GROUND WATER OPEN FILE REPORT

ALTERNATIVE STRATEGIES FOR GROUNDWATER MANAGEMENT IN THE STAGE GULCH AREA UMATILLA COUNTY, OREGON

By

Michael J. Zwart

OPEN-FILE REPORT NO. 91-01

STATE OF OREGON
WATER RESOURCES DEPARTMENT

RESOURCE MANAGEMENT DIVISION

WILLIAM H. YOUNG
Director

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INTRODUCTION

The Director of the Oregon Water Resources Department initiated proceedings in January 1985 to determine if the the Stage Gulch area should be a critical groundwater area. A study of the groundwater conditions in the area was conducted between 1978 and 1990 to determine the need for designation as a critical groundwater area. A hearing is required to resolve the proceeding.

This report presents a brief summary of groundwater conditions in the Stage Gulch area. Subareas are proposed for detailed management of the basalt groundwater reservoir in the Stage Gulch area. The initial determination of sustainable annual yield, and the method used, is given for four of the twelve proposed subareas. This report also discusses administrative alternatives for management of the basalt groundwater reservoir in the Stage Gulch area.

SUMMARY OF GROUNDWATER CONDITIONS IN THE STAGE GULCH AREA

The Stage Gulch area is located within the Umatilla Basin in north-central Oregon (Figure 1). It includes about 252 square miles and is entirely within Umatilla County. The area abuts the eastern boundary of the Butter Creek Critical Groundwater Area. The cities of Echo, Stanfield, and most of Hermiston are included within the boundaries (Figure 2).

The climate of the area is semiarid. Average annual precipitation is about 8.8 inches in Hermiston, and increases to the east to about 12.8 inches in Pendleton, about five miles east of the Stage Gulch area. Most of the precipitation usually occurs from late fall through winter. The average growing season varies from 158 to 184 days. Irrigated agriculture is an important part of the local economy.

Irrigation from groundwater sources, primarily the basalt groundwater reservoir, increased rapidly in the late 1960's through the late 1970's. At present, there are water rights for over 27,500 acres of primary and supplemental irrigation from the basalt groundwater reservoir within the Stage Gulch area.

The area is located within the southern part of the Columbia Plateau. This region is entirely underlain by a thick sequence of basalt lava flows of the Columbia River Basalt Group. Deposition occurred over a period of several million years beginning during Miocene time, about 17 million years ago. Structural uplift of the Blue Mountains during and after the time of basalt deposition has resulted in some folding and faulting of the basalt. The uplift

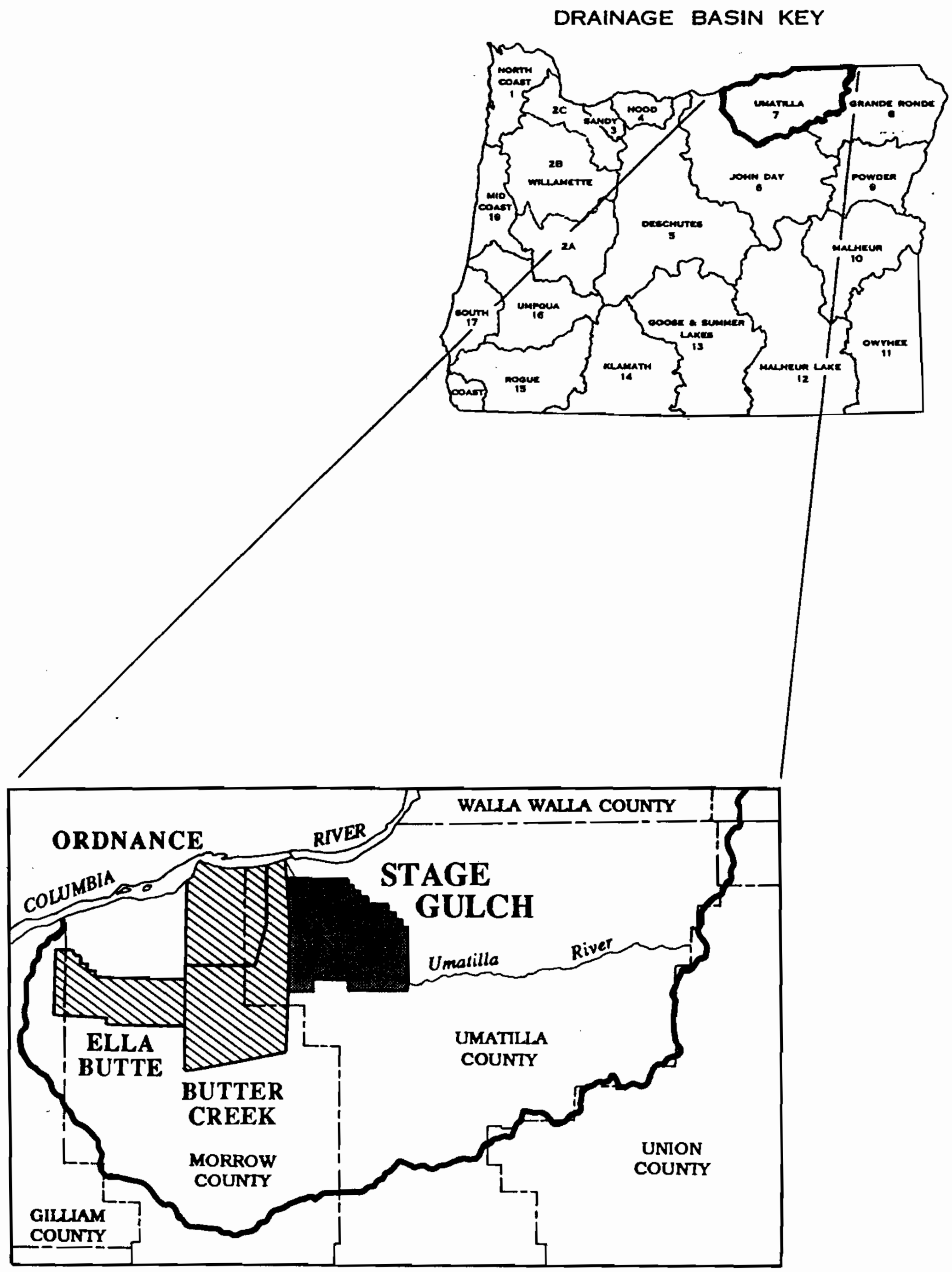

Figure 1. Umatilla Basin showing Location of the Stage Gulch Area and its Relationship to other Areas of Groundwater Control.

