Surface Drainage for Improved Crop Production
Michigan State University Extension Service
L.S. Robertson, D. L. Mokma, Crop and Soil Sciences; E. H. Kidder, Agricultural Engineering
Issued March 1979
8 pages

Extension Bulletin E-1295, March 1979. FILE 32.2
COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

Surface Drainage for Improved Crop Production

L. S. Robertson,[1] E. H. Kidder,[2] D. L. Mokma[1]

Surface drainage is the systematic removal of excess water from the surface of land. This is done by improving natural drainage ways, constructing surface drains, and by remodeling or shaping the land's surface. Surface drainage frequently is most effective when used in conjunction with tile (profile drainage).

Little information is available on how many acres in Michigan might respond to improved surface drainage. At least half of that already tile-drained and much of the 1.5 million acres of poorly drained land still needing tile would benefit.

This bulletin describes needs, benefits, and methods of surface drainage. Engineering specifications are reported in the M.S.U. bulletin "Recommended Standards for Drainage of Michigan Soils." Property rights and responsibilities should be seriously considered when planning for surface drainage. These topics are discussed in Extension Bulletin E-382 "Drain Law for Michigan Land Owners."

Objectives of Surface Drainage

The major objectives of surface drainage of crop land are to 1) prevent water from ponding, 2) remove excess water before crops are damaged, and 3) remove excess water safety with a minimum of soil erosion.

Surface drainage is needed most frequently on flat lands such as the lake and till plain areas of the state. Fine textured soils with slow water infiltration rates and permeabilities respond well. In some instances it

[1]*Crop and Soil Sciences Department*
[2]*Agricultural Engineering Department*

The authors express appreciation to Carter M. Harrison, Prof. Emeritus, Crop and Soil Sciences Department, George E. Merra, Professor, Agricultural Engineering Department, Dwight E. Quisenberry, Agronomist U.S.D.A.—S.C.S., and Harold W. Belcher, Asst. State Conservation Engineer, U.S.D.A.—S.C.S., for assistance in the preparation of this bulletin.

has been beneficial in areas subject to stream overflow. It may be of value in ditch overflow such as sometimes occurs in the Saginaw Bay area when wind from the northeast forces bay water back into the ditches.

Surface drainage using grass waterways is beneficial on rolling land. While the grassed waterway may be used on flat land, it is used most frequently where there is a slope, where its primary function is to dispose of excess water with little or no erosion.

Benefits from Surface Drainage

Most benefits come from the prevention of water ponding on the soil surface. This is most likely to occur in the winter, spring and early summer. Ponded water always excludes air from the soil, thus resulting in suffocation or an oxygen deficiency for growing crops. Winter wheat, barley and alfalfa are thus damaged. If ponding occurs during the summer, other field crops, especially beans and tomatoes, suffer in a similar manner (Figure 1).

Soil compaction problems are reduced with surface drainage because soil is drier during field operations. Because drained soil contains less water, it warms faster in the spring, thus permitting earlier field work, especially planting.

Heaving, an upward movement of plants caused by freezing and thawing of free soil water, is common in areas needing surface drainage. Alfalfa is especially susceptible to damage from the lifting action, thus surface drainage reduces winter killing.

Some disease organisms thrive in wet soil. Phytophthora root rot in alfalfa is a good example. This disease is most common in inadequately drained soil during extended periods of rain or excessive irrigation.

Surface drainage, together with tile drainage, permits more timely field operations such as spreading manure, fertilizer and lime and plowing, planting and harvesting. This is especially important in Michigan where the growing seasons are naturally short. Spring and fall rains too frequently delay planting and harvesting, thus accentuating the short season problem.

Surface drainage, especially when supplemented by tile drainage, increases the area of productive soil and the number of work days per year. This can have a tremendous impact on yield. Some less evident benefits include an increased efficiency in farm machinery use, a wider selection of crops that can be grown and fewer weed problems. In addition, there is a reduction in the levels of soluble metals such as iron and manganese which are sometimes toxic in poorly drained soil, especially those that are acid.

