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GROUND WATER BRANCH

GROUND WATER IN THE LOWER AHTANUM VALLEY, WASHINGTON, AND POSSIBLE EFFECTS OF INCREASED WITHDRAWAL IN THAT AREA

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CONTENTS

	Page
Introduction	1
Ground water in the lower Ahtanum Valley	~~2~~ 3
Description of the aquifers	~~2~~ 3
Water table	4
Ground-water recharge	6
Movement of ground water	7
Ground-water dischrage	~~8~~
Effluent seepage	~~8~~
Withdrawal from wells	~~10~~ 11
Evaporation discharge	~~11~~ 12
Chemical quality of ground water	~~13~~ 14
Possible effects of increased withdrawal	14
Lowering of water table	14
Decrease in effluent seepage	15
Increase in ground-water recharge	~~19~~ 20
Effects upon evaporation discharge	20
Summary of possible effects	21
References	26
Table 1. Monthly runoff in the Ahtanum-Moxee sub-basin and stations on the Yakima River	~~9a~~ 10
2. Records of water-level measurements at observations wells	23
3. Chemical analyses of ground water in shallow alluvium of the lower Ahtanum Valley	25
Map showing depths to water in represantative wells	In Back

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Introduction

The surface water resources of the Ahtanum Valley have been, for many years, completely apportioned among the farmers of the valley. Therefore, any agricultural expansion must depend upon a further development of ground-water supplies or upon some project which would bring more surface water into the valley. In recent years many questions have arisen as to what effects an increase in ground-water withdrawal would have upon the flow of surface water, especially in the downstream, or lower part of the valley. This report was prepared in cooperation with the State of Washington, Department of Conservation and Development, Water Resources Division, to serve as a basis for planning of the optimum use of the water resources of the valley. The data upon which this report is based, and much of the text of this report, will be incorporated in a more comprehensive report on the geology and ground-water resources of the Ahtanum Valley which is now being prepared.

This investigation was made under the general supervision of A. N. Sayre, Chief of the Ground Water Branch, and under the immediate direction of M. J. Mundorff, District Geologist.

The Ahtanum Valley is a small structural valley in the Yakima Basin in south-central Washington. Its eastern limit is the Yakima River,

and it extends westward for about 20 miles to the foothills of the Cascade Mountains. The valley is drained by Ahtanum Creek, a small eastward-flowing tributary to the Yakima River. The configuration of the underlying rocks divides the valley into a narrow trough in its upstream part, and a broader alluvial plain in the lower reach of Ahtanum Creek. It is the broad, lower valley with which this report deals.

Union Gap, with a population of 1,766 (1950) is the only incorporated city in the area covered by this report. Several small industries are located in and around Union Gap, but the lower valley is principally an agricultural area. As the climate is semi-arid (about 7.3 inches of precipitation each year), and because very little rainfall occurs during the growing season, almost all of the cultivated tracts in the lower valley must be irrigated.

~~GROUND WATER IN THE LOWER AHTANUM VALLEY, WASHINGTON,~~

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Ground Water in the Lower Ahtanum Valley

Description of the Aquifers

The unconsolidated alluvial material that floors the lower Ahtanum Valley is potentially a very productive source of ground water. The alluvium usually consists of basaltic gravel mixed with silt or sand, but the relative amounts of each particle size vary considerably in different localities. The thickness of the alluvium ranges from a few feet to 50 feet, and the average thickness is probably about 20 feet. Shallow dug wells penetrating this material yield water at rates reported to be as high as 400 gallons per minute (gpm), and in most of the lower valley, properly constructed dug wells should yield at least 200 gpm.

Underlying the alluvium is a series of cemented basaltic gravel, generally a few hundred feet thick, which is important as an aquifer only in the lower end of the valley, near the Yakima River. At the city of Union Gap, one well penetrating the cemented gravel unit to a depth of 370 feet has yielded 970 gpm. A few miles farther west, however, wells drilled through the cemented gravel have failed to obtain sufficient water for irrigation and were either abandoned or deepened to penetrate aquifers in the underlying Ellensburg formation.

The Ellensburg formation consists of several hundred feet of consolidated and semiconsolidated clay, silt, sand, and non-basaltic gravel. Permeability is low in the clay and silt strata, but in places, zones of sand and gravel yield large quantities of water. In the Ahtanum Valley, the most productive well obtaining water from this formation is located at the Yakima Farm Labor Camp, about 2 miles west of Union Gap. This well is 620 feet deep and has a reported artesian flow of 560 gpm.

Five other wells, ranging from 245 to 635 feet deep, have pumping yields reported to be 120-470 gpm. East of the town of Ahtanum, the Ellensburg formation is generally capable of yielding large quantities of ground water, but because of the depth, proper construction and development of large capacity wells in this aquifer involves considerable expense.

