of the supply, limited supplies, chemical and sediment, pollution, floods, and availability of the supply. Nevada is now affected by all these problems. Water demand for the western United States is shown as increasing from about 140 billion gallons per day in 1962 to nearly 180 billion gallons per day in 1972. From 1950 to 1980 the water demand in the west is expected to double.

For Nevada, studies by the U.S. Geological Survey show that the total water withdrawn for all uses increased from about 1,700,000 acre-feet per year in 1950 (200,000 ground water and 1,500,000 surface water) to about 2,500,000 acre-feet in 1960 (500,000 ground water and 2,000,000 surface water). Total runoff in the State probably averages less than 4,000,000 acre-feet per year, of which about half is carried by the Carson, Truckee, Walker, and Humboldt Rivers. About 900,000 acre-feet flows from the State, principally to the Snake and Colorado Rivers. Total recharge to more than 100 ground-water reservoirs probably averages roughly 2,000,000 acre-feet per year.

Thus, the estimates suggest that as of 1960 nearly half of the average annual water supply of Nevada was being used. Moreover, if the demand for water increases as anticipated, the demand may equal or exceed the supply within the next 20 years. Even more critical is the imbalance between areas where water is needed and where the supply exists. In 1962 at least five valleys were overdrawn, a few others were using nearly all the average annual supply, the surface-water supply was over-appropriated in several areas.

Principal Water Problems

The present and potential water problems in Nevada can be categorized as natural supply, natural losses, utilization, conservation and management, water quality, and legal. Nevada's principal water problem is the limited supply that can be developed on a perennial basis. Although Nevada is the seventh largest State, it also is one of the most arid.

Natural Supply

Limited quantity:-- For the State as a whole the average annual precipitation is less than 9 inches, runoff is less than 4 million acre-feet, and recharge to more than 100 basins is roughly 2 million acre-feet. Because the perennial recharge to even the largest valleys probably does not exceed 100,000 acre-feet and to perhaps half the valleys is less than 15,000 acre-feet, overdraft, which already has occurred in several areas, will pose a potential threat in many basins of the State. However, before the extent of this threat can be fully evaluated, the water resources of all the principal basins must be ascertained.

Maldistribution of the supply. --Although the average precipitation in Nevada is equivalent to roughly 50 million acre-feet, probably less than 8 percent of the precipitation falling within Nevada becomes available either as surface-water runoff or recharge to the valleys. The runoff of the Truckee, Carson, and Walker Rivers is contributed to a great extent from California watersheds. Moreover, about half the available supply is localized along the Sierra front and in the Humboldt River system. The southern part of the State is extremely arid, and several major areas are presently short of water.

Seasonal runoff and recharge are extremely variable. About 70 percent of the annual runoff occurs between April and June. Moreover, periods of drought may range from 2 to 20 years.

The degree to which it is economically feasible to export water from areas of surplus to areas of deficiency must be explored even though it is recognized that the quantities available are relatively small.

Floods and sediment transport -- Nevada's floods can be classified as snowmelt and cloudburst floods. They continue to cause loss of life and serious property and sediment damage. Moreover, large quantities of water are wasted as flood waters reach the dry lakes where they evaporate. Much of the damage and loss in Nevada could be reduced by properly located flood-control structures, including detention reservoirs to conserve the water for beneficial use.

An important part of any flood-control program is the collection of flood-runoff data through an adequate network of streamflow and sediment stations. These data are used to prepare the reports on flood-frequency, flow-duration, and sediment-transport studies which in turn, form the basis for flood-control planning and construction.

Yields of wells -- Much of Nevada's ground water occurs in fine-grained deposits of low permeability, and therefore development is impracticable. Thus, obtaining wells of adequate yield will continue to be a problem in many areas.

Water temperature. --The principal problems associated with above-normal ground-water temperature have arisen in the development of municipal supplies, such as for the cities of Elko, Reno, and Sparks, and for domestic supplies, as in parts of Truckee Meadows. On the other hand, thermal water may be sought for other uses, such as power development. The solution to these problems requires detailed studies of thermal water associated with mountain-building and volcanic activity.

Natural Losses

Evapotranspiration. -- The annual consumptive waste of ground water by about 3 million acres of phreatophytes in Nevada is roughly 1 1/2 million acre-feet. The water transpired by phreatophytes is a substantial part of the potential ground-water development remaining in the State. Maximum development of the available water in the State depends partly upon the extent to which this waste can

be salvaged for beneficial use. Determination of the distribution of phreatophytes and more accurate estimates of their use of ground water will provide valuable data in evaluating how the water so lost can be put to better use.

Evaporation from Lakes-- Runoff to dry lakes evaporates and is lost. Because of the arid climate, evaporation from free water surfaces is high, ranging from 3 1/2 feet in the northern part of the State to 7 feet in the southern part. Average annual evaporation from Lake Tahoe is about 370,000 acre-feet; that from Lake Mead, about 900,000 acre-feet. Reliable data on these losses will be of material assistance in evaluating the economics of measures designed to reduce these losses.

