As a second check on the validity of using Von Bernuth's statistically-derived equations, the pumping cost values obtained by Haynes for the Oakley Fan (Haynes, 1969) were recomputed using his data in Von Bernuth's equation No. 4. The annual costs obtained by Haynes from itemizing costs for various systems ranged up to 14 percent higher than costs for the same system calculated using equation No. 4 (fig. 3). Part of this variation is due to the inclusion of annual costs for concrete head ditches, siphon tubes, and land leveling in the values calculated by Haynes while these costs were not included in the estimate obtained using equation No. 4. The greatest variation between the costs obtained by the two methods were for very high lift systems (800 to 1,081 feet). Better agreement was indicated for the lower lifts which are more commonly encountered.

Because power rates, interest rates, depreciation rates, and other cost influencing factors are variable, a better agreement between the estimates obtained using Von Bernuth's equation No. 4 and those obtained by an itemizing procedure could not be expected when using a single equation to calculate costs for pumping in all areas of the state. Therefore, Von Bernuth's equation No. 4 was used to estimate total annual water costs in this study.

DATA ACQUISITION

Data for well and pump characteristics are available from several sources: pump retail companies, well drillers, departmental records, and well owners; however, the well owner is the only source of data on the actual details of well operation. Because operating hours and volume pumped are such key factors in determining costs, a method of collecting data directly from the well owner was used. Questionnaires requesting the data needed for calculating pumping costs using Von Bernuth's equation No. 4 were mailed to approximately 500 well owners. Names were obtained from well driller's logs on file with the IDWA for wells drilled since 1965. Corrected addresses were obtained from licensing applications on these same wells. Data for recently drilled wells were requested so that the investment values would represent current replacement costs. A total of 165 usable questionnaires were returned. Many others were returned, but lacked some of the necessary information. Follow-up letters were sent to clarify doubtful information.

Several methods were used to estimate the accuracy of the reported data. The volume in acre-feet per acre that would be applied to the farmland using the data reported was compared to the irrigation requirement for alfalfa for the area (fig. 4). Many of the reported use values were lower than the expected requirement. This is possible either because of application efficiencies being better than assumed, all crops not being alfalfa, or the well was being used as a supplemental supply. Many of the points for which the reported acre-feet per acre use was higher than the expected irrigation requirement were for areas of coarse soil and may actually be necessary. However, it is likely that part of the variation of the reported water use from the expected water use is due to inconsistencies in the reported data. The reported water use was calculated using data for pump discharge, hours pumped annually, and irrigated acreage. The acreage values are probably accurate; however, the irrigator probably tends to overestimate the pump discharge and the annual hours of use. This overestimate of the yield of the system biases the result by making the cost per acre-foot pumped as calculated by the Von Bernuth equation lower than actually exists.

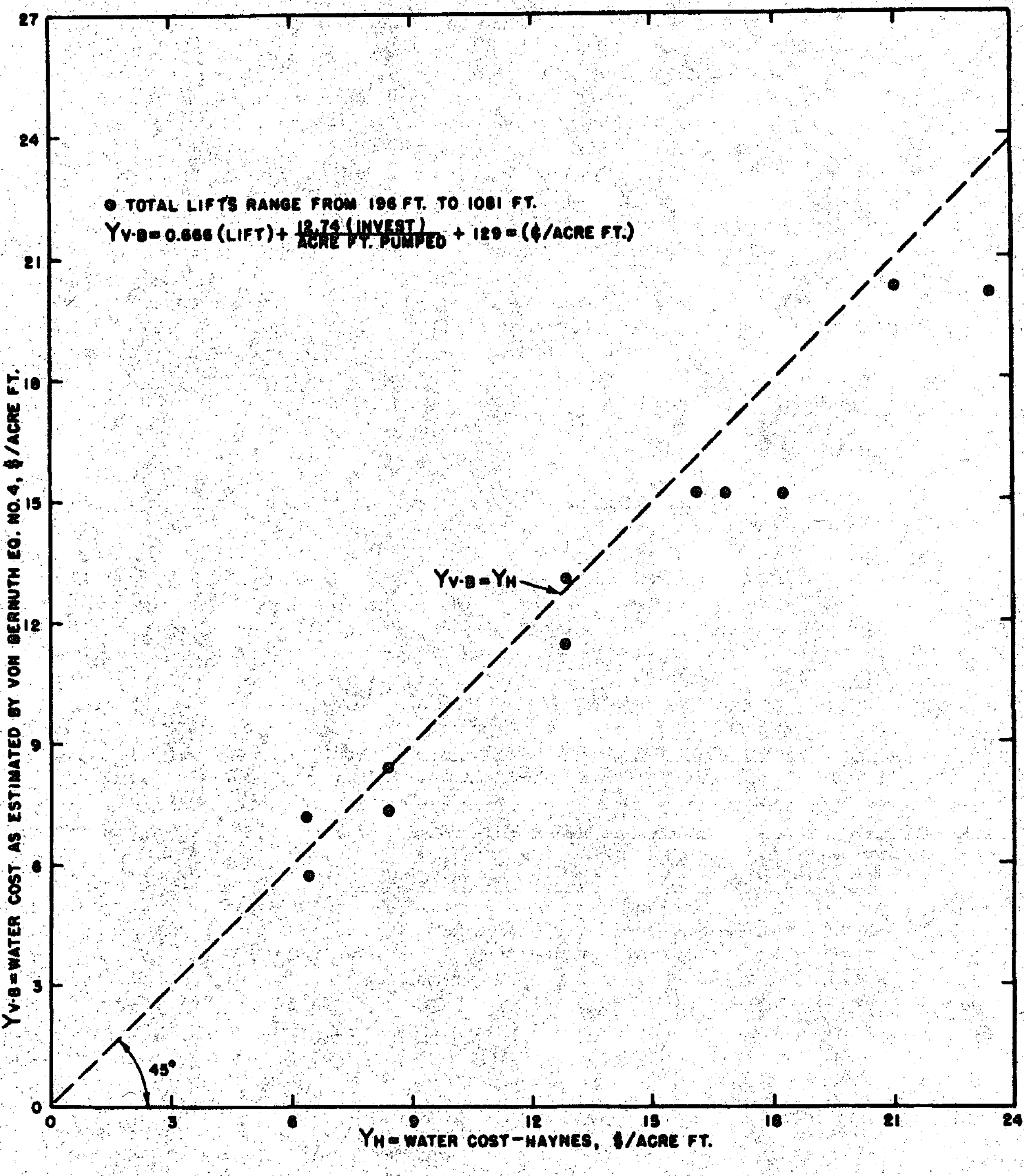

FIGURE 3. Comparison of water costs calculated using the Von Bernuth short-cut method to those for the same systems calculated by Haynes by itemizing

