I am glad to say that on projects undertaken to date, when we have passed on plans and specifications, we have had the fullest co-operation from the counties. I believe that those counties that have actually tried and experienced the requirements under this law will agree that our relationships have been marked with a spirit of co-operation.

This law may not be perfect—new laws often are not—but as we pioneer in this field, defects will be detected and corrected. I therefore ask this group to study the trends in highway administration and to help preserve the county as a unit in our highway program in the future.

ROAD DRAINAGE

G. P. Springer,
Assistant Professor of Civil Engineering,
Purdue University

Two primary sources of water are known—natural and artificial. For road drainage we are concerned mainly with the natural sources, i.e., precipitation in one of its forms: rain, snow, sleet, or hail. Some of this water will evaporate; some will run off over the surface of the ground; some will seep away or percolate through the soil to form a part of the underground supply; some may remain standing upon the surface of the ground in the form of pools until removed by natural or artificial means. Where needed, water has a value; but excess water is detrimental to property, perhaps to life, and should be drained away under control.

A good road must have a surface that is waterproof and a subgrade that is reasonably dry. Road drainage may then be defined as scientific directing of the removal of surface and ground waters, so as to safeguard the investment in the roadway structure. Some one has said, “You may not get any praise for the miles of smooth roadway, but you get blamed for every foot of rough road.”

Protective measures may take the form of works upon the surface of the ground, or works adjacent to and parallel...
the roadway, or works under ground and beneath the roadway surface.

Upon the surface of the ground we may construct intercepting ditches along the tops of cuts to prevent bank erosion. Headers may be constructed in water runways to slow up the stream velocity and form a series of stilling basins, the aim being to prevent erosion and at the same time prevent water from standing on the surface where it will, if concentrated, cause damage.

The surface of the roadway proper should be given a sufficient crown over the wearing surface area, so that the water coming upon it will be, easily and quickly, without damage or danger, delivered onto the shoulder. Shoulders should have drop enough to pass the water on into the ditch area, or to the adjacent soil. If the nature of the soil is bad, or the tilt of the shoulder due to grade is so high that the water would gain enough velocity to start erosion, then catch basins should be used along the edge of the metalled way, and the water taken away through covered tile lines. French drains, spaced relatively close together, set at slightly less than right angles through the shoulders, may be used to carry the water from the roadway to the adjoining side ditch. Where soils contain a large amount of very fine particles, sizes approaching silt, French drains may in time become clogged and fail to perform their function. Water should be kept away from the junction of the shoulders and the metalled surface, particularly on black-top secondary roads where the metalled surface is usually thin and non-rigid.
GROUND WATER

The present type of shallow ditch with easy drop from the shoulder edge to the ditch bottom, while offering high degree of safety to vehicles which may be forced over the shoulder and into the ditch, does not have much value in lowering the ground water level. Lowering of the ground water level in wet soils by use of a ditch necessitates a deep ditch, which should be set back as far as possible from the traveled way and protected by some type of guard rail. If right-of-way width does not permit going back a reasonable distance, then a shallow ditch over a covered drain tile may be a satisfactory solution. The tile line should be placed low enough to lower the water table under the roadway area. Inlets must be provided to admit the surface run-off from the ditch into the drain.

Covered drain lines are costly; therefore, the amount of traffic and the requirements for safety of travel must be balanced against a type of construction which gives the greatest mileage of ample protection for the lowest investment per mile of roadway.

Water must be removed from under the metal of the roadway surface. Some soils are of open texture so that very little difficulty is encountered in keeping the road grade in stable condition. Other soils contain varying quantities of clays and silts, and are with much greater difficulty kept in stable condition.

The active soil water can be taken care of by cross-cutting the flow line with lines of tile. If the underground line of flow is across the roadway, a line of tile laid below the bottom of the ditch, on the upper side of the road, with the tile trench backfilled with coarse material, may be all that is needed to collect the water and discharge it safely. The flow may be nearly parallel to the roadway centerline, and a herringbone or grid system of tile laid under the travelled surface may be required to collect the water and remove it.

