IDAHO WATER RESOURCES RESEARCH INSTITUTE
TECHNICAL NOTES

SIMULATION OF STEADY-STATE GROUND-WATER RESPONSE TO WATER USE TRANSFER IN THE MUD LAKE AREA, EASTERN IDAHO

by

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January, 1995

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TECHNICAL NOTES is a publication presented as a service of the Idaho Water Resources Research Institute. This brief publication provides a convenient means for researchers from the University of Idaho, Boise State University, and Idaho State University to make their research available to the citizens of Idaho.

INTRODUCTION

Agriculture and water use in southern Idaho are continually changing. Increased agricultural development and water use may be inhibited due to limited supplies. However, the capability to change must not be eliminated, just constrained to balance demand with supply. Transfers of water rights and mitigation of impacts are the tools that will make it possible to change agricultural water supply. Water right transfers will always create secondary effects, both positive and negative. Ground-water models will frequently be the best method available to assess and quantify the impacts of changes in water use on surface and ground-water resources.

In the 1980's, growing concern over the declining ground-water levels in the Mud Lake area prompted development of a ground-water flow model by the U.S. Geological Survey (Spinazola, 1994a). The model was applied to estimate the long-term change in ground-water levels and surface water flows resulting from seven different water use scenarios (Spinazola, 1994b). The model helped to resolve the immediate conflicts over water resources in the area, and continues to be the best tool available for assessing impacts of changes in water use.

The U.S. Geological Survey provided the Idaho Water Resources Research Institute with data sets and accompanying explanations for the nine different simulations resulting from their investigations. These data sets provide input to the U.S. Geological Survey MODFLOW model (McDonald and Harbaugh, 1988), which is probably the most commonly used ground-water flow model in the country.

The Idaho Water Resources Research Institute recognizes the need for continued evaluation of changes in ground-water use in the Snake River basin and throughout the State. It has, therefore, addressed the task of using the Mud Lake model developed by the U.S. Geological Survey to study the effects of additional proposed changes in water use. The results reported in this study are provided as a service to the water users in the Mud Lake area. It is hoped that these unbiased, quantitative estimates will be accepted by all parties and will minimize the need for litigation.

This document is not intended to describe the model developed by the U.S. Geological Survey. Readers are referred to the documents prepared by Spinazola (1994a, 1994b) for details of the model development, calibration, and simulation of prior water use scenarios.

PROCEDURE

The following procedure was followed:

1) Publications documenting the U.S. Geological Survey simulations in the Mud Lake area were reviewed (Spinazola, 1994a, 1994b).

2) Input and output data files for all of the final simulations used by Spinazola were obtained in ASCII format from the U.S. Geological Survey.

3) Details of a proposed water right transfer were obtained from the party requesting the transfer. This information included the quantity and location of the rights being transferred, and the proposed location for future use.

4) The location of sites from which and to which transfers are being proposed was plotted to determine model grid locations.

5) The 1980-to-1990 steady-state simulation was selected as the base, or reference, condition to be consistent with the methods of Spinazola (1994b).

6) Simulations were conducted of the 1980 and 1980-to-1990 steady-state conditions to verify that the model and data sets produce the same results as those generated by Spinazola.

7) The "well package" input data of the 1980-to-1990 data sets were altered to produce two data sets that represent:

    a) the effects of not pumping ground water at the locations from which the water rights are proposed for transfer, and

    b) the effects of pumping ground water at the sites to which water rights are proposed to be transferred.

The changes reflect the quantity of the water right, not necessarily the consumptive water use. It is expected that the consumptive crop use would be less than the simulated quantity, depending on the crop and acres irrigated. All changes in water use were assumed to come from the uppermost model layer.

8) Results were prepared and documented that describe the individual impacts of the scenarios described in item 7 above. These results describe changes in aquifer water levels in the uppermost model layer (that affected most), and in the interchange between surface and ground-water sources.