The sedimentary rocks described above are underlain by lava flows of the ~~Columbia River~~ Yakima basalt. The top of the basalt is about 800 feet below the surface at Wiley, and slopes eastward toward the Yakima River. Near the city of Union Gap, the top of the basalt is probably at least 1,500 feet below the surface. East of Wiley, in the Ahtanum Valley, no wells have entered the basalt, but in Wide Hollow, two wells reportedly encountered the lava at depths of 1,267 and 1,624 feet below the surface. Throughout the Ahtanum Valley, the ~~Columbia River~~ Yakima basalt is capable of yielding large, dependable supplies of water, but to the east of Wiley it occurs at depths which make the cost of drilling to this aquifer prohibitive.

All of these rock units contribute some ground water to the flow of the streams in the area, and the withdrawal of water by pumping from any aquifer probably decreases the total amount of that contribution. However, the net effect of pumping from the deeper aquifers--that is, from the cemented gravel, the Ellensburg formation, and the Yakima basalt--is distributed throughout the entire year, whereas most of the return flow of ground water used for irrigation occurs during the summer months. Thus, the heavy pumping from the deeper aquifers during the growing season may actually cause a slight increase in the streamflow at a time surface water supplies are needed most. On the other hand, the withdrawal of ground water from the shallow alluvium is more directly related to the flow of streams. Therefore, the remainder of this report will deal with the ground water in the unconsolidated alluvium.

Water Table

The water table in the lower Ahtanum Valley is a sloping, irregular, fluctuating surface. It has a gradient downward from areas of recharge (where water is added to the ground-water body) to areas of discharge (where water leaves, or is removed from, the ground-water body). Irregularities in the water table are related to, and comparable with, those of the land surface,

although more subdued. The irregularities are due to local differences in the gain and loss of water and to differences in the permeabilities of the water-bearing material. Fluctuations are caused chiefly by variations in the rate of natural recharge to, and discharge from, the ground-water body, but other influencing factors are the addition of water by irrigation, and withdrawal by vegetation and pumping.

During the summer and fall of 1951 the Ground Water Branch of the U. S. Geological Survey made an inventory of wells in the Ahtanum Valley and measured depths to water in many wells that obtain water from the valley alluvium. The position of the water table at representative wells in the lower valley is shown on the accompanying map. Numbers printed in green represent the depths to water, in feet, at wells measured during 1951. Figures in red indicate the deepest and shallowest positions of the water table at 7 seven observation wells in the lower valley. Complete records of the water-level measurements from the observation wells are shown in tables in the appendix of this report.

The water table in the lower Ahtanum Valley is quite shallow. With two exceptions, the wells shown north of Ahtanum Creek has have water levels less than 10 feet below the surface. Marshy areas are common, and a large part of the lower valley floor is so waterlogged as to be fit only for pasture. Ten of the wells shown had water levels less than 2 feet below the surface. A semi-continuous water-level recorder was established at an observation well located at Wiley in June 1951. This well is typical of shallow dug wells throughout the lower valley, and except during the autumn months, it exhibits the same major fluctuations as similar observation wells located farther east. The record of water levels at this well since the beginning of observation is shown in figure 1.

In general, fluctuations in the water table throughout the lower valley are ~~very small~~ moderate. No fluctuations greater than 5 feet have been observed in shallow dug or driven wells east of Wiley. The seasonal positions of the water table at seven observation wells in the lower Ahtanum Valley are shown in tables in the appendix.

Ground Water Recharge

Recharge of the shallow ground-water bodies is accomplished by the downward seepage directly from precipitation, from streams and irrigation distributaries, and from land surfaces drenched during irrigation.

Of the rain or meltwater that seeps downward from the surface, part is retained by the soil and is eventually evaporated or transpired into the atmosphere by plants. The remainder continues to percolate downward until it reaches the zone of saturation.

During high-water stage, Ahtanum Creek and similar streams contribute to the ground-water reservoir. At that time water from the streams seeps into the banks and downward to the water table. The streams are termed "influent" during this period. Later in the summer, when the stream levels drop, water from the higher ground-water reservoir seeps back into the streams. The streams are then called "effluent." Irrigation distributaries usually contribute to the ground-water bodies as long as they contain water, since they usually flow above the water table.

When the land surface is drenched during irrigation, part of the water seeps downward to the zone of saturation in much the same manner as water from precipitation.

Movement of Ground Water

The ground water in the shallow alluvium of the lower valley percolates slowly from areas of recharge to areas of discharge. Its rate of movement is determined by the permeability and porosity of the rock material, and the hydraulic gradient of the water table.