Utilization

Ground Water in Storage.--One of Nevada's largest resources is the water stored underground in more than 100 basins of the State. The amount in storage in the upper 100 feet of saturation is at least 200 million acre-feet, which is equivalent to about 100 years of average recharge. In the development of a ground water basin some lowering of the water table and depletion of the ground water in storage may be necessary to control losses and permit economical extraction of the allowable quantity of water. The problem then becomes one of determining how much water should be extracted and to what extent depletion of the ground water in storage and lowering of the water table should be permitted. Several basins in the State, of which the Las Vegas Valley is a notable example, are overdrawn and remedial measures to alleviate the effects of the overdraft are under consideration.

In the future it seems reasonable to expect that the available perennial supply will be fully used in large segments of the State. At that time, and even before, consideration may be given to the feasibility of planned over-development in selected basins of the State to meet the increased demand for water. Legislative action will be required to permit planned over-development, and of course, much detailed hydrologic study would be needed in the selection of basins.

Storage facilities.--Optimum use of the water resources of stream systems requires the conjunctive use of both surface and underground storage reservoirs. This can best be done through flood-control detention and storage reservoirs, which hold back flood or excess surface water for releases at later dates, to recharge ground water, or to supply users directly through diversion works. Detailed geology and flow-system analysis are required to examine the feasibility and operational pattern for such projects. The Humboldt, Carson, Walker, and Truckee Rivers, subject to existing water rights, could be considered for studies of this type. Advantages of conjunctive-use reservoirs are reduction of flood damage, as previously described, salvage of water that normally would go to waste, reduction of evaporation loss by storing the bulk of the water underground, and creation of a larger total storage capacity.

Land Subsidence. -- Withdrawal of fluids from certain types of materials in the earth's crust results in subsidence of the land surface. At Las Vegas, several feet of subsidence has occurred principally as a result of large withdrawals of ground water. Problems associated with land subsidence are damage to wells, buildings, streets, pipe lines, and other structures. In addition, capacities of low-gradient canals, storm drains, and sewers can be reduced substantially by local subsidence along their courses. Studies of land subsidence are costly, complex, and time consuming. Nevertheless, detailed geologic and hydrologic investigations are an essential part of any remedial work that might be undertaken.

Conservation and Management

Conservation of Water. -- To obtain the most water possible in a hydrologic system four principal activities are required: Effective watershed management, control of storm runoff, improved water-use practices, and reuse of water wherever possible. With regard to water-use practices alone, possibly as much as 50 percent of the water taken from streams and ground water for agricultural use is wasted by seepage from canals and ditches, improper methods of application, and tail waste. Artificial recharge in some valleys could salvage for beneficial use a part of the water that frequently ponds and evaporates on the dry lakes.

Drainage. -- Waterlogging and drainage are serious problems in some agricultural areas of Nevada, such as near Fallon, Lovelock, and Reno. In many areas waterlogging results from natural causes; in others, the problem is the result of man's activities. Although some remedial measures have been put into effect, better methods may be available. More data are needed on geology and hydrology of waterlogged areas to determine the most feasible and efficient methods for solving specific drainage problems.

Mine drainage has been a substantial problem in some areas of Nevada. Geohydrologic data in a number of cases in other parts of the United States have provided the basis for determining the means of economic handling of mine water.

Eradication of phreatophytes. -- Removal of phreatophytes to conserve water may cause or aggravate erosion problems.

Weather Modification. -- Weather modification may increase water supplies. At the present time a large scale cooperative Weather Modification Research Project is being carried on in Elko County to determine if such work would be economically beneficial for the Humboldt River drainage area.

Water Quality

Water quality problems are inherent in nearly all the preceding problem categories. Some of the more critical problems in Nevada are described herewith. Many of the water-quality problems arise from the fact that Nevada has numerous basins of internal drainage, resulting in the accumulation of salts locally or over large areas. The total area underlain by moderately to highly mineralized ground water may exceed 2 million acres. As a result, development of water for most uses may be severely restricted in many valleys.

Quality of water problems also result from small concentrations of naturally occurring chemical constituents, such as fluoride, boron, iron, and manganese, in an otherwise satisfactory water. Large withdrawals may cause nearby brines to invade wells and render the quality of water unsuitable for use. Saline-water conversion may resolve this problem in some areas.

Potential quality of water problems are inherent in population and industrial growth and can be identified principally as stream and ground-water pollution from industrial and other wastes. In recent years the synthetic detergents discharged from sewage treatment plants have created problems locally in several streams and presumably have affected nearby ground-water systems.

Problems related to radiohydrology are of particular and growing concern to Nevada with activities at the Nevada Test Site. Potential problems relate to any future sites for testing or industrial application of nuclear energy, such as electric power plants, that might affect the quality of surface and ground waters.