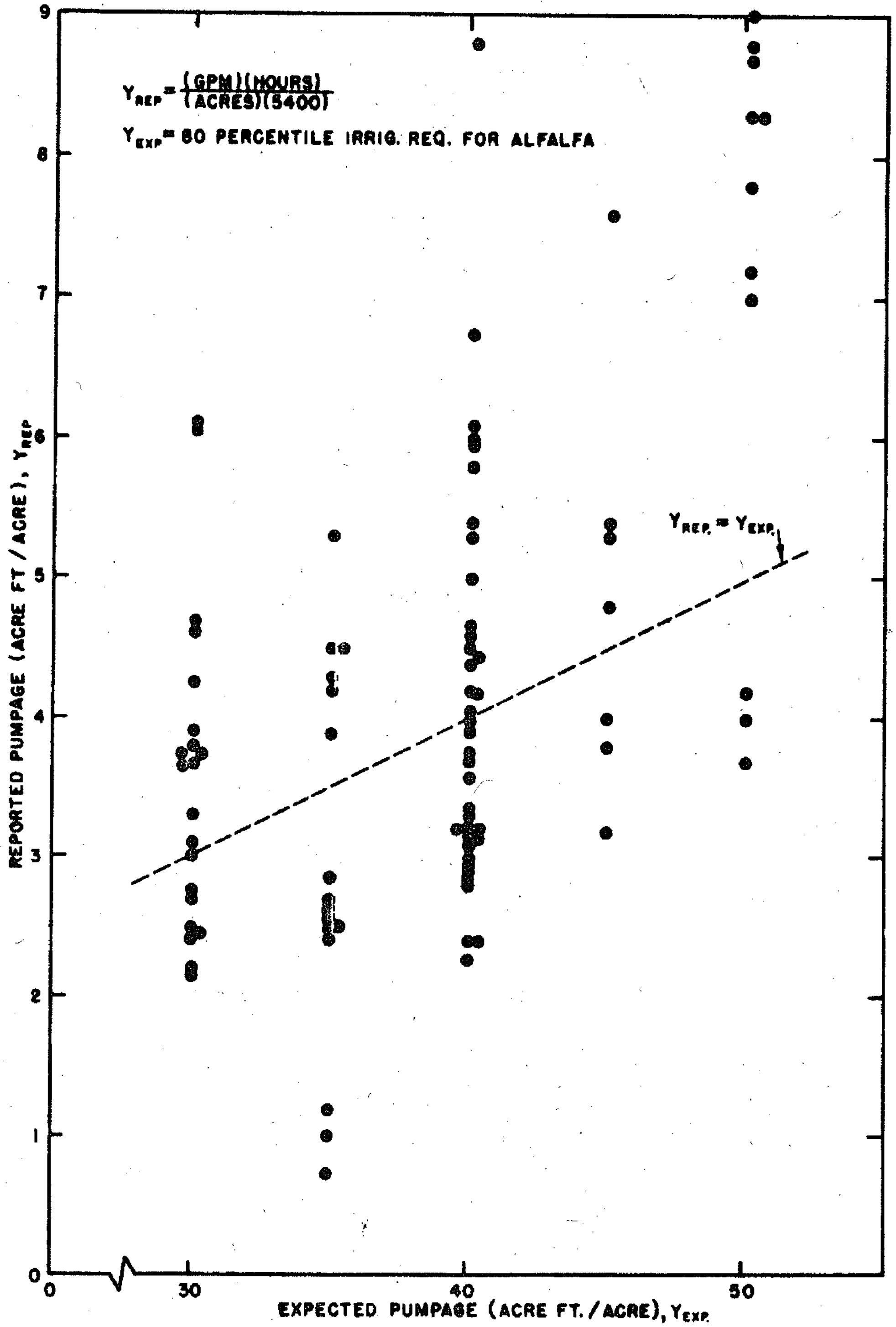

FIGURE 4. Comparison of reported water use to expected water use

Another method used to check the accuracy of the data was the comparison of the reported horsepower of the pump to that required to lift the reported discharge through the reported lift, assuming a reasonable efficiency (fig. 5). Again, considerable variation exists between expected values and calculated values. Part of the variation is due to the use of the single efficiency of 60 percent and the use of the same increase in lift for every sprinkler system. Part of the variation is undoubtedly due to inconsistencies in the reported data.

As a final check, the reported investment costs were compared to expected prices obtained from retail pump companies and well drillers. Although these checks are only general they indicate that the data, as a whole, are reasonable. The questionnaire data was used as reported in all cases.

CALCULATION OF PUMPING COSTS

A cost per acre-foot was calculated for pumping from each of the wells covered by the questionnaires using Von Bernuth's equation No. 4 for electrically-powered wells (fig. 6). At any given lift, a wide range of costs may be noted. Cost results as presented in figure 6 have been divided into groups on the basis of acre-feet pumped annually. It can be seen from this figure that costs per acre-foot decrease with volume pumped.

If it assumed that the returns represent a random sample of data for wells in Idaho, the costs should be good estimates of the cost of pumping irrigation water in Idaho.

ANALYSIS OF COST INFORMATION

The large range of costs that appear in figure 6 for each lift is the result of variation in two major factors: pumping time per season, and initial investment. Von Bernuth, in the development of his equation No. 4, divided the cost factors into two main groups: fixed or overhead costs and variable or operating costs. The variability of these costs with pumping time per season is important in explaining the range in results. As pumping volume per season increases, the fixed (overhead) costs tend to decrease per unit of water pumped because the costs are spread over more units of water. The variable (operating) costs remain approximately the same for each unit. The result is an over-all decrease in the total unit pumping costs as the volume pumped increases. This trend is intensified by power company contracts which specify a minimum yearly power cost up to a specified minimum number of hours and by rate schedules which reduce power rates as more electricity is used.

A well and pump system that is properly designed to produce the required volume of water for a farm will have a maximum number of operating hours per season. The number of operating hours per season will depend upon the length of the growing season, the availability of reservoir storage, the maximum irrigation demand rate, and the excess capacity desired for insurance in case of pump failure.

