1.0 INTRODUCTION

The Bureau of Road Design, Drainage Design Manual presents the current drainage policies, design criteria, and recommended design procedures of the Kansas Department of Transportation (KDOT). It provides guidance for drainage design on highway projects in both rural and urban settings. The Drainage Design Manual is intended to be used in conjunction with the Road Design Manual.

The Drainage Design Manual is divided into eight sections as follows:

Section 1.0	INTRODUCTION
Section 2.0	DRAINAGE POLICIES
Section 3.0	HYDROLOGY
Section 4.0	CHANNELS
Section 5.0	MEDIAN DRAINAGE
Section 6.0	CULVERTS
Section 7.0	URBAN DRAINAGE
Section 8.0	STRUCTURAL ASPECTS OF CULVERTS

The Drainage Design Manual does not purport to cover all situations that may arise in the design of highway drainage and culverts. It is intended that the designer be allowed sufficient flexibility to tailor the design of the drainage elements to the particular circumstances of the project. It is the responsibility of the designer to prepare an adequate and acceptable design in which the individual elements of the design are as compatible as feasible.

Although this Drainage Design Manual includes most of the formulas, tables, and charts needed for the recommended design procedures, it is not entirely self-contained. The designer is referred to technical guidance documents of the Federal Highway Administration (FHWA) and other organizations for certain information. Each section contains a listing of reference documents that provide additional information on the recommended procedures. Many of these documents are updated periodically.

The drainage design procedures in this Drainage Design Manual are appropriate for most situations encountered in highway projects. However, drainage situations of unusual importance or complexity may merit additional analyses that are beyond the scope of this manual.

The policies, design criteria, and procedures in this Drainage Design Manual apply to drainage structures other than bridges. A structure with a total clear span (including the interior wall thicknesses) greater than 20.0 ft (measured along the project centerline) is classified as a bridge. A multiple-pipe installation is considered a bridge if the spacing between the pipes (measured perpendicular to the centerlines of the pipes) is less than one-half of the pipe diameter and the total clear span (including the spacing between the pipes) is greater than 20.0 ft (measured along the project centerline). Bridge structures are subject to the requirements of the Bureau of Structures and Geotechnical Services.

1.1 ABBREVIATIONS AND SYMBOLS

A	Drainage area (ac or mi^2), or cross-sectional area of flow in a stream or channel (ft^2)
A_b	Area of open waterway within embedded culvert.
A_{cr}	Cross-sectional area of critical flow in a channel or culvert.
A_o	Area of flow opening for a median inlet (ft^2)
A_s	Area of pipe wall (in.^{2}/ft)
AASHTO	American Association of State Highway and Transportation Officials
ACSMAC	Aluminized Corrugated Steel, Metal Arch Culvert
ACSP	Aluminized Corrugated Steel Pipe
ADM-1	AASHTO Drainage Manual, a publication of AASHTO
AHW	Allowable Headwater or Allowable High Water
AISI	American Iron and Steel Institute
AMC	Antecedent Moisture Condition
AOP	Aquatic Organism Passage
AWS	Allowable Water Surface
b	Depth of embedment for culvert

B	Width of channel bottom or width of box culvert (total for all cells) (ft)
B_b	Width of channel bottom within embedded culvert
BV	Point rainfall reduction factor (dimensionless)
C	Composite runoff coefficient in the Rational formula
C_i	Runoff coefficient for impervious surfaces
C_p	Runoff coefficient for pervious surfaces
C_o	Discharge coefficient for orifice-type flow through a drop inlet
CAP	Corrugated Aluminum Pipe
CAPA	Corrugated Aluminum Pipe Arch
CDA	Contributing Drainage Area (mi^2)
cfs	cubic feet per second
CMP	Corrugated Metal Pipe
CMMAC	Corrugated Metal, Metal Arch Culvert
CN	Runoff Curve Number in the NRCS rainfall-runoff relationship
CRP	Cross Road Pipe
CSMAC	Corrugated Steel, Metal Arch Culvert (galvanized)

CSP	Corrugated Steel Pipe (galvanized)
d	Depth of flow in a channel (ft)
d_{cr}	Depth of critical flow in a channel or culvert (ft)
d_n	Depth of uniform flow (normal depth) in a channel or culvert (ft)
D	Nominal diameter of pipe (in.), or Duration of rainfall event (hr.)
D_b	Rise of embedded culvert
$D_{0.01}$	Test load, in pounds per lineal foot per inch of inside diameter of pipe, that produces a 0.01-in.-wide crack in a rigid pipe (lb/ft/in.)
D_{50}	Mean particle size for a granular material (50% finer, by weight) (in.)
D_{75}	75% finer (by weight) particle size for a granular material (in.)
D_L	Deflection lag factor for corrugated metal pipe
DWR	Division of Water Resources of the Kansas Department of Agriculture
E	Modulus of elasticity for pipe material (psi)
E'	Modulus of soil reaction (psi)
EP	Entrance Pipe
f_b	Buckling stress for pipe wall (psi)

