Drainage Needs and Returns in North-Central Iowa

R. S. Kanwar, H. P. Johnson, D. Schult, T. E. Fenton, R. D. Hickman
ASSOC. MEMBER ASAE FELLOW ASAE

ABSTRACT

CURRENT status of drainage and estimated drainage needs of the soils in the Des Moines River basin as indicated from an extensive survey are presented. A high percentage of the area has the potential for receiving benefits by improving county mains and on-the-farm drainage. Analyses have been made of the economic potential for drainage improvements by comparing three drainage input levels. Benefit-cost ratios indicate drainage of very poorly drained and poorly drained soils is a good investment for corn and soybean production.

INTRODUCTION

About 150 years ago, a large part of the upper Midwest area was considered unfit for human habitation. Flat areas in north-central Iowa frequently were flooded. Many depressions were marshes; the only farmable areas were the higher lands surrounding them. Today this area is known for its productive agriculture, largely the result of improvement through agricultural drainage (Wheaton, 1977).

At present, more than half of the soybean and corn production of corn-soybean belt is found in the five states of Illinois, Indiana, Iowa, Missouri, and Ohio. In Iowa, the Clarion-Nicollet-Webster Soil Association area is one of the most suitable areas for corn and soybean production. The upper Des Moines River basin lies within this area. Soils in this region were developed from the Wisconsin glacial till under prairie grass or prairie and marsh grass. These soils are very productive when properly drained. The topography (from flat to undulating) of this region often makes this area highly adaptable to intensive row cropping and to farming with multi-row equipment.

Most of the drainage systems in this area were installed from 1900 to 1915 by organizing the natural watershed into legal drainage districts (Hollander, 1968). The methods were diverse, including open ditch and tile drain combinations or underground systems only. The cost of improvements were assessed to all land within the district in proportion to the benefits received. Many of these water management systems are inadequate today; many were recognized as being inadequate the year they were completed. In some places, the need for larger-capacity systems was not recognized, and in many instances, landowners simply could not bear the cost of larger systems. These drained areas continue to be used for production of crops and have not reverted to a less intensive use. History and experience indicate that in depression-characterized (impounded type) watersheds, a drainage system should have the capacity to remove from 0.95 cm to 1.27 cm (3/8 in. to 1/2 in.) of water from the entire watershed in a 24-h period to assure adequate drainage (also called drainage coefficient) for field crops.

This paper is based on a recent study conducted in the upper Des Moines river basin. The objectives of this paper are: (a) to present the current status of drainage and (b) to estimate needs of the soils for additional drainage in the tiled portions of the organized drainage districts in the upper Des Moines river basin as indicated from an extensive survey. The physical and economic potentials for drainage improvements have been analyzed by comparing three drainage input levels, present, intermediate, and high, on four classes of natural soil drainage.

PROCEDURE

Area of study

The system for this study consisted of all farm operators who operated land in 1979, at least part of which was within the boundaries of an organized drainage district in an area designated as the Des Moines River basin in north central Iowa. Specifically this area consisted of 1.13 million ha (2.8 million acres) including all of the Humboldt, Pocahontas, and Webster counties and parts of Emmet, Palo Alto, Kossuth, Buena Vista, Wright, Calhoun and Green counties (Fig. 1).

The study area was further limited to tiled drainage districts. Thus the legal drainage districts served completely by open ditches (having no tile district mains) were excluded from the study. Therefore, this study pertains to the area that is in legal drainage districts served only by subsurface outlets. Applying these criteria, there were an estimated 394,788 ha (975,551 acres) in this study. Within the area of 394,788 ha, two classes of drainage districts were defined according to the capacity of the district main, namely, high success and low success districts. High success districts were those having a drainage coefficient* (d.c.) of at least 0.95 cm (3/8 in.). All the remaining districts were defined as low success districts. Applying these criteria, 5% of the area fell in high success districts and the remaining 95% of the area in low success districts.

Statistical Sampling Methods

The general sampling procedure was to select a sample

Article was submitted for publication in June, 1982; reviewed and approved for publication by the Soil and Water Div. of ASAE in November, 1982. Presented as ASAE Paper No. 82-2078.

Journal Paper No. J-10699 of the Iowa Agriculture and Home Economics Experiment Station, Ames, IA. Project 2450.

The authors are: R. S. KANWAR, Assistant Professor, H. P. JOHNSON, Professor and Head, Agricultural Engineering Dept., D. SCHULT, Research Assistant, Economics Dept., T. E. FENTON, Professor, Agronomy Dept., and R. D. HICKMAN, Professor, Statistics Dept., Iowa State University, Ames.

Acknowledgments: Support by the state office of the Soil Conservation Service, USDA, for this study is gratefully acknowledged. We particularly like to acknowledge the technical assistance given by Loren Elliott, Planning Engineer, and John Chenoweth of the Soil Conservation Service, Des Moines, IA.

*Information obtained from Loren Elliott, SCS Planning Engineer, Federal Building, Des Moines, IA (see Schult et al., 1981).