Surface Drainage and Crop Yields

Numerous observations suggest a great potential for improved crop yields with surface drainage even though there is little research in Michigan to substantiate the claim. Fortunately, data are available from a relatively close-by location. In Erie County, Ohio, an eight-year average increase in corn yields of 29

Figure 1. Navy beans destroyed by surface water which collected for only a few hours. This need not have occurred because the field is bounded on two sides with deep ditches, which could have served as outlets for surface drains.

bushels per acre was obtained on a Toledo silty clay (soil management group lc) as a result of only surface drainage.*

Some years, it was impossible to plant oats on this fine textured soil without surface drainage. Soybeans grown in a wet year without surface drainage yielded only four bushels per acre but with drainage yielded 43—an increase of 39 bushels per acre.

Other studies in Ohio showed that increased yields were not just the product of improved drainage but good drainage made extra fertilizer profitable. In one project, 200 pounds of fertilizer did not pay for itself on poorly drained soil, but 300 pounds more than paid for itself when the soil was drained. Such interactions show the great potential in Michigan for improved yields through surface drainage.

Soils Responding to Surface Drainage

Obviously, some soils respond to surface drainage better than others. The soil survey map is the best source of information on those that respond. Some county maps are readily available from the Soil Conservation District Office, County Extension Office, or from the Department of Crop and Soil Sciences at Michigan State University. All farms in Michigan are located within a soil conservation district. Thus, all farmers have the opportunity to have their soils mapped in detail.

The maps outline the location and boundaries of *soil series*. Each series is a member of a specific *soil management group*. The relationship of all soil series identified to date in Michigan and soil management groups is reported in Extension Bulletin E-906 and Research Report RR 254. The soil management group serves as a basis for predicting crop yield responses to surface drainage (Table 1). The opportunities for increasing crop yields and quality is greatest on those soils having an A slope (0–2%).

Because the needs for surface drainage are regulated by some factors not closely related to natural soil conditions, the information in Table 1 should be used primarily as a guide. "Slight" means that under normal circumstances a yield response to surface drainage is not usually expected but can be obtained under specific conditions. "Great" means that a great response would normally be expected such as in the Ohio research, but that under specific conditions may not be obtained. Tile may eliminate the need for surface drainage on the two-storied soils.

Use this table to help evaluate opportunities for significantly increasing crop yields with surface drainage.

G. O Schwab, Tile or Surface Drainage for Ohio's Heavy Soils (1976 Ohio Report, March–April).

TABLE 1. Opportunities for Increasing Crop Yields with Surface Drainage.

		Natural Drainage Class		
Dominant profile texture	*Symbols*	*Well and moderately well drained (a)*	*Somewhat poorly drained (b)*	*Poorly and very poorly drained (c)*
Fine clay, over 60% clay	0	Medium	Great	Great
Clay, 40–60% clay	1	Medium	Great	Great
Clay loam and silty clay loam	1.5	Medium	Medium	Great
Loam and silt loam	2.5	Slight	Medium	Great
Sandy loam	3	Slight	Medium	Medium
Loamy sand	4	Slight	Slight	Slight
Sand with strong subsoil development	5	Slight	Slight	Slight
Sandy loam, 14–40 in, over clay	3/1	Slight	Medium	Great
Sandy loam, 20–40 in, over loam to clay loam	3/2	Slight	Medium	Great
Sandy loam, 20–40 in, over gravelly sand	3/5	Slight	Slight	Slight
Loamy sand, 14–40 in, over clay	4/1	Slight	Slight	Slight
Sandy to loamy sand, 20–40 in, over loam to clay loam	4/2	Slight	Slight	Slight
Sand to loamy sand, 40–60 in, over loam to clay	5/2	Slight	Slight	Slight
Organic	M	—	—	Slight

Surface Drainage vs. a Complete Drainage System

This bulletin considers only surface drainage, but it should be recognized that this is just one part of a *complete drainage* system. There are situations where surface drainage alone is required and others where tile drainage is necessary. In most instances, however, the two working together produce the best results. Water removed with surface drains does not need to be removed with tile. The soil dries more rapidly with a combination of the two systems.