The other major factor which causes the variability in costs at a given lift is initial investment. A statistical correlation analysis of the well and pump data obtained from the questionnaires indicates a coefficient of determination between lift and initial investment divided by quantity of water pumped of only 0.019; that is, only 1.9 percent of the variation in the factor initial investment divided by quantity pumped is attributable to regression on

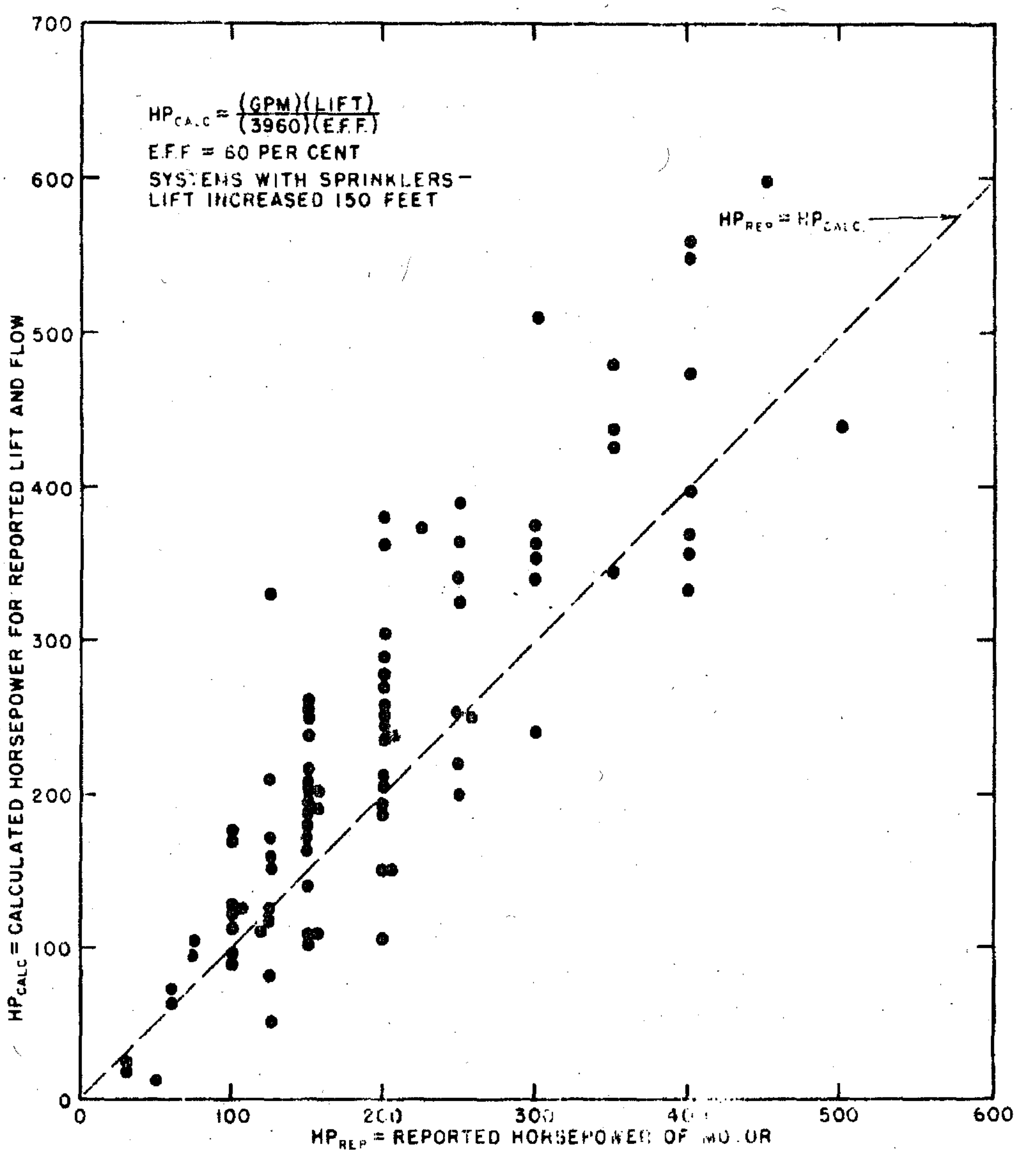

FIGURE 5. Comparison of power required for the reported lift and flow to the reported power of the pump motor

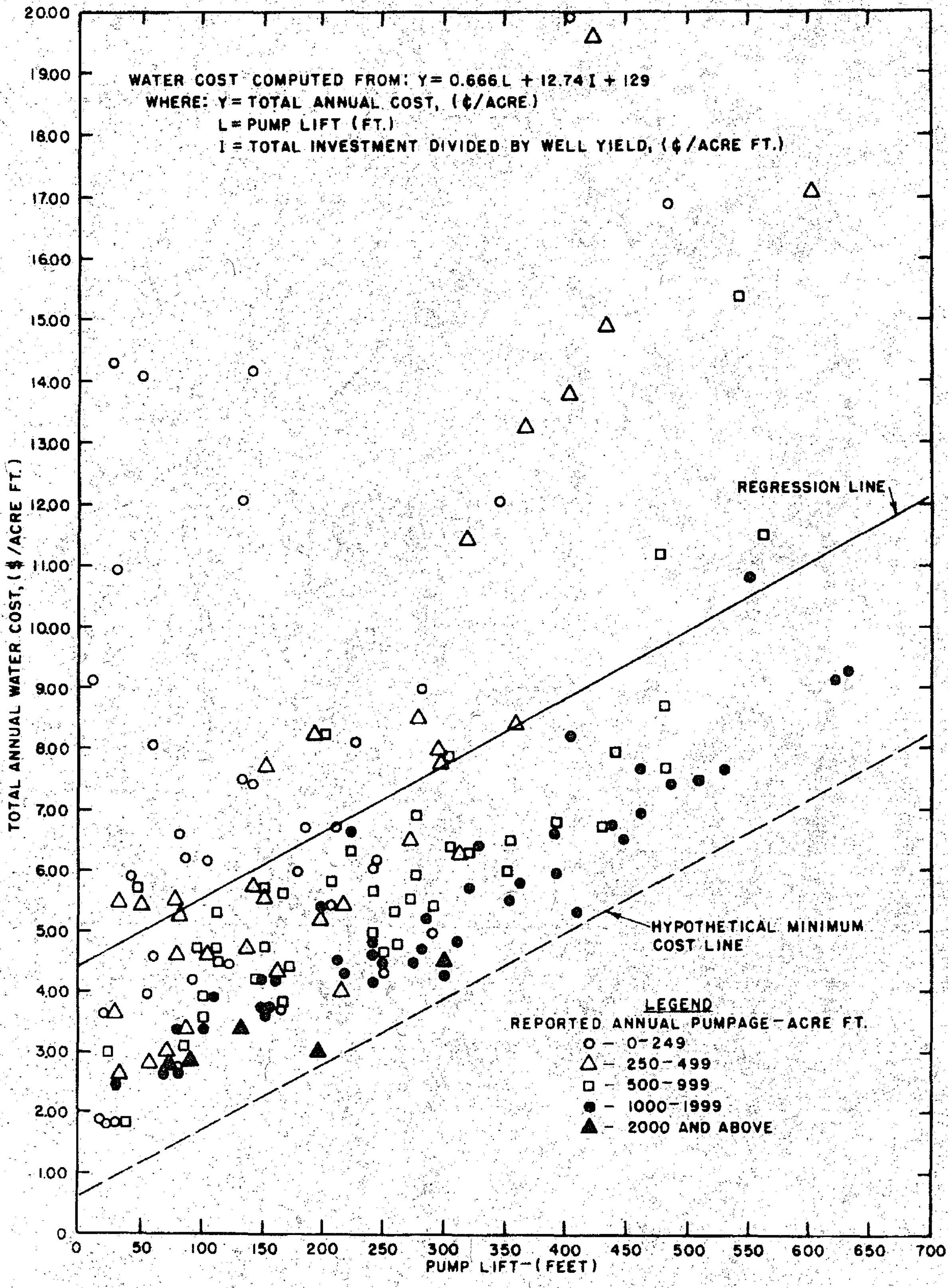

FIGURE 6. Relationship of pumping cost to pumping lift (all questionnaire data used)

