Water Consumption by Water-Loving Plants in the Malad Valley Oneida County, Idaho

By R. W. MOWER *and* R. L. NACE

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1412

A study of plant species and their distribution in relation to the geology and hydrology of their environment

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1957

UNITED STATES DEPARTMENT OF THE INTERIOR

Fred A. Seaton, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price 55 cents (paper cover)

CONTENTS

	Page
Abstract	1
Introduction	2
Purpose and scope	2
Location and extent of area	2
Agricultural and irrigation development	4
Field work and procedures	5
Idaho well-numbering system	7
Geology in relation to ground water	7
Water-loving plants in relation to water supply	10
Nature of the plants	10
Relation to total water supply in the Malad Valley	10
Types and distribution of water-loving plants	12
General characteristics and associations	12
Specific characteristics and associations	16
Consumption of water by phreatophytes and hydrophytes	19
Chemical quality of water	21
Phreatophytes and hydrophytes in relation to quality of soil and water	24
Quality of soil	24
Quality of water	26
Sources of water	28
Precipitation and surface water	28
Ground water	29
Salvage of water for beneficial use	30
Selected bibliography	30
Index	33

ILLUSTRATIONS

[Plates in pocket]

PLATE 1. Map of southern part of Malad Valley, Idaho, showing generalized distribution of phreatophytes.

2. Aerial photograph of a section of Malad Valley, showing typical phreatophyte areas.

	Page
FIGURE 1. Index map of southern Idaho	3
2. Index map of southeastern Oneida County	4
3. Well-numbering system	7
4. Percentage of area occupied by cattail in association with other plants	14
5. Percentage of area occupied by wire rush in association with other plants	14

		Page
Figure	6. Percentage of area occupied by cattail, adjusted to 100-percent density, in association with other plants	15
	7. Percentage of area occupied by wire rush, adjusted to 100-percent density, in association with other plants	15
	8. Chemical-quality classes of irrigation water in Malad Valley	27

TABLES

		Page
Table	1. Areas occupied by water-loving plants in Malad Valley	13
	2. Area-percentage relations of associated plant types	16
	3. Area-percentage relations of associated plant types (areas adjusted to 100-percent density)	16
	4. Sources of scientific names of water-loving plants in Malad Valley	17
	5. Seasonal evapotranspiration by water-loving plants in tank and lysimeter experiments	21
	6. Estimated consumption of water by water-loving plants in Malad Valley	21
	7. Chemical analyses of water from southern part of Malad Valley	22
	8. Assemblages of species of water-loving plants in some of the tracts outlined on plate 2	25
	9. Chemical analyses of soluble portion of soil from southern part of Malad Valley	25
	10. Chemical analyses of plants and soil from southern part of Malad Valley	26
	11. Examples of classification of irrigation water from southern part of Malad Valley	28

WATER CONSUMPTION BY WATER-LOVING PLANTS IN THE MALAD VALLEY, ONEIDA COUNTY, IDAHO

By R. W. MOWER and R. L. NACE

ABSTRACT

Nearly all available natural-flow surface water in the Malad Valley is appropriated for irrigation. Several small storage reservoirs on the Malad River and its tributaries add materially to the effective supply, and additional reservoir sites are available. The total surface-water supply, however, even with optimum development, would not be adequate for all irrigable lands in the valley. Several hundred flowing artesian wells and pumped nonartesian wells, and a few large springs, supply irrigation water for extensive tracts of land. Nevertheless, much of the irrigated land needs more water; also, additional dry lands could be irrigated if an adequate water supply were available. More efficient use of available water might be made by reducing low-value use by water-loving native vegetation. More profitable use of water could be achieved by eradication and control of low-value water-loving plants and substitution of vegetation having higher value.

In the southern part of the Malad Valley, water-loving plants occupy nearly 13,000 acres of land within an area of 25 square miles. In general, except for alfalfa, the economic value of these plants is low to nil. If profitable crops could be substituted, the economy of the Malad Valley would be benefited appreciably.

Sixteen species of water-loving plants in the Malad Valley consume water in amounts estimated to range from about 2 to 7.5 acre-feet per acre per year, and the estimated arithmetical average consumptive use is about 4.2 acre-feet. The total quantity of water consumed by these plants in the southern part of the valley is about 37,000 acre-feet a year. Alfalfa, the only high-value water-loving plant that is grown in the valley, consumes nearly 5,000 acre-feet of this water. The residual 32,000 acre-feet of water which is consumed by low-value vegetation would be adequate, in suitable circumstances, to irrigate 10,000 to 15,000 acres of profitable crops having lower water requirements.

Samples of water from 40 sources in the southern part of the Malad Valley have been chemically analyzed. The amount of dissolved solids in samples analyzed ranges from 254 to 5,130 ppm and the average is 970 ppm. The percent sodium ranges from 7 to 82 and the average is about 40. The electrical conductivity ranges from 429 to 8,760 micromhos at 25° C, and the average is about 1,580.

The soil in the area occupied by the water-loving plants is generally poor in quality, ranging from moderately to excessively saline or alkaline. No records have been found of changes in soil quality since irrigation began, although the inhabitants report that the soil quality in some tracts has been improved by the leaching action of water applied for irrigation. Some of the land that is now occupied by native vegetation reportedly once was barren and salt encrusted; this condition persists in some tracts.

The quality of the water that is available from sources in the area occupied by water-loving plants is generally poor for agriculture, though the quality of the water from some sources ranges from excellent to unsuitable. Much of the water would be usable for certain crops with the application of appropriately controlled irrigation methods.

Water consumed by vegetation is derived from soil moisture supplied directly by precipitation, from surface drainageways, springs and flowing artesian wells, and directly from the zone of saturation. Of the estimated 37,000 acre-feet of water that is consumed by the vegetation, about 5,000 acre-feet is soil moisture supplied directly by precipitation, about 3,500 acre-feet is from surface sources, about 14,500 acre-feet is from wells and springs, and about 14,000 acre-feet is withdrawn by the plants directly from the zone of saturation and the capillary fringe above the water table.

About 75 percent of the area occupied by water-loving plants is irrigated, including large areas where the water table or the capillary fringe above it is at or near the land surface. Eradication or control of nonbeneficial water-loving plants, substitution of high-value vegetation, and efficient management of water would assist reclamation of waterlogged land and cultivation of useful crops and might release for new irrigation some of the water that now is consumed by low-value vegetation.

INTRODUCTION

PURPOSE AND SCOPE

The purpose of this report is to present the results of an investigation of the water-loving plants growing in the Malad Valley, Oneida County, Idaho. The aim of the study was to determine the species of plants and their distribution in relation to the geology and hydrology of the environment. The study included determination of the area occupied by the plants, the density of their growth, the relative abundance of the individual types, estimation of the amount of water consumed by them, and consideration of the possibilities of salvaging water and of substituting vegetation. The results are presented as a preliminary report.

The study is part of the broad program of investigation by the U. S. Geological Survey of the occurrence of water-loving plants in the Western States and their relation to problems of water use and conservation. Ground-water studies in Idaho are under the general direction of A. N. Sayre, chief of the Ground Water Branch of the Geological Survey, Washington, D. C., and of Mark R. Kulp, Idaho State Reclamation Engineer, Boise, Idaho. Studies of water-loving plants in relation to water supplies are coordinated by T. W. Robinson, staff engineer, Menlo Park, Calif. Ground-water investigations in Idaho are supervised by R. L. Nace, district geologist, Boise, Idaho.

LOCATION AND EXTENT OF AREA

The Malad Valley in eastern Oneida County, Idaho, is bounded on the east by the Malad Range and on the west by the Blue Springs

Hills (fig. 1). On the north the valley is divided into two principal drainage systems which are separated by a spur of the Bannock Range. South of the Bannock Range the valley is an artesian ground-water basin which has a surface area of about 90 square miles. At its south end the valley is constricted between the Malad Range and spurs of the Blue Springs Hills.

The part of the Malad Valley described in this report includes about 25 square miles (16,000 acres) in parts of Tps. 14 to 16 S., Rs. 35 and

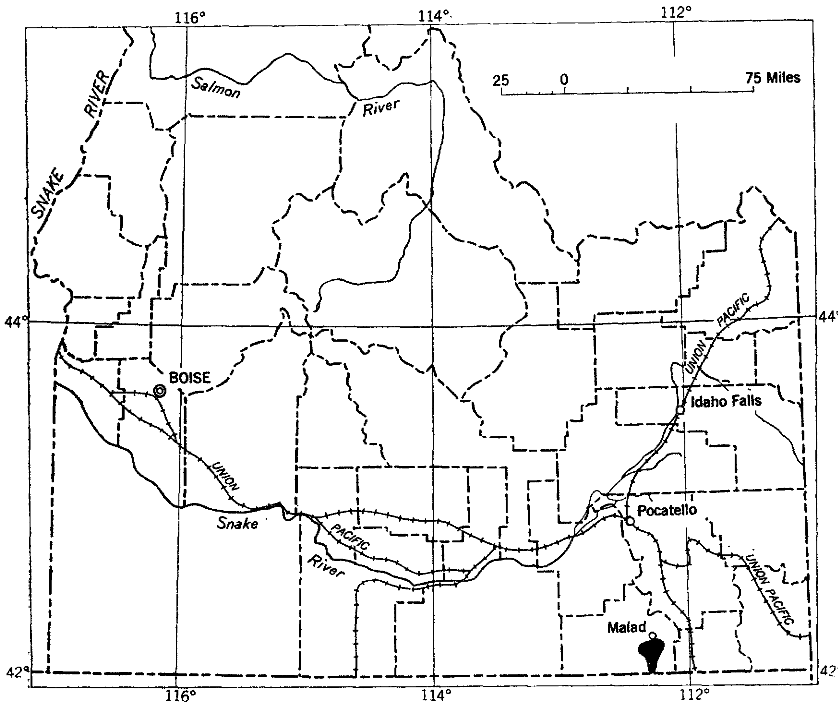

FIGURE 1.—Index map of southern Idaho, showing area covered by this report.

36 E., Boise baseline and meridian (fig. 2). In these townships about 12,860 acres, or slightly more than 20 square miles, is covered by water-loving plants. The principal area occupied by these plants ranges in width from about 1 mile on the south to about 6 miles on the north. Along stream channels north of this area small tracts of land are occupied by water-loving plants, but these tracts have not been mapped or studied. The unmapped area that is occupied by water-loving vegetation probably does not exceed a few hundred acres.

