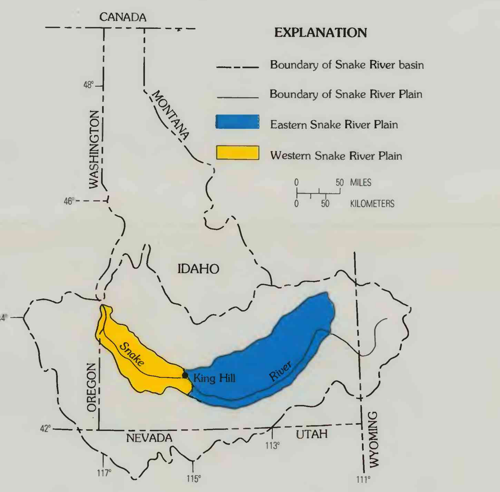
GROUND WATER

INTRODUCTION

This report is one in a series resulting from the U.S. Geological Survey's Snake River Plain RASA (Regional Aquifer-Systems Analysis) study that was initiated in October 1979. The purposes of the RASA study were to: (1) Understand the regional ground-water flow system, (2) determine effects of conjunctive use of ground and surface water, and (3) describe water chemistry (Lindholm, 1981). The purpose of this report is to present the location and volume of estimated 1980 water withdrawals for irrigation on the Snake River Plain. Sheet 1 depicts withdrawals from ground water; sheet 2 depicts withdrawals from the Snake River and its major tributaries. Kjelstrom (1984) summarized gravity diversions from the Snake River in 1980.

LOCATION OF STUDY AREA



The Snake River Plain is an arcuate area of about 15,600 mi² in southern Idaho and eastern Oregon. The plain is relatively flat and ranges in width from 30 to 75 mi and in altitude from about 2,100 ft in the west to about 6,000 ft in the east. The entire area is drained by the Snake River, whose course approximates the southern boundary of the plain.

For purposes of the RASA study, the plain was divided into two parts in the vicinity of King Hill, as indicated on the index map. The two parts, herein referred to as the eastern plain and western plain, exhibit significant geologic and hydrologic differences. A detailed description of the geohydrologic framework of the Snake River Plain was presented by Whitehead (1984). In a companion report, Kjelstrom (1984) presented water budgets for the eastern and western plain.

The eastern plain is underlain primarily by Quaternary volcanic rocks (primarily basalt) with interbedded sedimentary rocks along the margins. The high water-yielding basalts constitute the Snake Plain aquifer. The western plain consists largely of Quaternary and Tertiary sedimentary rocks. Sand and gravel zones and some basalts are the most productive aquifers. Contacts between Quaternary rocks and surrounding Tertiary and older rocks define much of the study area boundary.

The economy of the Snake River Plain is based largely on irrigated agriculture. According to a U.S. Geological Survey report, about 96 percent of consumptive water use in 1980 in Idaho was for irrigation (Solley and others, 1983). Concentration of irrigated agriculture on the Snake River Plain suggests that this reported percentage may be higher within the study area. In contrast, self-supplied industries account for about 3 percent of Idaho's consumptive water use, and public water supplies account for about 0.9 percent (Solley and others, 1983).