The general direction of movement of the shallow ground water is toward the Yakima River, but the movement at any location may be toward or from a stream, or toward a discharging well, depending entirely upon the local gradient of the water table. The general direction of movement of the shallow ground water during summer is indicated by arrows on the accompanying map of the lower Ahtanum Valley.

Although no direct measurement of rate of movement of the ground water has been made in the Ahtanum Valley, the probable range of velocities of water moving in the shallow alluvium may be calculated by the use of formulae (1) and (2) below:

$$(1) \quad V = \frac{(2.532 \times 10^{-5} \times P_f)\,(h)}{p},$$

where V is velocity of the water, in feet per day,
P_f is the field coefficient of permeability, in gallons per day per square foo
h is hydraulic gradient, in feet per mile, and
p is porosity, ~~in percent~~ written as a decimal fraction

$$(2) \quad P_f = \frac{T}{m}$$

where P_f is field coefficient of permeability, in gallons per day per square foot,
T is coefficient of transmissibility, ~~and~~ in gallons per day per foot
m is thickness of the water-bearing zone, in feet.

During autumn of 1951, pumping tests were made at five wells in the lower Ahtanum Valley, and data obtained from these tests were used to determine the coefficients of transmissibility (T) by Theis' recovery formula. Values for T ranging from 30,000 to 90,000 were obtained. Average thickness of the water-

bearing material (m) has been estimated to be 20 feet. Substituting these values in formula (2) gives a range of 1,500 to 4,500 for the field coefficient of permeability (P_f).

The average down-valley hydraulic gradient between Miley and the Yakima River is about 40 feet per mile. Average porosity of the aquifer probably falls between 20 and 35 percent. Substituting values in equation (1) so as to obtain the greatest numerical spread, the results are the limits of a range of down-valley velocities that might be expected in the unconsolidated alluvium in the lower valley:

$$V_{max} = \frac{(2.532 \times 10^{-5})(4,500)(40)}{0.20} = 23 \text{ feet per day}$$

and

$$V_{min} = \frac{(2.532 \times 10^{-5})(1,500)(40)}{0.35} = 4 \text{ feet per day.}$$

At the highest calculated velocity of 23 feet per day, almost 2 months would elapse while water in the valley alluvium moved one-quarter mile down-valley, and at the more probable average rate of movement of 10 feet per day, the water would travel the same distance in about 19 weeks.

Since the profile across the valley floor has a much flatter gradient than the downvalley profile, water moving laterally toward the small streams has a much lower gradient, probably not averaging more than 10 feet per mile. Therefore, the average rate of lateral movement of ground water in the alluvium probably would be only about one-fourth as rapid as the downvalley movement, or on the order of 2 or 3 feet per day.

Ground-Water Discharge

<u>Effluent seepage</u>.—Between Selah Gap and Union Gap the flow of the Yakima River increases considerably. Most of the water gained enters the river as effluent seepage. The amount of total gain (ground water + surface water) may be determined from measurements of the flow of the Yakima River at each end of

this reach, and if the amount of surface water entering the river is known, the gain from effluent seepage may be determined by subtraction. Thus, to obtain the total gain, the runoff measured at the gaging station on the Naches River at Selah Gap is added to the amount recorded for the Yakima River at Selah Gap, and this total is subtracted from the runoff for the Yakima River at Union Gap. All available runoff data from these three stations during corresponding periods are presented in table 1, together with the calculated total gains, and the runoff of Ahtanum Creek during the same periods. Where noted, observed values of runoff have been adjusted to compensate for diversions around the stations. Reasonable errors in the estimated amounts of these diversions probably will not materially effect the indicated relationship between stream flow and total gain for the reach.

Only two important perennial streams empty into the Yakima River between the Naches River and Union Gap. These streams are Ahtanum Creek, which flows through the Ahtanum Valley, and Wide Hollow Creek, which receives part of its flow from the lower Ahtanum Valley, and part from Wide Hollow, to the north. During the irrigation season, Wide Hollow Creek probably has an average discharge about one-half as great as that of Ahtanum Creek, so the amount of water that enters this reach of the Yakima River as stream flow during that time may be roughly estimated at about 1½ times the measured discharge of Ahtanum Creek. Actually however, except during periods of high water, this surface discharge to the Yakima River is maintained almost entirely by ground-water seepage into the small stream channels.

Omitting the runoff during June 1904, which must have been mostly snow-melt, the average total gain between Selah Gap and Union Gap for the periods shown was 1,450 acre-feet per month. It is estimated that the total discharge from Ahtanum Creek plus Wide Hollow Creek averaged about 1,600 acre-feet per

Table 1.—Monthly runoff recorded at several gaging stations in the Ahtanum-Moxee sub-basin, and the amount of water gained by the Yakima River between Selah Gap and Union Gap, during portions of 1904, 1911, and 1912. (Values indicate observed runoff unless otherwise noted).