DATA SET VERIFICATION

Simulations were conducted to verify that the data sets transferred by Spinazola (personal communication) would produce identical results using the version of MODFLOW available to the authors. Model results were compared to those of Spinazola for the 1980 steady-state simulation and for the 1980-to-1990 steady-state simulation. Node-by-node comparison of the resulting head distribution was made for the 1980 steady-state simulation. A comparison of individual terms of the mass balance was made for both simulations.

The head distribution resulting from the 1980 steady-state simulation compared favorably to that produced by Spinazola (electronic communication). The head difference at all model nodes was less than 0.1 feet, which was the resolution of model output.

Mass balance results from the 1980 and 1980-to-1990 steady- state simulations also compared well with those provided by Spinazola. Terms representing the flux from wells, drains (flowing wells), stream gains and losses, recharge from irrigation and precipitation, and boundary flows all matched those provided by Spinazola within 0.01 percent.

Head values, and some terms of the mass balance, do not exactly match those of Spinazola probably as a result of minor differences in the computers and versions of the model code used. These differences are not significant relative to the uncertainties in the conceptual model and the estimation of aquifer properties.

DESCRIPTION OF WATER TRANSFER

The proposed water rights transfer involves exclusively ground water pumped from the Snake River Plain aquifer in the Mud Lake area. Figure 1 shows the locations of the two groups of wells involved in the proposed water rights transfer. The wells to be removed from production are clustered toward the model's northwest boundary, between the towns of Small and Monteview. Hereafter, these wells will be referred to as "the western group." The wells to be put into production (that is, the wells to which water rights are to be transferred) are centered in the area between Camas and Dubois. In this report these wells will be referred to as "the eastern group."

Table 1 gives a breakdown of the locations of the wells in the two groups. The table shows the locations of wells in terms of township, range, section, and section fraction. Also shown are the pumping volumes associated with the well or wells in each section or section fraction, and the identity of the model node (column and row number) to which each pumpage value corresponds. In some cases, the pumpage associated with a given location could not be conveniently assigned to a single model node (because of a lack of correspondence between the township/range/section divisions and the model grid). Where this occurred, the pumpage associated with the section or section fraction in question was divided evenly between two nodes, as indicated in the table. As the table shows, the sum of the pumpage values involved in the proposed transfer is the same for both well groups.

Well discharge, representing the proposed transfer, was the only change in simulated conditions. All other conditions were identical to those used in Spinazola's simulation of average 1980-1990 conditions, the base case against which the current results are compared. The 1980-to-1990 steady-state simulation contained average annual pumping rates for wells within the model area that were in operation in 1990. Both the eastern and western well groups were in operation during 1990, and so withdrawals from the corresponding nodes in the amounts shown in Table 1 are included in the base simulation.

The model was run using two modifications of Spinazola's original well discharge data. In the first simulation, pumping rates associated with the eastern group of wells were subtracted from the existing well discharge for corresponding nodes. Thus the resulting input and the simulation results represent the head distribution in the aquifer, and the aquifer's interaction with surface water bodies and boundaries, when pumping occurs in the western well group, but not in the