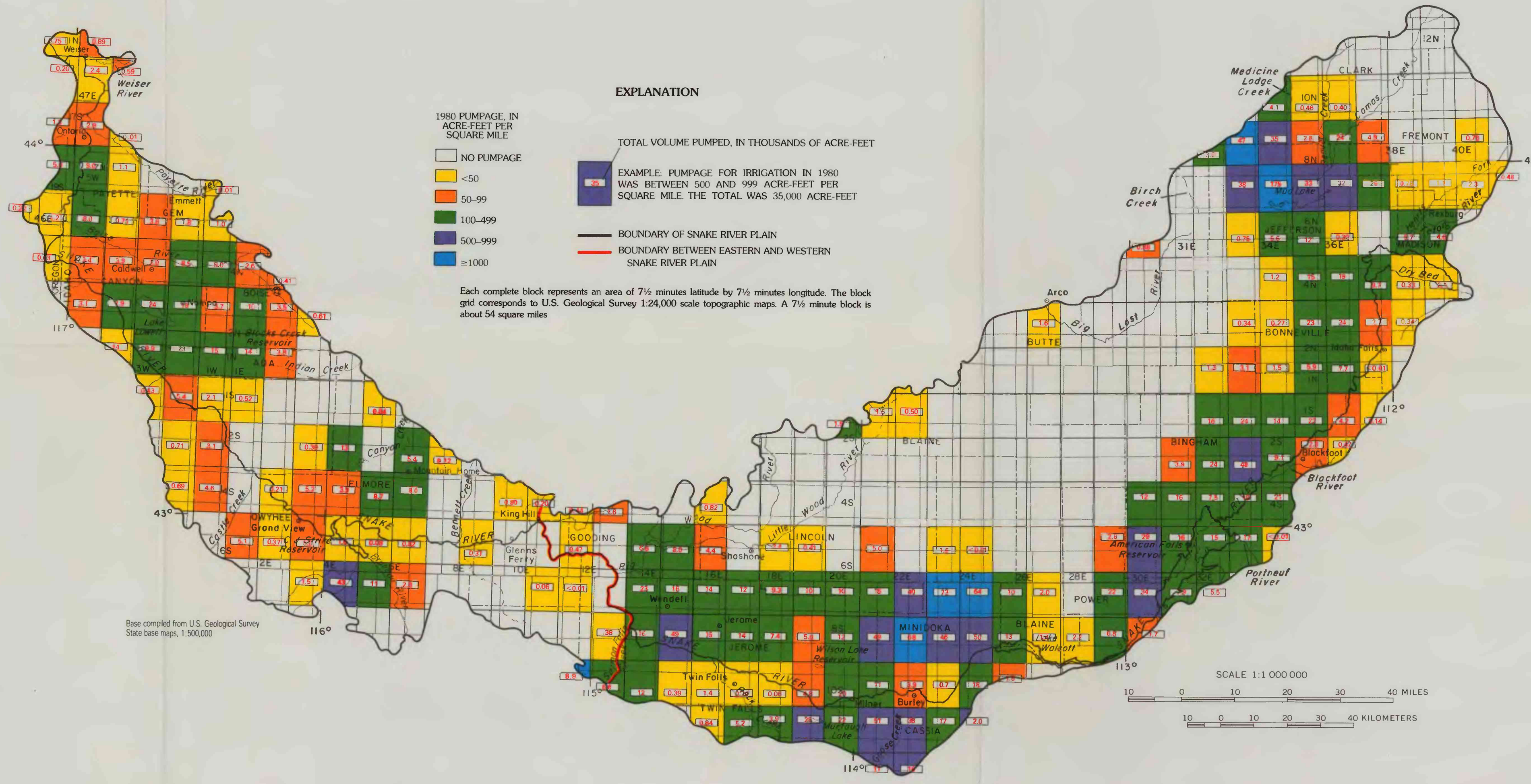
CONVERSION TABLE

For readers who prefer to use metric units, conversion factors for terms used in this report are listed below.

Multiply	*By*	*To obtain*
acre	*4,047*	*square meter*
acre-foot (acre-ft)	*1,233*	*cubic meter*
cubic foot per second (ft^3/s)	*0.02832*	*cubic meter per second*
foot (ft)	*0.3048*	*meter*
gallon (gal)	*3.785*	*liter*
gallon per minute (gal/min)	*0.06309*	*liter per second*
horsepower (hp)	*745.7*	*watt*
kilowatt-hour (kWh)	*3,600,000*	*joule*
mile (mi)	*1.609*	*kilometer*
pound per square inch (psi)	*70.31*	*gram per square centimeter*
square mile (mi^2)	*2.590*	*square kilometer*

NGVD of 1929 (National Geodetic Vertical Datum of 1929): The term "National Geodetic Vertical Datum of 1929" replaces the formerly used term "mean sea level" to describe the datum for altitude measurements. The geodetic datum is derived from a general adjustment of the first-order leveling networks in both the United States and Canada. For convenience in this report, the datum also is referred to as "sea level."

ESTIMATED GROUND-WATER PUMPAGE



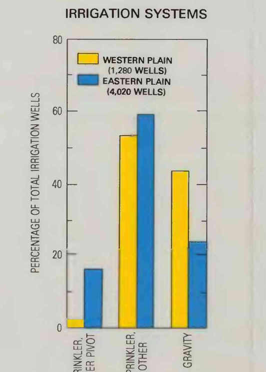
An estimated 2.3 million acre-ft of ground water were pumped from about 5,300 irrigation wells on the Snake River Plain in 1980. The following statements summarize 1980 ground-water pumpage:

--Pumpage on the eastern plain was 1.93 million acre-ft. Pumpage on the western plain was 0.36 million acre-ft.