Location	1904						1911			1912	
	June	July	Aug. (acre-feet)	Sept.	Oct.	Nov.	July	Aug. (acre-feet)	Sept.	Aug. (acre-feet)	Sept.
Yakima River at Selah Gap 1/	340,000	150,000	40,800	22,440	37,400	56,800	90,100	50,000	48,700	71,600	62,800
Naches River at Selah Gap 2/	250,700	129,800	29,600	13,900	20,300	52,200	61,300	25,600	34,400	13,300	23,100
Yakima River + Naches River (Selah Gap)	590,700	279,800	70,400	36,340	57,700	109,000	151,400	75,600	83,100	84,900	85,900
Yakima River at Union Gap 3/	684,000	307,100	82,200	54,600	63,700	124,000	155,100	84,900	100,600	101,500	105,000
Yakima River total gain between Selah Gap and Union Gap	93,300	27,300	11,800	18,260	6,000	15,000	3,700	9,300	17,500	16,600	19,100
Ahtanum Creek at its mouth	20,600	5,400	1,190	161	214	887	1,310	430	476	577	583

1/ Station has been bypassed by Selah-Moxee Canal since 1905. Values shown for 1911 and 1912 represent observed runoff adjusted to allow for a diversion of 128 acre-feet per day.

2/ Adjustments of 90 acre-feet per day have been made to allow for diversion by the Fruitvale Power Canal, which bypasses station.

3/ Station was bypassed by Union Gap Canal. Except during October and November 1904, observed runoff has been adjusted to allow for a diversion of 100 acre-feet per day.

month during the same periods. Therefore, an average of about 12,870 acre-feet per month must have entered the Yakima River as direct ground-water seepage or by way of short intermittent streams (maintained almost entirely by ground-water seepage). It is probable that considerably more than half of this effluent seepage came from the western side of the Ahtanum-Moxee sub-basin, because precipitation, irrigation, and surface discharge are greater in this part than in the eastern part. Because stream-flow records are so sketchy, it is not possible to estimate closely the amount of effluent seepage from the Ahtanum Valley alone. However, the discharge from the lower valley as effluent seepage directly into the Yakima River probably is considerably greater than the combined flow of Ahtanum and Wide Hollow Creeks except during periods of high runoff. ~~Most of~~ It is estimated that one-quarter to one third of the ground-water seepage is ~~believed to be~~ derived from the unconsolidated valley alluvium.

Withdrawal from wells.—The annual usage of the ground water withdrawn from wells in the lower Ahtanum Valley is summarized in the following table:

Type of Use	Amount used (acre-feet per year)
Domestic	400
Industrial	1,200
Institutional	10
Irrigation	4,400
Public Supply	250
* Total	6,340

* Besides the uses shown a few acre-feet are used each year for stock water.

Of the amounts shown in the table, about one-fourth of the irrigation water, or some ~~1,100~~ 900 acre-feet per year, is developed from the unconsolidated alluvium. Probably less than ~~200~~ 100 acre-feet per year of the industrial water, and about one-half of the ground-water supplies for institutions are from this

same aquifer. It is estimated that ~~more than~~ about ~~100~~ 300 acre-feet of the domestic water used each year in the lower valley comes from the shallow alluvium. The public supply water, used by the city of Union Gap, is developed entirely from other aquifers. Altogether, it is estimated that about ~~1,700~~ 1,300 acre-feet of ground water is withdrawn each year from shallow wells in the unconsolidated alluvium of the lower Ahtanum Valley.

It should be noted that a considerable part of the ground water withdrawn from both the shallow and deep aquifers recharges the valley alluvium.

Evaporation discharge.—The total discharge of ground water by evaporation from the lower Ahtanum Valley includes the consumptive use by crops and the evapotranspirative waste by natural vegetation.

The total consumptive use by crops irrigated from ground-water supplies in the lower Ahtanum Valley is not known. However, the water requirements of crops grown under comparable conditions have been estimated /, and indicate

/ Irrigation water requirements, Problem 4, Columbia River joint investigations: U. S. Bur. Reclamation Rept. Inv., p 68, 1945.

the requirements that may be expected in the Ahtanum Valley. The range of water requirements that would probably apply in the lower Ahtanum Valley are shown in the following table:

Crop	Total annual water requirements, in acre-feet per acre
Forage	3.68 - 3.98
Grain	2.00 - 2.43
Potatoes	2.38 - 2.93
Beets	3.77 - 4.65
Corn	2.11 - 2.60
Miscellaneous	2.70 - 3.56
Truck	4.38 - 4.90

Values shown are for total water required at the farm, part of which would be supplied by rainfall during the growing season. From 45 to 65 percent of the water required would probably be used in the actual plant growth, and an estimated 25 to 50 percent would recharge the ground-water reservoir or flow to the streams as surface runoff. A considerable amount would be lost by evaporation from the soil, and, depending upon the type of irrigation, directly from the surface of the irrigation water.