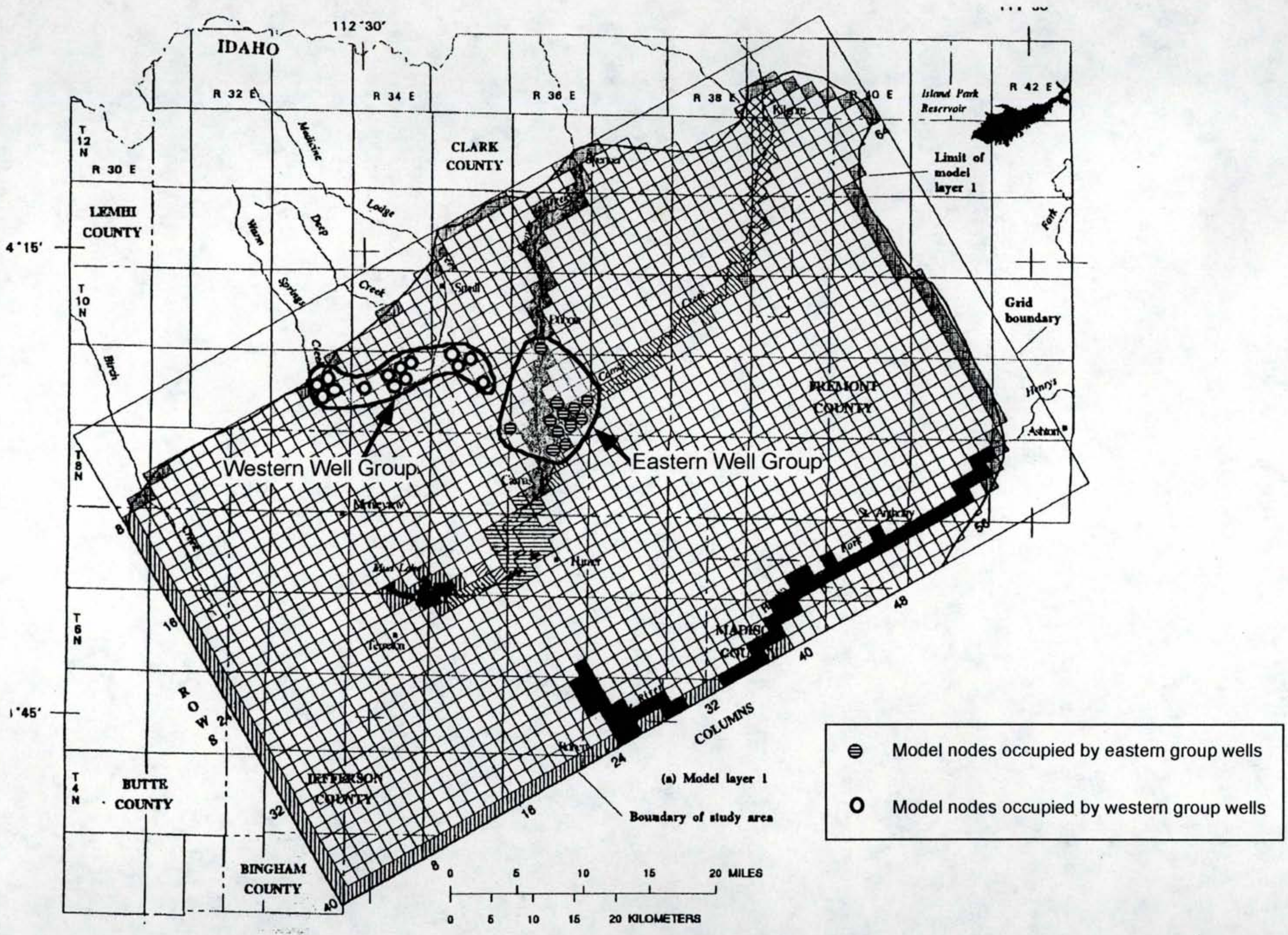


Figure 1. Locations of model nodes occupied by western and eastern well groups (after Spinazola, 1994b).

Table 1. Well locations, annualized pumping rates, and corresponding model node locations for "eastern group" and "western group" wells.