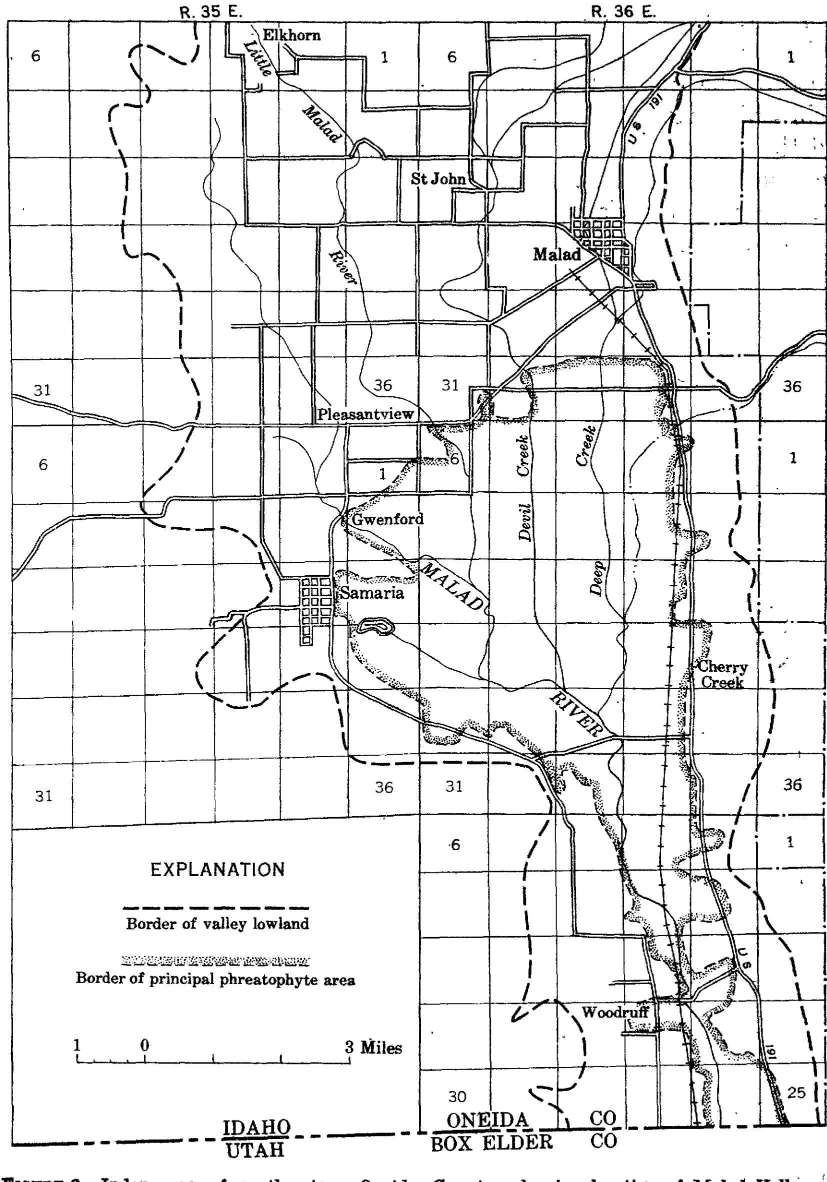

FIGURE 2.—Index map of southeastern Oneida County, showing location of Malad Valley and principal area occupied by water-loving vegetation.

AGRICULTURAL AND IRRIGATION DEVELOPMENT

The Malad Valley is an important and generally prosperous agricultural area. Potatoes and sugar beets are the principal irrigated row crops; wheat is the principal crop in irrigated valley-slope areas and foothill dry farms. Substantial amounts of alfalfa and other forage crops are grown also.

Agricultural development in the Malad Valley was begun about 1855 by a colony of pioneers. Within a few years nearly the entire natural flow of surface streams in the valley was being diverted for irrigation during the growing season. Further expansion was slow until about the turn of the century when the large potential yield of the artesian basin in the southern part of the valley was recognized. Thereafter many flowing wells were drilled to obtain irrigation water. Development of nonartesian water with pumped wells was begun about 1930, and substantial areas of new land are irrigated from these wells. Meanwhile, several small storage reservoirs had been constructed on small tributaries of the Malad River. Within the last 10 years three reservoirs have been rehabilitated and dams have been reconstructed at two others. The additional supply of stored water is used almost wholly to supplement the supply for land already under irrigation. Several other storage sites have been investigated with a view to future utilization if existing reservoirs become inadequate and if economic conditions justify constructing more reservoirs.

Surface-water users in Malad Valley are recognized for their proficiency in managing the comparatively small amount of water that is available from streams. The water users realize, however, that much improvement is possible in the distribution and control of surface water. Development and use of ground water has been largely by individuals, without much regard to the overall water economy of the valley. Thus, despite excessive applications of water to some parts of the valley, large tracts of arable land remain unirrigated because water has not been made available to them.

FIELD WORK AND PROCEDURES

Most of the field work on which this report is based was done in June and July 1952. A small area was mapped in May 1953. The best season for field study of water-loving plants in the Malad Valley is from about June 15 through July 31, when the plants are growing vigorously. By the end of July some of the species have reached maximum growth. Hay cutting in the area begins about August 1.

At the beginning of the field work a rapid reconnaissance was made to delineate the principal area that is occupied by water-loving plants, to determine the types of plants that are present, and to select representative areas containing plant stands of each species or combination of species approaching 100-percent density. The selection of representative areas was for the purpose of obtaining "type" stands of vegetation with which the density of growth in other areas could be

397768—57——2

compared. The areal density of growth is defined as the ratio of the area occupied by the plants to the total area in a given parcel of land. An areal density of 100 percent is a spacing of plants so closely that the addition of one new plant theoretically would crowd out an old plant of the same size. Most stands of vegetation have a density of less than 100 percent. In order to compare (1) the amounts of vegetation in different parcels of land, (2) the net area in each that is occupied by the plants, and (3) the amount of water consumed in each parcel, it is useful to "adjust" the density to 100 percent. For example, a 10-acre tract having a plant stand of 50-percent density is equivalent to a 5-acre tract having 100-percent plant-stand density. The writers believe that the use of this method (Gatewood and others, 1950) might lead to more consistency in the results of consumptive-use studies.

The plant-area subdivisions (pl. 1) were mapped on aerial photographs on a scale of 1:31,680. Plate 2 is an enlargement of one of the photographs, and on it a few areas that contain water-loving plants are outlined. Parcels of land were inspected to identify the plant types and assemblages, and a representative small plot in each parcel then was studied in detail. An estimate was made of the relative percentage and average height of each type in the parcels. Each entire parcel then was studied more carefully and the parcel boundary was traced on an aerial photograph. The perimeter of each parcel of land generally could be determined by ground inspection and also could be identified easily on the photographs because of the high contrast between the areas of water-loving plants. The shading on the photographs is caused by differences in the plant species and in their growth densities. When the boundaries of individual parcels were drawn, the parcels were numbered serially. Field notes show for each parcel the date of mapping, the kinds of plants present, their growth density, and the average height of each kind.

The following are typical field notes for a parcel:

Parcel No. 3: *Date: June 18, 1952*

Growth density: 75 percent.

Seaside arrowgrass: 2 to 2½ feet tall, comprises 60 percent of plants.
Wire rush: 1½ to 2 feet tall, 30 percent of plants.
Saltgrass: 6 inches tall, 10 percent of plants.

Parcel area: gross, 36 acres; adjusted to 100-percent density, 27 acres.

Adjusted area of seaside arrowgrass: 0.60 × 27=16.2 acres.
Adjusted area of wire rush: 0.30 × 27=8.1 acres.
Adjusted area of saltgrass: 0.10 × 27=2.7 acres.

The water-loving plants were mapped and studied by Mower, assisted by Glen Brandvold, in 1952–53. The geology and hydrology of the area were studied by Nace in previous years. Chemical analyses of the water samples were made by the Geological Survey at various times since 1931; those of the soil samples and plant specimens, by the U. S. Bureau of Reclamation in 1953.

IDAHO WELL-NUMBERING SYSTEM

The well-numbering system used in Idaho by the Geological Survey indicates the locations of wells within the official rectangular subdivision of the public lands, with reference to the Boise baseline and meridian. The first two segments of a number designate the township and range. The third segment gives the section number followed by two lowercase letters and a numeral which indicate the quarter section, the 40-acre tract, and the serial number of the well within the tract. Quarter sections are lettered *a, b, c,* and *d* in counterclockwise order, from the northeast quarter of each section (fig. 3). Within the quarter

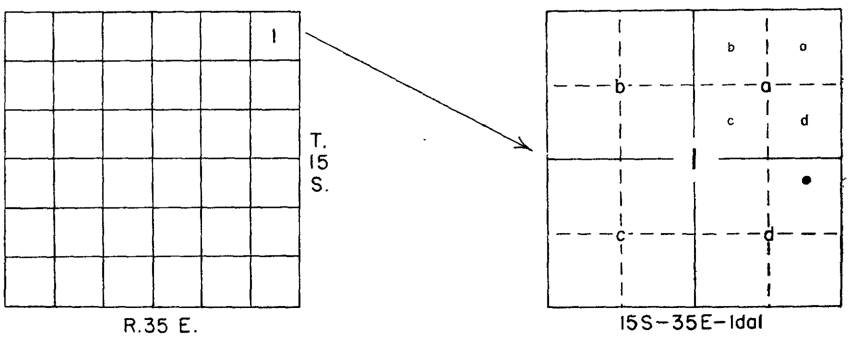

FIGURE 3.—Well-numbering system.

sections 40-acre tracts are lettered in the same manner. The digit following the letters indicates the order in which the wells were visited within the 40-acre tracts. Well 15S–35E–1da1 is in the NE¼SE¼ sec. 1, T. 15 S., R. 35 E. and is the well first visited in that tract. A modification of this numbering system is used to differentiate between objects investigated. A capital "*S*" following the two lowercase letters indicates a spring and a capital "*R*" indicates a sampling point on a river or other stream.

GEOLOGY IN RELATION TO GROUND WATER

The Malad Valley and surrounding mountains are part of the Basin and Range physiographic province. The mountains are composed principally of Paleozoic rocks, ranging in age from Cambrian (Brigham quartzite) to Pennsylvanian and Permian(?) (Wells formation). In the Malad Range the Salt Lake formation (Pliocene) is extensively exposed along the flanks of the range and at places extends across the crest. Rocks in the mountains were folded and faulted several times in the geologic past, but the dominant existing landforms are fault blocks that were formed in comparatively late geologic time. Horst and graben fault blocks dominate the regional geologic structure; the strike of most principal faults is slightly west of north but at least one major fault strikes about due west. The Malad Valley is an irregular, composite graben having a maximum width of about 8 miles from east to west. Formations exposed in surrounding mountains do not crop out in the floor of the valley except at the south end, where there are inliers of Paleozoic rocks. These ancient rocks undoubtedly occur beneath Cenozoic valley sediments forming an impermeable floor. Late Cenozoic sediments, chiefly the Lake Bonneville group (Quaternary), form most of the valley-floor area. Block faulting preceded deposition of the Lake Bonneville group, which covers the faults in many places. At the south end of the Malad Valley a major fault and conspicuous faultline scarp extend westward across the Blue Springs Hills. This fault is herein named the Woodruff fault, after Woodruff, the named place nearest the east end of the exposed fault trace. The fault trace is exposed 950 feet due north of the southeast corner of sec. 31, T. 15 S., R. 36 E. Eastward from there the fault trace was not definitely identified but it may be offset northward a few hundred feet along a transverse fault, and thereafter probably trends eastward or southeastward across the south end of the Malad Valley through inliers of Paleozoic rock and beneath beds of the Lake Bonneville group. Westward the fault is continuously exposed for about 8½ miles across the Blue Springs Hills into the Pocatello Valley, where it is covered by Quaternary gravel a few feet east of a road junction at the south quarter-corner of sec. 26, T. 15 S., R. 34 E. Downthrow along the fault is on the north but the displacement was not determined. Remnants of the eroded fault scarp, preserved as facets on hill spurs, are as much as a few score feet in height. The extension of this fault eastward across the constricted south end of the Malad Valley is one of the most important controlling geologic factors in the hydrology of the Malad Valley because the upthrown southern block of impermeable Paleozoic sedimentary rocks forms a closure of the south end of the basin. Probably some of the deeper water-bearing sediments in the Malad Valley abut against the fault block, which therefore is an element in the artesian structure of the basin.