f_u	Buckling stress for pipe material (psi)
FBFM	Flood Boundary and Floodway Map
FF	Flexibility factor for corrugated pipe (in./lb)
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
Fr	Froude number
g	Gravitational constant, 32.2 ft/s^2
HAC	Hydraulic Assessment Checklist (see, Bridge Design Manual)
HDG	*Highway Drainage Guidelines*, a publication of AASHTO
HDS	Hydraulic Design Series: a series of technical guidance documents on aspects of hydraulic engineering by FHWA
HEC	(1) Hydrologic Engineering Center: a laboratory of the U.S. Army Corps of Engineers or (2) Hydraulic Engineering Circular: a series of technical reports on aspects of hydraulic engineering by FHWA
HEC-1	U. S. Army Corps of Engineers computer program for flood hydrograph simulation
HEC-HMS	Hydrologic Modeling System: U. S. Army Corps of Engineers computer program for flood hydrograph simulation

h_f	Head loss due to friction (ft)
h_m	Local head loss (minor loss) in a storm sewer (ft)
H_{max}	Maximum height of fill over top of pipe (ft)
H_o	Head on drop inlet for orifice-type flow (ft)
H_w	Head on drop inlet for weir-type flow (ft)
HGL	Hydraulic Grade Line (ft)
HSG	Hydrologic Soil Group
HW	Headwater depth for a culvert (ft)
HWE	Headwater elevation for a culvert (ft)
HY-8	FHWA computer program for hydraulic analysis and design of culverts and energy dissipators
i	Point rainfall intensity in the Rational formula (in./hr)
I	Moment of inertia of pipe wall ($in.^4/in.$)
I_A	Basin-average rainfall intensity (in/hr)
K	Bedding constant in deflection formula for corrugated metal pipe
K	Hydraulic conveyance of roadway and gutter (cfs)

k	conveyance factor for uniform flow in trapezoidal channel
k	Soil stiffness coefficient
KDOT	Kansas Department of Transportation
K-TRAN	KDOT's Cooperative Transportation Research Program
L	Length of a culvert, storm sewer or longest drainage path (ft)
L_p	Length of region of higher shear stress in a channel downstream of a bend, measured from point of tangency (ft)
n	Roughness coefficient in Manning's equation
$\bar{n}$	Average Manning n value for embedded culvert
n_b	Manning n value for embedment (streambed) material in culvert
n_c	Manning n value for non-embedded culvert
NFIP	National Flood Insurance Program, administered by FEMA
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service (formerly Soil Conservation Service, SCS)
NWS	National Weather Service
OHW	Ordinary High Water

p	Projection ratio in the Marston-Spangler design procedure for flexible pipe
P	Mean annual precipitation in regression equations for flood discharge, or wetted perimeter of a channel
P_b	Total perimeter of open waterway within embedded culvert
P_c	Perimeter of conduit above channel bottom within embedded culvert
P_w	Perimeter for weir-type flow into a drop inlet (ft)
PEP	Polyethylene Pipe
PMF	Probable Maximum Flood
psi	pounds per square inch
PVCP	Polyvinyl Chloride Pipe
Q	Discharge (numerical subscript indicates recurrence interval in years) (cfs)
q_d	Bearing capacity of soil at corners of pipe arch (lb)
r	Radius of gyration of pipe wall (in.)
R_i	Impervious area ratio (dimensionless)
R_c	Radius of curvature of a channel bend (ft) or channel development ratio (dimensionless)
R_c	Corner radius for pipe arch (in.)

r_{sd}	Settlement ratio in the Marston-Spangler design procedure for rigid pipe
R/W	Right of Way
RCB	Reinforced Concrete Box
RCP	Reinforced Concrete Pipe
RCPA	Reinforced Concrete Pipe-Arch
RCPHE	Reinforced Concrete Pipe, Horizontal Elliptical
RFB	Rigid Frame Box
RI	Recurrence Interval (years)
S	Soil permeability in USGS regression equations for flood discharge (in./hr)
S	Slope of channel, culvert or storm sewer (ft/ft)
S_x	Cross-slope of roadway (%)
Sl	Average slope of longest drainage path (ft/ft) or average slope of main channel (ft/mi)
SPP	Structural Plate Pipe
SPPA	Structural Plate Pipe Arch
SRSP	Spiral Rib Steel Pipe
T	Top width of flow in a channel (ft)

T_c	Time of concentration (min)
T_{cr}	Top width of critical flow in a channel or culvert
T_{in}	Inlet time for a storm-sewer inlet (min)
T_{lag}	Basin lag time (min)
T_t	Time of travel in pipe (min)
TO	Top of Opening
TR20	Technical Release 20, a publication and computer program of NRCS
TR55	Technical Release 55, a publication and computer program of NRCS
TW	Tailwater depth for a culvert (ft)
TWE	Tailwater elevation for a culvert (ft)
USGS	United States Geological Survey
V	Velocity of flow (ft/s)
V_o	Velocity in outgoing pipe (ft/s)
w	Unit weight of embankment (lb/ft^3)
W	Average width of watershed (ft)

WSE	Water Surface Elevation (ft)
WSPRO	Water Surface Profile computer program of FHWA
Z_u	Elevation of the upstream invert of a culvert (ft)
γ	Specific weight of water, 62.4 lb/ft^3
μ	Coefficient of internal friction for fill material
τ_d	Maximum shear stress in a channel (lb/ft^2)
τ_ρ	Permissible shear stress in a channel (lb/ft^2)

1.2 DEFINITIONS

Aggradation – General and progressive buildup of the longitudinal profile of a channel due to sediment deposition.

Allowable Headwater – The allowable water surface elevation upstream from a culvert.

Allowable High Water (AHW) – The maximum elevation to which water may be ponded upstream of a culvert or structure as specified by law or design.