lift. Part of this lack of correlation is caused by pumping time differences and discharge rates, and part by variations in initial investment. Wells do not have identical depths for the same pumping lifts. Differences in pumping drawdown, artesian lift, and the owner's decisions concerning extra depth for insurance against water-level decline can result in a large variation in well depth and drilling costs. Differences in well diameter can have a similar effect on costs. Von Bernuth's equations do not account for these variables directly; however, it can be assumed that on the average these differences are accounted for by the regression analysis used.

A cost calculated for a single set of well characteristics can be inaccurate because of variations in investment costs and operating conditions from farm to farm. This variation is shown by the scatter of costs for pumping water at any given lift shown in figure 6. Therefore, it is more accurate to calculate costs for a large number of wells and analyze the resulting data to determine more representative costs. This was accomplished statistically by calculating regression curves of calculated costs versus lift. The calculations were made using an IBM 360 Model 40 computer at the University of Idaho. Both a linear regression line and a second order curve were calculated for the data (table 5). The coefficients of determination indicate that very little of the variation in cost are attributable to lift (11.9 and 14.4 percent for the line and curve, respectively). It also indicated that the degree of improvement using curvilinear regression as opposed to a straight line regression was not significant.

TABLE 5
RESULTS OF REGRESSION ANALYSIS OF CALCULATED PUMPING COST AS A FUNCTION OF LIFT
(Unit pumping costs estimated using questionnaire data in Von Bernuth's equation No. 4)

Description of Well Data Included in Regression Analysis	Type of Analysis	Y Intercept	Regression Coefficient for Lift (L)	Regression Coefficient for L^2	Coefficient of Determination (r^2)
All Data	Linear	$4.51	0.0108	–	0.119
	Curvi-Linear	$5.97	−0.00405	0.0002643	0.144
Data for Wells on 10 Acres and More	Linear	$3.61	0.0128	–	0.250
	Curvi-Linear	$4.84	0.000436	0.0000217	0.275
Data for Wells Pumping 500 Acre-Feet and More Annually	Linear	$1.97	0.0137	–	0.82
	–	–	–	–	–

It was determined from an analysis of the data that the cost per acre-foot for wells used on small acreages were the highest values shown in figure 6. Regression equations, both linear and curvilinear, were calculated for data remaining after cost data for wells on acreages of 10 acres and less were eliminated (table 5). The coefficients of determinations were 25.0 and 27.5 percent for the linear and curvilinear equations, respectively. This was a considerable improvement because data for only 4 wells were eliminated.

It was felt, however, that to keep the pumping costs determination coordinated with the payment capacity calculation, it was necessary to base the cost only on wells pumping for economic-sized units. A 150-acre farm using water at 3.5 acre-feet per acre requires 525 acre-feet of water per year. Arbitrarily, data for wells producing less than 500 acre-feet per year were excluded. The linear regression line (fig. 7) for the data for the remaining 97 large wells had a coefficient of determination of 0.82; that is 82 percent of the variation in calculated cost was attributable to lift for these wells. The large degree of improvement in the correlation coefficient is somewhat inherent in the method of analysis used because only three independent variables, lift, volume pumped, and initial investment are included in Von Bernuth's equation No. 4. Restricting one of the variables, volume pumped in this case, is certain to help the correlation of the other variables with respect to the calculated dependent variable, cost. However, it is felt that this approach is reasonable and necessary because of the limiting assumption on farm size. The regression line shown in figure 7 is used to estimate pumping costs as a function of lift in this study.

The regression coefficient or slopes are small for all of the regression lines calculated. Total costs, thus, do not increase rapidly with lift. Since the slopes are little more than would be expected due to increased power costs, a compensating effect must also be in force. A compensating increase in efficiency with increased lift is believed to exist. This increase is obtained as a result of matching the well and pump system to the farm and by better operating efficiency. Farmers lifting water 500 feet are more likely to be conscious of the necessity for good design and efficient operation than farmers lifting water only 50 feet, assuming similar payment capacities.

A minimum pumping cost line is apparent from the plot in figure 6. A line drawn approximately parallel to the regression line for cost on lift and just below the lowest data points (this line is shown dashed), represents a minimum cost relationship which only efficiently designed and operated systems attain. By efficiently designed, it is meant that the size, depth, and price of the well and size, capacity, and price of the pump were minimized to result in a minimum initial investment and maximum operating time to produce the required volume of water. Such a well might be termed an ideal well. The only way to get a cost lower than the minimum cost line would be to get a bargain on the price of the well or pumping system. If this relationship were firmly established by actually designing ideal wells for a given lift for a number of sets of required volumes (farm sizes), it would be a valuable tool for evaluating efficiencies of design and operation of actual systems.

QUANTITY OF WATER REQUIRED

A number of sources of data are available for estimating the quantity of water required for various crops for many parts of the state. Estimates of water requirements are available