Both the Bonneville and Provo shorelines of ancient Lake Bonneville, the precursor of Great Salt Lake, are well defined on foothill slopes surrounding the Malad Valley. The Bonneville shoreline extends far northward up the eastern and western branches of the valley. The Provo shoreline crosses the valley at the latitude of Malad City and was cut in the foreslope of an accumulation of sediment that probably began as a delta in the Bonneville stage. The delta beds were covered later with alluvial sand and gravel as the lake shore retreated to the Provo level.

The Lake Bonneville group is a sequence of sediments that accumulated beneath Lake Bonneville in Quaternary time. The group consists of layers, lenses, and tongues of permeable sand and gravel interbedded with less permeable to impermeable beds of silt and clay. The gravel beds are of small areal extent, generally fine grained, and commonly only a few inches thick. Silt and clay are the dominant sediments. Adjacent to the mountains, where coarser material might be expected, clay and silt commonly lap directly against Paleozoic rocks. An exception is the deltalike accumulation north of the Provo shoreline, at least part of which accumulated during the Bonneville stage. Coarse permeable sediments are more common there.

Beds deposited during the Provo stage are generally similar to those of the Bonneville stage, but the average grade size may be somewhat larger. Nearshore deposits, however, are not necessarily coarser than those of the Bonneville stage because wave action at many places merely caused reworking of sediments of Bonneville stage, which were redeposited.

The thickness of the Lake Bonneville group is not known. Wells exceeding 700 feet in depth do not reach bedrock. The group probably is underlain by permeable interglacial sediments confined between clay beds that were deposited in older lakes. Such beds have not been identified in well logs, and, so far as these logs and available evidence are concerned, the base of the Lake Bonneville group cannot be identified.

Artesian ground water occurs in the valley-fill sediments at depths ranging from a few tens of feet to more than 700 feet. The principal area of appreciable artesian pressure is south of the latitude of Malad City, where hundreds of wells tap aquifers in the Lake Bonneville group and perhaps in older beds. In the artesian area few or none of the confining beds are completely impermeable, and upward migration of artesian water through these beds is continuous in some areas, causing saturation of the ground to or nearly to the surface.

The artesian aquifers are recharged directly through their outcrops around the borders of the basin, by underflow from nonartesian aquifers that are continuous with or in contact with artesian beds, and by migration of water along faults that offset or are overlapped by the artesian beds. Considerable subsurface migration of artesian water takes place through uncased or leaky artesian wells.[1]

[1] Livingston, Penn, and McDonald, H. R., Underground leakage from artesian wells in Malad Valley, Idaho: Duplicated rept. (unpublished), 38 p., 4 pls. See p. 11-13, 17-18. [In files of U. S. Geol. Survey.]

Unconfined ground water also is tapped by a few irrigation wells. The most productive unconfined aquifers are in the deltalike area north of the Provo shoreline, where coarse delta and alluvial sediments store and transmit water readily. Recharge from precipitation and surface drainageways is accepted readily and these deposits probably transmit a large amount of water to artesian beds on the south.

The soil in the central lowland floor of the Malad Valley is very fine grained and was derived chiefly from sediments of the Lake Bonneville group and younger alluvial sediments. This soil is very low in permeability and, once wetted, does not drain readily. Extensive tracts are waterlogged and in large areas evaporation from the soil surface forms salt and alkali incrustations. The principal areas occupied by water loving plants are those having waterlogged fine soil and those where the water table or capillary fringe above the water table is on or near the surface.

It is not feasible at this time to delineate a "water table" in the area occupied by water-loving plants because a clear distinction has not been made between shallow, perched water tables and the main water table.

WATER-LOVING PLANTS IN RELATION TO WATER SUPPLY

NATURE OF THE PLANTS

In many parts of the Western States, large tracts of land are occupied by certain distinctive groups of plants which grow only where ground water occurs at shallow depth. This general group of water-loving plants was named "phreatophytes" (Meinzer, 1923, p. 55) derived from Greek word roots meaning "well" and "plant." Characteristically, phreatophytes extend their roots to the water table, or to the capillary fringe above it. The group is thus named for the fact that the plants commonly withdraw water from the zone of saturation, like a well.

Other types of water-loving plants live where the water table is on the land surface, or where water is ponded to shallow depth. These plants, which grow under water or have their roots under water, are called hydrophytes, derived from Greek word roots meaning "water" and "plant." Hydrophytes live only in water or in saturated soil where the water table is no more than 2 or 3 inches below the land surface during short, dry periods. Phreatophytes and hydrophytes may be referred to collectively as hydrophilic (water-loving) plants.

RELATION TO TOTAL WATER SUPPLY IN THE MALAD VALLEY

Water-loving plants are common in parts of the Malad Valley. The principal area of their occurrence is a group of sections aggregating about 25 square miles in the southern central part of the valley (pl. 1). It was selected for study because the area could be investigated in a single season and because the plants consume a substantial part of the somewhat limited supply of water.

Before the advent of irrigation in the Malad Valley, according to local tradition, water-loving plants already occupied substantial areas of land, and sizable tracts of soil were alkaline and saline. Irrigation disrupted the balance of natural ground-water recharge and discharge, surface runoff, and consumption of water, causing an increase in the area occupied by water-loving plants and possibly a spread of alkali. Hundreds of artesian wells have decreased the internal pressures that induce upward migration of water. However, nearly continuous flooding of large tracts of land with diverted surface water and with water from uncontrolled artesian wells causes saturation in thousands of acres of soil that is too fine grained to be drained naturally or artificially. Thus, much otherwise good land is waterlogged, usable only for pasture; much other land yields only low-grade hay, consisting largely of water-loving plants having low food value. The average water requirement of some of these plants is much higher than that of certain more desirable types of forage crop.

The total water supply, as it is now developed, distributed, and used, is not enough to supply all irrigable lands in the Malad Valley. Large supplies are available from artesian wells in the valley's bottom lands, but in border and foothill areas the ground-water supply is less dependable. Conservation and better management of ground water in the bottom lands might release surface water for border-area irrigation and, with eradication or control of nonbeneficial vegetation, might increase the effective total supply of water that is available from all sources for beneficial use. Reclamation of some lands that now serve only low orders of beneficial use also might be practicable. One effective means of conserving ground water would be with the use of substitute vegetation. Water-loving vegetation having low beneficial use might be replaced by cultivated phreatophytes having high beneficial use. For example, the area in which alfalfa is grown might be extended to replace low-value phreatophytes. Substitute plants must be adaptable to the quality of soil and water, the climate, and other environmental factors in the area where they are to be introduced. The subject of substitute vegetation, however, has been only partly investigated and a great deal of study is required to make vegetation substitution practical and economical. The Malad Valley, and many other valleys in the West, would benefit from agricultural research in methods of developing more valuable phreatophytes and the means of substituting them for native vegetation.

Controlled heavy pumping to lower the pressure in artesian wells, thereby decreasing the internal pressures that cause upward migration would reduce one source of water in waterlogged areas, but probably would not drain the land. Pressures would be lowered most by wells in the waterlogged area, but much of the pumped water might have to be piped elsewhere to be used effectively. Pumping of wells outside the waterlogged areas, on valley slopes near the recharge areas, would lower artesian pressures and provide water where it could be used. Reduction of pressures and of free artesian flow, however, might require considerable adjustment of water rights and use. Competition for water and conflicts of interest might discourage heavy pumping. Also, because of the low permeability of the soil in the waterlogged areas, the flatness of the land, and other generally poor drainage characteristics, as well as the high rate of application of water at the surface, the effectiveness of drainage by pumping is doubtful. The remedial measures most apt to be effective are the control of application of water to the land surface and substitution of vegetation.

TYPES AND DISTRIBUTION OF WATER-LOVING PLANTS

GENERAL CHARACTERISTICS AND ASSOCIATIONS

The distribution of water-loving plants in the southern part of the Malad Valley is shown on plate 1. The land parcels shown on the map were classified according to the general associations of plants that have similar water-loving characteristics or similar preferences or tolerances for special types of soil. Thus, the plants are approximate guides to the range of depths to the water table. Direct measurements of the depth to water were not made in each parcel of land. In general, alfalfa and rabbitbrush grow where the depth to water ranges from 10 to 35 feet; desert saltgrass, greasewood, and pickleweed grow where the depth to water is 1 to 10 feet and the soil is chiefly alkaline or saline; sedge, wire rush, marsh reedgrass, and desert saltgrass grow where the depth to water is 1 to 5 feet; rushes, cattails, and sedges grow where the depth to water is only a few inches, or where water is ponded to shallow depth during most of the growing season. In the Malad Valley, desert saltgrass grows also where the land surface is artificially flooded frequently during the irrigation season. Several other types of water-loving plants, such as watercress and "moss," occupy only small areas and their economic importance is so slight that they were not mapped or studied. The plants can be used only as approximate guides to the depth to the water table because the capillary fringe in fine-grained sediment is thick, and some phreatophytes can survive on this water above the water table.

Hay is harvested in about half the area that was studied; the other half is used only for pasture. The principal water-loving forage plants in the lowland are wire rush, threadleaf sedge, Nebraska sedge, desert saltgrass, and seaside arrowgrass. Much of the pasture land is too alkaline or saline to support more profitable crops.

Table 1 shows the gross area in which each type of phreatophyte and hydrophyte occurs in the parcels of land mapped, the net area occupied by each, and the net area for each type adjusted to 100-percent density. The density of the stand of vegetation varies considerably from parcel to parcel. The first column of the table lists the water-loving plants by name; the second column shows the number of parcels of appreciable size in which each type was sufficiently abundant to warrant mapping. The third column indicates the aggregate acreage in the parcels reported in column 2 (that is, the total area in which significant numbers of each plant occur). The fourth column shows the net area occupied by each type within the gross area of its occurrence. The fifth column states the number of acres occupied by each type, adjusted to 100-percent density. Cattails, for example, grow in 41 parcels having a gross area of 1,786 acres, of which 142 acres is occupied by cattail, representing the equivalent of 127 acres occupied by plants having a density of 100 percent.