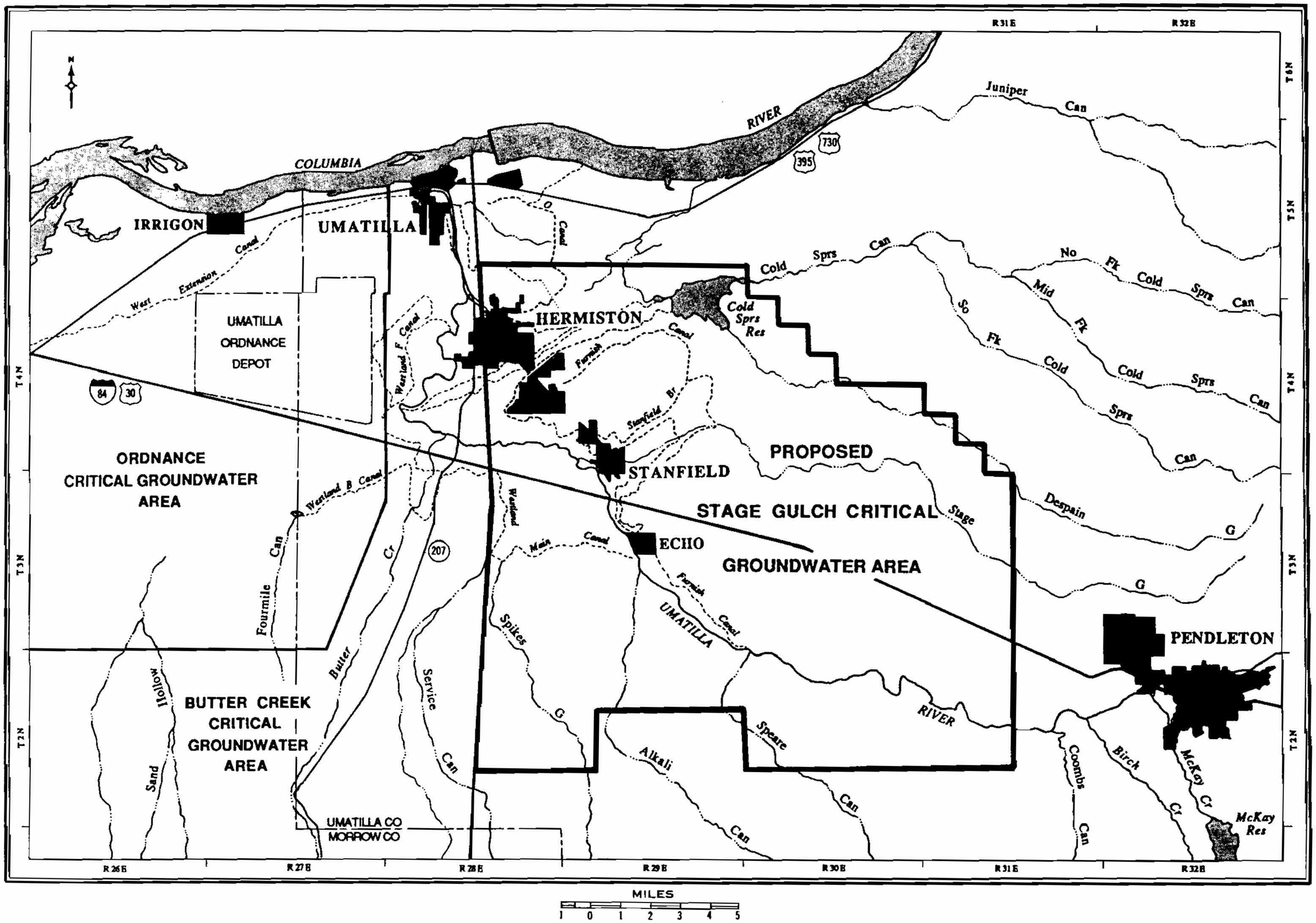

Figure 2. Location Map of the Stage Gulch area.

has also resulted in the basalt being thickest near the Columbia River, with estimates of 10,000 feet or more.

Younger sedimentary and windblown deposits overlie the basalt in most of the area. The sedimentary deposits are also an important groundwater reservoir in the northwestern part of the area and in the Umatilla River valley. In these locations, they generally have sufficient saturated thickness to yield significant quantities of water to wells. However, because long-term water level declines in the Stage Gulch area are evident only in the basalt, this report focuses on the basalt groundwater reservoir.

Groundwater in the basalt occurs and moves primarily in the interflow zones between individual basalt flows. Most of the groundwater occurs under confined conditions within these zones. In general, the basalt groundwater reservoir is a complex, layered system. Groundwater is able to move horizontally far more easily than vertically. Each interflow zone may have hydraulic and water quality characteristics which differ from the overlying and underlying zones. Structures such as folds and faults can serve as barriers and interrupt the horizontal movement of groundwater. These barriers compartmentalize the groundwater reservoir. Wells on different sides of such barriers typically have greatly reduced interference effects than would be expected in a more homogenous aquifer system. The hydrogeology of the area is further complicated by the fact that most large capacity wells penetrate multiple interflow zones to produce the greatest quantity of water. Water levels in such wells are composite levels (heads) for those interflow zones penetrated rather than being those of a single aquifer or interflow zone.

Investigations in the basin have resulted in the collection of a great deal of information regarding water levels and pumpage. In February of each year since 1979, the Department has made annual measurements of water levels and has read flowmeters and power meters. Flowmeters were first required in the Stage Gulch area in 1980. Data from these flowmeters have allowed increasingly better estimates of pumpage from the basalt groundwater reservoir. Estimates indicate that annual pumpage has decreased from nearly 36,200 acre-feet in 1980 to about 30,700 acre-feet in 1989.

A contour map of basalt water level elevations was prepared from measurements made at wells in February 1990. The map represents a surface known as the potentiometric surface. The shape of the potentiometric contours shows the direction of groundwater movement and aids in an understanding of recharge and discharge. This movement is in a direction perpendicular to the potentiometric contours and is generally to the north and west in the Stage Gulch area. Carbon 14 ages of groundwater suggest very slow natural movement of only a few feet per year.

Natural recharge to this groundwater reservoir is limited. It occurs mostly in the higher elevations of the Blue Mountains to the south and east and the extension of the Horse Heaven Hills to the northeast of the Stage Gulch area. The Columbia River is the principal discharge area for the basalt reservoir. Estimates by the U. S. Geological Survey of natural recharge and pumpage indicate that the basalt groundwater reservoir in the Stage Gulch area is overdrawn.

Water levels in the basalt groundwater reservoir have declined in many parts of the Umatilla Basin in response to pumpage. As part of a previous investigation, Department personnel prepared a map showing water level declines in the Umatilla Basin for the period 1965 to 1980 (Oberlander and Miller, 1981). This map indicated that water levels declined 50 feet or more in much of the Stage Gulch area. This area of decline was used, in part, to define the exterior boundaries of the Stage Gulch area. The more recent synoptic water level measurements have allowed the Department to monitor water level trends. Water levels in the Stage Gulch area declined in all of the wells measured during the period 1980 to 1989. These declines continue in spite of the reduced pumpage documented in the area during that same period. Further reductions in annual pumpage are necessary to stabilize water levels in the Stage Gulch area.