  0001-2351/83/2602-0457$02.00

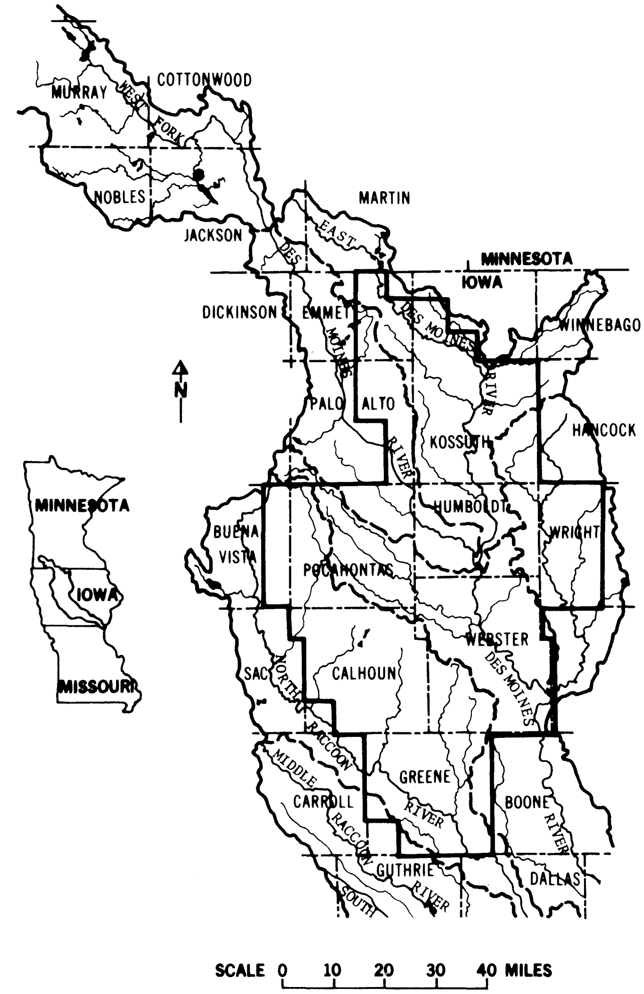

Fig. 1—Location of study area in the upper Des Moines River basin.

of drainage districts, and to include in the sample all fields and all farm operators into which sample points fell. A two stage sampling procedure was used. The first stage was the selection of drainage districts. The second stage was the selection of points within the selected districts. These points served to bring cultivated fields and operators into the sample.

For the first stage, two categories of drainage districts were defined. The first included high success districts of 405 ha (1,000 acres) or more. These districts were identified in advance of sampling and to include all these with certainty. Only 19 such drainage districts were identified in the area, and all were included in the sample. The second category included remaining districts which included all low success districts and high success districts of less than 405 ha (1,000 acres). These districts were sampled by selecting 54 of the 120 townships in the basin in a systematic manner with equal probability. Each sample township was divided vertically into left and right halves, and a sample point spotted at random in each half. If the sample point fell into an organized tiled drainage district not already included in the sample as a high success district of 405 or more hectares, the district was added to the sample. If the district extended into more than one half-township, it had a separate chance of being brought into the sample in each one. Forty-two districts were selected by this procedure, 41 low success districts and 1 high success district of less than 405 ha. Thus, a total of 61 drainage districts were included in the sample.

For the second stage, within each sample district a new sample of points was selected which determined fields and farm operators to be included in the sample. It was decided that the sample should yield at least 70 separate fields in the high success districts of greater than 405 ha (1000 acres) and at least 228 in the remaining districts. The 70 points to be assigned to the high success districts greater than 405 ha (1000 acres) were assigned to individual districts in proportion to their acreages. Because the remaining districts varied more in size, the 228 points to be assigned to these districts were allocated in proportion to the square root of their acreages. Within the sample districts, the points were spotted by selecting random horizontal and vertical coordinates. The randomization was controlled to assure to the extent possible a good spread over the district. These 298 sample points were located on maps and aerial photographs obtained from the Agricultural Stabilization and Conservation county offices which led to the delineation of 298 fields representing 256 farm operators.

The field interviewer used the photographs to locate the fields that existed at the time of the survey. Having determined the sample field, the interviewer then contacted the operator of the field to obtain the required information. One questionnaire was completed for each field and was assigned a weight based on the probability of having selected the field represented by the questionnaire, the weight being the inverse of this probability. Of these 298 questionnaires, 256 questionnaires containing data on the farm operator, each was assigned a second weight based on the probability of having selected that operator. These weights were incorporated into the estimates of population characteristics. This survey sampling procedure was used to gather information on the present level of on-farm drainage, farm management practices, crop yields, equipment miring and damage, drainage needs and the frequency and extent of yield reduction.

Natural Drainage Classes of Soils and Yield Estimates

Farm operators of sampled fields were requested, during the interview, to identify and locate on an aerial photo of their fields the areas having inadequate drainage. Farm operators encircled such areas on maps. These encircled areas were measured with a planimeter to secure land area. Also, transparent soil survey maps of the fields were superimposed on the aerial photos of the respective fields. All the soils in the fields, as well as in the encircled areas, were grouped into four natural drainage classes according to soil mapping units. The four natural drainage classes are very poorly drained soils, poorly drained soils, somewhat poorly drained soils, and well drained soils. The natural drainage classes are based on soil characteristics. As an example, the various soil types and associated yields according to their soil mapping units for naturally very poorly drained soils are given in Table 1. Naturally well drained soils need no tile drainage.