TABLE 1.—*Areas occupied by water-loving plants in Malad Valley*

Plant type	Number of parcels of land [1]	Gross area (acres)	Net area (acres)	Net area, adjusted to 100-percent density (acres)
Alfalfa	89	2,479	1,918	1,200
Cattail	41	1,786	142	127
Cottonwood	2	19	19	14
Desert saltgrass	206	9,922	3,644	2,349
Giant wildrye	55	1,220	204	128
Greasewood	91	2,535	847	423
Marsh reedgrass	5	138	8	7
Pickleweed	42	1,257	354	96
Rabbitbrush	22	588	173	36
Rushes	57	2,210	279	226
Seaside arrowgrass	53	4,280	409	352
Sedge, Nebraska	41	3,745	511	391
Sedge, threadleaf	136	8,493	2,001	1,610
Wild rose	4	67	6	5
Willow	5	62	12	10
Wire rush	139	8,562	2,337	1,867
Rounded totals	(2)	(2)	12,860	8,840

[1] The total number of parcels of land mapped was 349.
[2] These columns are not totaled because the number of parcels and the gross area in which each plant occurs includes part or all of the area in which other types grow.

397768—57——3

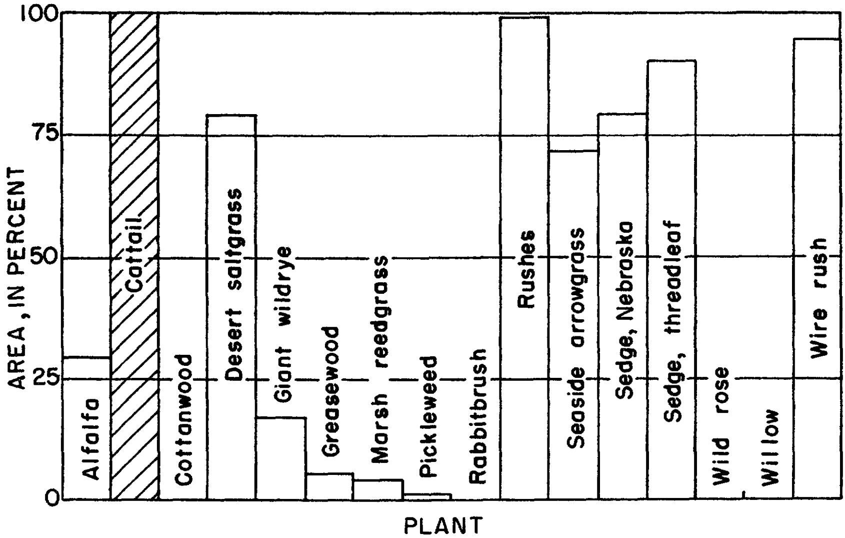

FIGURE 4.—Percentage of area occupied by cattail in association with other plants.

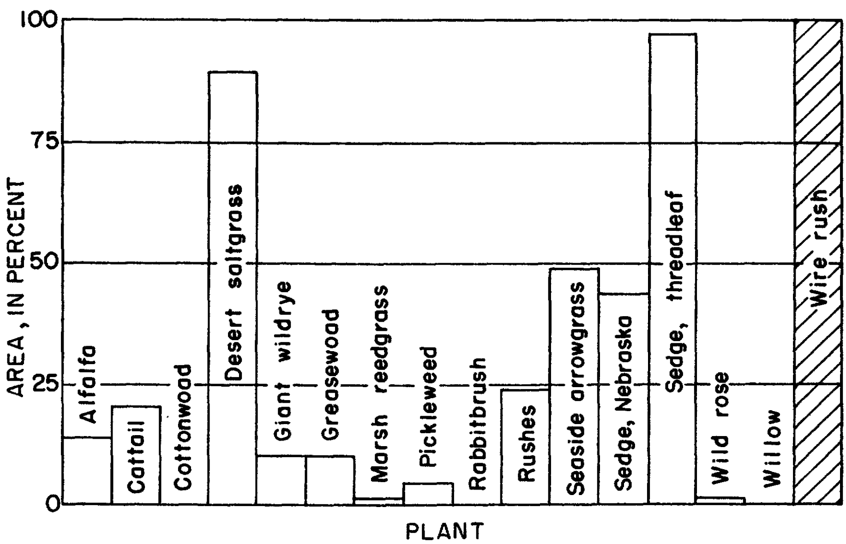

FIGURE 5.—Percentage of area occupied by wire rush in association with other plants.

Table 2 shows the associations of plant types as an area-percentage relationship. Table 3 shows the associations in the same way, but the areas are adjusted to 100-percent density. A principal value of tables 2 and 3 is that they reflect the influence of local minor environmental factors on the distribution of the plant species. In general, for example, reading from left to right and up, a plant having a low

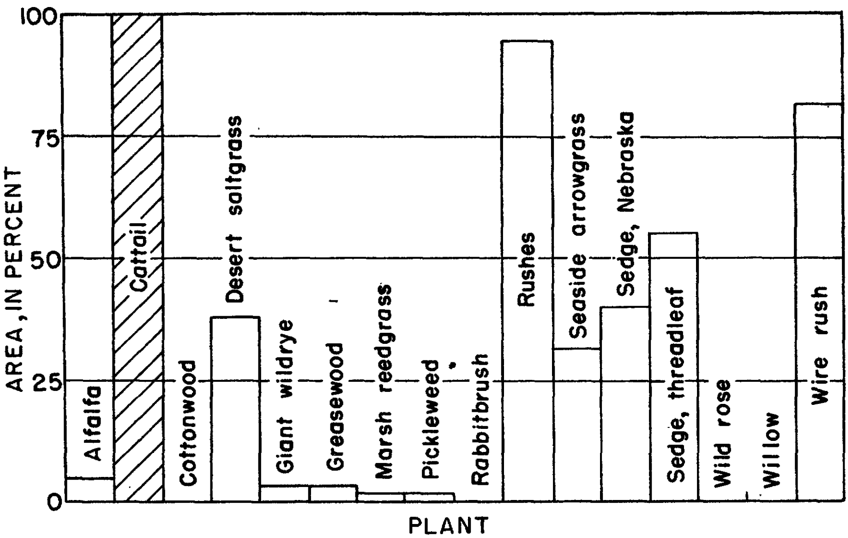

FIGURE 6.—Percentage of area occupied by cattail, adjusted to 100-percent density, in association with other plants.

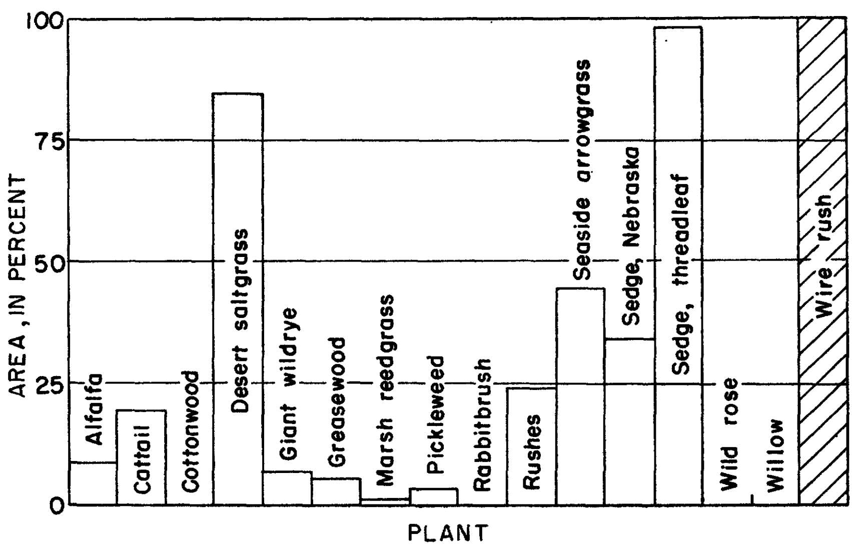

FIGURE 7.—Percentage of area occupied by wire rush, adjusted to 100-percent density, in association with other plants.

percentage association with another plant is not in the environment in which it normally grows. Some associations, such as that of rushes and pickleweed, are less real than apparent. The plants do not grow together intimately, but occur in adjacent or alternate tracts that are too small to be mapped separately on the scale used. Figures 4, 5, 6, and 7 illustrate graphically some of the data shown in tables 2 and 3.

TABLE 2.—*Area-percentage relations of associated plant types*

[Percentage of the area occupied by one plant type that is occupied in association with other types. Read from left to right and up]

	Alfalfa	Cattail	Cottonwood	Desert saltgrass	Giant wildrye	Greasewood	Marsh reedgrass	Pickleweed	Rabbitbrush	Rushes	Seaside arrowgrass	Sedge, Nebraska	Sedge, threadleaf	Wild rose	Willow	Wire rush
Alfalfa	100	21	0	47	27	14	2	5	2	21	18	33	44	0	0	45
Cattail	29	100	0	78	17	5	4	1	0	99	71	78	90	0	0	94
Cottonwood	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Desert saltgrass	12	14	0	100	10	25	1	12	4	18	36	33	77	1	1	77
Giant wildrye	55	25	0	79	100	25	5	1	10	26	26	46	64	4	0	73
Greasewood	14	3	0	96	13	100	2	32	17	3	8	12	32	0	0	33
Marsh reedgrass	41	54	0	100	41	41	100	28	0	71	37	54	90	0	0	100
Pickleweed	10	2	0	93	0	64	3	100	0	2	16	9	17	0	0	31
Rabbitbrush	7	0	0	67	20	73	0	1	100	0	0	2	0	0	0	5
Rushes	24	80	0	80	14	4	2	1	0	100	61	63	88	1	0	89
Seaside arrowgrass	10	30	0	83	7	4	1	5	0	31	100	60	49	0	0	96
Sedge, Nebraska	22	37	0	88	15	8	2	3	0	37	68	100	98	0	0	99
Sedge, threadleaf	13	19	0	89	9	10	1	3	0	23	98	43	100	0	0	97
Wild rose	0	0	0	92	79	0	0	0	0	21	0	17	35	100	18	96
Willow	0	5	0	90	5	0	0	0	0	18	0	18	18	17	100	18
Wire rush	13	20	0	89	10	10	1	4	0	23	48	43	96	1	0	100

TABLE 3.—*Area-percentage relations of associated plant types*

[Areas adjusted to 100-percent density. Read from left to right and up]