During the irrigation season, well interference may have a much greater influence on water levels in individual wells than does the annual water level decline. This condition is more extreme where the aquifers are compartmentalized by the presence of groundwater barriers. The water level in one unpumped well fluctuates over 500 feet during the year, yet its annual decline rate in February is only about three feet.

RESOURCE MANAGEMENT

Critical Groundwater Area

The Director of the Oregon Water Resources Department initiated a proceeding for the determination of a critical groundwater area for the basalt reservoir in the Stage Gulch area on January 31, 1985. This action was taken as a result of ongoing investigations which gave the Department reason to believe that:

1) Water levels were declining and had declined excessively,
2) The available groundwater supply was being overdrawn, and
3) Substantial well interference occurred in some areas.

These are several of the statutory criteria, under ORS 537.730, which allow such action to be taken. No new permits can be issued for the basalt groundwater reservoir under this proceeding. Final resolution of the question of a critical groundwater area will identify whether any new permits may be issued. It will also identify restrictions, if any, which will be placed on uses of basalt groundwater under existing water rights.

The Water Resources Commission adopted rules in 1988, under OAR Chapter 690, Division 8 (Appendix A), that define some of the relatively imprecise groundwater terms used in the statutes. These include "declined excessively," "excessively declining water levels," "overdraw," and "substantial or undue interference." The conditions that prompted the initiation of critical groundwater area proceedings satisfy the adopted definitions of these terms. Water level declines of greater than 50 feet below the highest known level are widespread. Declines representing an average downward trend of three or more feet per year for at least ten years are also common in the Stage Gulch area. These are two criteria which satisfy the adopted definitions of "declined excessively" and "excessively declining water levels," respectively.

The Department has been authorized by the Water Resources Commission to conduct a contested case hearing in the area on the question of a critical area determination. All groundwater appropriators using water from the basalt groundwater reservoir in the area have been declared parties to this proceeding. These include domestic well users and other groundwater users exempted from the requirement to have a water right of record on file at the Department (ORS 537.545).

If the hearing record establishes 1) that the circumstances under which the critical area proceeding was initiated are true, and 2) that the public welfare, health and safety require that corrective controls be adopted, the Water Resources Commission would, by order, declare that the area is a critical groundwater area (ORS 537.735). The major objective of a critical groundwater area order is to provide a framework for subsequent distribution of available water. The order may establish boundaries for certain subareas within the critical groundwater area. Subareas may be required to equitably distribute the available supply of groundwater within the critical area. The issues to be determined through the contested case hearing are:

1) Whether the statutory criteria for designating a critical groundwater area are met,
2) The external and subarea boundaries of the proposed critical area,
3) Which groundwater reservoir(s) should be included in the proposed critical area, and
4) The status of pending applications to appropriate groundwater in the proposed critical area.

The Department plans to conduct a rulemaking hearing as a second part of the critical groundwater area process in the Stage Gulch area. The hearing would follow the issuance of a proposed order resulting from the contested case part of the process. The adopted rule may include the following elements:

1) The method for determination of the volume of groundwater that can be appropriated on an annual basis from the proposed critical area, or any subareas within the larger area, necessary to stabilize water levels,
2) The method for distribution of the available water among the water users within the proposed critical area or subareas, including preference of use, if any, and
3) Duties of the Department and water users that are necessary to monitor and review the effectiveness of the rule.

Critical Area Boundaries

The external boundaries of the Stage Gulch area were set at the time of the critical groundwater area proceeding initiation in 1985. The western boundary of the area coincides with a portion of the existing eastern boundary of the Butter Creek Critical Groundwater area (Plate 1). This boundary follows the axis of the Service anticline, which is inferred to be a groundwater barrier along most of its length. None of the other external boundaries coincide with mapped or inferred geologic structures. These other boundaries initially encompassed the area of documented water level declines of 50 feet or more during the period 1965 to 1980. Additional areas were added to include wells experiencing water level declines of five feet or more per year at the time critical area proceedings were initiated. The area expanded further yet to provide a buffer zone, ranging from one to two miles wide, around these wells. The intent of the buffer zone was to protect the appropriators within the Stage Gulch area from the potential impacts of additional development of the resource immediately outside the area. The final boundaries were chosen to follow section lines to allow relatively easy field location of the boundaries for management purposes.

Proposed Subareas

Plate 1 includes proposed boundaries for subareas within the Stage Gulch area. These subareas are proposed as a logical subdivision of the area which may be used for more effective management and control of the basalt groundwater reservoir. Different provisions could be imposed in each subarea without significant effect on appropriations in adjacent subareas. Several criteria were used to locate most of the internal boundaries for the proposed subareas:

1) Where possible, the boundaries closely coincide with the locations of efficient barriers to groundwater movement, as identified by aquifer tests.
2) Where barriers were not located, the boundaries are located to separate wells with strongly differing water level elevations or water level decline trends.
3) Where water level information is not conclusive, the boundaries are located to provide the greatest distance possible between wells in adjacent subareas.
4) Wherever possible, the boundaries follow section lines to allow easy field location. If other criteria preclude such locations, they follow quarter, sixteenth, or sixty-fourth section lines.

The number of final subareas and the location of subarea and external boundaries are subject to changes that may be prompted as a result of hearing testimony. The twelve proposed subareas range in size from about 1.25 to 82 square miles. The proposed subareas are numbered as shown on Plate 1.

Sustainable Annual Yield

The Water Resources Commission adopted rules in 1990, under OAR Chapter 690, Division 507, that describe methods for determining and distributing the sustainable annual yield for subareas within the Butter Creek Critical Groundwater Area. From these rules, sustainable annual yield is defined as the volume of water that can be pumped on an annual basis while maintaining reasonably stable water levels. It is a measurement of the capacity of the available water supply which will result in no decline. Reasonably stable water levels are also the main objective in the Stage Gulch area. Therefore, annual pumpage from the basalt groundwater reservoir should be maintained at or near the sustainable annual yield for any proposed subareas.

Three of the twelve proposed subareas, subareas 1, 2, and 12, experience relatively limited pumpage and declines. It may not be necessary to control existing uses of basalt groundwater in these subareas. Use of basalt groundwater is more concentrated in the other subareas. The problems of excessive water level declines and interference between wells are most severe in them. If reasonably stable water levels are to be achieved in the Stage Gulch area, it is necessary to control groundwater use in these subareas.