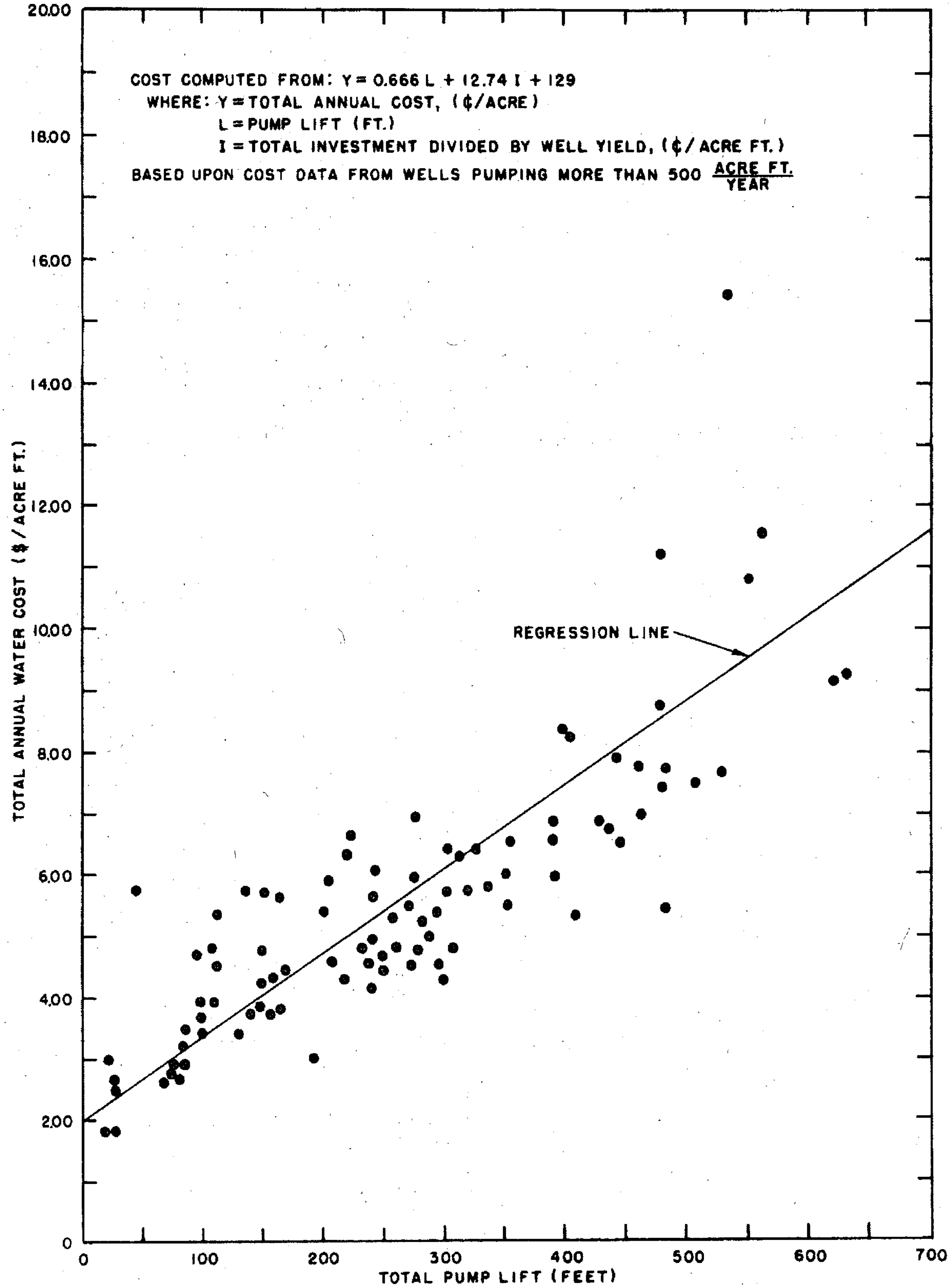

FIGURE 7. Relationship of pumping cost to pumping lift (large capacity well data only)

for particular areas in reports published by the U. S. Geological Survey, USBR, IDWA, University of Idaho, and other agencies. These data were developed using various equations and methods for estimating consumptive use. A bulletin published in 1952 by Jensen and Criddle, "Estimated Irrigation Water Requirements for Idaho", has been a standard guide for estimating water requirements by crop and area. These estimates are based upon the Blaney-Criddle consumptive use equation and climatic data for the area. Researchers at the University of Idaho, Department of Agricultural Engineering, have updated and extended the Jensen and Criddle bulletin by providing estimates of crop water requirement for each major agricultural area (Sutter and Corey, 1970). The water requirements were calculated for each crop using the modified Blaney-Criddle equation and climatic data from selected local weather stations. Consumptive use was calculated for each crop for each month of record at each station. Rainfall during the growing season was subtracted from consumptive use to give consumptive irrigation requirements. The resulting values were then reported in terms of percentiles for months requiring less than a certain value. This bulletin provides the most comprehensive source of data on irrigation water requirements available and is the basis for determining irrigation requirements used in this report.

DETERMINATION OF WEIGHTED AVERAGE IRRIGATION REQUIREMENT FOR EACH BASIN

A weighted average irrigation requirement was determined for each ground-water basin on the basis of the total water use by ten irrigated crops in a county representative of the basin. The total water use was calculated by summing the product of the number of acres of each crop grown in the county as reported in the 1964 Census of Agriculture and the corresponding 80 percentile consumptive irrigation requirement of the respective crops for a nearby weather station (Sutter and Corey, 1970). The 80 percentile requirement was chosen rather than the 50 percentile value because it is believed that reasonable pumping lifts should be based upon an adequate water supply. The 100 percentile value (the water capacity necessary to supply the crop requirements during the highest water use year on record) was not used because this value is affected by extreme years which do not occur frequently.

The weighted average irrigation requirement was obtained by dividing the total water use by the combined acreage of the ten crops in the county. The ten crops used in determining the average water use were the same ones as used in determining the gross income ratio for estimating payment capacity. The headgate irrigation requirement was obtained, assuming 60 percent field application efficiency, by dividing the weighted consumptive irrigation requirement by 60 percent. The field application efficiency used has been found to be reasonable for carefully applied surface irrigation. Irrigation requirements for basins were estimated by assuming the requirement to be similar to that for the county in which the basin is located or a county similar in climate and cropping patterns. The weighted average headgate irrigation requirement is listed in table 6 for each county used in this analysis and is shown by area in figure 8.

DISCUSSION OF CALCULATED WATER REQUIREMENTS

The actual water requirement is variable from farm to farm and from year to year. This variability requires making an administrative choice as to the water requirement that can be reasonably expected. Therefore, the 80 percentile values were used in order to insure an