	Alfalfa	Cattail	Cottonwood	Desert saltgrass	Giant wildrye	Greasewood	Marsh reedgrass	Pickleweed	Rabbitbrush	Rushes	Seaside arrowgrass	Sedge, Nebraska	Sedge, threadleaf	Wild rose	Willow	Wire rush
Alfalfa	100	1	0	12	5	4	0	0	0	2	0	5	8	0	0	5
Cattail	5	100	0	38	3	3	2	2	0	94	31	40	55	0	0	81
Cottonwood	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Desert saltgrass	9	13	0	100	7	2	1	1	1	21	37	36	83	1	1	54
Giant wildrye	11	2	0	50	100	29	1	0	6	1	10	5	32	2	1	36
Greasewood	4	0	0	93	10	100	0	17	9	1	1	9	6	0	0	10
Marsh reedgrass	0	29	0	100	21	83	100	6	0	94	14	3	41	0	0	100
Pickleweed	4	1	0	81	0	52	0	100	0	1	5	5	7	0	0	9
Rabbitbrush	2	0	0	36	26	52	0	0	100	0	0	1	1	0	0	0
Rushes	3	87	0	38	2	2	3	1	0	100	21	22	59	1	0	75
Seaside arrowgrass	3	12	0	67	4	6	1	7	0	13	100	25	93	0	0	88
Sedge, Nebraska	14	32	0	87	8	3	1	2	0	32	78	100	98	0	1	97
Sedge, threadleaf	9	16	0	83	7	3	2	3	0	19	64	38	100	1	0	99
Wild rose	0	0	0	72	23	0	0	0	0	70	0	53	72	100	0	72
Willow	0	0	0	62	0	0	0	0	0	44	0	16	61	44	100	60
Wire rush	8	19	0	84	7	5	1	3	0	24	44	34	98	0	0	100

SPECIFIC CHARACTERISTICS AND ASSOCIATIONS

General descriptions of each of the water-loving types of plants that grow in the Malad Valley are given below. The growth habits and other plant characteristics that are noted include the plant associations, the usefulness of types, the depth to which each sends roots to obtain water, and the tolerance of each for alkaline and saline soils. More complete descriptions are given by Meinzer (1927), the U. S. Forest Service (1937), and Hitchcock (1950). The authorities for the identification of plants are given in table 4.

TABLE 4.—*Sources of scientific names of water-loving plants in Malad Valley*

[Spelling and form as given in Webster's International Dictionary, 2d ed., unabridged, 1951. Citations are to list of references at end of report]

Common or local name	Scientific name	Authority	Section reference
Alfalfa	*Medicago sativa*	U. S. Forest Service (1937)	W 121
Cattail	*Typha* spp	U. S. Dept. Agriculture (1948)	[1] 841
Cottonwood	*Populus* spp	U. S. Forest Service (1937)	
Desert saltgrass	*Distichlis stricta* [2]	Hitchcock (1950)	[1] 177
Giant wildrye (ryegrass)	*Elymus condensatus*	U. S. Forest Service (1937)	G 52
Greasewood	*Sarcobatus vermiculatus*	do	B 54
Marsh reedgrass	*Calamagrostis inexpansa*	do	G 40
Pickleweed	*Allenrolfea occidentalis*	White (1932)	[1] 17
Rabbitbrush (broom sage)	*Chrysothamnus nauseosus*	U. S. Forest Service (1937)	B 54
Rushes (bulrushes)	*Juncus* spp	do	GL 14
Seaside arrowgrass	*Triglochin maritima*	do	GL 17
Sedge, Nebraska	*Carex nebrascensis*	do	GL 7
threadleaf	*Carex filifolia*	do	GL 5
Wild rose	*Rosa* spp	do	B 135
Willow	*Salix fluviatilis*	do	B 141
Wire rush (wiregrass)	*Juncus balticus*	do	GL 14

[1] Page reference only.
[2] Identified as *D. spicata* in many published reports. *D. spicata* is seashore saltgrass and grows only along the Pacific Coast and Coastal Plain of Texas (Hitchcock, 1950).

Alfalfa.—Alfalfa, *Medicago sativa,* is an economically valuable plant and is for that reason sometimes omitted from lists of phreatophytes, a word which commonly connotes "nuisance" plants. Alfalfa grows best on a neutral to moderately salty soil where the water table is from about 10 to 25 feet below the land surface. Alfalfa occupies about 15 percent of the phreatophyte area in the valley.

Desert saltgrass.—Saltgrass, *Distichlis stricta,* the most abundant phreatophyte in the Malad Valley, is present in about 9,920 acres (table 1), and the area adjusted to 100-percent density is about 2,350 acres. Saltgrass grows in all parts of the phreatophyte area, on all types of soils, and is associated with all the other species of phreatophytes (table 3). The heaviest growths are at places where the depth to water is less than a foot. Individual plants were observed, however, in places where the depth to water ranged from 0 to more than 10 feet below the land surface.

Giant wildrye.—Giant wildrye, *Elymus condensatus,* a phreatophyte having moderate beneficial use, makes good forage while young, and is fair winter forage. The most vigorous plants in the Malad Valley grow where the depth to water ranges from about 5 to 8 feet below the land surface, but plants were observed growing where the depth to water ranged from less than a foot to more than 15 feet.

Greasewood.—Greasewood, *Sarcobatus vermiculatus,* is a worthless phreatophyte which may be toxic to animals where it is the chief element in forage. The healthiest plants were observed growing where the depth to water below the land surface ranged from about 5 to 8 feet, and where the soil was moderately saline. Individual plants were growing where the depth to water ranged from 1 to more than 12 feet.

Marsh reedgrass.—Marsh reedgrass, *Calamagrostis inexpansa*, is a poor forage and hay plant of which only a small quantity grows in the Malad Valley. The plant probably should be classed as a phreatophyte. In the Malad Valley it grows where the depth to the water table at the time of observations was less than 3 feet, on soil that was relatively free of alkali and salt.

Pickleweed.—Pickleweed, *Allenrolfea occidentalis*, an apparently worthless phreatophyte, generally grows on soil that is too saline for most other plants. It was observed growing where the depth to water was less than about 8 feet. Two distinct sizes of pickleweed grow in the Malad Valley. Plants that tap ground water grow to a height of about 2 feet and have a root system that extends to a depth of several feet. These plants grow sparsely and have a density that generally is less than 25 percent. Small pickleweed plants, about 3 to 4 inches tall and having shallow root systems, grow profusely in several greasewood parcels of land. Evidently they are juvenile plants for which the available soil moisture is adequate for initial growth in the spring. Dead patches of these small plants, which occur throughout the pickleweed parcels, seemingly indicate that before their roots reach the water table the amount of soil moisture near the surface becomes too small to allow survival.

Rabbitbrush.—Rabbitbrush (broom sage), *Chrysothamnus nauseosus*, a phreatophyte that is worthless as a forage plant, is a conservative water user and occupies only a small area in the Malad Valley. Healthy, vigorous plants indicate a neutral to moderately salty soil where the depth to water is about 8 to 35 feet.

Rushes and cattail.—Rushes (sometimes called bulrushes), *Juncus* sp., and cattail, *Typha* sp., are hydrophytes that thrive under like conditions and therefore generally are associated. Table 3 shows that 94 percent of the rushes grow with cattail and that 87 percent of the cattail grows with rushes. They are associated with sedge and desert saltgrass on some of the irrigated tracts where the water is ponded during most of the growing season. Although rushes and cattail are practically worthless for feed, they grow on several hundred acres of hay land in the Malad Valley. Where the percentage associated with the more desirable sedge and desert saltgrass is low, however, rushes and cattail do not detract seriously from the food value of the forage.

Seaside arrowgrass.—Arrowgrass, *Triglochin maritima*, grows profusely as a phreatophyte in the Malad Valley in a total net area of about 400 acres, dispersed in a gross area of about 4,280 acres. The plant has a saline taste. Though succulent, the growing young plants concentrate hydrocyanic acid, an active poison, in their leaves. Sickness or death results if a toxic dose is consumed in a short time. The cut plant can be used for hay because much of the toxicity is lost during drying. Chemical analyses of plants show a high saline content. The most vigorous growths were observed on saline soil where the depth to water was less than 2 feet and where irrigation water was applied.

Sedge.—The hydrophytes threadleaf sedge, *Carex filifolia,* and Nebraska sedge, *C. nebrascensis,* are two of the chief components in hay and pasture lands in the Malad Valley, although they have only fair nutritive value and palatability. The more vigorous growths of sedge are on nearly neutral soils where the depth to ground water is less than 3 feet and where irrigation water is applied.

Wild rose, willow, and cottonwood.—Species of wild rose, *Rosa* sp., willow, *Salix fluviatilis,* and cottonwood, *Populus* sp., constitute only a small percentage of all the phreatophytes and are insignificant in the water economy of the valley. The plants provide some shelter for animals, and cottonwood is used extensively for windbreaks.

Wire rush.—Wire rush (sometimes called wiregrass), *Juncus balticus,* grows in most of the phreatophyte area and is one of the principal hay plants. Generally it makes good hay and a fair forage crop when it is mixed with 80 percent or more of other more palatable plants. The root system of wire rush is deep, but the plant thrives best where the water table or capillary fringe is within a few inches of the land surface. Hence the plant probably should be classed as a hydrophyte. Wire rush ordinarily prefers neutral or acid soils, but in the Malad Valley the plants seem to be healthy and vigorous on saline or alkaline soils where there is a plentiful supply of water.

CONSUMPTION OF WATER BY PHREATOPHYTES AND HYDROPHYTES

Compared to useful plants, most of the undesirable phreatophytes consume large amounts of water (Robinson, 1953). Moreover, hydrophytes occupy areas that are under ponded water or are only slightly above the water table, where water loss by evapotranspiration is even higher than in phreatophyte areas. In general, a substantial growth of native phreatophytes or hydrophytes is evidence that water is being wasted.

Direct measurements have not been made of the amount of water consumed by phreatophytes and hydrophytes in the Malad Valley. Studies elsewhere (Stearns and Bryan, 1925; White, 1932), in areas of similar climate, however, indicate the probable approximate amount of water that is consumed by water-loving plants in the Malad Valley and afford a basis for estimating their total consumption (table 6).

Direct measurements have not been made in the Malad Valley of rates of evapotranspiration. Though studies and measurements have been made in other areas having a similar climate, such measurements are lacking for some types of water-loving plants that grow in the Malad Valley. The published results of representative experimental studies elsewhere are summarized in table 5. Rates of evapotranspiration for areas occupied by plants that are not listed in the table either were not found in the literature or have been reported only for areas markedly different in climate from the Malad Valley. The rates estimated for the Malad Valley (table 6) differ substantially from those in table 5, for the following reasons:

First, in experimental studies of evapotranspiration, rates commonly are measured only from April or May to September or October, the period of most active plant growth. Evapotranspiration is much slower during other parts of the year, but is appreciable and should be included in estimates of total water depletion. Second, when vegetation is transplanted to experimental tanks, disturbance of the root system and natural environmental factors occurs, interfering with plant growth and reducing evapotranspiration. Third, the density of plant growth is an important factor in the rate of evapotranspiration, and "evapotranspiration rate" has little meaning unless plant density is specified. Experimenters commonly attempt to duplicate in tanks the density of natural growth in the experimental area. The results, though useful, do not permit direct comparison of separate areas. To facilitate areal comparisons and rate estimates for new areas where measurements have not been made, the writers believe that evapotranspiration rates should be determined for plant growths of 100-percent density. Using these rates and other factors as guides, field estimates of actual water depletion in other areas could be made by adjusting for the observed density in those areas.