The sustainable annual yield was initially determined for subareas 3, 7, 10, and 11, using a method similar to that described in the Division 507 rules (Appendix B). The method involves comparison of the average annual water level change in wells within a subarea, as measured in February or March, with the annual groundwater pumpage from non-exempt wells in that subarea. The pumpage data for each year during the period 1980 to 1989 are plotted versus the water level change for that year. A best-fit line through those data points is determined using the statistical method of least squares. The sustainable annual yield for each subarea is the annual pumpage (in acre-feet) at the point where the best-fit line (line of regression) intercepts zero water level change. Graphs of the data showing the lines of regression are presented in Appendix B. The sustainable annual yield is tabulated in Table 1, along with pumpage in recent years. The figures for sustainable annual yield have been rounded upward to the nearest 50 acre-feet.

Table 1. Recent Pumpage and Sustainable Annual Yield, in Acre-feet, for Proposed Subareas in the Stage Gulch Area.

Subarea	1989 Pumpage	1985-1989 Average Pumpage	Sustainable Annual Yield
3	11,121	11,864	11,450
4	637	761	800
5	46	174	200
6	142	384	400
7	3,465	3,051	3,250
8	53	63	100
9	169	151	200
10	3,016	3,877	2,750
11	11,297	10,275	8,850
TOTAL	29,946	30,600	28,000

The determination of sustainable annual yield was based on pumpage estimates and water level change data for 10 years, 1980 through 1989. Average annual water level change was calculated using most wells for which such data are available. The sustainable annual yield for subarea 10 is based on seven of these years, excluding 1980, 1982, and 1983. In those years, data regarding water level change were available at only one of the several wells in the subarea. Water level data collected at most of the municipal and industrial wells were excluded from this determination. Such wells can be pumped at any time of the year and therefore yield less reliable water level change data than do irrigation wells.

Sustainable annual yield was not initially determined by the linear regression method for subareas 4, 5, 6, 8, and 9. This is because insufficient water level data were collected during the period 1980 to 1990. The sustainable annual yield for these proposed subareas (Table 1) reflects simply the average pumpage in each for the period 1985 to 1989. The total sustainable annual yield represents about 93.5 percent of the quantity of groundwater pumped in 1989 from the Stage Gulch area, excluding subareas 1, 2, and 12. It is about 91.5 percent of the average pumpage for the period 1985 to 1989. The sustainable annual yield could be attained with a reduction in pumpage of 7 to 9 percent, on average, from that in recent years. As additional water level data are collected and estimates of annual pumpage are made, the determination of sustainable annual yield may be refined. Future refinement may reveal that the sustainable annual yields are more or less than those initially determined in this report.

Withdrawals and Classifications

At the time the critical area proceeding was initiated in the Stage Gulch area, the Department appeared to have no other administrative tool to control groundwater use in the area. Since its creation in 1985, the Water Resources Commission has exercised other authority to manage the groundwater resources of the State. This authority includes the ability to withdraw groundwater reservoirs from further appropriation pursuant to ORS 536.410, or restrictively classify them for specified new uses pursuant to ORS 536.340. The classification process appears to be tied statutorily to the basin planning process. Prior to 1985, this authority was used to manage only surface water resources.

Both the withdrawal and classification processes require a rulemaking hearing. Both can effectively halt or restrict new groundwater appropriations in an area. In the case of classification, the result could be an amendment of the Umatilla Basin Program. However, neither the withdrawal nor classification process can restrict existing groundwater use permits. Such reductions in pumpage can only be accomplished through the establishment of a critical groundwater area.

Alternatives for Administrative Action

The management goal is to arrest the water level declines that continue in the basalt groundwater reservoir of the Stage Gulch area. It appears that this can only be achieved by reducing the pumpage in the area below the present rate, based on analysis of sustainable annual yield. A critical groundwater area determination is the only administrative tool that allows the Department to reduce pumpage under existing permitted and perfected rights. Groundwater pumpage from the basalt has decreased during the 1980's, absent any Departmental controls. However, additional reductions are necessary to stabilize water levels. A summary of the major alternatives for administrative action in the Stage Gulch area follows:

1) Proceed to a critical groundwater area determination pursuant to ORS 537.730 to 537.740. This process requires holding at least one hearing. The Department has historically conducted these as contested case hearings. This has been found to be a laborious and expensive procedure. The final order is often opposed by potentially affected parties.

In the Butter Creek Critical Groundwater Area, one contested case hearing was held to establish the external and internal boundaries. This resulted in an order. The second part of the process, a rulemaking hearing, was held to identify proposed management strategies for each subarea. The adopted rule includes the initial determination of sustainable annual yield for each subarea and the method for distribution of the available water within the subareas. Any person who alleges to be aggrieved by the Department's improper rule application would be able to initiate a contested case proceeding to challenge the regulation. Department counsel has provided a written opinion which indicates that this course of action is preferable to other alternatives that require one or more hearings to be held to complete a critical groundwater area proceeding.

2) Withdraw the basalt groundwater reservoir pursuant to ORS 536.410, or restrictively classify it pursuant to ORS 536.340. Either alternative would

require a rulemaking hearing. Classification would result in amendment of the Umatilla Basin Program. The result would prevent permit issuance, but could not control existing uses of ground water. Withdrawal or classification could be considered either the final administrative action in the area or an interim step in the critical area process. The latter would allow the critical area process to be pursued only in the area, or areas, where reduction of groundwater use is envisioned. The proposed subareas 1, 2, and 12 include areas in which it is not presently considered necessary to regulate existing groundwater use. This alternative could exclude these areas from any contested case aspects of a critical area determination.

3) Postpone the critical area determination and continue under the Proclamation. This would prevent permit issuance while allowing the Department to collect additional data regarding water level trends and pumpage. If annual pumpage continues to decline, water level trends should respond favorably. Such additional data would be used to refine determinations of sustainable annual yield as well.

The Water Resources Commission, at its work session and meeting on October 25, 1990, considered the above alternatives for administrative action in the Stage Gulch area. The Commission authorized the Department to conduct a contested case hearing on the question of whether the basalt groundwater reservoir in the area should be a critical groundwater area. The Commission also authorized publication of a rulemaking hearing notice at the earliest appropriate time. Draft rules for determination and distribution of the available groundwater will come before the Commission for hearing authorization at a later time.

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APPENDIX A

Division 8 Rules

Oregon Administrative Rules
Water Resources Department
Chapter 690, Division 08
Definition and Policy Statements
Regarding Statutory Ground Water Terms

690-08-001 A number of terms are used in the statutes, ORS 537.505-.795, prescribing the management of ground water in Oregon. These rules define terms to qualify and clarify the statutes. In all statutes and rules employed in the management of ground water by the Water Resources Department and Commission, the following definitions shall apply, unless the context requires otherwise:

(1) Aquifer: means a water-bearing body of naturally occurring earth materials that is sufficiently permeable to yield useable quantities of water to wells and/or springs.