Thousands of acre-feet of ground water are virtually wasted each year in the Ahtanum Valley by phreatophytes, or "well plants." These include cottonwood, willow, cattail, and other water-loving species that grow only in areas where their roots can be sent down to the water table or to some other secure, perennial supply of water.

W. D. Criddle _/ has estimated that in the Columbia Basin, areas within

_/ Criddle, W. D., Estimated consumptive irrigation requirements of crops on Columbia Basin Project land, U. S. Dept. Agr., Soil Cons. Service, Unpublished data. 1952

medium to dense growths of willow and cottonwood and "high" water table have evapotranspiration losses averaging about 3 feet per year. Since climate and water-table conditions in the Ahtanum Valley are similar to those in the Columbia Basin, this same evapotranspiration may be expected. The area of stream-bank vegetation in the upper and lower Ahtanum Valley has been estimated, by the use of aerial photographs, to total about 1,200 acres. At the average rate of 3 acre-feet per acre, about 3,600 acre-feet of water is lost each year through consumtive waste by stream-bank vegetation in the entire Ahtanum Valley. The loss in the lower valley is estimated to be 1,900 acre-feet. No effort has been made to determine the evapotranspiration losses from marshy or water-logged land between the streams, but the annual non-beneficial discharge of

ground water by evapotranspiration in the upper and lower valley probably exceeds the 4,400 acre-feet of ground water used each year for irrigation in the lower valley. This consumptive waste probably represents the largest reclaimable source of water in the Antanam Valley. Even though not all of this water can be salvaged, the possibilities of utilizing this wasted ground water to alleviate the water shortage certainly warrants a careful study of the problem.

Chemical Quality of Ground Water

The results of two complete chemical analyses of ground water from the shallow alluvial material in the lower valley are shown on page --. These analyses indicate that, in general, all of the chemical constituents listed are present in amounts sufficient to meet basic requirements but not so large as to be troublesome for most uses. The water is, generally, clear and cool, with no objectionable tastes or odors.

The samples analyzed were of moderate hardness, although additional field checks of the hardness of the shallow ground water show that it becomes progressively harder as it percolates down valley. Shallow ground water in the vicinity of Union Gap may have an average hardness of about 200 parts per million, which is generally considered quite hard.

An important chemical characteristic of irrigation water is the ratio of sodium ions to the total cations present in the water ("percent sodium"). In the two samples tested the percent sodium was less than 27 and the water would therefore be classified as "good" for irrigation use.

Possible Effects of Increased Withdrawal

The previous part of this report deals with the aquifers and the hydrology under prevailing conditions in the lower Ahtanum Valley. Although it is impossible to predict the exact effects of any change in these conditions, a qualitative appraisal and rough quantitative estimate of the possible effects of increased withdrawal can be made. Some of the results of increased withdrawal of ground water would be a lowering of the water table, a decrease in effluent seepage to streams, an increase in ground-water recharge, and, if more water is exposed to evaporation (as in irrigation) an increase in the evaporation discharge. In order to arrive at a true picture of the over-all effects of increased withdrawal, it is necessary to consider not only the individual results, but the interrelation of all foreseeable results.

Lowering of Water Table

As soon as a pump begins discharging water from a water table well, the water around the well is drawn down in the shape of an inverted cone, known as a "cone of depression." Thus a hydraulic gradient is established, and water moves toward the well from greater distances. The drawdown in the well also continues at a decreasing rate. Eventually, the cone of depression becomes widespread enough that the aquifer receives recharge at the rate at which the

well is being pumped. The cone of depression then remains virtually stable as long as conditions remain unchanged.

Any increase in the withdrawal of ground water from the unconsolidated alluvium of the lower valley would tend to lower the water table in the vicinity of the well during the increased withdrawal. This effect, by itself, would be very desireable in some waterlogged areas; but along the banks of streams a general lowering of the water table might be ~~decidedly~~ considered undesirable, since it would decrease the gradient, and therefore the amount, of water moving to the streams. Or, is the water table was locally lowered below the stream levels, it would cause local ground-water recharge and thus contribute to depletion of stream flow.