Legal

Water Rights. --Problems associated with infringement of water rights already exist and will increase as Nevada's water resources are developed more fully. As the demand for water appraoches or exceeds the available supply, the problem of preferential use among domestic, municipal, irrigation, and other uses will arise. The competitive demand will also extend to conflict between surface- and ground-water uses.

Interbasin Movement of Ground Water. --Most basins or valleys in Nevada are closed topographically and have internal surface-water and ground-water drainage terminating at dry lakes. However, in many of these basins geologic controls are such that ground water moves from one basin to another beneath topographic divides. Most of these areas are in the eastern and southern parts of the State, such as at Gold Flat, Frenchman Flat, and Yucca Valley. Interbasin movement poses difficult problems in the management of the water resources, particularly for granting rights to the use of water under the water law of Nevada.

Water Compacts. --A large part of the runoff of the Truckee, Carson, and Walker Rivers originates in California. For the past several years the two states have been working on a compact including the three rivers and Lake Tahoe. Tributaries of the Snake River originating in Nevada discharge roughly 600,000 acre-feet per year to neighboring states. Determination of the relative rights of each State to the use of the water will need to be resolved in the near future. Nevada's rights to the use of the Colorado River water is most critical to the solution of water shortages in the southern part of the State.

Interstate ground-water reservoirs. --Another potential problem is the adjudication of water rights and management of ground-water reservoirs that lie astride state boundaries, such as Pahrump, Mesquite, Fish Lake, and Amargosa Valleys. As the use of water increases along state boundaries, this problem will need to be resolved.

The Need for Water Information

The water problems just described indicate the present and future need for water information of all types, not only for Nevada but for the Nation as a whole. To keep pace with this need, the Water Resources Division of the U.S. Geological Survey has recently set forth an expanded Nationwide program, balanced in accordance with the anticipated needs in the next 10 years. In its simplest form the nationwide needs and annual costs are envisioned as follows: Basic water facts, an increase from $14 to $24 million; interpretation and areal studies, from $12 to $21 million; and research, from $3 to $15 million. The Federal-State cooperative program is expected to increase from $17 to $28 million, with the greatest growth in the collection of basic records and interpretive studies.

It is anticipated that Nevada's need for water information will be at least as great as the nationwide average--possibly even more, if the population and industrial growth pattern proceed as predicted. Based on the wide variety of water problems that are expected to arise, or that already exist in the State, the types of water facts and studies needed to help resolve these problems must be defined. Obviously, the solution to the numerous water problems listed on the preceding pages requires the talents of many Federal and State agencies working in the field of water.

With specific reference to the cooperative program between the Nevada Department of Conservation and Natural Resources and the U.S. Geological Survey, much has been accomplished in the past 17 years in obtaining water information. Figures 3 and 4 show, respectively, the areas where streamflow data are being collected and where studies have been made. However, in the past 5 years water development has been increasing at an accelerated rate. Now the rate is threatening to outstrip the State's ability to provide adequate information on water resources for all areas in which the information is needed.

If adequate information can be provided when needed, it will be an important factor in promoting sound development and providing the necessary foundation for the optimum management of the limited supply, which is vital to the future growth and economic development of Nevada. Adequate water information is required to administer effectively the State water law, interstate agreements on water rights, and to manage the resources in the most efficient way to achieve optimum development. Moreover, the factors that relate to the economic, political, and social conditions change with time. Thus, a long-range program based solely on present conditions undoubtedly would be inadequate for future requirements.