(2) Critical Ground Water Area Boundary: means a line established in a critical ground water area order on a map that surrounds an area in which one or more of the statutory criteria for critical area declaration are met and which is located either 1) physically by coincidence with natural features such as ground water reservoir boundaries, hydrologic barriers, or recharge or discharge boundaries, or 2) administratively by surrounding an affected area when that area does not coincide with an area bounded by natural features.

(3) Customary Quantity: means the rate or annual amount of appropriation or diversion of water ordinarily used by an appropriator within the terms of that appropriator's water right.

(4) Declined excessively: means any cumulative lowering of the water levels in a ground water reservoir or a part thereof which:

a) Precludes, or could preclude, the perpetual use of the reservoir; or,

b) Exceeds the economic pumping level; or,

c) Constitutes a decline determined to be interfering with

A) A surface water diversion having a priority date senior to the priority dates of the causative ground water appropriations, or
B) A surface water body that has been administratively withdrawn with an effective date senior to the priority dates of the causative ground water appropriations unless the causative ground water appropriations are for uses that are exceptions to the withdrawals, or
C) An adopted minimum stream flow or instream

water right, or closure having an effective date senior to the priority dates of the causative ground water appropriations, or

D) A surface water body which has a classification that is senior to the priority date of the causative ground water appropriation(s) and the use or uses to which the ground water is being put are not included in the classification; or,

d) Constitutes a lowering of the annual high water level within a ground water reservoir, or part thereof, greater than 50 feet below the highest known water level; or,

e) Results in ground water pollution; or,

f) Constitutes a lowering of the annual high water level greater than 15% of the greatest known saturated thickness of the ground water reservoir. The saturated thickness shall be calculated using pre-development water levels and the bottom of the ground water reservoir, or the economic pumping level, whichever is shallower.

(5) Economic pumping level: means the level below land surface at which the per-acre cost of pumping equals 70% of the net increase in annual per-acre value derived by irrigating. (The value is to be calculated on a five year running average of the per-acre value of the three, if there are that many, prevalent irrigated crops in the region minus the five year running average of the per-acre value of the three, if there are that many, prevalent regional non-irrigated crops.)

(6) Excessively declining water levels: (Note: "Excessively" as used in ORS 537.730(1)(a) is taken to modify both "are declining" and "have declined") means any ongoing lowering of the water level in a ground water reservoir or part thereof which:

a) Precludes, or could preclude, the perpetual use of the reservoir; or,

b) Represents an average downward trend of three or more feet per year for at least 10 years; or,

c) Represents, over a five year period, an average annual lowering of the water level by 1% or more of the initial saturated thickness as determined by observation or investigation in the affected area; or

d) Results in water quality deterioration.

(7) Overdraw: means to artificially produce water, in any one year period, from a ground water reservoir, or part thereof, at an annual rate that

a) Exceeds the average annual recharge to that ground water supply over the period of record; or,

b) Reduces surface water availability resulting in

A) One or more senior appropriators being unable to use either their permitted or customary quantity of surface water, whichever is less, or

B) Failure to satisfy an adopted minimum streamflow or instream water right with an effective date senior to the causative ground water appropriation(s); or,

c) Reduces the availability of surface waters that have been

A) Withdrawn with an effective date senior to the priority dates of the causative ground water appropriations, or

B) Restrictivley classified with an effective date senior to the priority date(s) of the causative ground water appropriations.

(8) Substantial or undue interference: means the spreading of the cone of depression of a well to intersect a surface water body or another well, or the reduction of the ground water gradient and flow as a result of pumping, which contributes to:

a) a reduction in surface water availability to an extent that

A) One or more senior surface water appropriators are unable to use either their permitted or customary quantity of water, whichever is less, or

B) An adopted minimum streamflow or instream water right with an effective date senior to the causative ground water appropriation(s) cannot be satisfied; or,

b) The ground water level being drawn down to the economic level of the senior appropriator(s); or,

c) One or more of the senior ground water appropriators being unable to obtain either the permitted or the customary quantity of ground water, whichever is less, from a reasonably efficient well that fully penetrates the aquifer where the aquifer is relatively uniformly permeable. However, in aquifers where flow is predominantly through fractures, full penetration may not be required as a condition of substantial or undue interference.

(9) Substantial thermal alteration: means any change in water temperature of a groundwater reservoir, or a part thereof, which:

(a) Precludes, or could preclude, the perpetual heating or cooling use of the groundwater reservoir; or,

(b) Constitutes a change in the mean annual temperature within a groundwater reservoir, or part thereof, greater than 25 percent of the highest recorded naturally occurring Celsius (C) temperature.

(10) Substantial thermal interference: means the spreading of the radius of thermal impact of a low-temperature geothermal production well or low-temperature geothermal injection well to intersect a surface water body or another well, or the reduction of temperature or heat flow as a result of pumping or injection, which contributes to change in groundwater or surface water temperature to an extent that one or more senior appropriators of the low-temperature resource are unable to use water for the purpose(s) designated in the associated water right.

(11) Wasteful use (of ground water): means any artificial discharge or withdrawal of ground water from an aquifer that is not put to a beneficial use described in a permit or water right, including leakage from one aquifer to another aquifer within a well bore.