The rates shown in table 6 are estimates based partly on a survey of published data and partly on personal judgment. During the field work special attention was given to plants about which little information is available. The general characteristics, growth habits, associated plants, and preferred environment were noted. Likely evapotranspiration rates then were estimated for plants under the climatic conditions of the Malad Valley, adjusted to 100-percent density of plant stands. The rates are subject to future revision but are believed to be reasonably approximate for the Malad Valley.

The estimated rate of water consumption by water-loving plants in the Malad Valley, adjusted to 100-percent plant density, ranges from 2 to 7.5 feet a year, and the arithmetic average for 16 types is about 4.2 feet. The total consumption of water is about 37,000 acre-feet a year, of which about 4,800 acre-feet is consumed beneficially by alfalfa.

TABLE 5.—*Seasonal evapotranspiration by water-loving plants in tank and lysimeter experiments*

Type of plant	Locality	Period of measurements	Evapotranspiration		Source of data
			Inches	Feet	
Alfalfa	Escalante Valley, Utah.	Apr.–Oct. 1927	25.9	2.2	White (1932).
Do	Vernal, Utah	May 17–Oct. 6, 1948	43.3	3.6	Barrett and Milligan (1953).
Do	do	May 31–Nov. 5, 1948	29.8	2.5	Do.
Do	do	Apr. 12–Oct. 28, 1950	39.5	3.3	Do.
Cattail	Bonners Ferry, Idaho.	May–Sept. 1934–44	61.6	5.1	Criddle and Marr (1945).
Greasewood	Escalante Valley, Utah.	May–Oct. 1928	25.2	2.1	White (1932).
Rushes	Fort Collins, Colo	Jul.–Oct. 1930	52.6	4.4	Young and Blaney (1942).
Saltgrass	Escalante Valley, Utah.	May–Oct. 1927	22.6	1.9	White (1932).
Do	Vernal, Utah	Apr. 14–Oct. 28, 1950	[1] 23.7	2.0	Barrett and Milligan (1953).
Do [2]	do	do	[3] 37.3	3.1	Do.
"Sedge grass"	Fort Collins, Colo	May–Oct. 1930	53.6	4.6	Young and Blaney (1942).
Do	Isleta, N. Mex	Jun. 1936–May 1937	76.9	6.4	Blaney and others (1938).
Tules [4]	Mud Lake, Idaho	Jun. 12–Sept. 23, 1921	51.4	4.3	Stearns (1925).
Do	do	May 24–Sept. 30, 1922	63.4	5.3	Do.
Do	Grays Lake, Idaho	Jun. 22–Sept. 30, 1942–44	61.6	5.1	Criddle and Marr (1945).

[1] Depth to water was 2 feet.
[2] Some wire rush was included with the saltgrass.
[3] Depth to water was 0.5 foot after August 1.
[4] "Tules" is a common western name for a thick growth of rushes or cattail or both.

TABLE 6.—*Estimated consumption of water by water-loving plants in Malad Valley*

Plant	Rate of evapotranspiration (feet/year)	Amount of water consumed (acre-feet/year)	Net area adjusted to 100-percent density (acres)
Alfalfa	4	4,800	1,200
Cattail	7.5	950	127
Cottonwood	4.5	60	14
Giant wildrye	3.5	450	128
Greasewood	2.25	950	423
Marsh reedgrass	5	40	7
Pickleweed	3	290	96
Rabbitbrush	2	70	36
Rushes	7	1,580	226
Saltgrass	3	7,050	2,349
Seaside arrowgrass	5	1,760	352
Sedge, Nebraska	4.5	1,760	391
threadleaf	5	8,050	1,610
Wild rose	2.5	10	5
Willow	2.67	20	10
Wire rush	5	9,330	1,867
Rounded total		37,170	

CHEMICAL QUALITY OF WATER

Chemical analyses of water from 40 sources in and near the area of phreatophytes and hydrophytes in the Malad Valley were made by the Geological Survey from 1931 to 1952. Table 7 shows the results of analyses of water from 34 wells, 4 springs, and 2 locations in the Malad River. The location from which water samples were collected

TABLE 7.—*Chemical analyses of water from southern part of Malad Valley*

[Analyses by U. S. Geological Survey. Parts per million, except as indicated]

No. on fig. 3	Well or spring no. and location	Date of collection	Artesian pressure (ft. above land surface)	Discharge of well or spring (gpm)	Specific conductance (micromhos at 25° C.)	Temperature (° F.)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium +potassium (NA+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Parts per million	Dissolved solids: Tons per acre-foot	Hardness as $CaCO_3$	Percent sodium
	Flowing artesian wells																		
1	14S-36E-32da1	4-6-49	1.2	7	1,090	50	35	------	161	35	33	492	126	42	31	705	0.96	546	11
2	33da1	10-15-47	4.3	1	1,900	53	37	------	78	14	322	514	27	355	3.5	1,090	1.48	252	73
3	15S-35E-1da1	8-27-47	24.5	15	468	------	61	------	52	20	19	245	12	27	1.4	313	.43	212	16
4	1db1	4-7-49	17.4	28	475	57	56	------	53	21	17	242	15	28	1.3	310	.42	218	14
5	11ac5	10-17-47	5.9	18	678	53	59	------	62	22	47	276	23	69	.8	419	.57	245	29
6	12ab2	4-7-49	18.5	60	598	54	40	------	71	19	33	296	29	38	.7	376	.51	255	22
7	12bb1	4-7-49	4.8	2	1,080	56	45	------	110	38	54	306	71	158	1.0	628	.85	430	21
8	14ad1	4-7-49	6.0	2	634	56	30	------	59	21	42	256	22	65	.7	366	.50	234	24
9	15S-36E-3ac1	9-7-31	8.2	7	[1] 3,080	54	36	0.23	141	51	615	658	21	948	.9	2,160	2.92	562	70
10	3ac1	10-17-47	3.2	10	3,540	53	42	------	119	45	606	658	33	865	6.3	2,040	2.77	482	73
11	4bb2	10-15-47	13.8	------	796	49	36	------	81	19	72	420	28	35	16	494	.67	280	36
12	4da1	8-26-47	15.5	135	3,500	------	39	------	96	20	665	793	30	765	10	2,020	2.75	322	82
13	4db1	8-27-47	13.5	120	1,970	------	32	------	57	13	382	624	34	330	17	1,170	1.59	196	80
14	5aa1	12-5-31	1.4	15	[1] 587	49	13	.08	56	33	31	253	46	47	.4	411	.59	275	20
15	5aa4	10-15-47	13.8	12	955	50	37	------	131	27	41	440	93	39	18	603	.82	438	17
16	5aa4	4-7-49	12.7	------	958	49	33	------	134	28	36	436	93	35	29	603	.82	450	15
17	5ac2	4-7-49	7.3	7	491	54	36	------	62	15	18	259	14	20	1.9	294	.40	216	15
18	6ba1	4-6-49	15.1	19	457	56	46	------	55	17	17	254	14	15	.2	289	.39	207	15
19	8aa1	4-7-49	16.5	------	879	50	34	------	76	14	103	393	74	40	20	555	.75	247	47
20	8aa1	3-20-52	24.0	------	957	52	31	.02	88	20	115	423	99	41	29	626	.86	302	40
21	8aa5	8-27-47	25.1	200	861	------	43	------	87	24	58	314	13	120	2.2	502	.61	316	28
22	8bd2	8-27-47	10.4	------	724	------	41	------	88	18	43	345	35	45	5.8	446	.61	294	24
23	8dc1	8-27-47	9.9	125	816	------	36	------	72	16	92	380	49	51	14	517	.70	246	45
24	9bc1	9-8-31	15.8	200	[1] 817	52	34	.29	32	7.9	162	407	47	56	4.3	572	.80	112	46
25	9bd2	8-27-47	28.3	86	3,320	------	42	------	166	45	512	719	21	780	1.0	1,920	2.61	559	65
26	9bd3	8-27-47	12.3	86	1,990	------	30	------	52	12	382	644	30	310	17	1,150	1.56	179	82
27	10ad1	10-17-47	10.2	------	2,480	54	28	------	137	63	306	504	25	585	2.9	1,400	1.90	601	52
28	10bc1	8-27-47	16.2	130	5,710	------	48	------	208	55	999	879	22	1,540	2.6	3,310	4.50	745	74
29	10dc2	8-28-47	10.0	75	1,100	------	21	------	74	41	99	318	22	200	2.3	616	.84	353	38
30	10dd1	8-28-47	16.5	50	1,940	------	26	------	110	67	189	338	19	470	.9	1,050	1,43	550	42
31	15aa1	8-28-47	17.2	------	507	------	28	------	48	28	21	270	17	28	2.3	305	.41	235	16
32	22ab1	8-28-47	19.7	2	506	------	27	------	48	27	21	266	16	28	2.3	300	.41	231	16
33	27cc1	9-7-31	16.5	2	[1] 529	------	49	.22	56	29	27	287	15	47	.2	370	.50	259	18
34	28dd1	10-17-47	+	5	2,630	55	68	------	125	33	400	532	4.9	620	2.4	1,520	2.07	448	66
35	29ca2	4-7-49	12.0	1	456	58	92	------	48	15	29	240	11	25	.4	339	.46	182	25
36	30ab1	4-7-49	13.7	5	534	58	82	------	58	15	33	232	16	50	.0	368	.50	206	25
37	30ab2	4-7-49	11.5	5	529	57	94	------	58	13	35	230	15	50	.0	378	.51	198	27

Springs																			
38	14S-35E- 9adS1	9-24-31	----------	2,250	[1] 461	72	19	------	68	24	9.2	256	24	38	0.06	323	0.42	268	7
39	15S-35E- 3aaS1	9-24-31	----------	3,000	[1] 1,800	-------	22	0.32	118	35	284	343	112	466	.6	1,260	1.71	438	58
40	3aaS1	8-27-47	----------	3,900	2,120	-------	23	------	118	35	340	338	241	460	2.2	1,390	1.89	438	62
41	14d S1	7-25-43	----------	2,000	--------	-------	-------	------	------	------	----------	264	22	76	------	------	------	------	------
42	16S3-6E-10bbS1	10-17-47	----------	8,100	8,760	89	34	------	234	122	1,570	588	66	2,780	30	5,130	6.98	1,090	76
Malad River																			
43	15S-36E- 28R1	[2]12- 3-31	----------	----------	1,740	32	23	.16	126	59	212	394	214	326	0.4	1,220	1.68	557	45
44	16S-36E- 22R1	[3]12- 3-31	----------	----------	3,600	41	28	.14	132	62	703	425	146	1,125	.4	2,520	3.47	584	72

[1] Electrical conductivity computed by the approximate relationship, ppm/0.7.
[2] Malad River at Cherry Creek Lane crossing, 4.25 miles upstream from Woodruff Springs.
[3] Malad River at Woodruff Lane crossing, 3.4 river miles downstream from Woodruff Springs.

is shown on the accompanying map (pl. 1), except for spring 14S–35E–9aaS1, which is about 4.5 miles north of the northwest corner of the map.