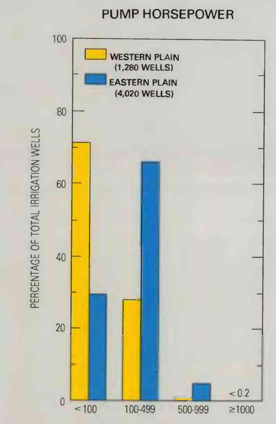
--Ground-water pumpage is concentrated in the Mud Lake area, the Minidoka Project area, and the Goose Creek drainage basin (see map above). The Goose Creek area corresponds to the Oakley-Kenyon, Cottonwood, West Oakley Fan, and Artesian City Critical Ground-Water Areas, as designated by the Idaho Department of Water Resources.

--Irrigators in the Mud Lake and Nampa-Caldwell areas consume less power per acre-foot of pumpage than those in other intensely pumped areas. Low power consumption per unit pumpage occurs because lifts are low and many wells discharge to gravity irrigation systems.

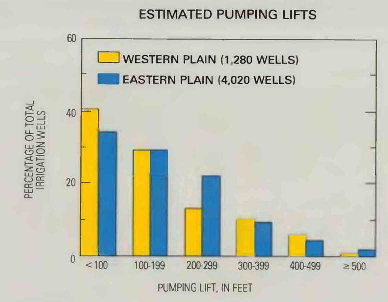
According to the RASA study, total annual ground-water recharge under current conditions is about 8 million acre-ft in the eastern plain and 2 million acre-ft in the western plain (Kjelstrom, 1984). On the basis of these estimates, 1980 ground-water pumpage was equal to about one-fifth of annual recharge to the ground-water system.



Reported types of irrigation distribution systems supplied by wells on the plain age: 29 percent gravity, 13 percent center pivot sprinkler, and 58 percent other types of sprinkler. Gravity systems are more common on the western plain and center pivot sprinklers are more common on the eastern plain.



Ground-water pumps by horsepower are: 39 percent less than 100 hp, 57 percent 100-499 hp, and 4 percent 500 hp or greater. Six pumping stations have greater than 1,000 hp. Most pumps with less than 100 hp have low lifts and discharge into gravity irrigation systems.