Township	Range	Section	Section fraction	Pumping rate (acre-feet)	Node ID (Row,column)
Western well group (from which water rights would be transferred):					
9	36	24	S1/2	966	17,34 & 17,35*
		22	SW1/4	636	16,33
		25		726	17,34 & 18,34*
		26		1410	17,33
		27		1260	17,32
		31	SW1/4	381	16,29
		34		1450	18,32
		35		540	18,33
8	36	3		1050	19,31
		10		585	19,31 & 19,32*
10	36	33		600	12,34
TOTAL WESTERN GROUP PUMPING CAPACITY				9604 acre-feet	
Eastern well group (to which water rights would be transferred):					
9	33	14	SW1/4	420	7,19
		14	NW1/4	468	6,19
		15	NE1/4	420	6,18
		15	SE1/4	432	7,18
		23	NW1/4	446	7,18
9	34	2	E1/2	233	8,25
		3	E1/2	186	8,25
		3	SW1/4	480	8,24
		10	W1/2	675	8,24
		10	E1/2	186	9,24
		15	E1/2	186	9,24
		15	W1/2	186	9,23
		17	W1/2	186	8,21
		9	E1/2	276	8,23
9	35	4	ALL	2144	10,28 & 10,29*
		5	E1/2	956	9,28 & 10,28*
		10	SE1/4	337	12,29
		14	NW1/4	197	12,29
10	35	32	E1/2	1190	9,28
TOTAL EASTERN GROUP PUMPING CAPACITY				9604 acre-feet	

*Pumping volumes of these wells divided evenly between the indicated nodes.

eastern group.

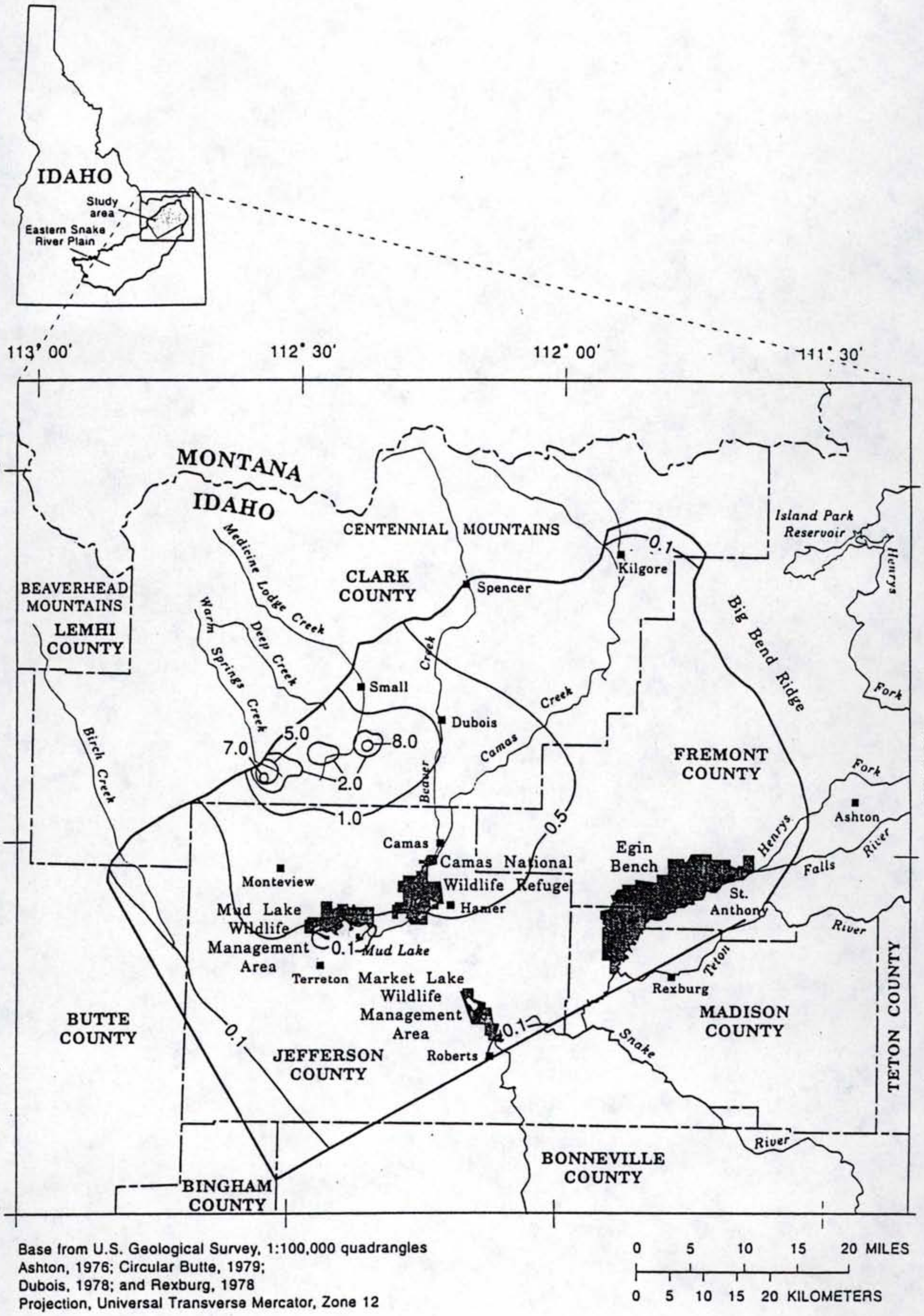
In the second simulation, pumping volumes associated with the western group of wells were subtracted from the existing well discharge at corresponding nodes in the base simulation. Consequently, results represent the situation where pumping occurs in the eastern well group, but not in the western group.