APPENDIX B

Method and Graphs showing Determination of Sustainable Annual Yield

METHOD FOR DETERMINING THE SUSTAINABLE ANNUAL YIELD

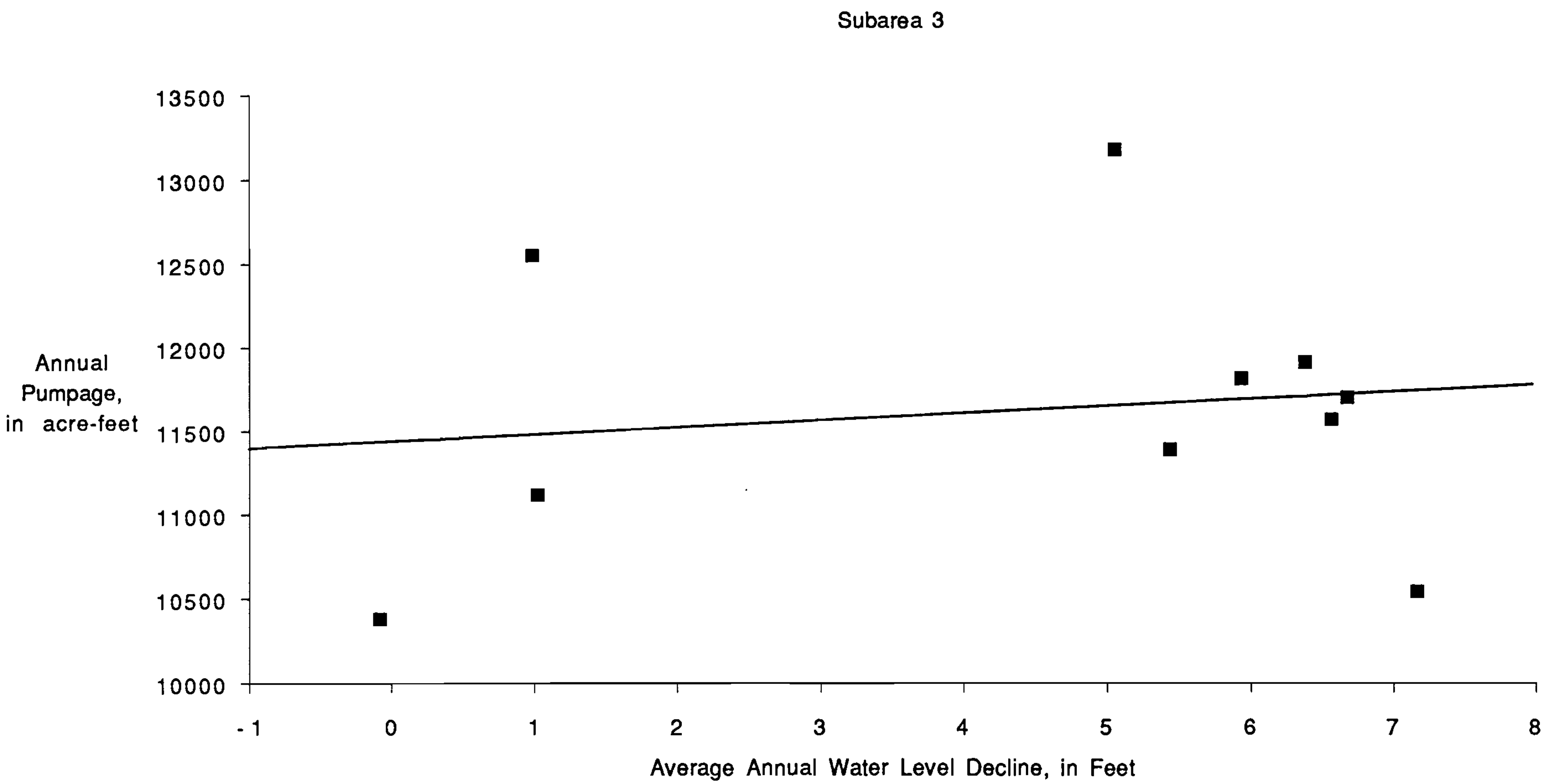
690-507-660 (1) The Department shall determine the sustainable annual yield for each subarea by comparing the volume of water pumped annually from each subarea for a given year to the average of the annual changes in groundwater levels for the subarea for the same year.

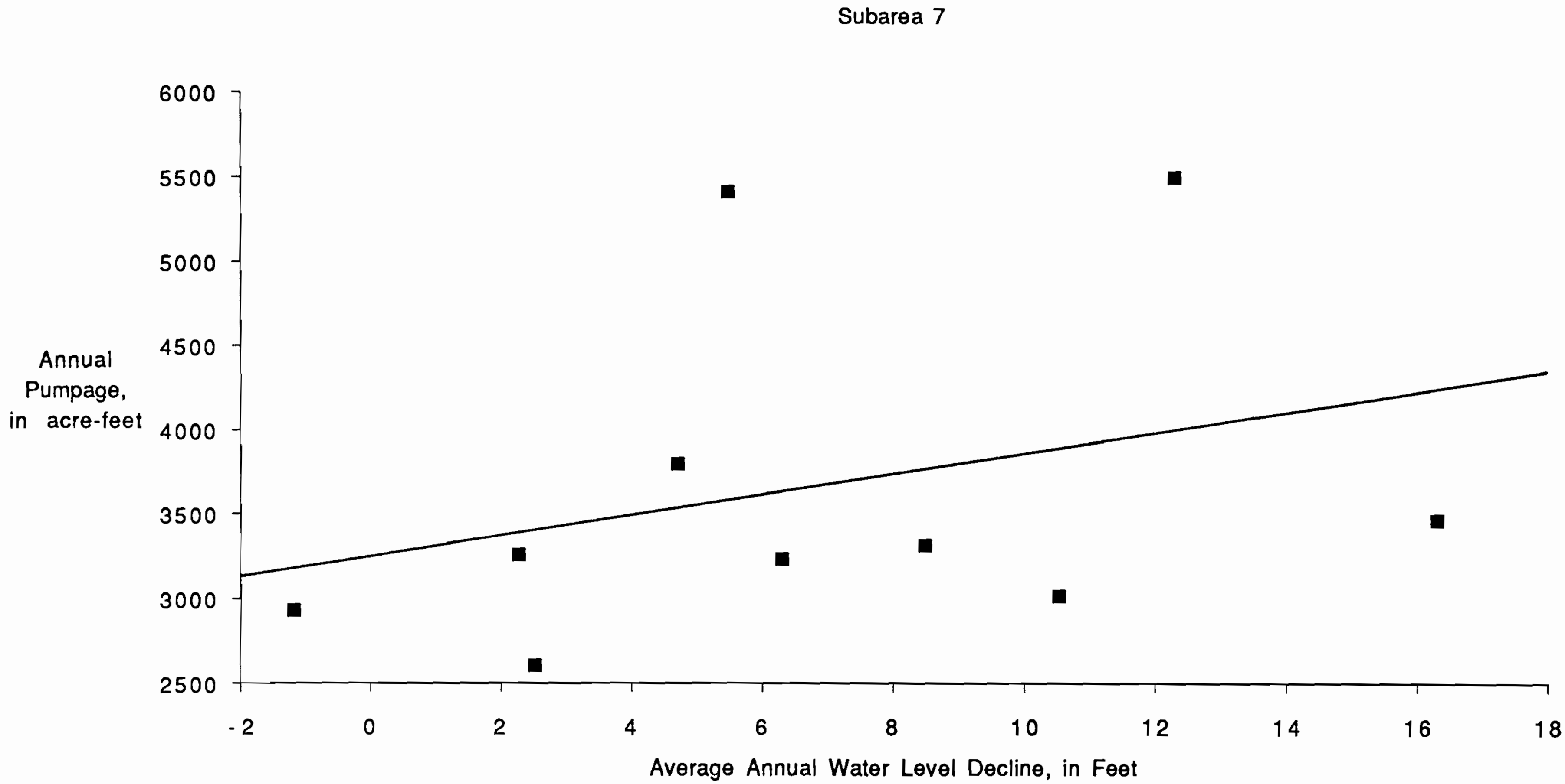
(a) The Department shall calculate pumpage from each well based on data collected by the Department and as submitted under 690-507-640. The pumpage for each subarea shall be calculated by totalling the pumpage from each non-exempt well in the subarea.