The estimated problem area, and the frequency and extent of yield reduction also were obtained from the farm operators. Further, farm operators gave estimates of the current levels of drainage on their fields. They defined the levels of drainage as no drainage level, poor

TABLE 1. CORN YIELD ESTIMATES (IN KG/HA) FOR DIFFERENT LEVELS OF DRAINAGE ON NATURALLY VERY POORLY DRAINED SOILS*

Soil type (soil mapping unit)	No drainage yield estimate	Poor drainage Yield estimate	Poor drainage Weight†	Poor drainage Weighted yield	Moderate drainage Yield estimate	Moderate drainage Weight†	Moderate drainage Weighted yield	Good drainage Yield estimate	Good drainage Weight†	Good drainage Weighted yield
Knoke, sicl (4)	0	1820	x 0.085 =	155	4895	x 0.085 =	416	7970	x 0.040=	319
Okoboji, sicl (6)	0	1832	x 0.605 =	1108	4973	x 0.605 =	3009	8200	x 0.503=	4124
Muck, shallow (21)	0	1832	x 0.108 =	197	4973	x 0.108 =	537	8200	x 0.069=	566
Okoboji, mucky sil (90)	0	1832	x 0.050 =	92	4973	x 0.050 =	249	8200	x 0.202=	1656
Palms, muck (221)	0	1820	x 0.018 =	33	4770	x 0.018 =	86	7782	x 0.018=	140
Rolfe, sil (274)	0	1946	x 0.005 =	10	5146	x 0.005 =	25	8347	x 0.009=	75
Boots, mucky peat (321)	0	1758	x 0.005 =	9	4518	x 0.005 =	23	7405	x 0.013=	96
Peat 18-40 in. (421)	0	1820	x 0.010 =	18	4770	x 0.010 =	48	7782	x 0.035=	272
Wacousta, sil (506)	0	2260	x 0.058 =	131	5962	x 0.058 =	345	9665	x 0.072=	696
Wacousta, sil var (508)	0	2197	x 0.007 =	15	5837	x 0.007 =	41	9477	x 0.003=	28
Blue earth, muck sil (511)	0	2134	x 0.054 =	115	5648	x 0.054 =	305	9163	x 0.024=	220
Lanyon, sic (606)	0	1820	x 0.000 =	0	4770	x 0.000 =	0	7782	x 0.012=	93
Weighted average yield (rounded)	0			1883			5084			8285

*Estimated yield averages based on the assumptions of high management levels and good weather. These estimates are based on the yield levels contained in T.E. Fenton, et al., "Productivity Levels of Some Iowa Soil", *Special Report No. 66,* Iowa State University, Ames, Iowa, 1971. These estimates are derived as follows:

Good yield estimate = 1.625 x moderate yield estimate
Moderate yield estimate = 0.95 x Special Report No. 66 yield estimate
Poor yield estimate = 0.375 x moderate yield estimate

†This weight is the proportion of that soil at that level of drainage within the naturally every poorly drained soils.

TABLE 2. ESTIMATED CORN AND SOYBEAN YIELDS (KG/HA) AT VARIOUS LEVELS OF DRAINAGE.

	Artificial Drainage Design Level							
	No drainage (0 cm d.c.)*		Poor drainage ($\leq$ 0.64 cm d.c.)		Intermediate drainage ($\geq$ 0.95 cm d.c.)		High drainage ($\geq$ 1.27 cm d.c.)	
Natural drainage	corn	soybean	corn	soybean	corn	soybean	corn	soybean
Very poorly drained soils	0	0	1,883	807	5,084	1,883	8,285	3,228
Poorly drained soils	0	0	5,398	2,085	7,281	2,825	8,160	3,161
Somewhat poorly drained soils	4,708	1,816	6,026	2,287	8,160	3,161	8,348	3,228
Well-drained soils	7,595	2,959	—	—	—	—	—	

*d.c. = drainage coefficient

drainage (⩽0.64 cm d.c.), moderate drainage (⩽0.95 cm d.c.), and good drainage (⩾1.27 cm d.c.). This information and soil survey maps were used to estimate the crop yields. Yield estimates were made on the assumption of high management levels, good weather conditions and yield levels shown by Fenton et al. (1971) for Clarion-Nicollet-Webster Soil Association. An illustration of the procedure used for yield estimation for naturally very poorly drained soils is given in Table 1. Similarly, yield estimates for other natural drainage classes were made (Schult et al., 1981); the summary of yield estimates for all four natural drainage classes are given in Table 2.