Where a known water condition exists under a roadway, it must be corrected. If not, the upward movement of the water, especially during the winter season, will cause trouble and destruction. There is a capillary upward movement of moisture until enough is collected to freeze into a thin, horizontal splinter of ice. This is followed by an additional rise of moisture due to this capillary attraction, and another splinter of ice forms. This process is continuous during freezing weather, especially in clayey and silty soils, and the ice slices increase in thickness and number, resulting in heaving of the pavement surface. Then in the spring when thawing commences, frost boils develop, with resulting destruction of the metalled surface under traffic. The upward movement of the capillary water must be prevented by removing the supply of free
water through a lowering of the ground water level until the upper limit of the capillary fringe is below the danger line. A knowledge of soils and soil mixtures is of value in developing the best method of handling these subgrade conditions which bring about frost boils and heaving during the spring thaws.

The size of tile to be used under the roadway area to drain the roadbed should be not less than 6-inch diameter. The amount of water to be carried by a subdrain is difficult to estimate. Under the roadway surface it is only necessary to remove the ground water and lower the water table until the capillary fringe is below the danger line. The depth to place the tile, dependent upon the nature of the soil, varies from 2½ feet to 6 feet. The slope of the cross drains or grid should not be less than 0.2% to the drain tile lines under the ditch. The tile lines under the ditches will have a grade parallel to the roadway surface, but this should be not less than 0.5% minimum. If soils are porous, little trouble may be expected; but if the soils contain varying amounts of clay and silts which tend to make seepage slow, then all trenches for tile under ditches and roadway surface should be backfilled with crushed stone, coarse gravel, or other coarse material, to assist in the collection of the underground water.

SURFACE DRAINAGE

Rainfall supplies the major part of the precipitation. The fall of rain is measured in inches of depth per hour over the watershed area. If flood damage is to be prevented, the system of drainage must be so designed as to remove this precipitation as rapidly as possible. To design a system properly, the intensity of the rainfall, or the measure of the fall in inches of depth per hour, must be known.

Fig. 2. An excellent reinforced-concrete culvert, 29° skew, 20' roadway, and 15-ton loading, built by contract in Hamilton County. Cost, $3,194.
Over any given area it can be said that, as the intensity of the rainfall increases, the frequency decreases, and, as the time of duration increases, the intensity decreases. High intensities are to be expected inside storms covering large areas.

Meyer has set up a formula indicating that the intensity of rainfall is equal to a factor representing the character of the storm, divided by the sum of two numbers, one representing the time of concentration and the other the frequency of the storm:

\[ i = \frac{c}{t + d} \]

"c" and "d" are dependent upon location in the United States; "t" is estimated from a knowledge of the topography. According to Meyer, for Indiana we would have

\[ i = \frac{181}{t + 21} \]

Knowing the intensity of the rainfall and the run-off factor (the portion of the rainfall that runs away over the surface of the ground), it is possible to determine the quantity of water to be handled at any desired place, and from this quantity to figure the opening area of the required ditch, pipe, culvert, or bridge.

The quantity of the surface run-off is determined by the equation

\[ Q = r i A \]

Q is the quantity in cubic feet per second; \( r \) is the run-off factor; \( i \) is the intensity of the rainfall in inches per hour; \( A \) is the drainage area under consideration in acres.

The amount of water carried is given by the formula

\[ Q = a v \]

where "\( a \)" is the cross-section of the flowing water in square feet, and "\( v \)" is velocity of flow in feet per second. Because most ditches are more or less rough, or contain obstructions in the form of weeds and shrubs, the quantity of flow should be reduced by some factor which represents the condition of roughness. The adjusted equation becomes:

\[ Q = c a v \]

"c" will be less than one and would be progressively smaller approaching zero as the obstructions to flow increase in the ditch. Therefore, to get the maximum flow, ditches should be kept clean.