TABLE 6

SUMMARY OF CALCULATION OF REASONABLE PUMPING LIFT ESTIMATES

(1) Basin No.*	(2) Basin Name	(3) County Used in Determining Payment Capacity	(4) Payment Capacity	(5) Weighted Ave. Irrigation Requirement	(6) Weather Station	(7) Payment Capacity	(8) Reasonable Pumping Lift Estimate
-	-	-	$/A	A-F/A	-	$/A-F	Feet
1	Rathdrum	Kootenai	8	2.73	Coeur d'Alene	2.95	75
2	Weiser	Adams	7	3.42	Council	2.05	0
3	Weiser River	Washington	25	3.48	Weiser	7.20	380
4	N.F. Payette	Valley	8	1.98	Cascade	4.05	150
5 & 6	Garden Valley, Stanley Basin	Boise	7	2.03	Cascade	3.45	110
7	Payette	Payette	14	3.27	Weiser	4.30	170
8	Payette	Gem	12	3.53	Caldwell	3.40	100
9	Boise	Canyon	45	3.45	Caldwell	13.05	800
10	Boise	Ada	15	3.49	Caldwell	4.30	170
11	Bruneau, Homedale, Murphy, Grand View	Owyhee	22	4.08	Grand View	5.40	250
12	Mountain Home	Elmore	40	3.60	Mountain Home	11.10	670
13 & 14	Salmon Falls, Sailor Creek	Twin Falls	25	2.87	Twin Falls	8.70	500
15	Camas	Camas	6	2.20	Fairfield	2.75	60
16	Big Wood, Silver Creek, Little Wood	Blaine	8	2.53	Hailey	3.15	90
17	Snake Plain	Gooding	15	3.14	Twin Falls	4.80	210
18	Snake Plain	Lincoln	10	3.07	Shoshone	3.25	90
19	Snake Plain	Jerome	25	2.94	Twin Falls	8.50	475
20	Snake Plain	Minidoka	34	3.08	Rupert	11.00	650
21	Michaud Flat	Power	37	3.05	Pocatello	12.15	740
22, 23 & 24	Rock Creek-Goose Creek, Raft, Rockland Valley	Cassia	26	3.12	Rupert	8.35	470
25, 26, 27 & 28	Malad, Arbon, Curlew-Black Pine, Pocatello	Oneida	9	2.90	Malad	3.10	80
29	Cache Valley	Franklin	11	2.77	Preston	4.00	150
30	Bear Lake	Bear Lake	7	2.12	Montpelier	3.30	100
31 & 32	Portneuf, Gem-Gentile Valley	Caribou	10	2.02	Grace	4.95	220
33	Snake Plain	Bingham, Madison, Bonneville	25	2.64	Idaho Falls	9.45	550
34 & 35	Lower Teton, Willow Creek	Fremont	18	2.00	Ashton	9.00	510
36	Upper Teton	Teton	7	1.91	Driggs	3.65	120
37	Mud Lake	Jefferson	15	2.54	Dubois	5.90	280
38	Birch Creek	Clark	7	2.48	Mackay	2.80	70
39 & 40	Big Lost River, Little Lost River	Butte	10	2.42	Mackay	4.15	160
41 & 42	Challis, Pahsimeroi	Lemhi	7	2.91	Challis	2.40	50
43	Lemhi River	Lemhi	7	2.61	Salmon	2.70	70

*Basin numbers refer to those shown in figure 8.

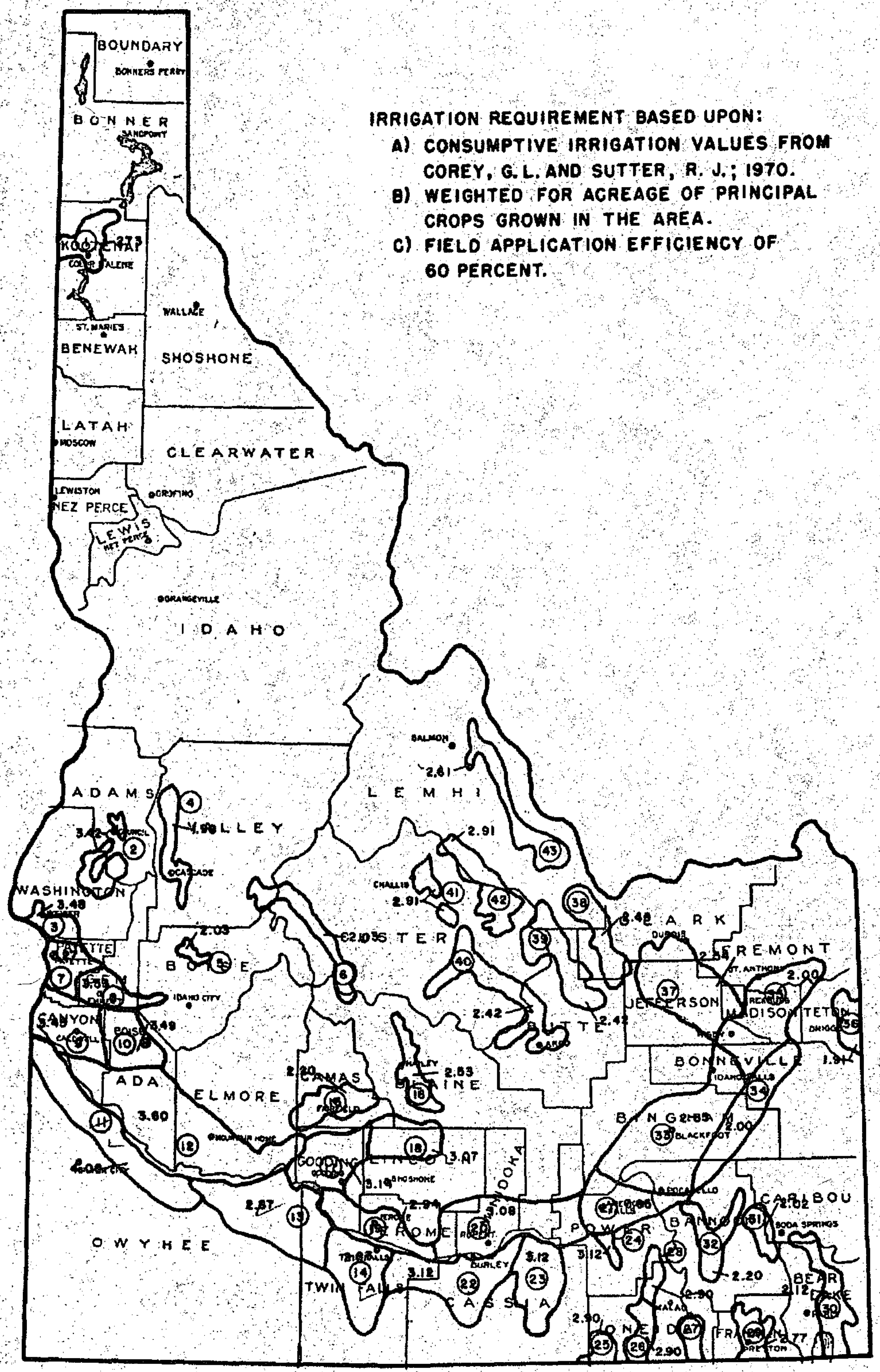

FIGURE 8. Weighted average irrigation requirement for ground-water basins in Idaho

adequate supply except on extreme years.

A potential source of error is apparent in deciding which county average should apply to which basin. The irrigation requirements as calculated are reasonably accurate for the station at which the data were collected; however, the station averages do not exactly fit each county or basin. The same problems were encountered here as in transferring the calculated gross income ratios for a representative county to a basin. The estimates are good when a county contains only the basin in question. However, a judgment factor is required when the county contains more than one basin or the basin extends over more than one county. Care was taken to insure that this judgment factor was as sound as possible by comparing basin and county elevations, climates, and cropping patterns.