Artificial Levels of Drainage

Three levels of artificial drainage were selected for design levels to associate with relative yields; namely, current level of drainage, intermediate level of drainage (≅0.95 cm d.c.), and high level of drainage (⩾1.27 cm d.c.). Current level of drainage was taken as it existed on the farm. No drainage level conditions were considered for areas having no drain tile. It was assumed that the intermediate level of drainage is associated with intermediate-level main capacity and intermediate level of on-the-farm tile capacity for any area drained to that level. The high level of drainage assumes that all land in a district was drained to a high level of main capacity, with an associated high level of drainage in the field.

Estimating Drainage Benefits

Several kinds of benefits may result from improved drainage, such as improved timeliness of operations, reduction of equipment miring problems, greater ease of agricultural operations, benefits to the environment, and improved crop yields. Aldabagh and Beer (1975) estimated the added economic benefit of tile drainage from increased mobility of agricultural machinery. They concluded that, on the average, a farmer may have about 16 extra days for a given soil in Iowa during critical periods for farm operations by decreasing the tile spacings from 96 m to 24 m, which resulted in a benefits of $27/ha per year at that time. Enviromental benefits consisting of reduction in disease and insect damages were examined; these benefits seemed already captured in the drainage basin, and hence, were not considered in this study.

The greatest benefit of agricultural drainage is improved crop yield. This finding seems consistent with findings reported by Found et al. (1976) and Leitch and Kerestes (1981), DeBoer and Ritter (1970). Leitch and Kerestes (1981) gave the following equation to estimate the monetary value of increased crop yields:

$$V = p_i q_i - dc_i$$

where

p_i = price of commodity i

TABLE 3. DESIGN CRITERIA FOR FIELD DRAINAGE AND TILING COSTS.

A. Laterals: Cost of laterals was taken as $2.95/m (1980 prices).

Natural soils drainage class	Tile spacings at different levels of drainage, meters		
	To go from no drainage level to high drainage level (0 to 1.27 cm d.c.)	To go from no drainage level to intermediate drainage level (0 to 0.95 cm d.c.)	To go from intermediate drainage to high drainage level (0.95 to 1.27 cm d.c.)
Very poorly drained soils	24.4 plus one inlet per field	30.5	Additional designs as needed to bring the intermediate levels to high levels
Poorly drained soils	30.5	45.8	
Somewhat poorly drained soils	36.6	61.0	
Well drained soils	0	0	0

B. Submains:
Submain costs were taken equal to the 10% of the lateral costs, and the total costs for laterals and submains were taken as $3.28/m

C. Relief mains:
By use of the relative cost graph developed by Hollander [1968], the average cost of relief main was found to be about $101/ha for low success districts, and $87/ha for high success districts at 1968 price levels. These costs were converted to 1980 costs by using a factor of 3.02 obtained from Engineering News Record (1981).

q_i = change in agricultural production expenses of commodity i

Assuming that values are invarient with respect to time, the present value, V_p of the flow of benefits in the form of increased crop production is estimated in this study as:

$$V_p = (p_i q_i - dc_i) Z$$

wherein Z is the present value multiplier.†

Prices: A farmer usually has a crop price in mind when making investment decisions. Crop prices are perhaps the single most important tangible stimulus to drainage. The 1980 average price for corn was taken as $0.10 per kg ($2.50 per bu) and the price for soybeans was taken as 0.24 per kg ($6.40 per bu) in this analysis.

Discount Rate: The benefits from drainage improvements occur over a period of years though most of the costs are incurred in the initial year. Benefits must be discounted to account for this difference in time perspective. Discounting the benefit stream facilitates a comparison with costs incurred at the start of the project. In times of volatile interest rates, as presently experienced, the market rate is difficult to establish for long-term investments. It varies among lenders and borrowers. Discount rates of 12 and 16% are used in this analysis for comparison.

Project Life: The Bureau of Reclamation (1978) uses a 100-year life expectancy for most irrigation drainage. A planning horizon of 20 years is used in this analysis. Caldwell (1981) states that the life of the structural measures of the tile system may be longer than 50 years.

Drainage Costs: Two major costs involved in the improvement of drainage levels are the costs associated with the upgrading of the existing district main system and the costs associated with on-farm drainage. The relative cost graph developed by Hollander (1968) for calculating the cost of relief main tile needed to supplement the existing inadequate main tile system was used to calculate the cost of improving the main. These costs were based on 1968 prices; therefore, these costs were adjusted to 1980 prices by using the relative cost information from the Engineering News Record (Dec. 4, 1980). Costs of main relief tile were calculated for each drainage district, and then one average was computed for low-success districts and second average for high-success districts (Table 3). On-the-farm costs associated with extra laterals and submains were calculated according to the design criteria developed in Table 3 and current costs of tile installations. It was assumed that cost of submains will be approximately 10% of the costs of laterals. At current prices, the costs of laterals and submains were taken $2.95/m ($0.9/ft) and $0.33/m ($0.10/ft) of lateral, respectively.

The total costs of drainage per acre are given in Table 4. Cost estimates do not include fertilizers and other associated crop-production costs. This assumption was made because, in most fields, small areas are affected by drainage problems, and farmers would be putting crop production inputs in those areas with the hope of getting some yield increase. Costs of relief main tile were allocated to three naturally drained soils at various levels of artifical drainage according to the benefits received (Table 4).