Decrease in Effluent Seepage

Since the flow of Ahtanum Creek and the other streams in the lower valley is maintained almost entirely by ground-water discharge during most of the year, the removal of more water from the shallow ground-water body than is returned through recharge must eventually be reflected by a decrease in the stream flow. The lag in time before a withdrawal would affect the stream flow depends upon the distance of the stream from the point of withdrawal and the rate of expansion of the cone of depression. The shape and rate of expansion of a cone of depression depends mostly upon the rate of pumping, the ability of the aquifer to transmit water, and the relative amount of water stored in the rock material. A well in material of high transmissibility has a much flatter cone of depression than a well penetrating material of lower transmissibility, all other conditions being the same. Similarly, material of low storage requires a more rapidly expanding cone of depression than material with higher storage capacity.

It is impossible to determine quantitatively the effects that each pumping well has upon the flow of a nearby stream. However, by assuming certain physical conditions, the decline of the water table near a pumping well may be roughly calculated by Theis' non-equilibrium method _/. Some of

_/ Theis, C. V., The significance and nature of the cone of depression in ground-water bodies: Econ. Geology, Vol. 33, no. 8, 1938, pp 889-902.

the assumptions ~~upon which~~ inherent in the Theis formula ~~is based~~, are as follows:

(1) No recharge to the aquifer occurs within the cone of depression of the well.

(2) The well penetrates the entire thickness of the water-bearing formation.

(3) The undisturbed water surface (before pumping) is essentially horizontal.

(4) Water taken from storage by the decline in water level is discharged instantaneously with the decline in head.

The following tables show values of drawdown, calculated by Theis' formula, for two theoretical wells, "A" and "B", with aquifer properties that might be expected in the valley alluvium. Values shown are drawdown, in feet, at various distances from a continuously pumped well, at various times after pumping is begun.

Drawdown, in feet, produced by
pumping well "A"

Assumed conditions:
Coefficient of transmissibility (T) = 30,000
Coefficient of storage (S) = 0.20
Rate of continuous discharge (Q) = 200 gpm
(total in 150 days would be 132 acre-feet)

Time (days)	Distance from well (feet)					
	100	500	1,000	2,000	5,000	10,000
10	2.89	0.73	0.1	0	..	..
30	3.70	1.35	0.50	0.04	0	..
60	4.27	1.90	0.97	0.22	0	..
90	4.60	2.20	1.20	0.38	0	..
150	5.46	3.02	2.00	0.60	0.1	0

Drawdown, in feet, produced by
pumping well "B"

Assumed conditions:
Coefficient of transmissibility (T) = 90,000
Coefficient of storage (S) = 0.30
Rate of continuous discharge (Q) = 150 gpm
(total in 150 days would be 99 acre-feet)

Time (days)	Distance from well (feet)					
	100	500	1,000	2,000	5,000	10,000
10	0.87	0.28	0.08	0	..	..
30	1.05	0.45	0.22	0.05	0	..
60	1.20	0.59	0.34	0.12	0	..
90	1.28	0.67	0.42	0.18	0.01	0
150	1.36	0.76	0.50	0.24	0.03	0

Because actual physical conditions in the lower Ahtanum Valley differ from the assumed conditions, the actual drawdowns may be different from the drawdowns calculated. Some of the inconsistencies are as follows.

In the Ahtanum Valley there generally is considerable recharge within the area of influence of a pumping irrigation well penetrating the valley alluvium, because most of the irrigation water is applied in the immediate vicinity of the well. Also, an expanding cone of depression may intercept some stream or irrigation canal, and thereby increase recharge to the aquifer. If water recharges an aquifer within the area of influence of a pumping well the drawdown would be less than if no recharge had occurred.

If a well fails to completely penetrate an aquifer the drawdown near the well will probably be greater, in most cases, than if the well completely penetrates the aquifer.

As was stated previously, the undisturbed water table in the lower Ahtanum Valley has a considerable gradient. As a result, the drawdown near a pumping well is more pronounced upgradient, and less pronounced downgradient

than it would be in an area where the undisturbed water table is essentially horizontal. Calculated values of drawdown may be considered averages of the drawdown at the given distances from the wells.

Contrary to the assumed condition, the draining of water-bearing material in the vicinity of a pumped well causes the water table to decline rapidly at first and then more slowly as draining proceeds. As a result, drawdown occurs at a different rate than if all the water is drained instantaneously. This causes the natural drawdown to be somewhat inconsistent with the calculated drawdown, especially near the well.

The over-all effect of errors in calculated drawdown would be greatest close to a well. Therefore, the values of drawdown closest to the wells should be considered merely as indications of the magnitude of the drawdown that might be expected in the unconsolidated alluvium. For greater distances from the wells, the tables may indicate fairly closely the actual range in drawdown, and rates of enlargement of the cone of depression that would result from the pumping of wells under the conditions shown.

It has been shown that the ground water in the unconsolidated alluvium of the lower valley might be expected to have a down valley velocity in the order of 10 feet per day. Considering this rate of movement, and the calculated values of drawdown, it is most unlikely that irrigation withdrawals from wells located more than 1 or 2 miles west of the city of Union Gap would have any effect upon the seepage of ground water directly to the Yakima River during the irrigation season.