Allowable Water Surface (AWS) – The water surface elevation above which damage will occur.

Backwater – The increased depth of water upstream from a dam, culvert, bridge or other obstruction, due to the existence of such obstruction.

Bridge – A structure having a length of 20 ft or more from face to face of abutments or end bents, measured along the roadway centerline.

Channel – A perceptible natural or artificial waterway that periodically or continuously contains moving water. It has a definite bed and banks that confine the water. A road ditch, therefore, is considered a channel.

Clear Zone – The unobstructed, traversable area provided beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes.

Clearance – The vertical distance between the top of opening and the design high-water elevation for a bridge.

CMMAC - Corrugated Metal, Metal Arch Culvert - A general term used for corrugated steel arch pipe including CSMAC and ACSMAC.

CMP - Corrugated Metal Pipe - a general term used for round corrugated steel pipe including CSP and ACSP.

Crown – The top of the inside of a pipe.

Culvert – An enclosed conduit, not classified as a bridge, that provides for the free passage of water under an embankment. The clear opening is less than 20.0 ft measured along the roadway centerline.

Design Backwater – The backwater upstream of a culvert or bridge at the design discharge, measured above the design high-water elevation.

Design Discharge or Design Flow – The discharge for which a drainage structure is designed. A design flow is associated with a specific recurrence interval that is appropriate for the particular situation.

Design High Water Elevation – The headwater elevation needed to pass the design discharge through a drainage structure.

Degradation – A general and progressive (long-term) lowering of the channel bed due to erosion, over a relatively long channel length.

Detention Storage – Temporary ponding of water upstream of a drainage structure during a storm.

Discharge – The volume of water per unit time that passes a specified cross-section in a channel or conduit.

Discharge Rating Curve – A curve that expresses the relationship between the discharge through a drainage structure and the water surface elevation upstream of the structure.

Drainage Easement – A permanent easement for channel changes, short outlet channels, and dikes along with associated drainage construction, such as channel lining, jetties, and erosion control appurtenances, outside the normal right of way line.

Ephemeral Stream – A stream or reach of stream that does not flow for parts of the year.

Excavation Boundary Plane – A horizontal plane at a given elevation denoting the boundary between Class I and Class II excavation, located 1.5 ft above Ordinary High Water.

Flood - In common usage, an event that overflows the normal flow banks or runoff that has escaped from a channel or other surface waters. In frequency analysis it can also mean an annual rainfall event that may not overflow the normal flow banks.

An overflow or inundation that comes from a river or other body of water and causes or threatens damage. Any relatively high streamflow overtopping the natural or artificial banks in any reach of a channel. A relatively high flow as measured by either gage height or discharge quantity.

In technical usage, it refers to a given discharge based, typically, on a statistical analysis of an annual series of rainfall events.

Floodplain – (1) The area that would be inundated by a flood with a specific recurrence interval, or (2) an area that has been inundated by historic floods, or (3) an area designated as a floodplain by a regulatory agency.

Floodway – The channel of a stream plus adjacent floodplain areas which, when kept free of encroachments, would carry the 100-year flood without substantial increases in flood heights.

Flowage Easement – A permanent easement for managing or preserving the flow and/or storage of water within the easement. A flowage easement is intended to reasonably preserve the flow and/or storage characteristics and provide access for maintenance activities in the storage area.

Flowline – The bottom of a channel or the bottom of the interior of a drainage structure.

Freeboard – The vertical distance above a design stage that is allowed for waves, surges, drift and other contingencies.

Froude Number - A dimensionless number that represents the ratio of inertial to gravitational forces. High Froude numbers may indicate high flow velocity and scour potential.

Hydraulic Grade Line (HGL) –the piezometric head (elevation plus pressure head) in an enclosed conduit.

Headwater – The water surface elevation or depth of flow directly upstream of a culvert or bridge.

Historic High Water – The highest water level known to have been reached at the upstream face of a culvert or bridge.

Hydrograph – A graph of discharge versus time at a specific location in a channel or conduit.

Hyetograph – A graph of rainfall intensity versus time for a historical or hypothetical storm.

Inlet Control – The case where the discharge capacity of a culvert is controlled at the culvert entrance by the depth of headwater and the entrance geometry, including the barrel shape, cross-sectional area, and inlet geometry.

Invert – The bottom of the interior of a drainage conduit (also termed the flowline).

Longitudinal Encroachment – A highway embankment in a floodplain on an alignment that is approximately parallel to the stream.

Normal Depth – The depth of uniform flow in a channel or conduit.

Ordinary High Water – The line on the shore established by the fluctuation of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas. Ordinary High Water will normally be established by a field survey of the site. Where Ordinary High Water is not determined by survey of the physical characteristics, it may be established by procedures as outlined in K-TRAN Report KU-13-1, Estimating the Discharge of Ordinary High Water Levels in Kansas.

Outlet Control – The case where the discharge capacity of a culvert is controlled by the elevation of the tailwater in the outlet channel and the slope, roughness, and length of the culvert barrel, in addition to the cross-sectional area and inlet geometry.

Overtopping Elevation – The water surface elevation at which the roadway is overtopped.

Permit – Authorization from a regulatory authority to proceed with work.

Perennial – A stream that flows continuously, except during an extreme drought.

Probable Maximum Flood – The greatest flow that would occur under the most severe circumstances. The probable maximum flood has a recurrence interval much greater than 100 years.