RESULTS AND DISCUSSION

Present Drainage Conditions

One of the main objectives of this study was to determine the existing levels of drainage at the field and district level. The survey of the farmers supplied data to estimate the present drainage conditions. Of the estimated 394,788 ha (975,551 acres) in the study area at the field level, 19% of the area was of naturally well drained soils (needing no tile drainage); 69% of the area was estimated to have a high level of drainage (≥1.27 cm d.c.); 8% of the area had an intermediate level of drainage (≅0.95 cm d.c.); 4% of the area had no tile

†Benefits associated with improved drainage generally occur over long periods of time (20 years in this study). Costs, however, are incurred at the start of the project. To account for this difference in time frame, the stream of expected future benefits must be discounted to reflect its present value. The multiplier is the sum of discounted annual benefit fractions.

TABLE 4. COSTS OF LATERALS AND SUBMAINS, AND RELIEF MAINS FOR LOW- AND HIGH-SUCCESS DISTRICTS.

	Natural Drainage of Soils					
	Very Poorly Drained		Poorly Drained		Somewhat Poorly Drained	
Level of drainage improvement	Cost of laterals and submains, $/ha	Cost of relief main, $/ha	Cost of laterals and submains, $/ha	Cost of relief main, $/ha	Cost of laterals and submains, $/ha	Cost of relief main, $/ha
			Low success districts			
No drainage level to high level of drainage	1,387	659	1,076	300	897	124
No drainage level to intermediate level of drainage	1,076	461	718	201	538	87
Intermediate level of drainage to high level of drainage*	311	659	359	300	359	124
			High success districts			
No drainage level to high level of drainage	1,387	218	1,076	98	897	40
No drainage level to intermediate level of drainage	1,076	0	718	0	538	0
Interemdiate level of drainage to high level of drainage	311	218	359	98	359	40

*Intermediate level for low success districts means that on-the-farm drainage is at 0.95 cm d.c. but mains are at poor level of drainage ($\leq$ 0.64 cm d.c.).

drainage. This means 96% of the field area has usually adequate drainage ($\geqslant$0.95 cm d.c.) on-the-farm.

At the district level the capacity of the district main often is a constraint on the actual level of field drainage achieveable. If the capacity of a district main is at 0.95 cm drainage coefficient, all areas within that drainage district would be constrained by the 0.95 cm drainage coefficient level. The survey indicates that 95% of the study area lies within low success districts having a district main capacity of less than 0.95 cm d.c. (3/8 in. d.c). These inadequate district mains are a contraint on the benefits received by the on-farm drainage. In low success districts, 18% of the sampled area is naturally well drained, and the remaining 77% of the sampled area would receive benefits from improvement of district mains. In high success districts, 1% of the sampled area is naturally well drained, and the remaining 4% of the sampled area would receive benefits by increasing district main capacities to a high level of drainage ($\geqslant$1.27 cm d.c.) from the current level of drainage ($\cong$0.95 cm d.c.). This shows that 81% of the study are has the potential to be improved to high level of drainage ($\geqslant$1.27 cm d.c.) by increasing the capacity of the district mains.

Physical Potentials for Improving Drainage

For present levels of drainage, the average production of corn in the entire study area is estimated at 5,649 kg/ha (90 bu/acre) of corn and 2,220 kg/ha (33 bu/acre) of beans. When present corn and soybean yields are compared with maximum potential yields that could be obtained at high levels of drainage, 68% of the maximum yield is currently realized. The intermediate level of drainage is estimated to produce yields that are 90% of the maximum potential, although, experiments in Ohio (Schwab et al., 1981, 1982) indicate that the response of corn and soybeans to the various levels of drainage will be of different percent of the maximum potential. They indicate that an average corn yield of 100% with tile and surface drainage was reduced to 92% with tile only and 73% with surface drainage only. In comparison, the average soybean yield of 100% with tile and surface drainage was reduced to 89% with tile only and 83% with surface drainage only.

Therefore, much of the production potential as estimated for the study area is not fully captured. Considerable yield increase in corn and soybeans could be obtained by improving the present level of drainage at field and district levels to intermediate or high levels of drainage.

Economic Potentials for Improving Drainage

Net Return: The return over the cost of drainage is the profit or net return. Expected net annual returns for low and high success districts can be calculated by use of Table 5. The present value of the stream of annual benefits is compared with the current cost of drainage to determine profitability. Present value of average annual benefits was calculated for a project life of 20 years. Present net returns ranges from $1197/ha ($484/acre) for somewhat poorly drained soils with level III drainage improvements to $4,398/ha ($1,780) for poorly drained soils with level I drainage improvement in low success districts for a 12% discount rate. Similar net returns for high-success districts range from -$170/ha (-$109/acre) to $4,602/ha ($1,862/acre).