SIMULATION RESULTS

The presented results represent an approximation of long-term changes that are expected to occur in aquifer water levels and aquifer interaction with surface water bodies in response to changes in location of ground-water pumping. Because these results are from steady-state simulations, they represent only an average, long-term equilibrium condition. Seasonal variations in aquifer water levels and surface water fluxes can not be simulated with a steady-state model and consequently are not shown. Simulation results are approximate due to inexact knowledge and representation of aquifer conditions and properties.

Results of the model runs are presented in Figures 2 and 3, and in Table 2. Figure 2 shows the simulated difference in water levels (in comparison to the base-case simulation) resulting from cessation of pumping at the western group wells. The map shows that water levels in the aquifer would rise by one foot or more within an area measuring less than 150 square miles south of Small. The greatest increases in water level elevation occur at and near the model nodes occupied by clusters of the western group wells. The contour representing a 0.5-foot water level increase encloses an area which extends nearly to Mud Lake and includes the Camas National Wildlife Refuge. Aquifer water levels increase by more than 0.1 feet over all the study area except the extreme northeast and southwest.

The greatest increases in water level shown in Figure 2 occur in a small areas immediately surrounding grid cells where large changes in pumping rate have been simulated. The magnitude of change in these areas may not be correct due to inexact representation of the location of wells. Actual water level changes in the near vicinity of the simulated change may be greater or less than those shown in Figure 2.



Base from U.S. Geological Survey, 1:100,000 quadrangles
Ashton, 1976; Circular Butte, 1979;
Dubois, 1978; and Rexburg, 1978
Projection, Universal Transverse Mercator, Zone 12

Figure 2. Increase in water levels caused by cessation of pumping in western-group wells. Comparison to average 1980-1990 conditions as reported in Spinazola, 1994b. Contour values in feet.