Rating Curve – A graph of water surface elevation or depth of flow versus discharge at a specific location in a drainage system. If the location is directly upstream of a drainage structure, the graph is termed a headwater rating curve. If the location is directly downstream of a drainage structure, the graph is termed a tailwater rating curve.

Recurrence Interval or Return Period – (1) The average time interval between floods that equal or exceed a specified magnitude, or (2) the reciprocal of the probability that a flood of a specified magnitude will occur in any given year. The first definition is used for rainfall depth-duration-frequency estimates such as those published in the NWS rainfall frequency atlases and the KDOT Rainfall Tables for Counties in Kansas. The second definition is used for flood discharge-frequency applications. The two definitions are essentially equivalent for recurrence intervals of 10 years or greater.

Regulated Floodway – A floodway adjacent to "navigable waters of the United States" under the authority of the Corps of Engineers or a floodway that has been defined by FEMA for flood insurance purposes and the local public authority has adopted the floodplain zoning regulations of FEMA.

Riparian – Pertaining to, or situated on, the bank of a natural watercourse.

Riprap – A facing of stone used to prevent erosion. Riprap is usually dumped into place, but is occasionally placed by hand.

Risk Assessment for Encroachment Design – Guidelines for hydraulic aspects of highway bridges in the Bridge Design Manual.

Scour – Localized erosion caused by higher-speed flow near a structure.

Sedimentation – The processes of erosion, entrainment, transportation, deposition and compaction of sediment.

Subgrade – The uppermost material placed in embankments or unmoved from cuts in the normal grading of the roadbed, generally considered to be the topmost 18 in.

Spur Dike or Guide Bank – A wall or mound built or extended out from the upstream side of an abutment to direct the floodplain flow through the bridge and to prevent erosion of the stream bank.

Streambed – The bottom of a channel bounded by banks.

Tailwater – The water-surface elevation or depth of flow directly downstream of a culvert or other drainage structure.

10'-20' Structure (formerly known as ‘500’ Series Culvert) – A structure with a total width that is 10.0 ft or greater (measured perpendicular to the centerline of box) up to a width that is less than 20.0 ft (measured along the centerline of roadway).

Thalweg – The line extending down a channel that follows the lowest elevation of the streambed.

Unregulated Stream - A stream that is not controlled by constructed devices as dams, flood control measures, navigational locks, etc or by natural diversions.

Watershed – The land that drains to a specified location on a stream.

1.3 DESIGN PROCEDURE

The principal steps in the design of drainage structures for highway projects are as follows:

1. Collection of relevant information
   Discussion included in this section
2. Determination of design criteria
   See appropriate section: 4.3 - Design Criteria for Road Ditches
   5.2 - Design Criteria
   6.0 - Culverts
   7.1 - Street Drainage
   7.2 - Storm Sewers
3. Hydrologic analysis
   See Section 3.0 - Hydrology
4. Selection of structure type and alignment
   See Section 6.0 - Culverts or
   Section 7.0 - Urban Drainage
5. Hydraulic analysis and sizing of structure
   See Section 6.0 - Culverts or
   Section 7.0 - Urban Drainage
6. Structural design
   See Section 8.0 - Structural Aspects of Culverts
7. Development of preliminary plans
   See Section 1.5 - Plan requirements
   See Road Design Manual,
8. Field check
   See Road Design Manual,
9. Completion of final plans
   See Road Design Manual,

Relevant information includes survey notes, topographic maps of the U. S. Geological Survey (USGS), soil survey reports of the Natural Resources Conservation Service (NRCS), flood studies and maps of the Federal Emergency Management Agency (FEMA), high-water data, stream data for Kansas from the USGS National Water Information System (NWIS) and other available information on local flooding. The items typically included in the survey notes are listed in Survey Manual. The watershed boundary should be delineated on the topographic map and the drainage area should be measured. The designer should contact the appropriate District personnel (usually the Area Supervisor) regarding the frequency and extent of roadway overtopping and other drainage issues at the project site. Individuals or agencies engaged in adjacent flood control or irrigation projects should also be contacted. A field inspection of the site may be necessary. The appropriate level of detail for the design study depends on the project scope, the project cost, the complexity of the hydrologic and hydraulic conditions, and the regulatory requirements.

The hydrologic and hydraulic design criteria for highway drainage structures are presented in Sections 4 through 7. An allowable headwater (AHW) is determined and an appropriate recurrence interval (RI) is selected in accordance with these design criteria. The objective of the hydrologic analysis is to compute the peak discharge or hydrograph for a flood with the selected recurrence interval. Section 3 presents the recommended procedures for hydrologic analysis. The structure type and alignment should be selected on the basis of economics and the various practical considerations and constraints. The structure is sized to pass the design flow without exceeding the allowable headwater. The objective of the hydraulic analysis is to determine the maximum headwater level and other hydraulic characteristics for structures of different sizes. In some cases the structure can be sized directly, but in other cases alternatives may need to be analyzed. Sections 4 through 7 present the recommended procedures for hydraulic analysis and design of channels, median drains, culverts, street inlets, and storm sewers.

Structural design follows the hydraulic design. For pipe culverts and storm sewers, structural design consists of the selection of the appropriate pipe gauge or strength class to withstand the imposed loads. Section 8 provides guidance for structural design of culverts and storm sewers. Once the dimensions of the structure have been determined, the preliminary plans should be prepared in accordance with the requirements in Section 1.5.