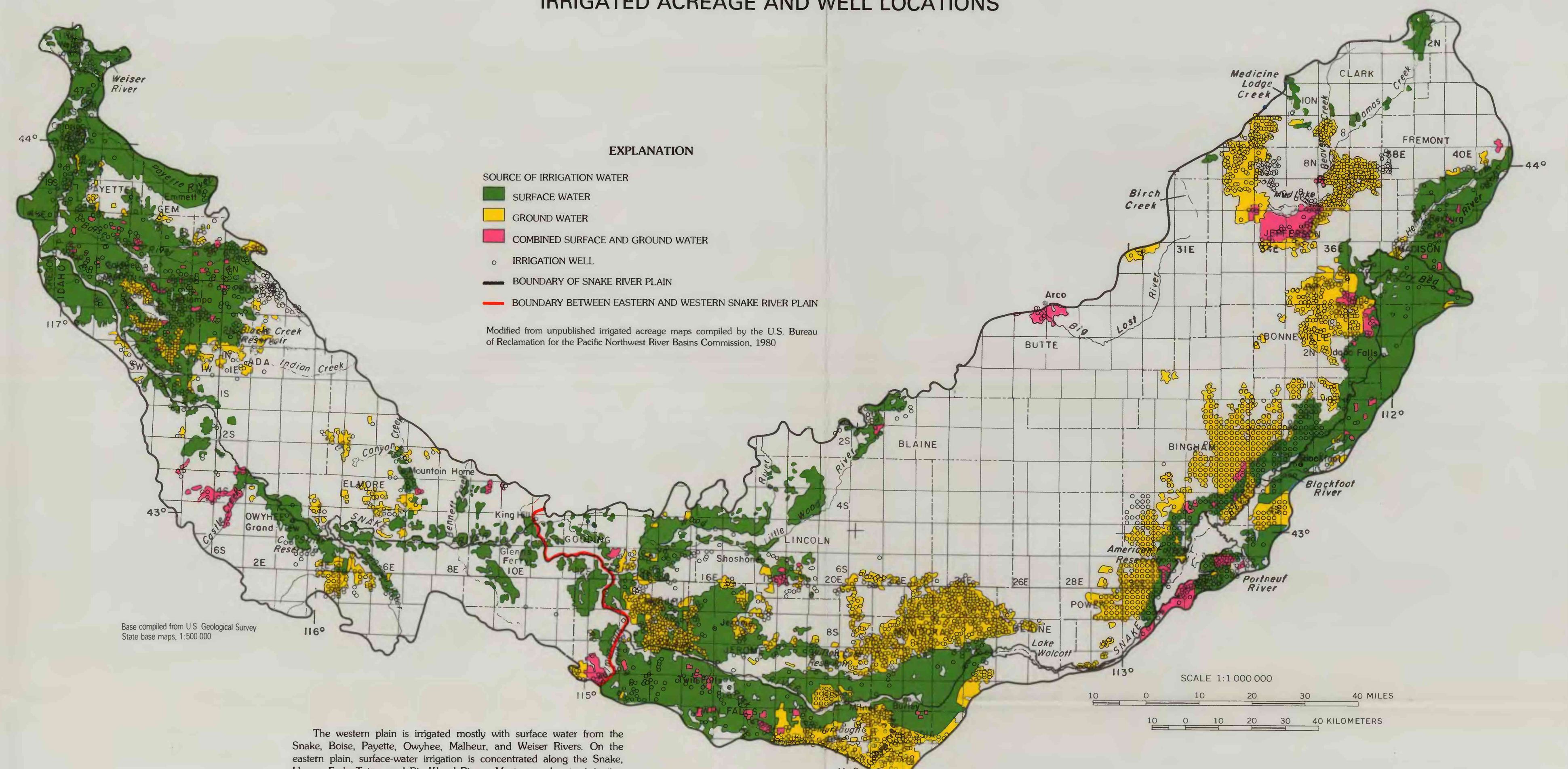


Estimated pumping lift is less than 200 ft in 65 percent of the irrigation wells and less than 300 ft in 85 percent of the wells.

ELECTRICAL POWER CONSUMPTION

Electrical power consumption for irrigation is included as an indirect indicator of 1980 irrigation pumpage. Changes in electrical power consumption from year to year are a measure of relative changes in pumpage. Data from power consumption and ground-water pumpage maps also can be used to calculate kilowatt-hour consumption per acre-foot of pumpage. Power consumption per acre-foot of pumpage varies with total head as described previously.

IRRIGATED ACREAGE AND WELL LOCATIONS



The western plain is irrigated mostly with surface water from the Snake, Boise, Payette, Owyhee, Malheur, and Weiser Rivers. On the eastern plain, surface-water irrigation is concentrated along the Snake, Henrys Fork, Teton, and Big Wood Rivers. Most ground-water irrigation is on the eastern plain.

The Idaho Department of Water Resources (1978) mapped 1975 irrigated acreage from small-scale color infrared aerial photography. These maps were updated to 1979 from U-2 photography and satellite imagery by the U.S. Bureau of Reclamation (1980).

Generally, irrigation well locations coincide with areas classified by State and Federal agencies as ground-water irrigated. Some wells in areas classified as surface-water irrigated are supplemental water sources. On the western plain, many wells drain waterlogged areas (Nace, West, and Mower, 1957, p. 9). The density of wells in some surface-water irrigated areas suggests that the importance of ground-water as a source for irrigation has been underestimated

Well symbols are absent in a few areas classified as ground-water irrigated. Well pumps in these areas may have power sources other than electricity, or electric power data may be in error.

Uniform distribution of well symbols in some areas, such as Bingham County, does not indicate a similar distribution of wells on the ground. In those areas, utility company well locations are accurate to the nearest section. Plotting each well in the center of the appropriate section results in the uniform distribution. For the same reason, density of well symbols does not accurately indicate density of wells. Several wells located in the same section are represented by one symbol.

GROUND–WATER DEVELOPMENT

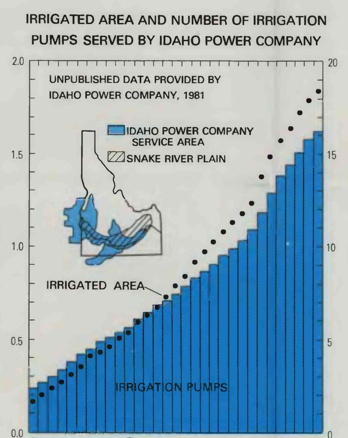
Steady increases in irrigated acreage and number of irrigation pumps since 1950 reflect a trend that began in the 1860's. Although the Idaho Power Company service area shown at right does not correspond directly to the Snake River Plain, the trend illustrated by the data is typical of expanding irrigation on the plain.