The present value of net benefits due to improved drainage depend on type of soil, current level of drainage, the desired level of drainage improvment, type of drainage district, and discount rate used. Losses imply that the cost of drainage for that particular soil group, not only equals potential net benefits, but exceeds the present value of the stream of future expected returns to drainage. Leitch and Kerestes (1981) reported that the present value of net benefits ranged from more than $4,942/ha ($2,000/acre) to a loss of more than $3,954/ha ($1600/acre) in Minnesota. Per-hectare benefits of over $4,602 benefits being realized in the

TABLE 5. BENEFIT-COST RATIOS OF SOILS OF DIFFERENT NATURAL DRAINAGE AT DIFFERENT LEVELS OF DRAINAGE FOR LOW-SUCCESS DISTRICTS WHEN MAXIMUM POTENTIAL BENEFITS ARE OBTAINED.

Type of soil at various levels of drainage improvement	Cost of drainage, $/ha	Avg. annual benefits, $/ha	DISCOUNT RATE 12% Present value of sum of avg. annual benefits, $/ha	12% B/C*	16% Present value of sum of avg. annual benefits, $/ha	16% B/C*
Very poorly drained soils						
(a) Level I	2,046	787	5,880	2.87 (3.66)	4,668	2.28 (2.90)
(b) Level II	1,538	472	3,523	2.29 (3.27)	2,796	1.82 (2.60)
(c) Level III	970	600	4,479	4.62 (4.46)	3,556	3.67 (3.54)
Poorly drained soils						
(a) Level I	1,377	733	5,775	4.20 (4.92)	4,584	3.33 (3.91)
(b) Level II	927	690	5,168	5.57 (7.20)	4,094	4.42 (5.70)
(c) Level III	658	262	1,960	2.98 (1.35)	1,556	2.36 (1.07)
Somewhat poorly drained soils						
(a) Level I	1,021	345	2,579	2.52 (2.75)	2,047	2.00 (2.18)
(b) Level II	625	328	2,450	3.92 (4.55)	1,945	3.11 (3.61)
(c) Level III	483	225	1,680	3.48 (0.31)	1,334	2.76 (0.26)

Level I — No drainage level (0 cm d.c.) to high level (1.27 cm d.c.) of drainage.
Level II — No drainage level (0 cm d.c.) to intermediate level (0.95 cm d.c.) of drainage.
Level III — Intermediate level of drainage (on-the-farm drainage at 0.95 cm d.c. but mains are at $\leq$ 0.64 d.c.) to high level of drainage (1.27 cm d.c.)

*Within prarenthesis are the benefit-cost ratios for the high success districts under similar drainage levels and soil types.

upper Des Moines River basin.

Benefit/Cost Ratios: The benefit/cost ratios for various soils at different levels of drainage are shown in Table 5 for low-success and high-success districts. The highest benefit/cost ratio of 5.57 was obtained for poorly drained soils when level of drainage was improved from no drainage level (0 cm d.c.) to high level (1.27 cm d.c.) of drainage in low-success districts. Benefit/cost ratios of greater than one are obtained for very poorly drained and poorly drained soils in low- as well as in high-success districts at 12% and 16% discount rates. Benefit/cost ratios of less than one are obtained for somewhat poorly drained soils in high-success districts when level of drainage was improved from intermediate level (0.95 cm d.c.) to high level (1.27 cm d.c.) of drainage. This indicates that it is not economical to drain somewhat poorly drained soils, more net returns are obtained when soils currently at no drainage level are improved to high level of drainage. For high-success districts, when drainage is improved to intermediate level, the only costs are for tiling the farm because mains already are designed to the intermediate level of drainage.

Table 5, however, shows benefit/cost ratios when maximum potential benefits are derived from all years, which is not true. Results of the survey indicate that farmers do not receive maximum benefits every year. The benefit/cost ratios were calculated on the basis of frequency of benefits derived as discussed in the following paragraphs.

FACTORS AFFECTING BENEFIT/COST RATIOS

There are numerous factors that affect benefit/cost ratios of a drainage system, but the following few factors are considered quite important inasmuchas these were not presented in the main text of the paper.

Frequency of Benefits Derived

Drainage benefits are based upon the increase in crop yields due to the improvement of existing drainage conditions. The extent and frequency of benefits derived were estimated from the sample of farm operators' interviews. These estimates on frequency of benefits derived were used to calculate the monetary returns to drainage. The summary of farm operator estimations is given by Schult et al. (1981) which contains the number of years in 10 years crop damages are expected from poor drainage in inadequately drained areas. For areas with somewhat poorly drained soils problems were expected 5 years in 10, including 1 year in 10 resulting in crop failure and 4 years in 10 resulting in yield reductions. For areas with poor drainage, problems were expected 7 years in 10, including 2 years in 10 resulting in crop failure and 5 years in 10 resulting in yield reductions. In very poor drainage areas, problems were expected 9 years in 10, including 4 years in 10 of crop failure and 5 years in 10 of yield reductions.

These expectations of crop failures and reduced crop yields by farm operators interviewed in the study provide their estimates of potential benefits that may be realized by improvements in drainage. Benefit/cost ratios were calculated by using these estimates. These benefit/cost ratios are given in Table 6. When we compare the benefit/cost ratios given in Tables 5, and 6, we find that the benefit/cost ratios given in Table 6 are lower than in Table 5 for similar drainage conditions. It also is quite clear from Table 5 that, in high-success districts, it is not economical to drain areas already having a tiling system on the farm designed at 0.95 cm drainage coefficient at a 16% discount. If money could be obtained at 12% or at a lesser discount rate, similar areas containing very poorly and poorly drained soils could be drained to a high level of drainage producing benefit/cost ratios of greater than one.