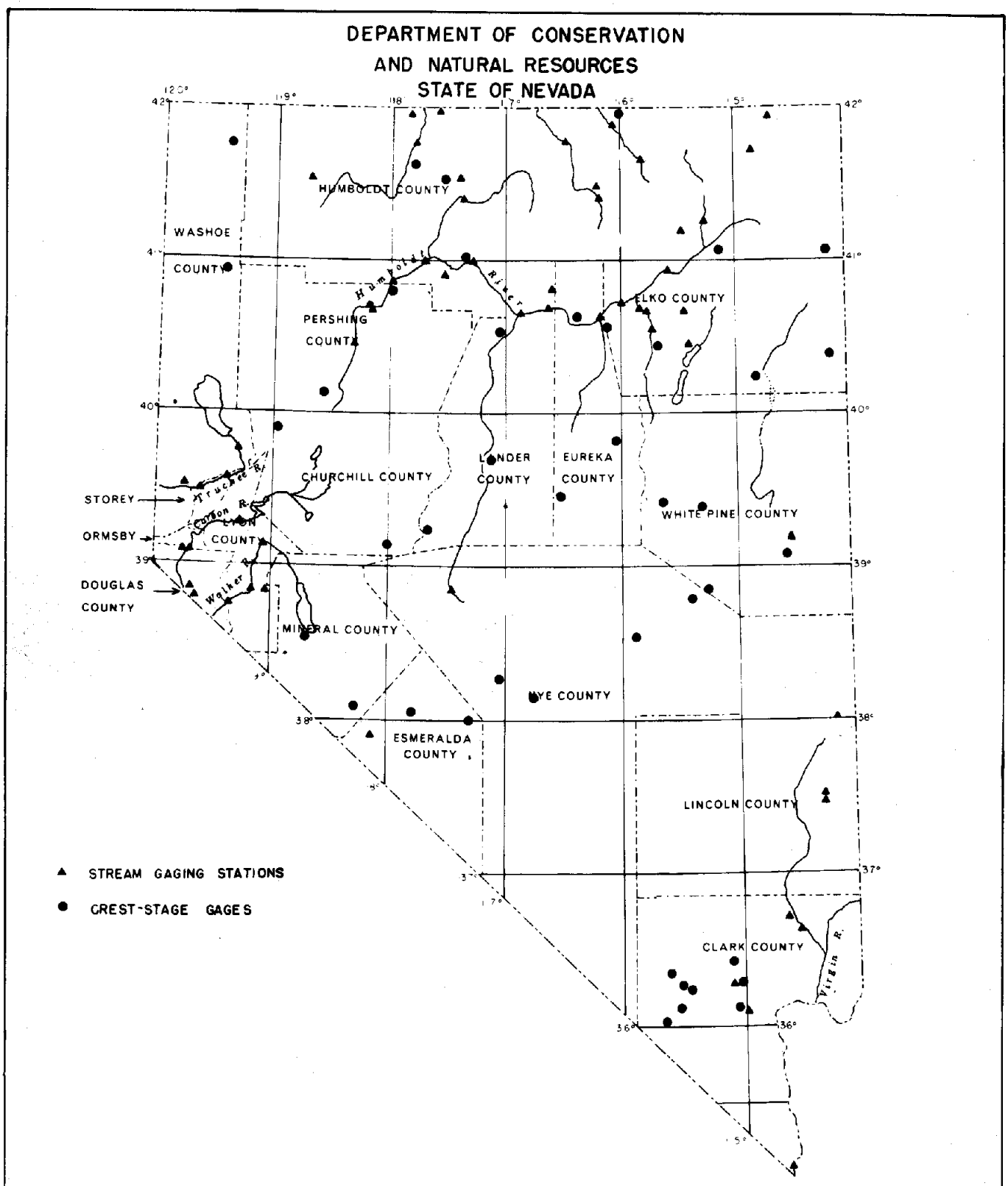

Figure 3. Map of Nevada showing active stream-gaging station and crest-stage gages