Prior to the field check, the designer may elect to inspect the sites of the proposed drainage structures to check the reasonableness of preliminary designs and the information used in their development. The equipment and documents needed for the drainage review may include a hand level, a level rod, a measuring tape, the USGS contour maps, and a print of the preliminary plans. If more accurate measurements are needed, a drainage survey should be performed. Items to check and document include:

1. Characteristics of watershed upstream of structure:
    a. Drainage area
    b. Land use
    c. Lakes and ponds

2. Allowable headwater: Impacts on upstream structures and land

3. Tailwater: Backwater effects from downstream structures

4. Performance of existing drainage structures on site and directly upstream and downstream:
    a. Erosion (local scour or streambed degradation)
    b. Evidence of high water

5. Channel conditions, upstream and downstream of structure:
    a. Hydraulic roughness of main channel and overbanks
    b. Cross sectional geometry (typical) of main channel and overbanks
    c. Bank stability
    d. Alignment of proposed structure with channel

Design changes resulting from the drainage review and the field check should be incorporated into the final plans.

The designer should retain documentation for the design of drainage structures including the determination of the design flow, structure size, headwater elevations, allowable headwater elevation quantity computations, and other relevant information, This documentation should be retained with the other project records.

See Volume I, Part B, Section 5.4, “DOCUMENTATION.”

1.4 PROJECT PERMITS

The Environmental Services Section (ESS) is responsible for obtaining and processing appropriate permits related to the environment. The Environmental Services Section will then determine which permits are required. The designer will need to provide additional project information requested by the Environmental Services Section at various stages of project development. The timely submittal of this information is necessary to avoid delays in project construction activities so that they may be completed within the time limits specified in the permits.

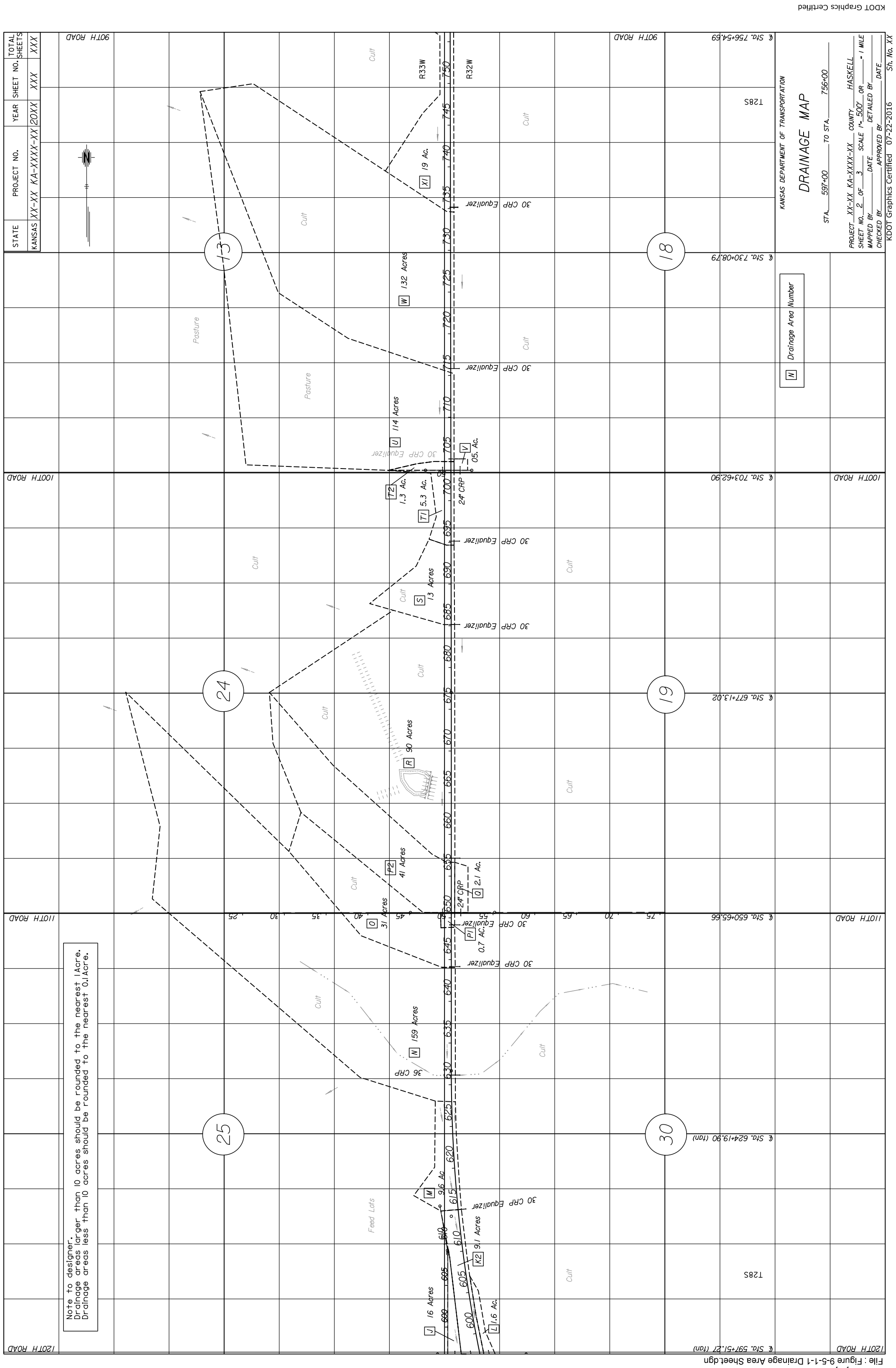
Other approvals for the project may be required that are not the responsibility of the Environmental Services Section. These include FEMA Conditional and Final Letters of Map Revision (CLOMR, LOMR) and the US Army Corps of Engineers (USACE) Section 408 approval. The project designer is responsible for obtaining these. See Section 2.2 **COORDINATION WITH OTHER GOVERNMENTAL AGENCIES** .