Surface Drainage Methods

While some fields or farms have uniform slopes and are naturally well suited for surface drainage, others vary in slope direction, length and steepness. Minor alterations in the soil surface are necessary before a satisfactory surface drainage system can be established.

Figure 2. Land grading is a job for professionals. Here, an earthmover got stuck while preparing a field for surface drainage because the soil conditions were not correctly evaluated. Land grading should be used in Michigan with caution because surface soil layers are usually thin. Soil physical and chemical problems are common when subsoil is exposed.

Four methods have been used in Michigan to improve surface drainage: land grading, land leveling (smoothing), field ditches, and open ditches. An engineer or soil and water conservation specialist, who is knowledgeable about local weather, soil, and crop requirements can help design each system. The Soil Conservation District is usually able to provide this assistance to district cooperators.

Land grading is reshaping the surface of the land to planed grades. It consists of cutting, filling, and smoothing the surface to predetermined and continuous grades so that there are not water collecting depressions. Land grading is the most expensive surface drainage treatment because it usually involves specialized heavy equipment such as is sometimes used in road construction projects (Figure 2). Land grading is also the most complete surface treatment that can be given to a farm or field. It is best suited to flat lands with thick top soil because exposing raw subsoil in the cutting process creates new problems related to dense subsoils, low organic matter levels, and low micronutrient availability, especially manganese, zinc and boron. Because most Michigan soils are relatively young and were formed under forest vegetation, surface horizons are relatively thin. Therefore, this method is not used extensively and should be used with caution.

Land leveling, sometimes called land smoothing or land planing, is similar to land grading except that less soil material is moved and a field may have more than one slope after being leveled. Land leveling equipment is available in several Michigan counties from farm machinery dealers or Soil Conservation Districts (Figure 3). Land leveling involves smoothing or planing the soil surface to mechanically eliminate or reduce elevated areas and to fill in minor depressions so that surface runoff can rapidly move to shallow field or open ditch drains.

Depressions up to six inches deep and several feet across may economically be filled with the use of

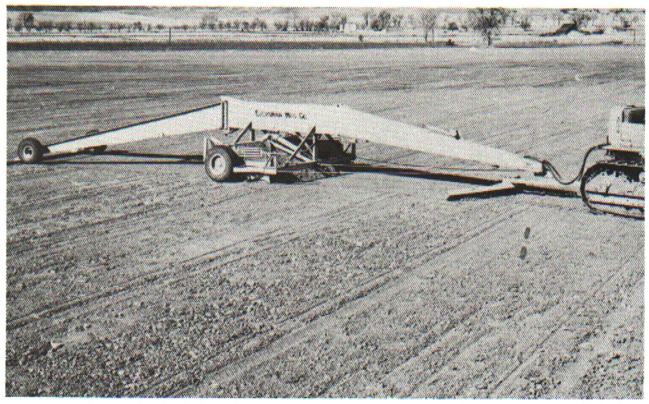

Figure 3. Land level only recently tilled soil where no crop residues or trash are exposed. A minimum of three treatments, each in a different direction, is recommended. This should be repeated one or two years later because the transported soil material will settle.

leveling equipment. Large depressions may be drained by a shallow field ditch *(see next section)*. The surrounding area should then be smoothed to drain to the depression. The finished surface of a leveled field ideally should not contain depressions, but be graded so that runoff water flows easily from the entire area to shallow field or open ditches.

