REPORT OF SUBCOMMITTEE ON DRAINAGE AND DRAINAGE STRUCTURES

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SYNOPSIS

The report recognizes the fact that drainage practices are distinctly different in humid regions where vegetation can be relied upon to control erosion, as compared with those in dry regions where vegetation can only be established with difficulty.

In regions of deficient rainfall, the emphasis is on keeping water away from the highway. In both humid and dry regions, water should be discharged from the highway as soon as possible in a manner which will not cause damage to property below the highway.

The outline is limited to conditions normally occurring on rural highways without storm sewers and similar elaborate installations.

PRINCIPLES OF HIGHWAY DRAINAGE

The following report recognizes the distinct differences in drainage practices in humid regions and in regions of deficient rainfall. These differences arise mainly from the fact that in the first case vegetation can be relied on to control erosion and, in the other, vegetation may be entirely absent or play only a minor role (Figs. 1 and 2).

Figure 1

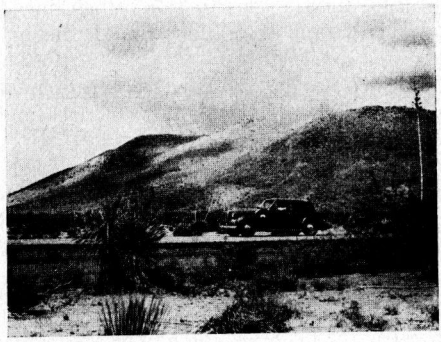

Figure 2

The cost of maintaining a highway in serviceable condition is closely related to the thoroughness of provisions made for adequate drainage. The designer must visualize the paths of all drops of water reaching the highway from the skies, the adjacent land, and even from underground, following them through as the paths converge until the water is finally discharged away from the highway. The more water that must be carried along the highway, the more difficult the problem becomes. The major part of the stormwater usually comes from adjacent land, and therefore the problem is simplified by locating the highway as near to the drainage divide as other principles governing location will permit.

Interference with existing drainage courses should be kept to a minimum unless it is known that improvement of natural drainage is essential to the safety of the highway. When channel changes become necessary the hydraulic effect should be carefully studied in order that erosion, sedimentation, or flooding may not bring about excessive maintenance costs or damage to adjacent property.

This report does not attempt to include detailed instructions on design. The principles of design of roadside drainage channels have previously been covered in the 1941 Report of the Committee on Roadside Development.[1] An excellent series of articles on culvert design recommendations has been

[1] Also in *Public Roads*, March 1942.

appearing in *California Highways and Public Works*, beginning August 1942. This material was also presented at the meeting of the Highway Research Board.[2]

The general principles which the Subcommittee has brought together in concise form according to the several elements of the complete drainage system are in accord with approved practices of the States with which the members of the subcommittee are familiar. Discussion in person or by letter with the committee personnel is invited.

To clarify the outline the following definitions are presented:

Overland flow, flow of water over the surface in thin sheets before any channelization occurs.

Intercepting channel, a channel placed at the top of the cut slope to intercept runoff from hillside, also includes similar channel at toe of fill.

Roadside gutter, a channel alongside the shoulder of the highway.

Ditch check, a permanent barrier across a channel usually flush with the upstream flow line, dropping water to an apron flush with the downstream flow line.

Drop structure, similar to a ditch check but on a larger scale with a well-defined weir notch and a stilling pool or other energy-dissipating device on downstream apron.

Flume, a channel or spillway on a steep grade; usually paved but sometimes sodded.

The outline is limited to conditions normally occurring on rural highways No attempt is made to include drainage problems arising in urban areas requiring storm sewers and similar elaborate installations. Note that in region of deficient rainfall the emphasis is upon keeping water away from the highway. In both regions water should be discharged from the highway as soon as possible in a manner which will not cause damage to property below the highway.

[2] Tilton and Rowe, *Proceedings*, Highway Research Board, Vol. 23 (this volume), page 165

OUTLINE OF RECOMMENDED PRACTICES

Humid Region	Region of Deficient Rainfall (little or no vegetation)
OVERLAND FLOW	
ABOVE HIGHWAY	
Avoid disturbance of existing ground cover; restore ground cover when torn up by construction operations; don't channelize unless necessary. See Intercepting Channels	Since erosion is difficult to control, divert runoff from highway wherever possible by means of terraces, diversion ditches or contour furrows This involves agreement with property owner for construction and maintenance. Point out that conservation of water improves grass yield on range land Diversion is most successful on gently sloping land and may be impracticable on steep hillsides.
ON HIGHWAY SLOPES	
Slopes	
Use flat slopes permitting satisfactory establishment and maintenance of appropriate vegetation, in snow regions use slopes not steeper than 4 to 1, preferably 6 to 1, to lessen snow drifting on highway where economically practicable	Take steps to reestablish native vegetation if any exists, using flat slopes in such cases Keep water away from slopes as much as possible in other cases
Shoulders	
Turf shoulders should be given ample slope for drainage and may be constructed slightly low Runoff should be permitted to drain uniformly over edge of shoulder and down embankment slope except where (1) water concentrates, or (2) embankment slope cannot be adequately protected against erosion In such cases water may be held on shoulder by sodded or paved dike, discharging at frequent intervals into pipe or flume down embankment slope. The shoulder on the low side of a superelevated curve on a high fill at a sag in roadway grade may require such treatment	Protect by appropriate surfacing, permit water to drain over edge of shoulder only on low fills with flat, protected slopes Otherwise protect edge of shoulder and slope by installing paved gutter (dike section preferred except in snow-drift country) with frequent outlets to pipe or paved spillways
INTERCEPTING CHANNELS	
Use to intercept water which would otherwise cause damage to cut or fill slope or overtax hydraulic capacity of roadside gutter Necessity for use should be carefully examined at each site Best design is to build dike, thereby avoiding breaking existing ground cover in flow line as would be done in cutting a ditch Check for capacity and erosive velocity, follow grade contour where feasible, avoid abrupt flattening of grade at points where sedimentation would cause water to spill over, damaging other parts of highway Design sodded or paved section as velocity indicates the need	Use generously to keep water away from cut slopes unless slope is being vegetated, in which case runoff from limited area aids plant growth by supplying additional moisture. Channels should be carefully designed to avoid excessive erosion, very long channels should be avoided Since water will be silt-laden care must be taken to avoid checking velocity by flattening flow line at points where overflow would cause damage Use ditch section at toe of fill against hillside to intercept water moving laterally through topsoil, especially on low fills