On an individual farm basis the calculated weighted-average irrigation requirement will not always apply. It is doubtful that any farmer grows the rotation exactly average for the county. Consequently, a farmer growing crops with high water requirements (alfalfa, potatoes, sugar beets) will have a higher average farm water requirement than that listed for the basin. Such a farmer would be penalized with respect to a farmer growing low water requirement crops (grain, vegetables).

DELINEATION OF GROUND-WATER ADMINISTRATIVE BASINS

It is not possible to denote a single value of reasonable pumping lift for the state because of the wide variations in payment capacities and water requirements. A review of Section 42-237a of the Idaho Code makes it apparent that the Legislature intended for the reasonable pumping lift estimates to be determined for each individual hydrologic ground-water basin.

> *..., he may establish a ground-water pumping level or levels in an area or areas having a common ground-water supply as determined by him as hereinafter provided...*

Areas of common ground-water supply were determined by reviewing reports of previous hydrologic and geologic studies of ground water in Idaho. Ground-water basin boundaries in areas not previously studied in detail were estimated using geologic and topographic maps. Many of the hydrologic ground-water basins encompass areas of significantly varying elevations, climates, soil types, crop rotations, and crop yields. The reasonable pumping lift thus changes over the basin. Section 42-237a of the Idaho Code, quoted above, allows for the possibility of setting more than one reasonable pumping lift for a basin. For this study, boundaries were determined for areas within ground-water basins having similar payment capacities. This was necessarily accomplished only on a gross scale because data on crop yields are available only on a county-wide basis. The Snake Plain ground-water basin is basically an area of common ground-water supply, but changes in elevation, soil, and other factors cause the payment capacity to vary considerably from one end to the other. Therefore, the basin was divided into a number of subbasins and data for counties typical of these subbasins were used to determine reasonable pumping lifts for each of them. This procedure was used to subdivide each basin with areas of obviously varying payment capacities. It is realized that within each of these subbasins the reasonable lift varies widely. The process of subdivision of basins could be carried to the extent of saying that one field has a different reasonable pumping lift than another field on the same farm. Subdivision must be discontinued at some point, and it is felt that these subdivisions are adequate for the present estimates of reasonable pumping lifts. The administrative basins as subdivided are shown in figure 9.

REASONABLE PUMPING LIFT ESTIMATES

A reasonable payment capacity has been estimated for each county having significant irrigated acreage; a reasonable estimate of costs for pumping water from wells has been determined; and an estimate of the volume of water required to grow crops in each county has been made. Using these results, an estimate of the reasonable pumping lift can be made for each of the administrative ground-water areas that have been delineated. The details of determining reasonable pumping lift are shown in table 6. For each administrative basin the following data are listed: the county used in determining the payment capacity, the payment capacity in dollars per acre, the irrigation requirement, the payment capacity in dollars per acre-foot (column 4 divided by column 5), and the reasonable pumping lift (obtained from the pumping cost curve, fig. 7, using the payment capacity listed in column 7).

Based upon the values obtained in column 8, table 6, seven ranges of reasonable pumping lift have been delineated. Each ground-water basin has been assigned to the range indicated by the calculated value in column 8 of table 6. For basins having two or more counties, reasonable pumping lifts are assigned also to subareas within the basins (table 7). The reasonable pumping lift ranges are shown by areas in figure 9. Care must be exercised in applying the reasonable pumping lift estimates to individual farms or areas in any basin. The productivity values utilized in determining the payment capacities are county averages and may not apply to a particular area within a county.

The wide variations possible in each of the factors that determine an economic pumping lift for an operation make it imperative that any estimate of reasonable pumping lift for an area be qualified by the assumptions made in determining it. The reasonable lift values shown for each area (fig. 9) were estimated assuming a 150 to 200-acre farm growing crops typical of the basin with average yields. It was also assumed that the irrigation requirement was not excessive and that the pumping costs were similar to those shown in figure 7. As has been emphasized throughout the report, each of these factors is variable if a study is attempted on other than a gross scale. The reasonable pumping lift may be much less than that from which some irrigators can economically afford to pump. A farmer could have a larger payment capacity because of a larger farm size, lower production costs, higher value crops, better than average yields, or more efficient use of water. The same farmer could be paying less per acre-foot for water than is indicated by the administrative line in figure 7 if his pump systems were efficiently designed and operated. The economic maximum pumping lift for such a farm could be several times greater than the reasonable pumping lift shown. On the other hand, a farmer with a low payment capacity because of a small acreage, poor soil, low value crops, below-average management, or high pumping costs because of inefficiently designed and operated pumping systems cannot afford to lift water nearly as far as the estimated reasonable pumping lift. Therefore, it is important to realize that the