Land leveling aids crop production by eliminating low areas and pockets. This is reflected in more uniform soil moisture levels at tillage time. Obviously, this is an advantage when preparing a seedbed. Uniform soil structure and moisture levels result in uniform planting depths. This insures faster and more complete seed germination and, therefore, improved stands. Graded and smoothed areas are easier to cultivate after a row crop is up without packing the soil and weed removal is more complete.

Leveling improves the harvest efficiency in some crops by permitting closer to the ground operation of cutting and picking machinery. Higher field operating speeds are sometimes possible.

Field ditches have not been used extensively in Michigan but crop yields on thousands of acres could be improved if producers would more seriously consider this method to supplement tile drainage.

There is some confusion in drainage terminology. Here a "field ditch" is a shallow graded surface drain that does not seriously interfere with tillage, planting or harvesting procedures. It is dry except after a heavy rain or in the late winter when snow melts. Its purpose is to collect excess water within a single field and to intercept excess runoff for removal to an outlet.

The field ditch may be located in a flat field, or it may drain depressions. Excess runoff may be sheet flow from natural, graded, or planed land surfaces or channeled flow from natural depressions, dead furrows, crop row furrows, or from bedding system furrows.

Field ditches will improve fields that:

1. Are flat and have compact subsoils,
2. Have surface barriers or depressions which trap rain and snow water,
3. Have insufficient slope for rapid movement of runoff water,
4. Receive seepage or runoff from uplands,
5. Have soil with low infiltration rates and permeability, either natural or artificial.

Field ditches are not common in most of Michigan because producers have not had the opportunity to see how effective they can be. There has been little or no demonstration or research in the state on this topic, and the benefits have not been given wide publicity.

There are several types of field ditches and the success of all depends upon a good outlet. Soil and slope characteristics help dictate which system is best. Before making a final decision, consult a drainage engineer or a soil and water conservation specialist. They can assist in selecting and designing a system that meets your requirements.

Studies of many successful field ditches in other states show that at least two types of field ditches could be extensively and profitably used in Michigan. The two systems are referred to as parallel and random.

The parallel field ditch system is well suited to the nearly level (0–2% slopes) areas of poorly drained soils where numerous shallow depressions occur (Figure 4). Where large fields can be planted up and down the slope, parallel ditches are sometimes used to break the field into shorter units. The ditch is flat enough for machinery to operate smoothly across the ditch. The success of this system depends upon pro-

Figure 4. Parallel field ditches for surface drainage work well on nearly level fields. Spacings vary with kinds of soil and distance and amount of soil material to be moved. Make outlet ditches at least 1 foot deeper than field ditches. Grade to outlet ditch should be such that erosion does not occur.

per spacing of the field ditches. Land leveling between the ditches is usually necessary.

In designing and operating this system, be certain that:

1. Crop rows are parallel to the direction of the greatest slope,
2. Ditches are located across the slope,
3. All rows drain into a ditch,
4. Ditches are designed to have a minimum of 0.05 feet fall in 100 feet,
5. Dead furrows are eliminated or located on a continuous grade,
6. The field is plowed in the direction of the greatest slope because water erosion is not a great problem on nearly level fields,
7. Ditches and grades are systematically and regularly maintained.

The random field ditch system is well adapted to many farms in Michigan, especially those where the soil has slow permeability and is relatively flat and the depressions are too large to eliminate with land leveling (Figure 5). The shallow, permanent ditches over which machinery can cross easily connect the low spots and provide an outlet for excess water.

The channels should follow the natural slopes or drainage ways in the field. Spoil (soil material removed from ditch) can be moved to low areas. Land leveling improves the effectiveness of the random field ditch system. Many Michigan farmers use this system but without benefit of assistance in design and without land leveling. As a result, ditches are sometimes not located where needed. Furthermore, with the kinds used today, they must be rebuilt each year.