The run-off over the surface of the ground having been determined within logical limits, then the intercepting ditch on the hillside to protect the slope of a cut should be designed
to start with a small cross-section area and descend the hillside on a reasonable grade. This ditch should become wider and deeper as it nears the bottom of the slope, but be always of a cross-sectional area sufficiently large to handle the accumulated quantity of run-off water. If the soil is readily eroded, it may be necessary to pave the ditch bottom and protect the sides with hand-picked rubble stone, or with grouted stone, or with concrete, as a protection against erosion. It may be necessary to place intercepting walls, baffles, or small dams with aprons in the ditch to slow up the velocity of flow.

Drainage provisions alongside the main highways should be ample. On secondary and farm roads such facilities are usually insufficient. Here the run-off from adjacent fields and from the roadway may collect and pond in side ditches which are not properly excavated to a draining gradient, and thus cause a softening of the subgrade by seepage.

The crown of the road and the slope of the shoulder are to prevent water from collecting and standing upon the wearing surface or the protective shoulder. A hard surface requires less crown than a bituminous or unstabilized surface. A smooth surface requires less crown than a rough one. Traffic and good appearance demand a very slight crown. The crown used should vary from 1/16 inch per foot of width to 1 inch per foot of width, according to the nature of the wearing surface. Shoulder drop should be from 1/2 inch to 1 inch per foot.

The side ditch should never be larger than necessary; should never carry water a long distance, but should discharge its load at the first practical outlet.

Safety for traffic requires that the ditch be broad and shallow. The present practice is to make the ditch one foot

Fig. 3. A concrete culvert illustrating effects of dirty aggregate and possible skimping on cement. Note thin mortar covering to conceal defective concrete mix.
minimum depth below the edge of the metalled way, or slightly
deeper if necessary. The slope from the shoulder into the ditch
should be 2:1 or 3:1. If the ditch grade is too steep, erosion
troubles may develop. Where it is obvious that this might
occur, the ditch should be paved or baffie walls used. However,
some baffie walls may cause additional erosion troubles. If
bad erosion occurs, or is likely to occur, then a tile line several
feet below the bottom of the ditch, with properly placed inlets,
must be used. The tile should be large enough to take the full
flow, and the inlets should be placed close enough together
so that ditch erosion is prevented.

Where open-ditch drainage, or stream flow, must be taken
through pipe culverts under farm driveways, or under the
roadway proper, the required area of opening can be deter­
mined by the equation.

\[ A = c \sqrt[4]{D^3} \]

where “A” is the area of opening in square feet; “c” is a run­
off factor; and “D” is the drainage area in acres.

The demand now is for safer roads, improved grades,
straight alignment, less crown, and shallow ditches. Snow
removal bares the road surface to daily changes of tempera­
ture during winter months. This has an appreciable affect in
aiding the softening of the roadway, the formation of frost
boils, and the breaking up of the surface. These damages to
the surface are aggravated by the heavier vehicles that travel
the roads. Better drainage is required to save the roadway
surface.

The engineer has a reputation at stake in the road he
builds, and if he wants to serve all and serve well, his roads
must be well built. If he builds well, he will merit the praise
of the traveling public and avoid the wrath which otherwise
might be poured upon him. Build well, if only for your own
satisfaction in a job well done, and words of praise will be
forthcoming from sources least expected.

**DRAINAGE LAWS AND PROCEDURES**

Arthur Call, Attorney,
Anderson, Indiana

Westcott in *David Harum* says, “There is as much human
nature in some folks as there is in others, and sometimes a
little bit more.” This is true with the average farmer concern­
ing drainage, the man you must deal with in the construction
and repair of drains.

Throughout Indiana we have a wonderful system of roads,
and any farmer would say that it would be a crime to pile his
junk, his debris, into the highway, and he would be correct.
Nevertheless, six out of every ten farmers who are assessed