The rate of lateral movement to the small streams is certainly much lower, and is estimated to be about 2 or 3 feet per day. However, since it is almost impossible to locate a well in the lower valley more than

¼-mile from all streams and irrigation canals, the cones of depression of most irrigation wells in the valley alluvium would probably be extensive enough, by the end of the irrigation season, to cause at least slight decreases in canal and stream flow.

Increase in Ground-water Recharge

Any increase in irrigation in the lower valley would increase the amount of water recharging the ground-water reservoir, and would therefore partially offset the lowering of the water table due to increased pumping. The relative amount of irrigation water that would reach the water table depends upon the amount and type of irrigation, soil conditions, and rate of evapotranspiration. Under normal conditions from 25 to 50 percent of the irrigation water pumped would probably recharge the ground-water reservoir or flow off as surface water.

Water would also be added to the ground-water body whenever the cone of depression of a pumping well intercepted a stream. In that case, the pumping well would not only decrease the seepage of ground water into the stream, but would actually receive water by influent seepage from the stream. Such a condition might exist whenever a shallow well located near a stream is pumped heavily, and the water level lowered below the surface of the stream.

Effects Upon Evaporation Discharge

Additional cultivation and irrigation in lower Ahtanum Valley would of course increase the evapotranspiration of water by crop vegetation. Evaporation losses from the soil would also be increased during the application of the irrigation water. On the other hand, the non-beneficial evapotranspiration loss would be virtually eliminated on the tracts brought under cultivation. Also, if the water table were lowered generally through increased pumping, the consumptive waste by phreatophytes in surrounding areas would probably be decreased somewhat, because in general, the shallower the water table, the higher the waste by phreatophytes. The net effect that increased irrigation would have upon the amount of annual evaporation discharge depends upon the degree to which these factors would balance each other.

On much of the reclaimable land in the lower Ahtanum Valley, the natural vegetation and the high water table almost certainly cause annual evapotranspiration losses as high as two acre-feet per acre. In localities having rather dense phreatophytic growth, present evapotranspiration probably reaches 3 feet per year. Except where the land is used as pasture, this water is virtually wasted.

It was previously estimated that, of the total water required to irrigate a tract of land in the lower valley, from 25 to 50 percent returns to the ground-water reservoir or to surface streams. Thus if 4 acre-feet of irrigation water were to be applied to each acre of land that is presently wasting 2 or 3 acre-feet per year, the additional evapotranspiration discharge per year would probably be no more than about one acre-foot per acre.

Summary of Possible Effects

In general, additional irrigation in the lower Ahtanum Valley would result in a greater amount of water being discharged each year by evaporation from the valley, and an equivilant decrease in the annual discharge of surface and ground water into the Yakima River. If the water for this increased irrigation were supplied by additional withdrawl of ground water from the unconsolidated alluvium, the seepage of ground water into the Yakima River and the small streams would be decreased. However, the resulting decrease in stream flow would not be apparent until some time after pumping was increased. Since the down-valley movement of ground water in the shallow alluvium might be expected to be in the order of 10 feet per day, irrigation withdrawals from wells located farther than one or two miles west of Union Gap probably would not effect the ground-water seepage directly into the Yakima River until after the irrigation season. Some decrease in the flow of the small streams would probably be felt sooner,

but the time lag and the amount of the decrease would depend largely upon the distances between the points of withdrawal and the streams and irrigation canals, and upon the amount of additional withdrawal.

The present non-beneficial evapotranspiration from the lower Ahtanum Valley is very high. On many reclaimable tracts of land the high water table and phreatophytic growth cause annual losses probably as great as 2 and 3 acre-feet per acre. By bringing this land under cultivation almost all of the evapotranspiration loss from the cultivated tracts would be diverted to the consumptive use of the crops. If reasonably efficient irrigation methods were used, any crop suitable to the lower Ahtanum Valley would not require the application of more than about 4 acre-feet of irrigation water per acre, and of this amount, from 1 to 2 acre-feet per acre probably would return to streams or ground-water bodies. Therefore, it is estimated that the proper reclamation of a considerable area in the lower Ahtanum Valley could be accomplished with an increase in the annual evaporation discharge of not more than only about one acre-foot per acre of land reclaimed. The resulting decrease in stream flow would be felt partly during the latter portion of the irrigation season, but most of the decrease would occur after the irrigation season, when the flow of the Yakima River and small streams is no longer critical.