A soil and water conservation specialist can adapt a plan to your needs and the characteristics of the field. For example, some of the spoil material can be moved to low areas. Where the farming operations are parallel to the ditch, the ditch may be deeper and not as wide as elsewhere. When farming operations cross the ditches, they can be wider and have a shallower profile to carry the same volume of water. In designing such a system, the grade should be at least 0.05 foot per 100, otherwise siltation and ponding are likely thus causing the system to be less effective. As with the parallel field ditch system, regular and systematic maintenance is required.

Other field ditch surface drainage systems that may have a place in Michigan, even though limited, include the diversion ditch, bedding and the "W" ditch. None of these systems appear to be well adapted to extensive areas. All have been tried by a few farmers but frequently were abandoned.

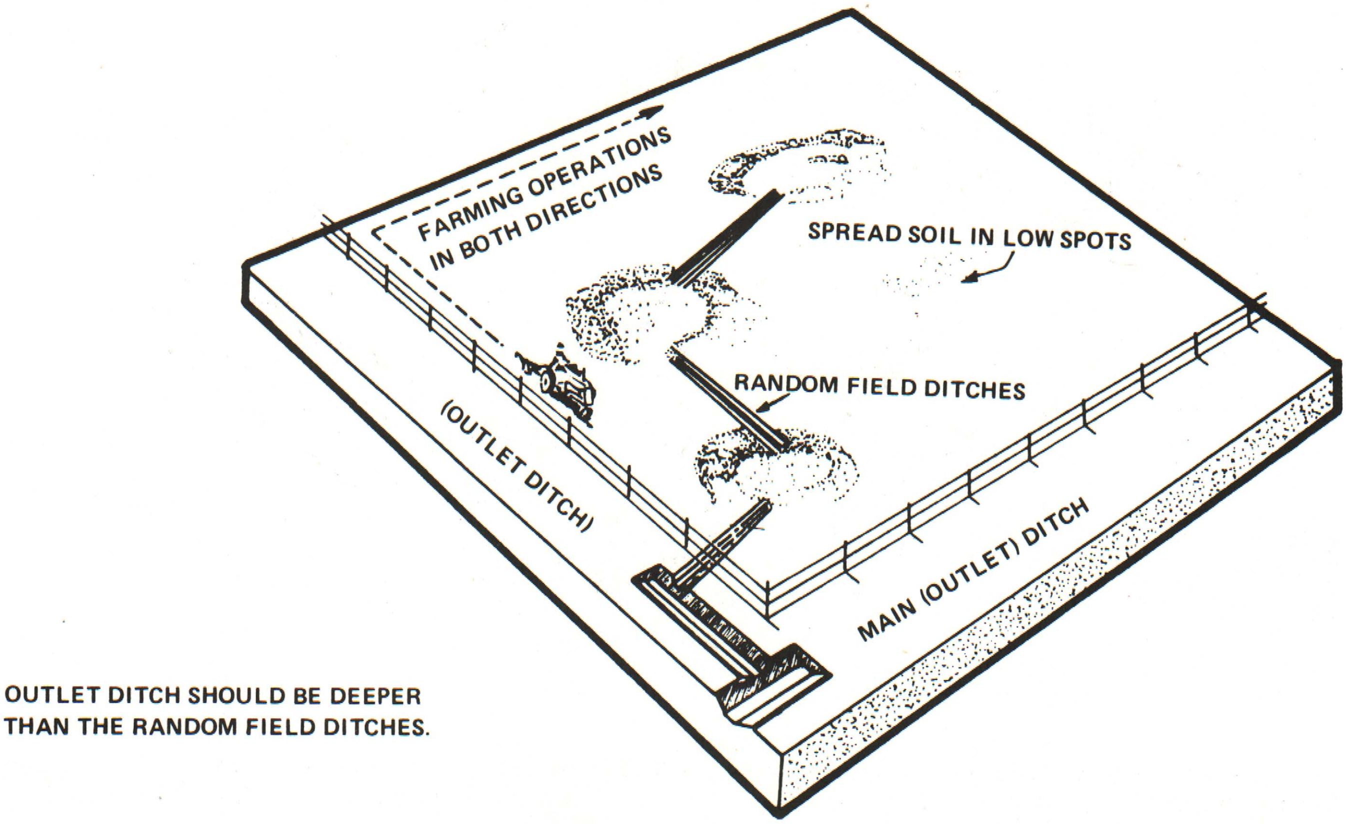

Figure 5. Random field ditches can improve crop yields in many parts of the state.