September 1962

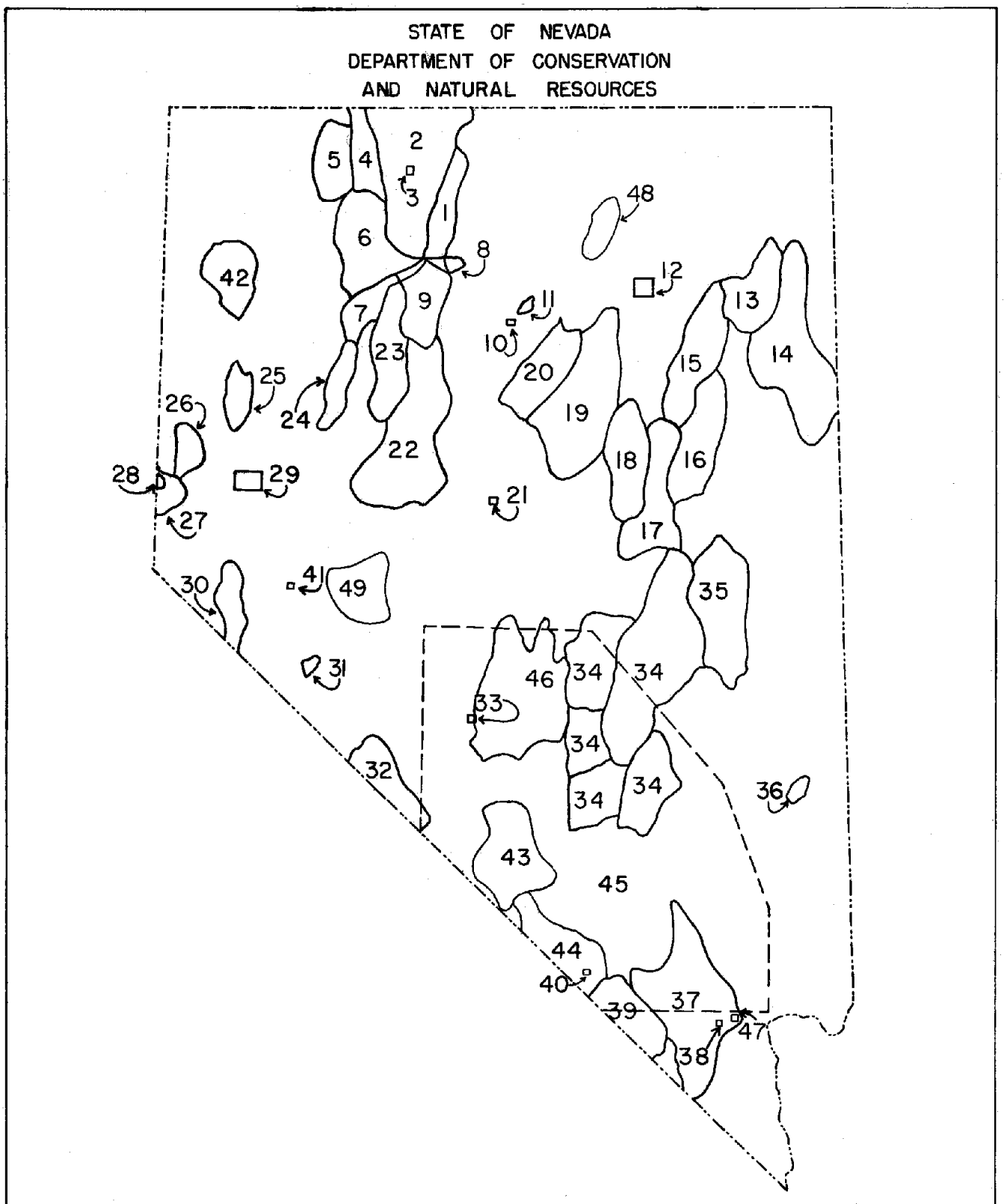

Figure 4. Map of Nevada showing area for which reports on ground water are available or are in progress as a result of the Nevada Department of Conservation and Natural Resources cooperative program with the U.S. Geological Survey — — 1944 to September 1962

Figure 4.--Explanation

Map No.	Valley	County
1	Paradise	Humboldt
2	Quinn River	do
3	Orovada area	do
4	Kings River	do
5	Pine Forest	do
6	Desert	Humboldt, Pershing
7	Imlay area	do
8	Humboldt near Winnemucca	Humboldt
9	Grass	Pershing, Humboldt
10	Battle Mountain area	Lander
11	Argenta Swamp area	do
12	Elko area	Elko
13	Clover, Independence	do
14	Goshute, Antelope	do
15	Ruby	Elko, White Pine
16	Long	do
17	Newark	White Pine
18	Diamond	Eureka, Elko
19	Pine	do
20	Crescent	Eureka, Lander
26	Spanish Spring, Sun	Washoe
27	Truckee Meadows	do
28	Verdi area	do
29	Fernley-Wadsworth area	Churchill, Lyon, Storey, Washoe
30	Smith	Lyon, Douglas
31	Whiskey Flat	Mineral
32	Fish Lake	Esmeralda
33	Tonopah area	Nye
34	Railroad, Hot Cr., Reveille, Kawich, Penoyer	Nye, Lincoln, White Pine
35	White River	White Pine, Nye, Lincoln
36	Meadow Valley Wash	Lincoln
37	Las Vegas, Pahrump, Indian Spring	Clark, Nye
38	The Strip, Las Vegas	Clark
39	Pahrump	Clark, Nye
40	Ash Meadow area	Nye
41	Schurz area	Mineral
42	Hualapai Flat	Washoe, Humboldt, Pershing

Figure 4 -- (continued)

Map No.	Valley	County
21	Austin area	Lander
22	Dixie, Fairview	Churchill
23	Buena Vista	Pershing
24	Lovelock area	Humboldt
25	Winnemucca Lake	Pershing, Washoe
43	Sarcobatus Flat, Oasis	Nye
44	Amargosa Desert	Nye
45	Nevada Test Site and vicinity	Clark, Nye
46	Ralston, Stonecabin	Nye
47	Lake Mead Base	Clark
48	Independence	Elko
49	Gabbs	Mineral, Nye

LONG-RANGE PROGRAM

Scope

The types of water information that could best be gathered and analyzed in the next 10 years under the cooperative program between the Nevada Department of Conservation and Natural Resources and the U.S. Geological Survey to meet the needs in specific categories are:

(1) Continuing water-resources inventory--The basic-records program.

(2) Reconnaissance studies--First-stage quantitative hydrologic studies of a valley or basin, preliminary in scope.

(3) Areal studies--Second-stage quantitative hydrologic studies of a valley or basin, detailed in scope.

(4) Comprehensive studies--Third-stage quantitative hydrologic studies of a valley or basin, flow-system analysis.

(5) Specific-problem studies--Fourth-stage studies of a valley or basin, detailed studies of specific aspects of hydrology in limited areas or in an entire hydrologic unit.

(6) Applied research--Specifically directed toward solution of hydrologic problems in Nevada.

(7) Topic reports--Generally Statewide or regional in scope, dealing with selected aspects of hydrology.

The continuing inventory (item 1) is recognized as the basic Statewide program, intended to monitor the natural fluctuations and the progressive artificial modifications in the water-resources pattern. This program, which now constitutes about 35 percent of the effort, supplies the water facts--when, where, how much, and of what quality.