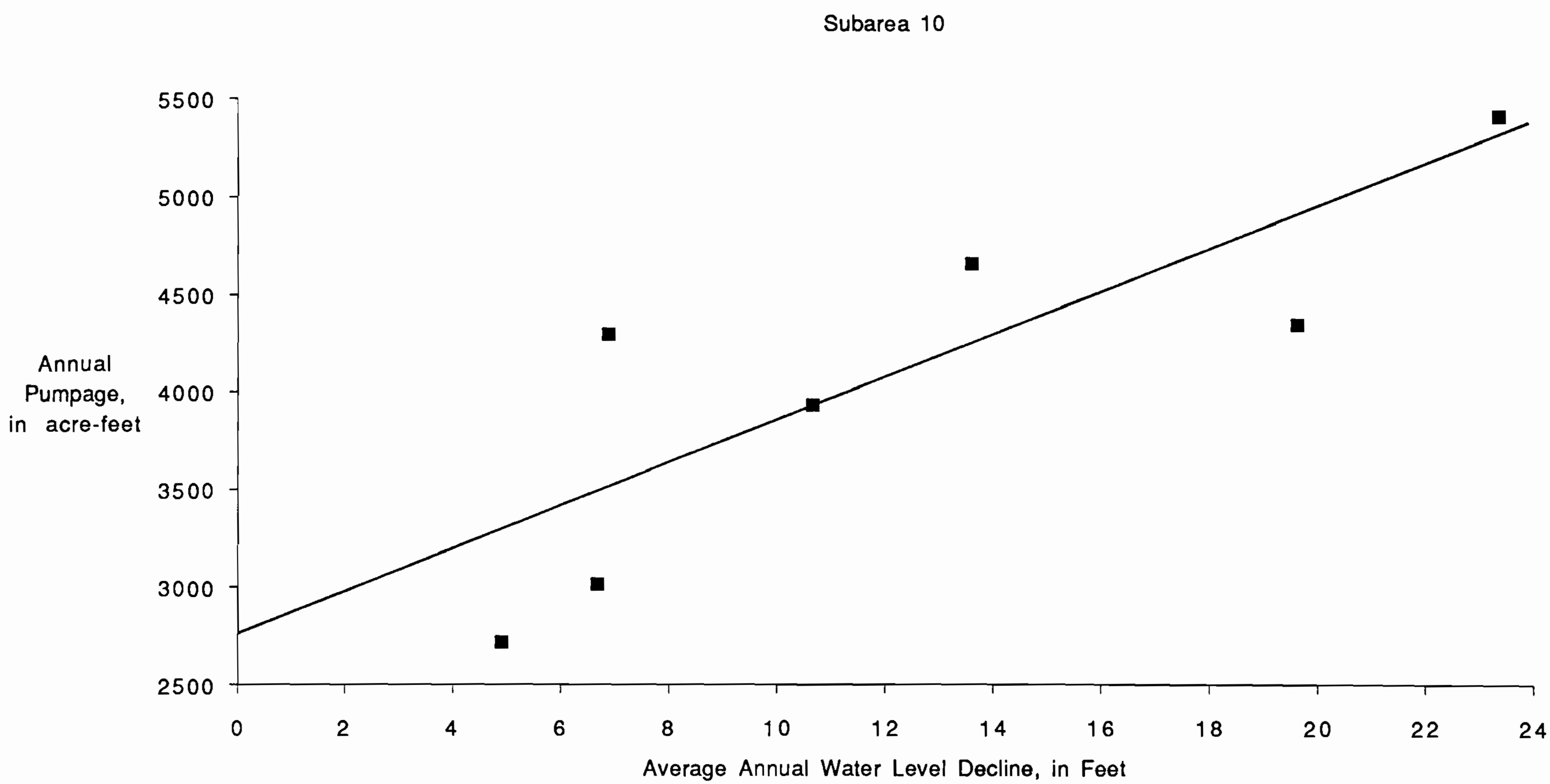
(b) The Department shall calculate annual change in groundwater levels for a subarea by subtracting the current year's February or March water level from the previous year's February or March water level. The average shall be calculated by adding the change at each well in the subarea and dividing by the number of wells with available water level data. Data from all permitted or certificated wells in each subarea that are measurable shall be used to calculate the average annual change. If water level data cannot be collected at a particular well, data from a nearby well may be substituted.

(2) The total volume of groundwater pumped from each subarea for a given year shall be plotted against the average change in groundwater levels from that subarea for that year.

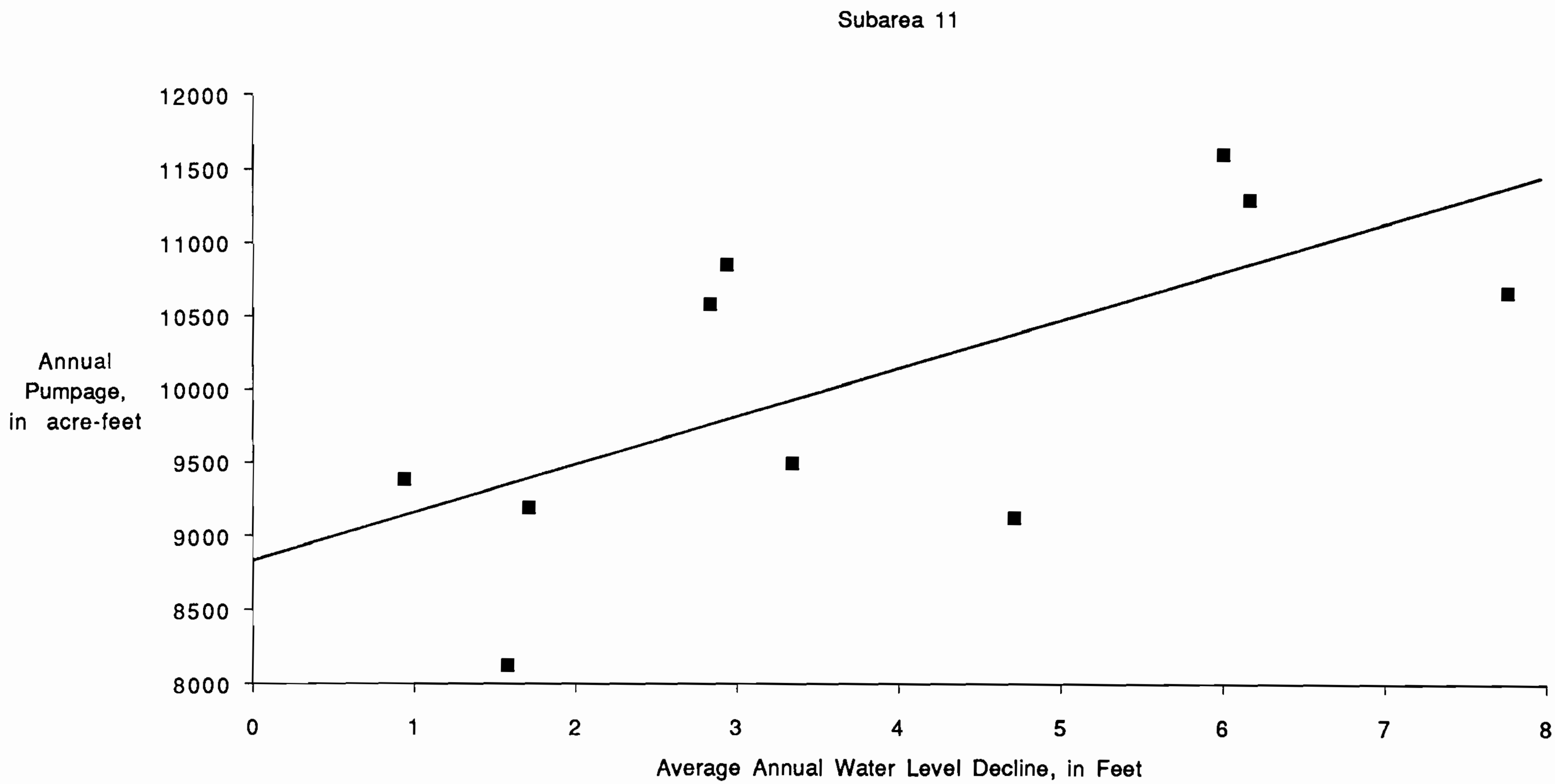
(3) A line of regression is drawn through the data using the least squares fit method and extended through the zero decline axis.