1.5 PLAN REQUIREMENTS

1.5.1 Drainage Area Sheets

Drainage area sheets showing existing drainage patterns are provided with the field surveys. These drainage area sheets should be included in the plans. Figure 1.5.1-1, "Drainage Area Sheet" shows an example drainage area sheet. See the Road Design Manual, Section 6.13, “DRAINAGE AREA SHEETS” for instructions.

Figure 1.5.1-1 Drainage Area Sheet



1.5.2 Drainage Data Sheet

The plan set should include a standard Drainage Data Sheet, as shown in Figure 1.5.2-1, "Drainage Data Sheet". The Drainage Data Sheet should list new crossroad pipe and box culvert installations. Include pipes and box culverts under side roads. Include pipes larger than 36 in. under entrances and multiple-pipe installations larger than 24 in. under entrances. Median pipes, storm sewers and temporary pipe installations are generally not listed on the Drainage Data Sheet. Crossroad pipes and box culverts that are extended in rehabilitation projects should be listed.

1.5.3 Crossroad Pipes

Crossroad pipe data are shown on the plan-profile sheet and in the drainage structure summary on the summary of quantities sheet. Crossroad pipes for median inlets, ditch inlets and storm sewers should also be included. Figure 1.5.2-1, "Drainage Data Sheet" shows an example Drainage Data Sheet with hydrologic method information. Figure 1.5.2-2, "Summary of Quantities Sheet with Drainage Structures" shows a standard summary of quantities sheet with a drainage structure summary. The appropriate standard drawings for pipe end treatments should be included in the plans.

If alternate pipe materials are permitted, the designer should see the Design Manual, Section 7.21.2.3, “Pipe Culverts”. This section provides references to example sheets of pipe culvert summaries, construction notes, and summary of drainage structures. If a larger pipe size is required due to a higher roughness coefficient, as with corrugated pipe, it should be noted in the Summary and Recapitulation of Drainage Structures with Alternates.