For some samples the electrical conductivity of the water was measured in the laboratory; for others this factor was computed from tables. The percent sodium in all samples was computed, and the computed values may not coincide with the true values because sodium and potassium, which were not determined separately, were calculated together as sodium. The proportion of potassium to sodium in these water samples, however, is generally small; therefore, the total error is small. The quality of water, in terms of percent sodium, is somewhat better than is apparent from the table.

PHREATOPHYTES AND HYDROPHYTES IN RELATION TO QUALITY OF SOIL AND WATER

QUALITY OF SOIL

The soil in the southern part of the Malad Valley is moderately to excessively alkaline or saline. Substantial areas of land reportedly were alkaline or saline before agricultural development began, and some local residents report that the general quality of some tracts of soil is being improved by the leaching action or irrigation water. The quality of the soil reportedly has improved considerably in tract 1 (pl. 2). Before the Malad Valley was developed agriculturally, tract 1 is said to have been salt encrusted and almost barren, but it now contains one of the heaviest growths of water-loving plants in the valley (table 8). For many years the tract has been flooded continuously during the growing season and the salts possibly are being leached gradually from the soil. Several other tracts reportedly are being improved by leaching. It is not known whether the leached salts are carried out of the valley in surface water or whether they are redeposited in other parts of the valley.

The valley still contains tracts of almost barren salty land. Tract 7 (pl. 2) is a typical example in which the generally flat surface contains scattered low mounds, some of which appear as dark spots on the aerial photograph. The mounds range from about 5 to 25 feet in diameter and from about 3 to 6 feet in height. Areas between the mounds are encrusted with salt and support only a sparse growth of pickleweed. The pickleweed grows on about the lower 2 feet of the mounds; greasewood grows above the pickleweed. The soil in the mounds is of better quality than that in the flat areas, owing to the fact that it is above the capillary fringe of the water table and that it is leached by rainwater.

TABLE 8.—*Assemblages of species of water-loving plants in some of the tracts outlined on plate 2*

Tract no.	Density of growth (percent)	Area (acres)	Area, in acres, occupied by plant types								
			Cattail	Rushes	Wire rush	Sedge, threadleaf	Sedge, Nebraska	Desert saltgrass	Seaside arrowgrass	Greasewood	Pickleweed
1	85	540	147	135	27	27	14	188		2	
2	70	67			2.4	2.3		60		2.3	
3	75	36			10.8			3.6	21.6		
4	55	27.6						27.6			
5	25	30.4						15.2			15.2
6	50	26.4						8		15.8	2.6
7	20	60.4								6	54.4
8	90	656			295	99		262			
9	95	205			82	82			41		
10	90	11.4			6.9	3.4		1.1			
11	90	105			42	31.5			31.5		
12	90	62.4			18.7	9.4		25	9.3		
13	80	11.6			2.3	.6		8.7			

Most of the saline tracts of land in the valley contain seaside arrowgrass, which flourishes where the soil is moderately to strongly saline and where water is plentiful. Tract 3 is a representative arrowgrass tract in about the center of the area of most strongly saline soils. The tract includes about 36 acres, in which about 60 percent of the plantlife is arrowgrass.

TABLE 9.—*Chemical analyses of soluble portion of soil from southern part of Malad Valley*

[Analyses by U. S. Bureau of Reclamation in milliequivalents per liter, except as indicated]

	15S-36E-21da (greasewood area)	15S-36E-21dc (pickleweed area)
Date of collection	4-25-53	4-25-53.
Depth of soil sample (inches)	1 to 3	0 to 4.
Kind of soil	Sandy loam	Silty loam.
pH (1:5 dilution)	9.7	8.4.
Saturation extract:		
Conductivity (micromhos at 25°C)	1,190	95,500.
pH	8.9	7.5.
Dissolved solids (ppm)	1,350	75,400.
Boron (B)	1.69	.59.
Bicarbonate (HCO_3)	11.3	10.0.
Chloride (Cl)	1.68	1,170.
Sulfate (SO_4)	1.30	3.10.
Calcium (Ca)	.42	14.4.
Magnesium (Mg)	.52	139.
Potassium (K)	1.23	34.2.
Sodium (Na)	12.2	997.
Percent sodium	19.7	36.5.

Chemical analyses (U. S. Salinity Laboratory Staff, 1954, p. 8) were made of saturation extracts from two soil samples (table 9) and one sample each of greasewood and pickleweed (table 10). One soil sample and the greasewood specimen were obtained in the NE¼SE¼ sec. 21, T. 15 S. R. 36 E.; the other soil sample and the pickleweed specimen were obtained in the SW¼SE¼ sec. 21, T. 15 S., R. 36 E.

These areas are in tract 7 (pl. 2). The plant specimens consisted of the entire plant, including the roots (except some roothairs). Soil samples were collected a few inches from the plant in order to obtain soil representing that in which the plant was growing. The top inch of soil was discarded at the greasewood site because it contained plant debris. The sample was from a depth of 1–3 inches. Soil at the pickleweed site contained little or no organic material and the sample was from the land surface to a depth of 4 inches.

TABLE 10.—*Chemical analyses of plants and soil from southern part of Malad Valley*

[Analyses by U. S. Bureau of Reclamation. Milligrams per gram of plant tissue or soil]

Sample location	Date of collection	Material	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)
15S-36E-21db (greasewood area)	4-25-53	Soil	0.0034	0.0026	0.1120	0.0192
		Root	8.81	.58	1.89	3.24
		Branch	4.74	.69	1.46	2.54
		Stem	8.06	1.03	5.29	8.21
		Leaf	9.21	3.16	69.54	29.15
15S-36E-21dc (pickleweed area)	4-25-53	Soil	.1380	.8159	11.0271	.6412
		Root	3.75	6.39	25.93	6.80
		Branch	6.84	6.64	30.36	7.14
		Leaf	12.47	7.94	20.42	3.11

Sample location	Date of collection	Material	Chloride (Cl)	Sulfate (SO_4)	Boron (B)	Total of constituents analyzed
15S-36E-21db (greasewood area)	4-25-53	Soil	0.0238	0.0250	0.00068	0.1867
		Root	1.16	8.52	.005	24.205
		Branch	.10	4.53	.02	14.08
		Stem	2.05	4.22	.00	28.86
		Leaf	20.53	10.49	.005	142.085
15S-36E-21dc (pickleweed area)	4-25-53	Soil	19.9812	.0716	.00028	32.6753
		Root	26.64	5.11	Trace	74.62
		Branch	37.74	5.90	.00	94.62
		Leaf	9.94	11.15	.055	65.085

QUALITY OF WATER

A method of evaluating the quality of water for irrigation developed by the Roubidoux Unit, U. S. Regional Salinity Laboratory, was described by Wilcox (1948). A modification of the method, for application to the common types of water in Idaho, was used by Jensen and others (1951). The water in the Malad Valley, however, is very similar to that in the Great Basin in Utah because its environment is, in fact, a part of the Great Basin. Thorne and Thorne (1951) developed another modification of the Department of Agriculture method for special application to the common types of water in Utah. The Thorne and Thorne method is applied here to irrigation water in the Malad Valley (table 11). A diagrammatic classification of the water (fig. 8) shows that the quality ranges from class 1A,

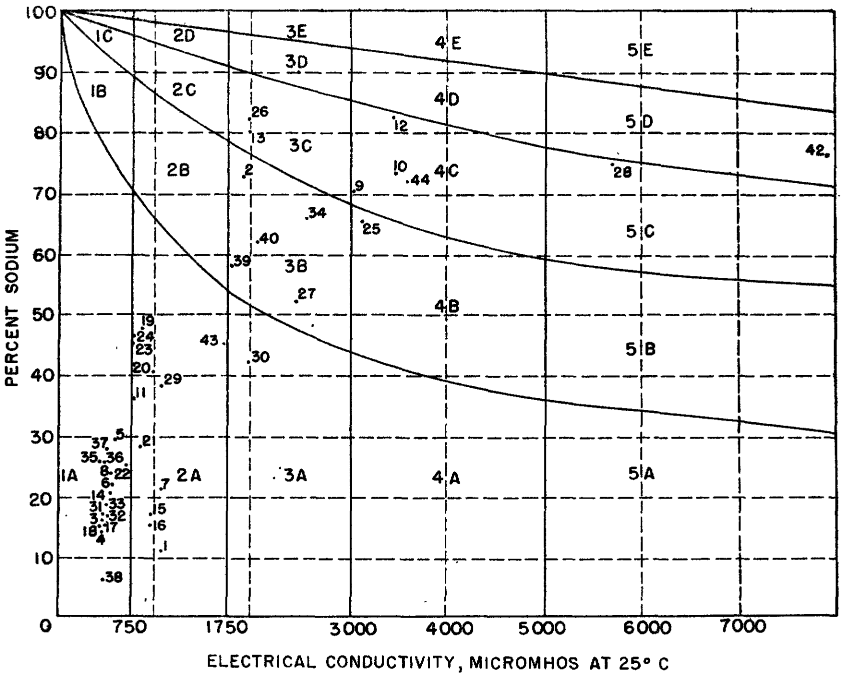

Figure 8.—Chemical-quality classes of irrigation water in Malad Valley, Idaho. Sample numbers correspond to reference numbers in column 1 of table 7.

water that can be used safely on any type of soil, to class 5E, water that can be used only under special circumstances and is generally unsuitable. Classes 1 to 5 represent grades of water that are successively poorer in quality, owing to increasing salt concentration, expressed as conductivity. Classes *A* to *E* represent grades of water that are successively poorer in quality because of the increasing percentage of sodium. With respect to the two characteristics, Thorne and Thorne rated water as follows:

Class of water (by electrical conductivity)	Arbitrary standard	Class of water (by percent sodium)	Arbitrary standard
1	Excellent	A	Excellent.
2	Good	B	Good.
3	Fair	C	Fair.
4	Poor	D	Poor.
5	Unsuitable	E	Unsuitable.

The terms, excellent, good, and the like mean little without reference to the specific purpose for which the water is classified. Examples of how the waters are classified in terms of agricultural utility are contained in table 11.

TABLE 11.—*Examples of classification of irrigation water from southern part of Malad Valley*

Class of water	Arbitrary standard	Remarks
1A	Excellent	Safe for all plants and soil with ordinary drainage.
2A	Excellent to good	Soil must have fair drainage.
3A	Good to fair	Soil must have good drainage and crops must have moderate salt tolerance.
3B	Fair to poor	Soil must be free of gypsum and lime and have good drainage. Water must be low in carbonate and bicarbonate. Crops must have moderate salt tolerance.
3C	Poor	Soil must be coarse grained, well drained, and free of gypsum or lime; water must be low in carbonate and bicarbonate. Crops must have moderate salt tolerance.
4C	Poor to unsuitable	Soil must be coarse grained, well drained, and free of gypsum and lime; water must be low in carbonate and bicarbonate. Crops must have high salt tolerance. Irrigation and soil management must be skillful.
5C	Unsuitable	Alkali conditions can be produced in all except permeable, well-drained soil. Usable if special precautions are taken.