Roadside Gutters

Use streamlined cross section Check for capacity and velocity and protect against erosion Insofar as possible maintain grade of not less than 0 5 per cent for sodded gutters, especially on clay soils On flatter grades place tile underdrain with previous backfill Avoid flattening of grade where sediment is carried by water in order to eliminate depositing sediment where velocity is checked Paving of channel on flatter grade will help maintain velocity, and if sedimentation does occur cleaning is simplified Flow line should be below level of bottom of granular base course, especially when course is placed to full crown width Generally speaking, flow line should be not less than 12 in below outside edge of shoulder, and preferably 18 in below in regions of heavy rainfall Gutters should be discharged at least every 500 ft where possible unless it is more economical to increase cross section Water should be turned loose without damage to adjacent property or to highway, sodded or other protected waterway may be required, especially against toe of fill

Best practice is to elevate roadway to eliminate gutter on downhill side, providing frequent culverts for relief of water intercepted on uphill side of roadway Where highway grade parallels the ground slope use elevated grade line and construct frequent diversion terraces to keep water from accumulating against toe of fill When roadside gutters are unavoidable use flat cross section of ample depth on flat grades (allowing for sedimentation from side slopes) On steeper grades cost of paving gutter and hydraulic considerations permit narrower cross section, but avoid gutters which would be hazardous to traffic Outlet gutters as frequently as possible to get water away from the highway.

Culverts

LOCATION

Place culverts at natural cross-drain and elsewhere when relief of road drainage is advisable and outlet available. Culverts should be generously used

SIZE

Size should be not less than 24 in under high embankment or 18 in elsewhere Best procedure is to design for operation without head above top of entrance for frequent floods and to permit culvert to operate with entrance submerged at maximum floods Overflow of roadway may be permitted depending on potential damage and inconvenience which may result Culvert should be modified if velocity at outlet is excessive and can be reduced by changing proportions or size of culvert

PROFILE

Fit flow line to natural streambed unless good reasons for variation exist Upstream flow line may be raised to permit backfilling of gully, thereby eliminating unsightly and hazardous conditions, by use of drop inlet or broken back culvert (check for outlet velocity) Sidehill location with culvert serving as spillway outlet for artificial pond created by highway embankment is inadvisable unless fill is designed as a dam and outlet channel adequately protected

APPROACH CHANNEL

Avoid unnecessary relocation but provide streamlined approach to culvert entrance to maximum extent feasible Bring in roadway channels on streamlined approach to avoid excessive disturbance of main flow approaching culvert

OUTLET CHANNEL

It is important to provide ample capacity because water cannot come through culvert any faster than water can get away in outlet channel Streamline with direction of flow from culvert as much as possible Protect against scour at culvert by lining channel, or checking velocity with stone blocks, stilling pool or other energy-dissipating device Check channel conditions downstream for possible backwater effect of restrictions or of high water in connecting streams Where water carries much silt or debris, desilting basin above culvert may be used For large debris flows, see recommendations of article in *California Highways and Public Works*, October 1942

Bridges

The determination of waterways for bridges and streambank protection are separate subjects beyond the scope of this report This outline covers only minor surface drainage around bridgeheads which is essentially the same for both regions

Water draining off end spans of bridge should be carried in a paved gutter swinging out from curve line on bridge on easy curve and continuing down embankment slope to a point where water can be turned loose without damage Spans above erodible banks should be drained in this manner, as it is inadvisable to drop water vertically from scuppers on bridge to sloping bank below

Miscellaneous Structures

DITCH CHECKS

Where good sod can be established, ditch checks are not recommended Use in roadside gutters where they will be a hazard to traffic should be avoided, if possible
See discussion in *Public Roads*, March 1942

Ditch checks may be necessary to control erosion In roadside gutter use drop not greater than 6 in with notch of ample depth fitted to normal gutter section, and adequate apron to prevent undercutting In other channels notch may constrict waterway and have greater drop, care must be taken to prevent water overtopping wings and cutting around

DROP STRUCTURES

Use occasionally at abrupt breaks in channel grade but not where hazardous to traffic Must be designed by hydraulic principles with ample notch capacity, otherwise maintenance cost will be excessive
See reference in next column

Do not use where hazardous to traffic Design according to hydraulic principles
See "Hydraulic Design of Drop Structures for Gully Control," Morris and Johnson, *Proceedings*, American Society of Civil Engineers, January 1942, p 17

FLUMES

A flume is essentially a paved channel on a steep grade They are preferable to drop structures in many cases They must be designed with extra depth because discharge may come in waves Stepped flumes aid in controlling velocity

UNDERDRAINS

Install where necessary to intercept groundwater causing slope and subgrade saturation, install as necessary for drainage of pervious sub-bases