Figure 1.5.2-1 Drainage Data Sheet

STATE	PROJECT NO.	YEAR	SHEET NO.	TOTAL SHEETS
KANSAS	XX-XX KA-XXXX-OX	20XX	XX	XXX

SITE DATA							HYDROLOGY						HYDRAULICS	
DRAINAGE STRUCTURE NUMBER	LOCATION STATION	DRAINAGE AREA NUMBER	DRAINAGE AREA ACREAGE	RECURRENCE INTERVAL YEARS	A. H. W. ELEVATION FEET	REMARKS	METHOD	DATA TC	DATA C	DATA I	Q cfs	REMARKS	H. W. ELEVATION FEET	REMARKS
	US-83													
1	90+23.30	1,2	39	25	2952.42	Top of Subgrade @ Sta. 89+00	Rational	30	0.27	3.72	39	Flow split between Culverts	2950.55	
2	91+23.32	1,2	67	25	2952.42	Top of Subgrade @ Sta. 89+00	Rational	23	0.26	4.31	75	Flow split between Culverts	2950.75	
3	115+25.95	3	168	25	2946.94	Top of Subgrade @ Sta. 115+26	Rational	51	0.36	2.68	162		2945.81	
4	162+24.52	4,6	10	25	2943.09	Top of Subgrade @ Sta. 162+25	Rational	17	0.45	5.00	23		2942.97	
5	177+94.46	7	323	25	2939.8	Top of Subgrade @ Sta. 177+94	Rational	47	0.36	2.84	330	Upstream flow is Metered by 18" RR CIP- 46 cfs	2937.07	
6	250+74.25	8	11	25	2926.01	Top of Subgrade @ Sta. 250+74	Rational	16	0.47	5.15	27		2923.25	
9	264+14.38	9	4.1	25	2922.44	Top of Subgrade @ Sta. 264+14	Rational	17	0.42	5.00	9	9.8cfs Bypasses to Sta. 286+83 along Lt. Ditch- 21 cfs	2920.68	
7	286+82.74	10	48	25	2912.84	Top of Subgrade @ Sta. 286+83	Rational	26	0.37	4.04	72	90.5cfs Bypasses to Sta. 286+83 along Rt. Ditch	2910.4	
8	309+08.56	11	110	25	2901.46	Top of Subgrade @ Sta. 309+09	Rational	35	0.37	3.41	139	Upstream flow is Metered by 18" RR CIP- 35 cfs	2898.87	
9	352+23.95	13,14	60	25	2898.88	Top of Subgrade @ Sta. 352+24	Rational	30	0.38	3.72	85		2898.41	No History of Overtopping
10	399+47.92	15	166	25	2889.35	Top of Subgrade @ Sta. 399+48	Rational	32	0.37	3.60	221	Upstream flow is Metered by 24" RR CIP- 75 cfs	2886.66	
10	437+75.10	16	9.4	25	2882.99	Top of Subgrade @ Sta. 437+75	Rational	26	0.43	4.31	17		2881.3	
12	492+56.19	19	134	25	2848.8	Top of Subgrade @ Sta. 492+56	Rational	56	0.37	2.52	125		2848.65	No History of Overtopping
13	518+55.00	20,21	7.1	25	2852.29	Top of Subgrade @ Sta. 520+00	Rational	24	0.33	4.22	10		2851.43	
14	548+76.70	22,23	6.6	25	2851.42	Top of Subgrade @ Sta. 548+77	Rational	12	0.45	5.96	18		2850.00	
15	578+09.92	25,26	146	25	2836.45	Top of Subgrade @ Sta. 578+00	Rational	41	0.37	3.10	167	Upstream flow is Metered by 30" RR CIP- 66 cfs	2836.38	
16	603+51.85	27	13	25	2829.5	Top of Subgrade @ Sta. 603+52	Rational	26	0.42	4.04	22		2827.04	
17	651+51.28	29,30	22	25	2830.17	Top of Subgrade @ Sta. 650+00	Rational	23	0.38	4.31	36		2829.31	No History of Overtopping
18	668+27.16	31	36	25	2828.14	Top of Subgrade @ Sta. 676+00	Rational	40	0.38	3.15	44		2825.9	
	Rd. 150W													
19	48+91.14	2	1.1	10	2953.18	Top of Subgrade @ Sta. 48+25	Rational	5	0.33	7.23	3		2951.69	
	Rd. 140W													
20	49+33.48	4	8.6	10	2945.86	Top of Subgrade @ Sta. 49+17	Rational	13	0.36	4.64	14		2943.77	
21	50+67.00	5	10	10	2944.79	Top of Subgrade @ Sta. 50+79	Rational	20	0.39	3.75	15		2943.46	
	Rd. 100N													
22	50+66.62	8	3.9	10	2940.05	Top of Subgrade @ Sta. 51+70	Rational	10	0.38	5.29	8		2940.03	
	Rd 110W													
23	49+28.00	12	2.4	10	2903.34	Top of Subgrade @ Sta. 49+44	Rational	5	0.41	7.23	7		2901.41	
24	50+71.00	13	0.9	10	2903.27	Top of Subgrade @ Sta. 50.86	Rational	5	0.42	7.23	3		2901.31	
	Rd 90W													
25	49+37.00	17	15	10				33	0.32	2.86	14			
				25	2873.51	Top of Subgrade @ Sta. 460+00	Rational	35	0.32	3.41	16	Includes 5.9cfs Bypass from Sta. 437+75	2872.53	
26	50+65.00	18	13	10				20	0.28	3.75	14			
				25	2873.51	Top of Subgrade @ Sta. 460+00	Rational	21	0.39	4.51	23		2872.88	
	Rd 80W													
27	49+39.00	20	2.5	10	2852.18	Top of Subgrade @ Sta. 49+24	Rational	8	0.33	5.88	5		2850.89	
	Rd 130N													
28	49+39.00	22	4.4	10	2852.28	Top of Subgrade @ Sta. 49+07	Rational	11	0.34	5.05	6		2849.93	
	W 6th St.													
29	50+67.12	24	2.6	10	2848.00	Top of Subgrade @ Sta. 51+50	Rational	5	0.33	7.23	4		2849.01	
	Rd 70W													
30	49+25.00	26	2.4	10	2836.44	Top of Subgrade @ Sta. 51+50	Rational	5	0.33	7.23	6		2834.44	
	Rd 60W													
31	49+37.00	28	2.9	10	2833.53	Top of Subgrade @ Sta. 49+00	Rational	12	0.33	4.83	5		2831.99	
32	50+58.00	29	6.4	10	2834.12	Top of Subgrade @ Sta. 50+73	Rational	14	0.28	4.46	8		2833.00	

NO.	DATE	REVISIONS	BY	APP'D
2	10-8-90	Detailed on CADD, no change	R.J.S.	J.O.B.
1	5-29-80	Assigned standard number	W.L.H.	J.O.B.

KANSAS DEPARTMENT OF TRANSPORTATION

DRAINAGE DATA SHEET

RD653

FHWA APPROVAL	01-17-91	APP'D. James O. Brewer	
DESIGNED	DETAILED	QUANTITIES	TRACED B.N.B.
DESIGN CK.	DETAIL CK.	QUAN.CK.	TRACE CK. R.J.S.

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KDOT Graphics Certified

Drawn By : jhobelman Plotted :22-JUL-2016 10:59
File : Figure 9-5-2-1 Drainage Data Sheet.dgn