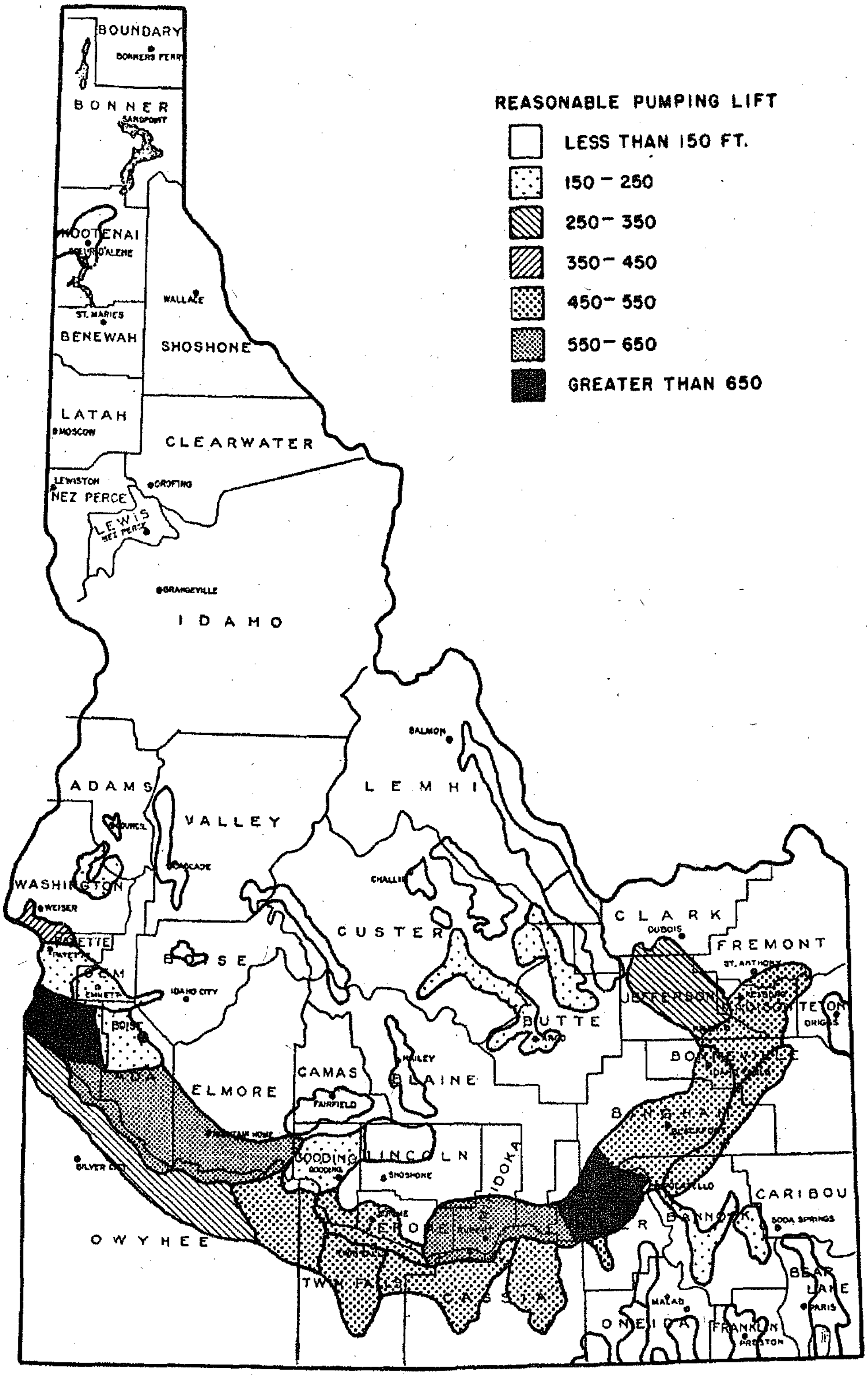

FIGURE 9. Ranges of reasonable pumping lifts for ground-water basins in Idaho

TABLE 7

REASONABLE PUMPING LIFT CLASSIFICATIONS

Depth Range	Basins Included
No. 1 (Less than 150 ft.)	Rathdrum Prairie, Upper Weiser River, N.F. Payette, Garden Valley, Stanley Basin, Camas, Big Wood, Silver Creek, Little Wood, Northwestern Snake Plain (Lincoln County), Malad, Arbon, Curlew-Black Pine, Pocatello, Cache, Bear Lake, Upper Teton, Birch Creek, Challis, Pahsimeroi, Lemhi River Valleys.
No. 2 (150-250 ft.)	Payette, Boise (Ada County), Western Snake Plain (Gooding County), Portneuf, Gem, Gentile, Big and Little Lost River Basins, Middle Weiser River.
No. 3 (250-350 ft.)	Bruneau, Grand View, Homedale, Murphy, Mud Lake.
No. 4 (350-450 ft.)	Lower Weiser River.
No. 5 (450-550 ft.)	Salmon Falls, Sailor Creek, Snake Plain (Jerome, Madison, Bonneville, Bingham Counties), Rock Creek-Goose Creek, Raft, Rockland, Willow Creek, Lower Teton.
No. 6 (550-650 ft.)	Snake Plain (Minidoka County).
No. 7 (Greater than 650 ft.)	Boise (Canyon County), Mountain Home, Michaud Flat.

reasonable pumping lift estimate is not necessarily reasonable for all ground-water users in a basin, but it is representative of economic-sized farms having reasonably efficient pumping systems.

Application of the reasonable pumping lift estimates will require consideration of pumping drawdowns, seasonal water-level changes, and well construction difference. Each of these factors is variable and should be evaluated for each basin to allow effective application of reasonable pumping lift values.

SUMMARY AND CONCLUSIONS

The Idaho Code charges the Director of the IDWA with the administration of the use of the water resources of the state. One method of ground-water administration provided by the code is the maintenance of reasonable pumping lifts. The purposes of this study are to evaluate the methods of determining reasonable pumping lifts and designate values for each ground-water basin in the state. The study is divided into four parts: determination of payment capacity, pumping costs, irrigation requirements, and ground-water administrative basins.

Payment capacities are based upon economically-sized family farms raising crops typical for the basin. It is assumed that a full water supply is available and necessary, and that the resulting crop yields are typical of those to be expected on the better land classifications in the basin. Payment capacity estimates for a number of areas are available from previous studies by various governmental agencies. These estimates are adjusted so that the rate of return to management (profits) are similar in each case. Payment capacities for basins not previously studied are estimated by interpolation from the known payment capacities assuming that a relationship exists between payment capacity and the over-all productivity of the area.

Costs for pumping irrigation water are estimated using data from 165 wells operating in Idaho using a statistically-derived equation (Von Bernuth's equation No. 4). Because the volume of water pumped and the initial investment often have a greater effect than does lift on the unit pumping costs, the cost analysis is limited to systems producing adequate water for economically-sized farms (500 acre-feet or more annually). A regression line that can be used for administration is calculated for costs versus lift. The slope of this line indicates that water costs increase $1.37 per 100 foot of lift.

Consumptive irrigation requirements are based upon providing an adequate supply 80 percent of the years in each area. Headgate irrigation requirements are then computed assuming 60 percent field efficiency. An estimate of average headgate requirement is obtained by weighting the average by the acreage of the principal crops grown in each basin in 1964.

Hydrologic ground-water basins are delineated and areas within these basins having similar reasonable pumping lifts noted. From the estimates of payment capacity, costs for pumping water, and irrigation requirement, reasonable pumping lifts are calculated and presented for each of these areas (tables 6 and 7 and fig. 9).

The variability of economic pumping lift due to factors such as farm size, management ability, soil fertility, efficiency of water use, volume of water pumped, and initial investment makes it necessary to base reasonable pumping lifts upon certain typical or average factors for each basin. Although a number of assumptions are necessary to limit the range of the result, the estimates should be valuable as a guide for administrating ground-water basins.

RECOMMENDATIONS

1. Accept the estimates of reasonable pumping lifts presented in table 7 and figure 9 as a guide for administration of the ground-water basins.

2. Initiate a detailed economic evaluation of basins in which the pumping lifts are

now approaching the preliminary estimate presented in this report.

3. Evaluate the outlined technique of pumping level determinations with respect to new methods and data being generated by research at Washington State University and the University of Idaho.

4. Develop a program of data acquisition to improve confidence in the estimated lifts.

   a. Collect accurate data on well characteristics and costs as a part of licensing for water rights.

   b. Encourage data-reporting agencies to collect data in a manner that can be presented as statistical distributions.

5. Encourage studies of pumping costs and payment capacities by statistical methods such as used by Von Bernuth to reduce the quantity of data collection required.

6. Initiate a new study of reasonable pumping lifts in several years including new data and methods developed in the intermediate period and the public acceptance, suggestions, and general reaction to the present study.

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