In connection with a study of the possibilities of increasing ground-water withdrawal in the lower valley, special consideration should be given to the feasibility of obtaining additional irrigation water by eradication and control of non-beneficial phreatophytic vegetation. It is estimated that the total consumptive waste of ground water in the entire Ahtanum Valley exceeds 4,400 acre-feet per year. Although it is not possible to reclaim all of this water, it should be possible to eradicate enough stream-bank vegetation to provide for irrigation of several hundred additional acres of land.

TABLE 2

Water-Level Measurements from Observation Wells in the Lower Ahtanum Valley, Washington

(Locations and Highest and lowest observed water levels are shown on the accompanying map. Depths given are in feet below land surface.)

Well 12/17-10N1. William Bunger. About 2 miles southwest of Wiley

Date	Depth to water
1952	
Oct. 20	~~4.55~~ 4.35
Nov. 20	~~4.11~~ 3.91
Dec. 17	~~3.83~~ 3.63
1953	
Jan. 20	~~2.80~~ 2.60
2/16	2.82
3/10	3.09

Well 12/17-16Q1. Kenneth Withers. About 3 miles southwest of Wiley.

Date	Depth to water
1951	
Mar. 19	4.86
. . . .	. . .
May 15	4.84
June 15	4.82
July 14	5.10
Aug. 10	6.02
Sep. 19	5.00
Oct. 18	4.90
Nov. 20	4.87
Dec. 19	4.96
1952	
Jan. 22	4.99
Feb. 20	4.78
Mar. 17	4.98

Well 12/18-3K4. Herman Center. About 3½ miles west of Union Gap

Date	Depth to water
1952	
Oct. 20	8.25
Nov. 25	8.26
Dec. 18	8.62
1953	
Jan. 20	7.00
Feb. 16	6.20
Mar. 10	6.51
Apr. 7	6.68

Well 13/18-33N1. R. H. Crow About 2 miles east-northeast of Ahtanum.

1952	
Oct. 20	5.04
Nov. 25	4.72
Dec. 18	5.20
1953	
Jan. 20	4.68
Feb. 16	4.84
Mar. 10	4.99
Apr. 7	4.77

Well 12/18-1N1. U.S. Geological Survey. About 1 mile west of Union Gap.

1952	
Dec. 17	~~5.56~~ 5.16
1953	
Jan. 19	2.70
Feb 16	3.94
Apr 7	5.34
May 2	3.19
June 26	3.15
July 20	3.00
Aug 14	3.12
Sept 4	4.01

Water-Level Measurements from Observation Wells in the Lower Ahtanum Valley, Washington.—Continued.

Well 12/18-4F1. Adam Lust. About 2½ miles east of Ahtanum.

Date	Depth to water
1951	
Mar. 20	5.31
. . . .	. .
May 15	2.78
June 15	4.48
July 14	3.85
Aug. 11	6.98
Sep. 19	6.64
Oct. 18	5.37
Nov. 20	4.88
Dec. 19	6.16
1952	
Jan. 22	6.65
Feb. 20	5.17
Mar. 17	5.31
Apr. 18	5.68
May 19	2.20
June 23	5.15
July 25	5.87
. . . .	. .
Sep. 17	7.84
Oct. 20	7.77
Nov. 25	6.82
Dec. 18	6.71
1953	
Jan. 19	4.82

Well 12/19-6E2. Elmer Close. About 3/4 mile west of Union Gap

Date	Depth to water
1951	
Mar. 21	1.62
. . . .	. .
June 15	1.07
July 14	1.82
Aug. 12	1.48
Sep. 19	1.40
Oct. 18	0.63
Nov. 20	0.93
Dec. 19	1.76
1952	
Jan. 22	2.17
Feb. 20	1.63
Mar. 17	2.46
Apr. 18	2.57

TABLE 3

Chemical Analyses of Ground Water in Shallow Alluvium of the Lower Ahtanum Valley

	Well 12/18-5G2, H. E. Anderson, about 5 miles west of Union Gap	Well 12/18-5J1, Joel Richwine, about 5 miles west of Union Gap
Date of collection	8/30/51	8/30/51
Siliva (SiO_2)	52	51
Iron (Fe) solution	0.03	0.02
Manganese (Mn) total	0.28	0.00
Calcium (Ca)	23	24
Magnesium (Mg)	12	14
Sodium (Na)	19	16
Potassium (K)	5.3	5.6
Bicarbonate (HCO_3)	160	180
Sulfate (SO_4)	8.0	5.1
Chloride (Cl)	11	2.5
Fluoride (F)	0.2	0.3
Nitrate (NO_3)	1.5	1.8
Dissolved solids:		
Sum--ppm	211	209
--tons/acre-ft	0.29	0.28
Hardness as $CaCO_3$:		
Total	107	117
Noncarbonate	0	0
Percent Sodium	27	22
Specific conductance (Micromhos at 25°C)	285	284
pH	7.2	7.2

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