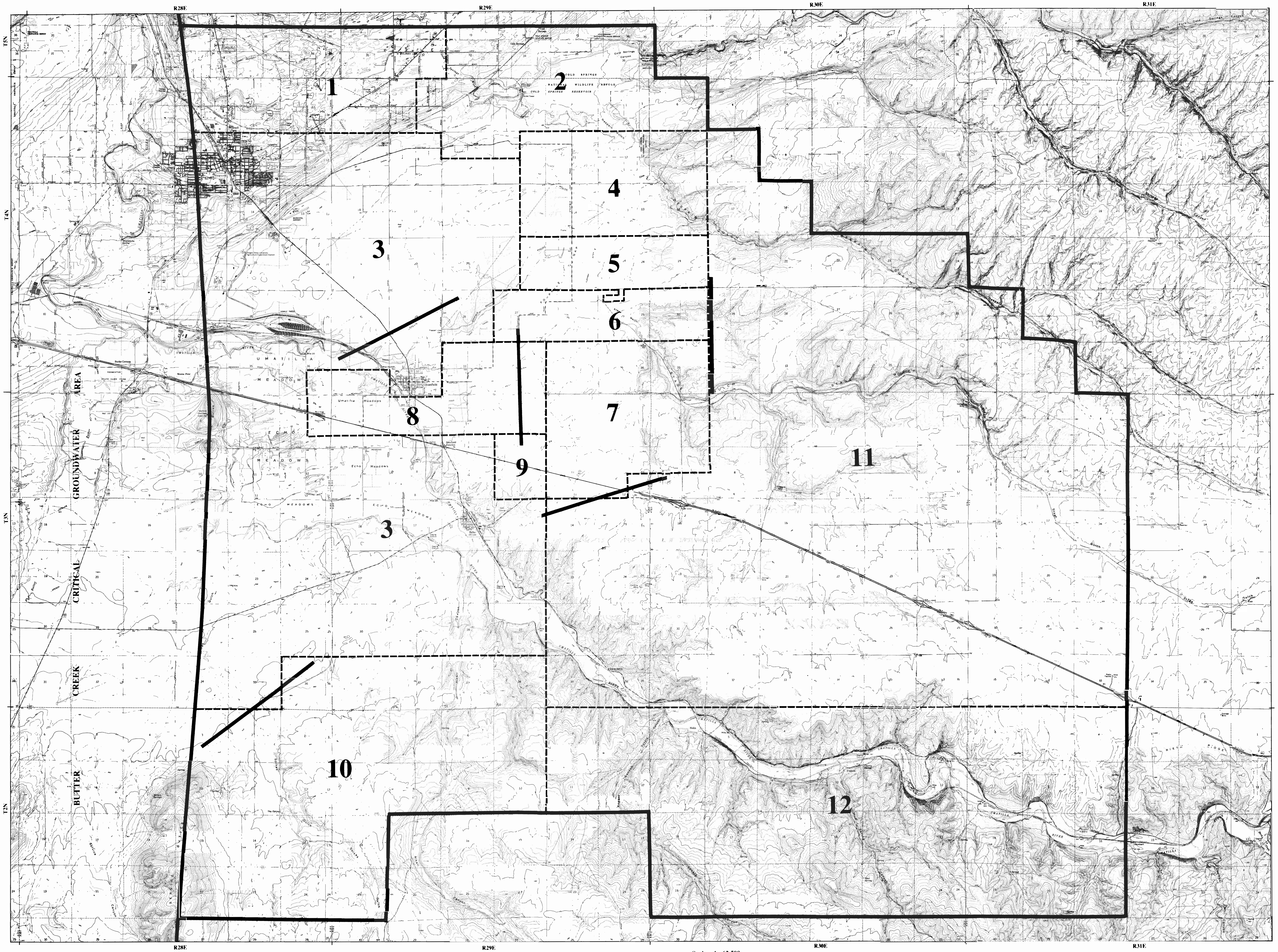

Subarea 3
13500
13000
12500
12000
11500
11000
10500
10000
Annual Pumpage, in acre-feet
-1
0
1
2
3
4
5
6
7
8
Average Annual Water Level Decline, in Feet


Subarea 7
Annual Pumpage, in acre-feet
6000
5500
5000
4500
4000
3500
3000
2500
-2
0
2
4
6
8
10
12
14
16
18
Average Annual Water Level Decline, in Feet



Subarea 10
Annual Pumpage, in acre-feet
5500
5000
4500
4000
3500
3000
2500
0
2
4
6
8
10
12
14
16
18
20
22
24
Average Annual Water Level Decline, in Feet


Subarea 11
12000
11500
11000
10500
10000
9500
9000
8500
8000
Annual Pumpage, in acre-feet
0
1
2
3
4
5
6
7
8
Average Annual Water Level Decline, in Feet



PROPOSED SUBAREA BOUNDARIES IN THE STAGE GULCH AREA

EXPLANATION

- - - - - Location of proposed subarea boundaries

——— Inferred location of groundwater barrier

4 Proposed subarea number

Scale - 1 : 62,500

Kilometers 1 0 1

Miles 1 0 1

Base map produced from U. S. Geological Survey
1:24,000 quadrangle maps

Contour Interval - 20 Feet

OREGON WATER RESOURCES DEPARTMENT
OPEN FILE REPORT #91-01