Basin or valley studies are shown as reconnaissance, areal, comprehensive, and specific-problem studies (items 2 through 5) and represent successive stages of work in individual hydrologic units. These programs together, which now constitute about 40 percent of the effort, supply reports on hydrologic investigations.

Applied research (item 6), which now is largely devoted to the Humboldt River Research project, is a much needed program to develop and refine methods used in the solution of hydrologic problems in Nevada. Also, this work will include application of the results of basic research obtained elsewhere.

As water information accumulates areally and in detail, topic reports (item 7) should be prepared on a Statewide or regional basis. These reports would provide not only a Statewide analysis of particular aspects of hydrology but also part of the necessary framework for management decisions on a broad areal basis.

Elements of the Program

The seven categories of hydrologic effort listed above are described in detail on the following pages and are related to the water problems previously outlined. The descriptions are brief and in some instances are expressed in general terms, because it is recognized that changing emphasis on development and management as well as improvements in technology will require flexibility in the overall plan.

Figure 1 shows the distribution of effort among the seven categories of work, beginning in July 1963. The scope of the first two years (1964 and 1965 fiscal years) has been prepared for legislative consideration. (See page 17). It is planned that the overall program will be reviewed every second year to permit successive adjustments to meet needs. In this sense the long-range program is a guide to evaluate biennial "short-range" programs in the light of new or changed conditions.

Continuing water-resources inventory

Stream-gaging network. --The stream-gaging network to collect basic records on streamflow in Nevada under the cooperative program now totals 52 stations. To complete the minimum network necessary to inventory the surface-water resources of the State, about 40 new gaging stations should be installed in the next 10 years. About one station should be discontinued each year as sufficient data are collected.

This program is supplemented by additional gaging stations supported by cooperative programs between the U.S. Geological Survey and Nevada Department of Highways, irrigation districts, and other Federal and local agencies.

Observation-well network. --The observation-well network to collect water-level records is essential to determining the natural and man-made changes in the ground-water systems of Nevada. Because the Nevada Division of Water Resources has the prime responsibility of administering the ground-water law, it is proposed that the bulk of the continuing program of water-level measurements be carried on and a Statewide pumpage inventory be started by the State under an expanded program.

To carry on an effective water-level and pumpage-inventory program sufficient to meet the needs of management and the administration of the law, the Nevada Division of Water Resources will require an additional engineering staff of 5 by the 1968 fiscal year and 10 by the 1973 fiscal year. The State already has the nucleus of a program in Las Vegas, Pahrump, and Smith Valleys.

To assist the State in this work it is proposed that Geological Survey maintain a skeleton Statewide network of observation wells at about the same level of effort now in effect; that is, continue to expend about one-man year of effort on this program in each of the next 10 years.

Water-quality network. -- A water-quality network should be established at key gaging stations and wells where quantitative records also will be available. The network should also include points where changes in water quality with time are anticipated because of development.

Similarly a network of sediment sampling stations should be started at key points to provide the necessary information, principally for existing and proposed dams and to evaluate effects on irrigated land.

Soil-moisture network. --A soil-moisture network is a most urgent need in Nevada, whose precipitation and runoff are about the least in the nation, and where the volume and movement of water in the unsaturated zone are controlling factors in the recharge and discharge of ground water. The value of this work has been demonstrated experimentally by use of the neutron-scatter meter on the Humboldt River Research project near Winnemucca. Instruments have not yet been developed to the point where they provide standard indexes of unsaturated volume and flow, but it is anticipated that application of this type of instrument to solution of quantitative problems will be possible within the next few years.

Reconnaissance Studies

Purpose and need. --One of the greatest deficiences in the water knowledge in Nevada is the lack of hydrologic data in approximately half of the valleys in the State. Legislation enacted in 1960 provides for reconnaissance studies of ground-water basins in Nevada under the cooperative program with the U.S. Geological Survey. As a result of this legislation, by October 1962, 10 reports describing the water resources in 11 areas had been published in the State's "Ground-water resources--Reconnaissance Series."

Although the reconnaissance program has helped immensely in supplying information to the State and general public, a two-fold program is proposed to obtain the necessary coverage of the major basins in the State. First, it is proposed that the effort and number of reconnaissance studies be increased to 25 to 30 areas in the 1964 and 1965 fiscal years in an effort to keep pace with the need for information. This major effort would provide coverage of the major basins of the State. In the 1966 and 1967 fiscal years the program would be greatly reduced to provide only for reconnaissance studies in a few residual areas.

The second part of the program provides for an increase in the scope of the studies, starting in the 1964 fiscal year, for the purpose of including information on the runoff and water-quality aspects wherever possible.