The 44 water analyses in table 9 represent 38 ground-water sources and 2 locations on the Malad River, 1 above and 1 below Woodruff Springs (16S–36E–10bbS1). According to the Thorne and Thorne classification, the water of the Malad River is fair for irrigation above Woodruff Springs but of questionable quality below. Of the 38 wells and springs, water from 16 is excellent to good in quality, that from 17 is fair to questionable, that from 5 is poor, and that from 2 is unsuitable. The largest single area having ground water of poor quality is to the northeast (pl. 1). As the ground water moves through this area, however, it mixes with water of good quality, and by the time it reaches the center of the area the water is of fair quality.

The simple classification by quality and number of sources, however, does not fully disclose the quality of the water because the various sources differ in the quantity of water they yield. About two-fifths of the ground-water sources yield water that is classed as good to excellent, but they contribute less than a tenth of the total ground-water yield from all sources. Some of the most productive springs yield strongly mineralized water. Pleasantview Springs (15S–35E–3aaS1) discharges about 3,400 gpm of water that is of poor quality for irrigation. Woodruff Springs (16S–36E–10bbS1) yield about 8,000 gpm of water, by far the largest yield of any ground-water source in the phreatophyte area, but the water is highly mineralized and would be injurious to crops. On the whole, therefore, the water available in the area studied is of generally poor quality for agriculture.

SOURCES OF WATER

Water-loving plants in the Malad Valley consume water from three sources; namely, precipitation, surface water, and ground water.

PRECIPITATION AND SURFACE WATER

At the Malad City airport the average annual precipitation is about 14 inches. The airport is in about the center of the Malad Valley near the north edge of the principal phreatophyte area. Assuming equal and uniform precipitation throughout the area studied, precipitation contributes yearly about 15,000 acre-feet of water directly to the phreatophyte area. The estimated loss by runoff and evaporation is about 10,000 acre-feet, leaving about 5,000 acre-feet of soil moisture for plant use.

Most surface water used by water-loving plants enters the area from the north but the mountains on the east and west contribute some surface water. The estimated volume of surface water consumed by the plants is about 3,500 acre-feet a year.

GROUND WATER

About 300 flowing artesian wells in the Malad Valley discharge about 8,000 gpm, or about 13,000 acre-feet a year. An unmeasured quantity of water leaks upward along the outside of the casings of many wells and either reaches the surface directly or migrates laterally in permeable zones below the surface. A large but unmeasurable quantity of water also is forced upward from deeper artesian aquifiers through imperfect confining beds and reaches the root zone or the surface. Artesian springs and seeps discharge large amounts of water, but much of this cannot be measured or estimated.

Local zones of saturation in the valley floor are replenished at times by downward percolation from the surface, by underflow from adjacent sources, and by upward leakage from artesian aquifiers. Water from these zones is discharged naturally through springs and seeps and by evapotranspiration. Several large springs, distributed chiefly around the border areas of the valley floor and near foothill slopes, discharge a large amount of unconfined water. Some border-area springs may be fed by artesian water that is forced to the surface along faults or fractures, or by potential recharge water that is rejected by artesian aquifers. Some of the spring water is warm and salty.

The amount of water discharged from wells and from many springs can be measured directly or estimated within reasonable limits of error. A considerable and probably much larger natural discharge by mass seepage and leakage, however, can neither be measured nor estimated. The amount from wells that can be measured or estimated is about 13,000 acre-feet annually, of which about 95 percent (nearly 12,500 acre-feet) is consumed by evapotranspiration in areas of phreatophytes and hydrophytes. An estimated 2,000 acre-feet per year of unmeasured ground water discharged from springs and seeps is similarly consumed.

The estimated total quantity of water consumed by water-loving plants is about 37,000 acre-feet annually (table 6), of which about 23,000 acre-feet may be obtained from precipitation, surface runoff, and discharge from wells and springs. The remaining 14,000 acre-feet is withdrawn directly from the zone of saturation and from the capillary fringe immediately above the zone of saturation.

SALVAGE OF WATER FOR BENEFICIAL USE

About 75 percent of the 25 square miles that was investigated and classified is irrigated, including large areas where the water table or the capillary fringe is at or near the surface. Large parts of the area are flooded artificially during most of the year and water commonly is ponded to depths of several inches during warm months. During the cold season thick sheets of ice form in the fields. The water now consumed by native water-loving plants other than alfalfa might irrigate adequately 10,000 acres of useful plants, including substitute vegetation. Eradication or control of nonbeneficial water-loving plants, substitution of high-value phreatophytes, and efficient management of water would assist the reclamation of wet lands and cultivation of useful crops, and might release for new irrigation some of the water that now is being consumed by water-loving plants of low value.

SELECTED BIBLIOGRAPHY

Barrett, W. C., and Milligan, C. H., 1953, Consumptive water use and requirements in the Colorado River area of Utah: Utah State Agr. Coll., Agr. Expt. Sta. Special Rept. no. 8, 28 p.

Blaney, H. F., 1952, Determining evapotranspiration by phreatophytes from climatological data: Am. Geophys. Union Trans., v. 33, p. 61–66.

Blaney, H. F., Ewing, P. A., Israelsen, O. W., and others, 1938, Water utilization, Upper Rio Grande basin: Natl. Res. Comm., pt. 3.

Bowser, C. C., 1952, Water conservation through elimination of undesirable phreatophyte growth: Am. Geophys. Union Trans., v. 33, p. 72–74.

Criddle, W. D., and Marr, J. C., 1945, Consumptive use of water in Idaho: U. S. Soil Conserv. Service, Div. Irrigation, (duplicated), 46 p.

Gatewood, J. S., Robinson, T. W., Colby, B. R., and others, 1950, Use of water by bottom land vegetation in lower Safford Valley, Arizona: U. S. Geol. Survey Water-Supply Paper 1103, 210 p.

Hitchcock, A. S., 1950, Manual of the grasses of the United States: U. S. Dept. Agriculture Misc. Pub. no. 200 (revised), p. 1051.

Jenson, M. C., Lewis, G. C., and Baker, G. O., 1951, Characteristics of irrigation waters in Idaho: Univ. Idaho Agr. Expt. Sta. Research Bull. 19, 44 p.

Koogler, J. G., 1952, Phreatophyte control on irrigation projects in New Mexico: Am. Geophys. Union Trans., v. 33, p. 74–77.

Meinzer, O. E., 1923, Outline of ground-water hydrology, with definitions: U. S. Geol. Survey Water-Supply Paper 494, 95 p.

——— 1927, Plants as indicators of ground water: U. S. Geol. Survey Water-Supply Paper 577, 95 p.

Robinson, T. W., 1952, Phreatophytes and their relation to water in western United States: Am. Geophys. Union Trans., v. 33, p. 57–61.

——— 1953, Phreatophytes—appropriators of ground water: Proc. 26th Ann. Convention Assoc. Western State Engineers, p. 106–114.

Stearns, H. T., and Bryan, L. L., 1925, Preliminary report on the geology and water resources of the Mud Lake Basin, Idaho: U. S. Geol. Survey Water-Supply Paper 560–D, p. 97–102.

Thorne, J. P., and Thorne, D. W., 1951, Irrigation waters of Utah, their quality and use: Utah State Agr. Coll., Agr. Expt. Sta. Bull. 346, 64 p.

Turner, S. F., and Skibitzke, H. E., 1952, Use of water by phreatophytes in 2,000-foot channel between Granite Reef and Gillespie Dams, Maricopa County, Ariz.: Am. Geophys. Union Trans., v. 33, p. 67–72.

United States Department of Agriculture, 1948, Grass: The Yearbook of Agriculture: U. S. Dept. Agriculture, p. 892.

United States Forest Service, 1937, Range plant handbook: U. S. Dept. Agriculture.

United States Salinity Laboratory Staff, 1954, Diagnosis and improvement of saline and alkali soils: U. S. Dept. Agr. Handbook No. 60, 160 p.

White, W. N., 1932, A method of estimating ground-water supplies based on discharge by plants and evaporation from soil. Results of investigations in Escalante Valley, Utah: U. S. Geol. Survey Water-Supply Paper 659–A, p. 77–93.

Wilcox, L. V., 1948, Explanation and interpretation of analyses of irrigation waters: U. S. Dept. Agr. Circ. 784.

Young, A. A., and Blaney, H. F., 1942, Use of water by native vegetation: Calif. State Div. Water Res., Bull. 50.

INDEX

	Page
Alfalfa	12, 17
Alkaline soil	24
Artesian aquifers, recharge of	9
Artesian ground water	9
Artesian wells, discharge	29
Blue Springs Hills	8
Bonneville shoreline	8
Brigham quartzite	7
Cambrian rocks	7
Capillary fringe	10
Cattail, areas occupied by	13
depth to water	12
description of	18
Cenozoic sediments	8
Chemical analyses of soil	25, 26
Chemical analyses of water	21
Classification of water	26-28
Conservation and reclamation	11
Cottonwood	19
Density of vegetation	6
Depth to water	12
Desert saltgrass, depth to water	12
description of	17
Drainage by pumping	12
Electrical conductivity of water	24
Evapotranspiration rates	20
Faults	8
Field notes	6
Flooding of land	11
Forage plants	13
Giant-wildrye	17
Greasewood, depth to water	12
description of	17
Horst and graben	8
Hydrophilic plants	10
Hydrophytes, definition of	10
Ice sheets	30
Irrigation	5
Lake Bonneville	8, 9
Malad Valley, geology of	7
location	2
Marsh reedgrass, depth to water	12
description of	18
Measuring ground water	29
Paleozoic rocks	7, 8
Pennsylvanian rocks	7
Percent sodium	24
Permian rocks	7
Phreatophytes, definition of	10
Pickleweed, depth to water	12
description of	18
Plant-area subdivisions	6
Pleasantview Springs, discharge	28
Pocatello Valley	8
Pressure reduction	12
Provo shoreline	8
Pumping	12
Rabbitbrush, depth to water	12
description of	18
Rate of water consumption	20
Rushes, depth to water	12
description of	18
Saline soil	24, 25
Salt Lake formation	7
Seaside arrowgrass	18
Sedge, depth to water	12
description of	19
Soil characteristics	10
Substitute vegetation	11
Total water consumed	29
Unconfined ground water	10
Vegetation density	6
Vegetation substitution	11
Water supply in Malad Valley	11
Water table	10
Wells formation	7
Wild rose	19
Willow	19
Wire rush, depth to water	12
description of	19
Woodruff fault	8
Woodruff Springs, discharge	28