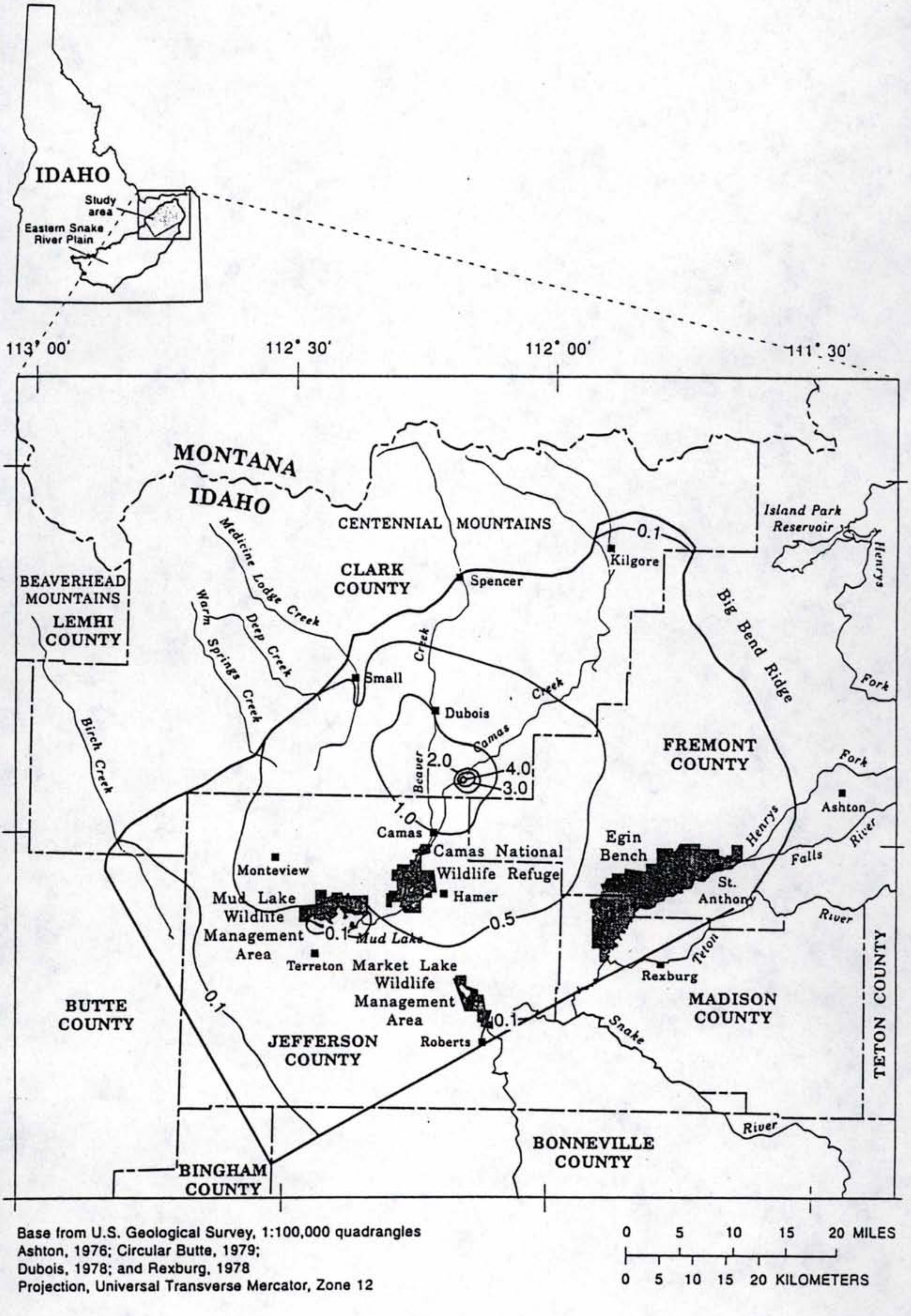


Figure 3. Increase in water levels caused by cessation of pumping in eastern-group wells. Comparison to average 1980-1990 conditions as reported in Spinazola, 1994b. Contour values in feet.

Table 2. Effects of proposed transfer on flow between aquifer and stream segments

		Well groups pumping:			
	Reach numbers	Both groups	Eastern only	Western only	Difference
GROUPED STREAM SEGMENTS					
MEDICINE LODGE	1	48901	48893	48901	8
BEAVER CRK	2,3,4	16453	16361	16328	-34
UPPER CAMAS	5	5206	5205	5205	0
MIDDLE CAMAS	6,8,9	5308	5294	5281	-13
RAYS LAKE	10,11	11526	11149	11070	-80
MUD LAKE	15,16,17,18	6378	5336	5307	-29
WOODS DIVERSION	7	7399	7390	7390	0
HENRYS FORK	19	-76536	-78111	-78321	-209
SNAKE RIVER	20	-74885	-75715	-75841	-126
CAMAS REFUGE	12,13,14	6157	5579	5477	-102
MARKET LAKE	21	-1488	-1530	-1538	-8
DRAINS					
Drain 1 (r24, c22)			-5390	-5419	-29
Drain 2 (r25, c23)			-7484	-7537	-53