Diversion ditches are graded channels constructed across slopes to intercept and divert water to a suitable outlet. The capacity of such ditches may be increased by shaping the spoil into a continuous dike or terrace. Again, a drainage specialist can help determine the value and need of such a system.

Bedding as used in Michigan is a surface drainage system constructed on level fine textured soil with a moldboard plow with short distances between dead furrows. In other states, this system is known as blading, crowning or ridging. Such terminology suggests that implements other than the moldboard plow are sometimes used for construction.

The "W" ditch system, also known as twin or double ditch, involves shallow parallel ditches with the spoil placed between the two ditches. This system is no longer used in the state because producers felt that it required too much land and was difficult to maintain.

Grassed (sod) waterway systems are not necessarily field ditches for improving drainage, but they can safely dispose of water from the previous field drainage systems. The grassed waterway is a vegetated, well defined channel in which water can flow without causing erosion (Figure 6).

Open ditch systems—collection ditches, county ditches, main ditches, lateral ditches, etc. all represent different designs and locations than field ditches (Figure 7). They have relatively steep sides, are generally deeper than field drains, cannot easily be crossed with farm machinery, and are usually located outside of a field boundary. The deeper ditches can serve as outlets for both tile and field ditches, while the shallower ditches are suitable only as outlets for field ditches (Figure 8).

Surface drainage without erosion may be improved by using mechanical structures in open ditches when spoil material interferes with surface water movement or when there is a significant change in elevation of the field ditch and the open ditch. Pipes, chutes, and flumes have been effective. Again, a drainage specialist should be consulted for best design.

Some open ditches, especially on organic and very sandy soils, are used for water table control. This is achieved through a series of dams with removable boards. The same ditches also act as surface drains during wet seasons. Open ditches should be designed by a drainage engineer who considers size of the drained area, kinds of soil, water flow velocities, channel depth, bottom width, berm width (distance from the edge of a ditch to the edge of a spoil bank), spoil bank, etc. He/she also assists with specifications for bridges, culverts, and stock and low water crossings.

Figure 6. Grassed waterways remove surface water rapidly with little or no erosion.

Figure 7. Open ditches can be dry part of the year or contain water. Engineers should design open ditch systems, but ideally, crop producers should maintain them. Seed grass to stabilize sides of ditch so that sedimentation does not reduce ditch depth.

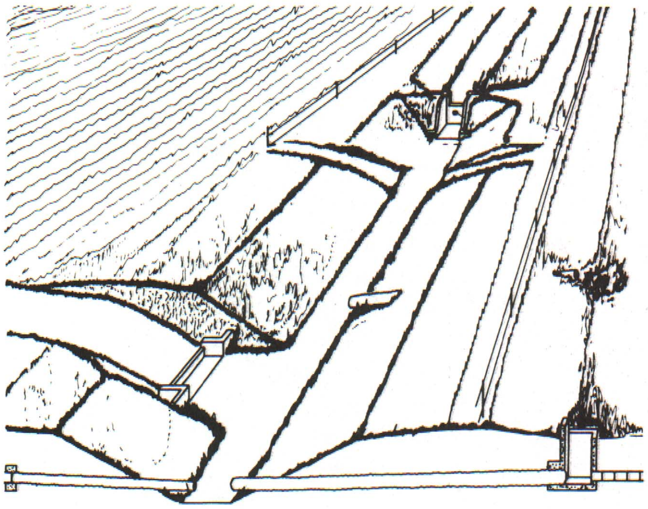

Figure 8. Suitable outlets for both surface and tile drains frequently require special structures which increase initial costs but lengthen the life of the ditch.