Early irrigation on the Snake River Plain was by gravity diversion of surface water. Surface-water irrigated area reached about 550,000 acres in 1899 and increased to 2.5 million acres by 1945 (G. F. Lindholm and S.A. Goodell, U.S. Geological Survey, written commun., 1982). After 1945, the use of ground water for irrigation increased rapidly. Use of ground water allowed irrigation of lands inadequately supplied by or inaccessible to surface water. Most of these lands are located on the eastern plain, which is underlain by fractured basalt that yields large volumes of good quality water.

Landsat data indicate that 3.1 million acres were irrigated on the Snake River Plain in 1980. Of these, about 1.0 million acres were irrigated with ground water, 2.0 million acres with surface water, and 0.1 million acres with combined surface and ground water (G. F. Lindholm and S. A. Goodell, U.S. Geological Survey, written commun., 1982).

Several previous studies of ground-water pumpage for irrigation have been made for parts of the Snake River Plain: Mundorff, Crosthwaite, and Kilburn (1964, p. 23) estimated that about 1.5 million acre-ft were pumped on the entire Snake River Plain in 1959; Norvitch, Thomas, and Madison (1969, p. 9) estimated 2.1 million acre-ft were pumped on the eastern plain 1966; and Young and Harenberg (1971, p. 22) estimated 1 million acre-ft were pumped on the eastern plain in 1969. No previous ground-water pumpage estimates have been made for the western plain, as defined in this report.

Differences in ground-water pumpage estimates point to the need for more accurate data. Accurate estimates of pumpage are needed as input to ground-water flow models and as an aid to managers and planners for surface- and ground-water management strategies.



METHOD OF ESTIMATING PUMPAGE

APPROACH

Pumpage from irrigation wells was estimated from electrical power consumption data. Most pumping stations in the study area are electrically powered. Data collected by Young and Harenberg (1971, p. 11) indicated that nonelectrical power was used for less than 1 percent of the irrigation pumps on the eastern plain.

Power consumed by a pump to lift and deliver water is related to total head (head from lift and from pressurized distribution systems) and quantity of water pumped.

Expressed mathematically:

$$kWh = (TH)\,(Q)\,(K) \qquad (1)$$

where

kWh = total power consumed in a year, in kilowatt-hours;
TH = total head, in feet, which in turn equals pumping lift (the distance from land surface to pumping water level), H_L, plus the pressure head associated with the irrigation distribution system, H_p;
Q = total volumne of water pump in a year, in acre-feet; and
K = number of kilowatt-hours required to lift 1 acre-ft of water 1 ft, in kilowatt-hours per acre-foot-foot.

The annual volume of pumpage for individual pumping stations can be calculated by the following equation:

$$Q = kWh\,/[(K)\,(TH)] \qquad (2)$$

If Q, kWh, and TH are observed and recorded, then K can be determined statistically.

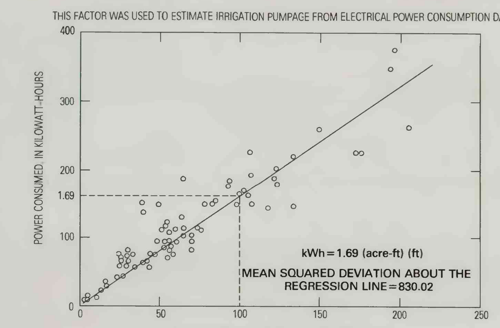
PUMPAGE CALCULATIONS

Using equation (2), 1980 pumpage was calculated for each of 5,300 electrically powered irrigation wells on the plain. Power consumed at each well in 1980 was supplied by utility companies. The value for K was estimated statistically on the basis of field data, and total head (H_L plus H_P) was estimated hydrologically.

Measurements of volume discharged (acre-ft), power consumed (kWh), and total head (ft) were made at 72 wells and 7 river pumps over short intervals to determine site-specific values of K. A representative value of K, subsequently used as a constant in pumpage calculations, was estimated by applying the method of linear regression to the data as shown in the graph below.