Scope. --Fundamentally, the scope of the reconnaissance reports has been designed to assist the State Engineer in the administration of the Nevada ground-water law by making preliminary estimates of average annual recharge to,

discharge from, and the perennial yield of valleys and basins. In addition, the reports have included pertinent information on climate, geologic environment, extent of the hydrologic systems, ground water in storage, water quality, and conclusions, such as outlining favorable areas for potential development, describing existing and potential problems, and outlining the need for additional studies.

In effect the preliminary reconnaissance studies are first-stage hydrologic studies, short-time, small-scale, which summarize hydrologic observations. They generally describe conditions prior to major ground-water development, when springs, domestic wells, and unregulated streams are the sources of water sparsely tapped by the inhabitants. These studies suggest the potentials of water development, but only tentatively because of lack of data and the uncertainty of future economic use of the area. Nevertheless, they provide the basic framework for second, third, and fourth-stage hydrologic studies during and after basin development.

Areal Studies

Purpose and Need.--After development in a valley or basin has reached a moderate to substantial level and records have become available through the continuing inventory, problems will arise that require more detailed study than that afforded by the first-stage reconnaissance. Overdraft, either local or areal, is one of the common problems. For example, as of 1962 overdraft had occurred in Las Vegas, Pahrump, Quinn River, Kings River, and Diamond Valleys. Other problems may relate to drainage and water quality, or it may be considered necessary to make an areal study in a valley where substantial data have been collected and for which no first-stage study has been made, such as the Amargosa Desert-Ash Meadows area.

To keep pace with the development of ground water in these areas and to eliminate the back-log of areas needing study, it is proposed to expand the areal studies in developed basins to two a year in the 1964-65 biennium, to three a year in the 1966-67 biennium, and then to reduce the effort in succeeding years if the need decreases.

Scope.--The areal studies generally are quantitative and are considered the standard studies covering the hydrologic framework and boundaries of a specific area, the inflow and outflow, ground water in storage, extent of depletion of stored water, movement, water quality, runoff, and the effects of development and use of water. In effect, second-stage studies provide a substantial amount of physical data at an early stage in the development history of an area. Each study would take about 1 year to complete and could be carried on effectively only where topographic quadrangle maps at a scale of 1:62,500 (about 1 inch to a mile) are available.

Comprehensive Studies

Purpose and Need.--After development in a valley or basin has been substantial for a number of years and long-term records have become available

through the continuing water-resources inventory, a comprehensive evaluation of the flow system would be required to answer specific problems that could not be answered in the first or second-stage studies. For example, the information obtained could be used to prepare analog and mathematical models of the hydrologic unit to show the long-term effects of pumping both areally and with time. Such data are invaluable to management in determining the most effective operation of the hydrologic unit.

It is anticipated that these third-stage comprehensive studies would not be needed until about the 1969 fiscal year (fig. 1). Beginning in about 1970 about two studies per year would be in progress to meet the anticipated need at that time. The extent to which comprehensive studies would be required toward the end of the 10-year program would depend on the number of areas, the stage of development, available records, and need for the detailed information.

Scope. -- The comprehensive evaluations are quantitative and require not only all the detailed information described in the areal studies but also accurate subsurface information and delineation of flow-system boundaries, including areas of recharge and discharge and boundaries formed by the rocks surrounding the hydrologic unit. In effect, third-stage studies would provide detailed operational information after a relatively long period in the development history of a basin. Each study would take 1 to 3 years to complete, depending upon the complexity of the hydrologic system.

Specific-Problem Studies

Because specific problems will arise in a hydrologic unit before and after the third-stage comprehensive studies are made, provision is allowed in this 10-year plan to make investigations to resolve these problems. For example, changes in the pattern of development and use, a water-quality problem, waterlogging, or a drainage problem may occur at about any stage in the full development of a basin and require special attention. A further illustration would be a study concerning artificial recharge.

About one-man year of effort is proposed for each year of the 10-year plan to assure that these investigations are adequately financed and the necessary reports prepared for State and local agencies.

Applied Research

The applied research program envisioned as part of the 10-year program relates to deficiencies of knowledge and techniques peculiar to the water problems in Nevada. This broad category may include application of the results of basic research elsewhere to these problems, the testing of new instruments or ideas--any means of improving standard operations or attacking complex problems. When considering comprehensive or specific-problem investigations, we must recognize that adequate and refined methods have not as yet been developed to define accurately most quantitative elements of the flow system.

Nationwide, increasing effort is being placed on research of fundamental principals of hydrology. As the demand for water increases, the need arises for progressively more rigorous definition of the flow systems to obtain optimum development of the water resources.

For Nevada, some of the need for the development of improved methods and techniques can be grouped under factors relating to recharge, ground water in storage, and discharge of the flow systems, and the causes for the variations in water quality. For example, although several methods have been devised to estimate recharge, all are general or empirical; the results may best be classed as approximations. Furthermore, most methods relate to an "average" condition and usually are not valid for any specific year. Tracing the movement of water through the unsaturated zone at several points would not answer the needs for an entire hydrologic unit, but it might help to indicate where and when recharge occurs. In this regard the results of the neutron meter on the Humboldt Research Project at Winnemucca are promising, and would strongly support a continuing and expanding program in Nevada, including the testing of new devices as they may be developed.