Therefore, it is very important to consider the frequency of benefits derived before presenting the economics of a particular drainage project designed for a particular region.

Discount Rates and Project Life

These two factors were considered in the present

TABLE 6. COMPARISON OF BENEFIT-COST RATIOS WHEN MAXIMUM POTENTIAL BENEFITS DUE TO DRAINAGE IMPROVEMENTS ARE DERIVED TO THE BENEFIT-COST RATIOS WHEN PARTIAL BENEFITS ARE EXPECTED AS INDICATED BY FARMERS AT 12% DISCOUNT.

	LOW-SUCCESS DISTRICTS		HIGH-SUCCESS DISTRICTS	
Types of soils at various levels of drainage improvement	B/C when maximum potential benefits are derived	B/C when partial benefits are derived	B/C when maximum potential benefits are derived	B/C when partial benefits are derived
Very poorly drained soils				
(a) Level I	2.87	2.44	3.66	3.11
(b) Level II	2.29	1.86	3.27	2.66
(c) Level III	4.62	3.98	4.46	4.02
Poorly drained soils				
(a) Level I	4.20	2.02	4.92	2.37
(b) Level II	5.57	2.51	7.20	3.24
(c) Level III	2.98	2.13	1.35	0.95
Somewhat poorly drained soils				
(a) Level I	2.52	0.68	2.75	0.74
(b) Level II	3.92	1.00	4.55	1.17
(c) Level III	3.48	0.62	0.32	0.16

Level I — No drainage level (0 cm d.c.) to high level (1.27 cm d.c.) of drainage.

Level II — No drainage level (0 cm d.c.) to intermediate level (0.95 cm d.c.) of drainage.

Level III — Low Success District: Intermediate level of drainage (on-the-farm drainage at 0.95 cm d.c. but mains are at 0.64 cm d.c.) to high level of drainage (1.27 cm d.c.).

High Success District: Intermediate level of drainage (0.95 cm d.c.) to high level of drainage (1.27 cm d.c.).

analysis. Selection of a discount rate for public investment projects has been a disputed issue for economists, however, the rate for private projects is the market rate. There is always a possibility that some borrowers are able to acquire government-subsidized rates for investments while others are not. Lower discount rates increase the present value of drainage benefits while higher rates reduce the value of future benefits.

Effects of discount rates on benefit/cost ratios were analyzed and are shown in Fig. 2 for very poorly drained soil in low-success districts. From this analysis it was found that benefit/cost ratios could increase by a factor of greater than 2 if money could be obtained at 7% discount rate rather than 16%. Fig. 2 also shows the effect of project life on benefit/cost ratios. Benefit/cost ratios increase with the increase of project life. At lower discount rates, effect of project life is more visible. At 7% discount rates, the benefit/cost ratio increases from 4.0 to 5.31 when project life is increased fom 20 years to 50 years (Fig. 2). Similar increase in benefit/cost ratio at 16% discount rate was from 2.28 to 2.40.

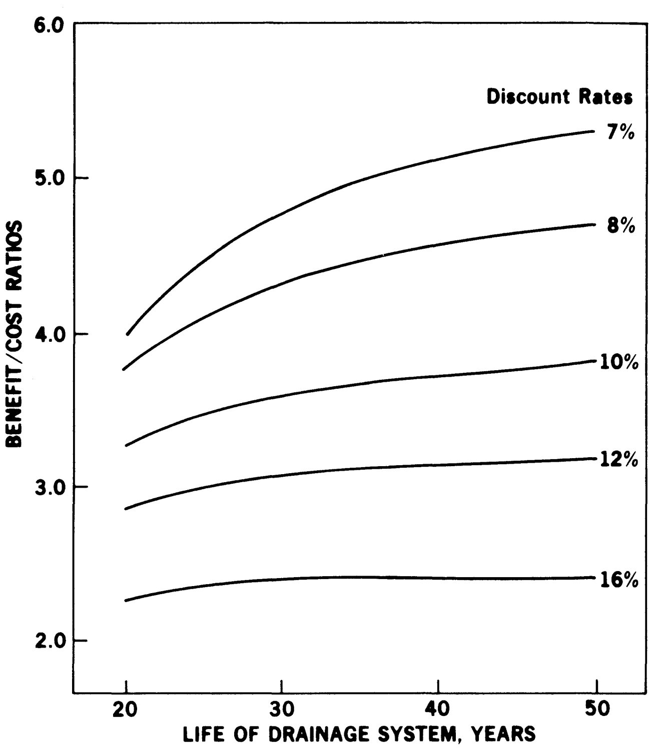

Fig. 2—Effect of discount rates, and life of the drainage project on benefit/cost ratios for very poorly drained soils in low-success districts.