Figure 3 shows the water-level difference that would result from cessation of pumping at the eastern well group (in comparison to the base-case simulation). Alternately, this can be viewed as the amount of water-level decline that would be expected after pumping from these wells was initiated. The area of greatest water-level change in Figure 3 occurs along Camas Creek, roughly midway between Camas and Dubois. The shape of the contour representing the 0.5-foot water-level change and the area enclosed within it are similar in Figures 2 and 3, but in Figure 3 the 0.5-foot contour extends slightly more to the east. The two figures show little change in the position of the 0.1-foot water level difference contour. Again, determinations of localized effects in the immediate vicinity of wells may be in error due to inexact representation of well locations.

The net effects of transferring ground-water pumping from the western well group to the eastern group can be determined by subtracting the water level increases in Figure 3 from those presented in Figure 2. The result of this operation results in net increases in aquifer water level in the area between Small and Medicine Lodge Creek, and a decline in aquifer water level of a few feet in a small area northeast of Camas.

The effects of pumping from the eastern group of wells and not from the western group are also reflected in changes in flow volumes between surface-water bodies and the aquifer. Consolidated stream segments that lie within the model domain are listed in Table 2. For convenience of reporting, the 21 individual stream segments recognized by the model have been combined into a smaller number of natural groupings. Also shown are two "drains," used to represent flowing wells.

The table shows gains and losses from the consolidated stream segments for each of the three simulated scenarios: the base-case scenario reflecting average 1980-1990 conditions, the scenario in which the western group of wells is removed from production (eastern group is pumping), and the scenario in which the eastern group of wells is removed from production (western group is pumping). Flow rates are in units of acre-feet per year. Positive numbers indicate that a stream segment is losing water to the aquifer. Negative numbers indicate that the stream segment is gaining water from the aquifer. The final column in the table shows the difference between the western-only pumping scenario and the eastern-only scenario.

Simulation results indicate that shifting from a mode of pumping only the western wells to pumping only the eastern well group results in depletion of surface-water bodies with the exception of Medicine Lodge Creek. The net depletion resulting from the proposed transfer is indicated by a negative sign in the last column of Table 2. The net depletion of most surface-water sources results from the closer proximity of the eastern well group to surface-water bodies than the western group. Gains of the Henry's Fork of the Snake River from ground water were reduced by an estimated 210 acre-feet per year in response to the proposed transfer. The surface water entities exhibiting the largest changes are the Henry's Fork, the Snake River, Camas Refuge, and Ray's Lake. Together, these account for a decrease in discharge to the surface from the aquifer of 520 acre-feet annually.

Flowing wells to the northeast of Mud Lake are simulated as drains. Discharge for the two drains is shown in Table 2 and indicates that when pumping takes place at the eastern well group instead of at the western group, flow from the wells is diminished by a total of about 80 acre-feet per year.

SUMMARY

A transfer of ground-water rights equal to 9,604 acre-feet per year is proposed in the Mud Lake area. The transfer would relocate ground-water pumping locations from a western group of wells to an eastern group in the Mud Lake area. An assessment of the impacts of the proposed transfer is assisted by application of a ground-water flow model. Simulations conducted using the steady-state model of the Mud Lake area developed by Spinazola (1994a) represented two variations from the 1980-to-1990 steady-state situation: 1) cessation of pumping from the western group of wells, and 2) cessation of pumping from the eastern well group. The difference between simulation results from these two scenarios represents the approximate impact of the transfer of pumping locations, relative to conditions that would exist if the transfer is not implemented. Results indicate local variations in aquifer water levels, perhaps as large as a few feet, and a net depletion of surface water sources totaling about 600 acre-feet per year.

REFERENCES

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