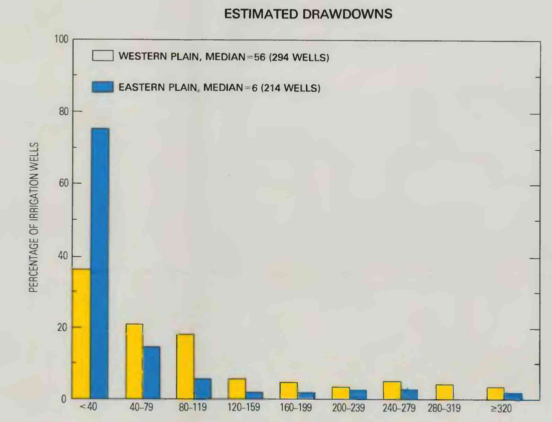
AN EMPIRICAL FACTOR, K, DETERMINED FROM FIELD DATA

THIS FACTOR WAS USED TO ESTIMATE IRRIGATION PUMPAGE FROM ELECTRICAL POWER CONSUMPTION DATA



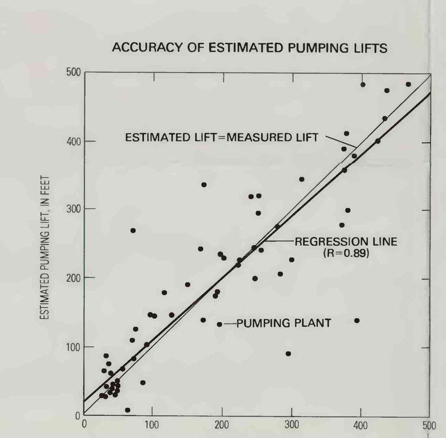
The estimated value of K is the slope of the regression line. On the basis of sample data, K equals 1.69; that is, 1.69 kWh were used to lift 1 acre-ft of water 1 ft.

Total head was estimated for each well by summing estimates of pumping lift and pressure head. Pumping lift includes static lift and pumping drawdowns. Static lift is the difference between altitude of land surface at point of discharge and altitude of static ground-water level. Land surface altitude were interpolated from topographic maps and static water levels were interpolated from the March 1980 water-table map (Lindholm and others, 1983).



A pumping drawdown of 56 ft was added to estimated static lift for all wells on the western plain and 6 ft for all wells on the eastern plain. Drawdowns are medians from data reported by well drillers for wells yielding more than 300 gal/min. Medians rather than means were used to dampen the effects of a few extremely high drawdown values.

Differences in drawdown estimates for the eastern and western plain are due largely to differences in aquifer transmissivity. Most wells on the eastern plain are completed in high water-yielding basaltic rocks, whereas most wells on the western plain are completed in relatively low water-yielding sedimentary rocks.



To assess the accuracy of estimated lifts, pumping lifts measured at 72 test sites were compared to estimated lifts for the same sites. (Data from 7 of the original 79 tests were eliminated because heads were estimated in the field rather than measured.)

The relation between estimated and measured lifts is depicted in the graph above. A correlation coefficient of 0.89 for the linear regression between estimated and measured values indicates that estimated lifts are reasonably close to measured lifts within the confidence of the data.

Pressure head was estimated for each well on the basis of type of distribution system as reported by utilities. Reported distribution systems agreed with those observed at 90 percent of the test sites.

Heads for center pivot and other sprinkler systems are averages of pressure estimates reported in a survey of companies that sell and install irrigation systems in the study area. The estimates are shown in the following table:

Irrigation distribution system	Estimated pressure head, in pounds per square inch	Estimated pressure head, in feet
gravity	0	0
sprinkler, center pivot	90	208
sprinkler, other	60	139

Annual kilowatt-hour consumption data supplied by utility companies were used to estimate 1980 pumpage for each pumping station within the study area. Pumpage estimates for individual wells then were summed over areas of 7½ minutes latitude by 7½ minutes longitude.

In areas where total head is low owing to gravity distribution systems and shallow depth to water, pumpage may be overestimated. For example, in the Mud Lake area, the estimation method resulted in a pumpage 35 percent greater than that obtained by other investigators (Johnson and others, 1982, p. 26; U.S. Geological Survey, unpubl. data, 1982) who used several different estimation methods.

Errors in pumpage estimates presented in this report probably result from error in estimated variables. However, pumpage calculations used the best data presently available. Future pumpage estimates would benefit from improved estimates of static lift, drawdown, and K.

WATER WITHDRAWN FOR IRRIGATION IN 1980 ON THE SNAKE RIVER PLAIN, IDAHO AND EASTERN OREGON

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1987