Income Tax Considerations

Income taxes can have a significant impact on the returns of drainage investments, but depend on the income of the farm operator. That drainage investments are deductible would have no impact on a farm operator with no taxable income. However, tax deductions would reduce the real cost of drainage significantly for an operator in an upper income bracket. Tile drainage costs also qualify for investment credit. If all these factors are considered, benefit/cost ratios would improve further.

Nonmonetary Benefits of Drainage

The nonmonetary benefits of drainage should not be overlooked. Drainage promotes root growth, makes fertilizer application more effective, extends growing and harvesting periods, reduces runoff and erosion, increases land value, and reduces nuisance weed and wildlife problems. Many of these benefits go back to increased production or reduced cost of production, but others such as reducing runoff or erosion and avoidance of nuisance problems have no obvious dollar benefits. Sometimes farmers are willing to spend money to save time and reduce the chance of getting mired in a wet spot (Leitch and Kerestes, 1981). With large machinery any obstacle in an open field can cause delays and unnecessary avoidance costs (Corps of Engineers, 1981).

CONCLUSIONS

Inadequate drainage in the upper Des Moines River basin is currently responsible for crop production losses in legal drainage districts amounting to nearly 32% of the maximum production potential for high levels of improved drainage. Therefore, farm operators and owners are not taking full advantage of the potential benefits of improved drainage.

Ninety-five percent of the area in the upper Des Moines River basin lies within low-success districts with inadequate district mains (currently at ⩽0.64 cm drainage coefficient). Of this area, 69% already has a high level of on-the-farm drainage systems designed at 1.27 cm drainage coefficient at the field level. Therefore, if only district mains in the low-success districts are improved from the present low level of drainage (⩽0.64 cm d.c.) to high level of drainage (⩾1.27 cm d.c.), more than 80% of the potential benefits could be received in low-success districts.

If individual farmers have to make an investment for drainage improvement on their farms, very poorly drained and poorly drained soils should be considered first because these soils give the highest benefit/cost ratios. While benefits are higher for the very poorly drained soils, the groups are too closely associated to be feasible to improve one group without improving the other. From the analysis, it was found that somewhat poorly drained soils were not very economical to improve.

According to the interviews of the operators, uncertainty of receiving benefits from drainage because of weather hinders farm investment in improved drainage. Because some tilting is already in place and additional drainage investment will bring only marginal expected benefits, farm operators tend to be more cautious about additional drainage investments.

References

1. Aldabagh, A. S. Y. and C. E. Beer. 1975. Economics of increased mobility from tile drainage. TRANSACTIONS of the ASAE 18(1):116-121.
2. Bureau of Reclamation. 1978. Drainage Manual. U.S. Bureau of Reclamation, Engineering Research Center, Denver, CO.
3. Caldwell, L. W. 1981. Alternatives in the design and maintenance of stable channels. ASAE Paper No. 81-2101, ASAE, St. Joseph, MI 49085.
4. Corps of Engineers. 1981. The economics of wetland drainage in agricultural Minnesota. U.S. Army Corps Eng., St. Paul, MN 55101.
5. Engineering News Record. 1981. McGraw Hill, Inc., New York, NY 10020.
6. DeBoer, D. W. and W. F. Ritter. 1970. Flood damage to crops in depression areas of north-central Iowa. TRANSACTIONS of the ASAE 13(5):547-549, 553.
7. Fenton, T. E., D. R. Duncan, W. D. Shrader, and L. C. Dumenil. 1971. Productivity levels of some Iowa soil. Agric. Home Econ. Exp. Sta., Iowa Coop. Ext. Serv. Spec. Rep. 66.
8. Found, W. C., A. R. Hills, and E. S. Spence. 1976. Economic and environmental impacts of agricultural and land drainage on Ontario. J. Soil Water Conserv. 31(1):20-24.
9. Hollander, G. W. 1968. Improving old water management systems in the cornbelt. ASAE Paper No. 67-744, ASAE, St. Joseph, MI 49085.
10. Leitch, J. A. and D. Kerestes. 1981. Agricultural land drainage costs and returns in Minnesota. Staff Paper P. 81-15, Dept. of Agricultural and Applied Economics, Univ. of Minnesota, St. Paul.
11. Schult, D. L., T. E. Fenton, R. D. Hickman, H. P. Johnson, R. S. Kanwar, and J. F. Timmons. 1981. Present and potential agricultural drainage situations in the upper Des Moines River basin—Ten County Area. Special Report, Departments of Agricultural Engineering, Agronomy, and Economics, Iowa State University, Ames.
12. Schwab, G. O., B. H. Nolte, and M. L. Palmer. 1981. Drainage—What is it worth on corn land. Soil and Water No. 23. Co-op Ext. Service, Ohio State Univ., Columbus.
13. Schwab, G. O., B. H. Nolte, and M. L. Palmer. 1982. Drainage—What is it worth on soybean land. Soil and Water No. 24. Co-op Ext. Service, Ohio State Univ., Columbus.
14. Wheaton, R. Z. 1977. Drainage needs of the upper Midwest. ASAE Paper No. 77-2086, St. Joseph, MI 49085.