Other methods and techniques requiring research to help resolve water problems in Nevada include direct estimates of runoff from ungaged streams, return flow to ground water following application of surface and ground water to irrigated areas, and evapotranspiration losses. Although improved methods and techniques certainly could be used at the present time for the current studies in several parts of Nevada, they will be critically needed within the next several years.

In the 1960 fiscal year the Legislature appropriated $40,000 for the Humboldt River Research Project, of which the amount of $10,000 was designated by the Department for the Survey's participation. The Survey has been requested by the Nevada Department of Conservation and Natural Resources to prepare the summary report on the research study in the 1964 fiscal year, and of the $40,000 budgeted by the Department, an amount of $22,000 is being requested for this purpose. Thus, although this type of project is somewhat different than the research needs outlined above, still the interest of the Legislature in accomplishing research work under the cooperative program is clearly indicated.

The 10-year program provides for research studies to continue on a moderate scale of about two- to three-man years of effort for each year of the plan. Starting in the 1965 fiscal year, more emphasis should be placed on the search for more refined methods of making direct estimates of the quantitative elements of the flow system. This pattern of effort is required for the scheduling and work on the comprehensive studies, starting in the 1969 fiscal year, and on specific-problem studies. It is hoped that the results of the several applied research studies will provide the necessary quantitative techniques for direct application in the detailed studies of the water resources of Nevada.

Topic Reports

As information on water resources accumulates areally and in detail, there will be a need to evaluate the data on a Statewide or regional basis to provide a broad base for the development, conservation, and management of the water resources of Nevada. Ordinarily the work would not involve a field study, but rather would be a compilation and analysis of available data for the specific purpose of the report. Thus, topic reports might include regional or Statewide analysis of runoff, low-flow analysis, recharge, ground-water storage capacity, occurrence and movement of ground water, discharge, and water quality. The reports might also include analysis of water use, or distribution of development in the State. An example of this type of report is Ground-Water Resources--Information Series, Report 1, "The Ground-Water Situation in Nevada, 1960", by O. J. Loeltz and G. T. Malmberg.

In response to the greater demand for water information of this type, it is proposed that an average of about one-man year of effort be provided for each year of the 10-year plan. Although circumstances may require a varying amount of effort on the topic reports, it is more than likely that the demand for information on a Statewide basis will increase as development and need for water information expand.

Short-Range Segments of the Program

The long-range program provides a broad framework or pattern of effort for the cooperation between the Nevada Department of Conservation and Natural Resources and the U.S. Geological Survey in the next 10 years. Because changes in emphasis and needs for water information doubtless will occur during the 10-year period, it seems logical to develop short-range programs, or segments of the long-range program, to permit successive adjustments of the distribution of effort. Thus, the short-range programs would be developed on a biennial basis to meet the needs at that time and to coincide with fiscal presentations to the State Legislature.

For the 1964-65 biennium the short-range program has already been prepared and is the same as the first two years of this 10-year plan. The average distribution of effort proposed by categories for the two years is about 27 percent for the continuing inventory, 22 percent for reconnaissance studies, 21 percent for areal studies, 4 percent for specific-problem studies, 18 percent for applied research (including the Humboldt River Research project), and 8 percent for topic reports. No comprehensive studies have been scheduled for the 1964-65 biennium.

In even more detail there is sufficient flexibility in the short-range program to allow for any adjustments that might be mutually agreed upon on an annual basis.

Estimated Cost of the Program

The funds provided for the cooperative program between the Nevada Department of Conservation and Natural Resources and the U. S. Geological Survey must be increased substantially if the required water information is to be obtained in the next 10 years. It can be expected that if the population, agriculture, and industry double in the next decade, the effort expended to help resolve the increasing water problems and to meet the need for water facts probably should more than double.

Figure 2 shows that the Nevada Legislative appropriations for the cooperative program for the 5-year period 1959-63 increased from about $40,000 to more than $80,000, or doubled in 5 fiscal years. For the period 1964-73, the 10-year plan proposes that the program be doubled again to meet the anticipated needs, with most of the increase beginning in the 1964 fiscal year and rising gradually to a maximum in the 1970, 1971, and 1972 fiscal years. For the period 1966-73 the costs are based on the 1962 dollar value. The dashed line suggests a rate of inflation, or increasing costs, of 3 percent per year. If this inflationary projection is reasonable, then legislative appropriations in the 1973 fiscal year would be somewhat more than $200,000 for the effort shown by categories on figure 1.

Although this estimate of costs is substantial, it seems to be entirely consistent with the expected population and industrial growth and with the probable requirements at that time. The per capita dollar cost of the program probably would be approximately the same as in 1962. Furthermore, an annual program of this magnitude has been shown to be warranted in several other states where water development has expanded at a rapid rate, such as that now being experienced in Nevada.