Do-It-Yourself Systems

Many farmers prefer to plan and install their own surface drainage systems on a cut and try basis. There are successful do-it-yourself systems in operation today, but they are only a small portion of the total surface drainage needed. In addition, they represent solutions to the more simple drainage problems which involve only a few acres of relatively flat land with uniform grades.

It is usually best to design a system for a farm and not for a single field. This can be a problem since it increases the volume of water that must be handled and the variability in soil and slope conditions. The best systems are usually designed and installed by those knowledgeable about surveying methods, hydraulics, soil variability and crop requirements.

A good drainage engineer should eliminate the need to use trial and error methods. A well designed system permits a farmer to alter certain crop and soil management practices, thus increasing yields more than is possible from improved drainage alone.

Designing a Surface Drainage System

The professional drainage engineer should have the final word on design. He/she integrates several kinds of information such as weather patterns, soil characteristics, crop requirements, size of drainage areas, etc. and then designs a system with the capacity you need. He/she considers water runoff rates, ditch depth, side slopes, grades, channel size, spacing, locations, outlets for the ditches, and, in some instances, surface inlets to tile drains. In addition, the system designer can easily serve as a consultant after the system is established.

Constructing Surface Drains

Ideally, construction work should be done when the soil is dry so that it will not be puddled in the process. The amount of cut and fill should be outlined by stakes in the field. Very little, if any, subsoil should be exposed in this process or when land leveling.

When land leveling, the surface should be free of vegetation and trash. Make at least three passes with a land leveler, each in a different direction. Make one pass along each of the diagonals and the last in the direction of the maximum slope. Smoothing sometimes needs to be repeated a second or third year to eliminate depressional areas that are filled in.

With both field ditches and open ditches, the areas to be excavated and those where spoil is deposited should be free of vegetation and trash. Spoil materials should be spread in low areas. Spread spoil away from the ditch so that farm machinery can easily move across the spoil. It is sometimes desirable to leave openings in the spoil material (banks) to allow water to rapidly enter the ditches. Special structural devices may be necessary to safely lower water from the field to open ditch.

Maintaining Surface Drainage Systems

A good maintenance program is the secret to making a surface drainage system produce maximum benefits. Plowing, planting, cultivation and harvesting sometimes cause ruts or ridges that disturb surface water movement. The soil surface can even be disturbed enough to actually impound water. Erosion is another problem when the surface is changed enough to alter the location, rate, or direction of water flow.

Maintain field ditch size and grade from year to year. This can be done by shaping with a grader, small scoop or other tools where the area has not been planted to sod. Where permanent grass is present, mowing or spraying may be desirable. If herbicides are used, check the local, state, and federal regulations and then carefully follow the instructions on the labels.

Summary

Every year some farms in Michigan lose crops because excess water collects on the soil surface, and every year some farmers have reduced yields for the same reason. The removal of excess water from the surface of the land is one way that crop yields can be increased from present-day levels.

While the drainage in many Michigan fields can be improved by the farmer alone with implements that are readily available, many fields could be greatly improved by land grading, land leveling, or field ditch drainage systems. Do not consider surface drains as a substitute for tile drainage systems but only as supplemental.

Such treatments are expensive, sometimes involving several hundred dollars per acre. Therefore, field drainage systems should be designed and installed by drainage engineers or specialists who are knowledgeable about hydraulics, weather, soil and crop requirements.

Cooperative Extension Service Programs are open to all without regard to race, color, or national origin. Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Gordon E. Guyer, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824. Price 15¢. Single copy free to Michigan residents.

1P—10M—3:79—UP

O-11347