Figure 1.5.2-2 Summary of Quantities Sheet with Drainage Structures

STATE	PROJECT NO.	YEAR	SHEET NO.	TOTAL SHEETS
KANSAS	XX-XX KA-XXXX-OX	20XX	XX	XX

DRAINAGE STRUCTURES

STATION	SIDE	SIZE	TYPE	CROWN GRADE ELEV.	FLOW LINE LT	FLOW LINE RT	DEG. OF ROT.	LENGTH OF PIPE Lt.	LENGTH OF PIPE Rt.	Height of Fill (max.) Ft.	CONC. PIPE AASHTO CLASS NO.	CROSS ROAD PIPES RC,CS,CA,PE,PVC 24"	CROSS ROAD PIPES RC,CS,CA,PE,PVC	CROSS ROAD PIPES RC,CS,CA 24"	CROSS ROAD PIPES RC,CS,CA 30"	CROSS ROAD PIPES RC 30"	CROSS ROAD PIPES CAPA,CMMAC 2.5□'	CROSS ROAD PIPES CAPA,CMMAC 5.0□'	ENTRANCE PIPES RC,CS,CA 24"	ENTRANCE PIPES RC,CS,CA 30"	ENTRANCE PIPES RC,CS,CA,PE,PVC 24"	ENTRANCE PIPES RC,CS,CA,PE,PVC 30"	END SECTIONS RC 30"	END SECTIONS ◔ 24"	END SECTIONS ◔ 30"	END SECTIONS ◔ 2.5□'	END SECTIONS ◔ 5.0□'	END SECTIONS TYPE I LT.	END SECTIONS TYPE I RT.	REMARKS
90+23.30	℄	5.0 ft^2	CRP Exten. Lt. & Rt.	2953.69	2948.77	2947.82	0	16	13	3								29									2	1	1	
91+23.32	℄	5.0 ft^2	CRP Exten. Lt. & Rt.	2953.75	2948.87	2948.41	0	16	13	3								29									2	1	1	
162+24.35	℄	30"	CRP Exten. Lt. & Rt.	2944.94	2940.43	2940.24	0	32	4	2	II					36							2					1	1	
228+11	Lt.	24"	E.P.	2943.77	E 2939.88	W 2940.17	0	22	22	2	II										44			2				1	1	
250+74.25	℄	30"	CRP Exten. Lt.	2927.86	2921.36		0	26	0	4	II					26							1					1		
264+14.36	℄	30"	CRP Exten. Lt.	2924.30	2919.09		0	32	0	3	II					32							1					1		
278+47	Rt.	30"	E.P.	2917.70	E 2913.11	W 2913.35	0	24	22	2	II											46			2			1	1	
279+98	Lt.	30"	E.P.	2917.43	E 2912.74	W 2913.07	0	34	12	2	II											46			2			1	1	
398+00	Rt.	24"	E.P.	2888.41	E 2884.36	W 2884.46	0	23	23	2	II										46			2				1	1	
400+06	Lt.	24"	E.P.	2890.90	E 2884.30	W 2884.12	0	38	40	5	II										78			2				1	1	
429+25	Rt.	30"	E.P.	2886.77	2882.88	2883.08	0	21	19	2	II									40					2			1	1	
437+75.10	℄	30"	CRP Exten. Lt.	2884.85	2879.02		0	29	0	3	II					29							1					1		
440+93	℄	24"	E.P.	2883.02	E 2877.98	W 2878.16	0	32	28	3	II										60			2				1	1	
444+76	Rt.	24"	E.P.	2881.30	E 2876.89	W 2877.20	0	26	24	2	II										50			2				1	1	
479+26	Rt.	30"	E.P.	2861.01	E 2857.12	W 2857.50	0	17	19	2	II									36					2			1	1	
518+55	℄	30"	CRP	2854.17	2849.13	2848.93	0	44	44	3	II					88							2					1	1	
536+10	Rt.	24"	E.P.	2857.86	E 2853.15	W 2853.38	0	30	28	3	II										58			2				1	1	
545+02	Rt.	24"	E.P.	2852.05	E 2848.64	W 2849.05	1	19	19	2	II										38			2				1	1	
547+68	Rt.	24"	E.P.	2851.21	E 2847.40	W 2847.48	6	19	19	2	II										38			2				1	1	
548+76.69	℄	30"	CRP	2853.62	2847.66	2847.61	0	18	18	4	II					36							2					1	1	
557+94	Rt.	24"	E.P.	2849.80	E 2845.74	W 2846.04	0	23	21	2	II										44			2				1	1	
559+66	Rt.	24"	E.P.	2848.66	E 2844.88	W 2845.19	0	24	22	2	II										46			2				1	1	
562+36	Rt.	24"	E.P.	2846.84	E 2842.34	W 2842.70	0	27	25	3	II										52			2				1	1	
568+78	Lt.	24"	E.P.	2843.06	E 2839.83	W 2840.13	0	25	25	2	II										50			2				1	1	
576+80	Lt.	24"	E.P.	2837.36	E 2833.91	W 2834.17	8	53	29	2	II								84					2				1	1	
615+78	Lt.	24"	E.P.	2833.89	E 2829.56	W 2829.42	0	24	24	2	II								48					2				1	1	
615+78	Rt.	24"	E.P.	2833.50	E 2830.36	W 2830.21	0	16	16	2	II								32					2				1	1	
625+78	Rt.	24"	E.P.	2834.06	E 2831.98	W 2831.80	0	18	19	2	II								37					2				1	1	
655+71	Lt.	24"	E.P.	2831.93	E 2828.77	W 2828.59	0	18	18	2	II								36					2				1	1	
Sideroad Sta. 99+08.30																														
Sideroad Sta. 48+91.14	℄	24"	CRP	2955.52	2950.95	2950.75	36.5°Lt.	39	38	3	II			78										2				1	1	
Sideroad Sta. 156+71.93																														
Sideroad Sta. 49+33.48	℄	24"	CRP	2946.51	2941.07	2941.53	26.7°Lt.	38	34	3	II	72												2				1	1	
Sideroad Sta. 50+67.00	℄	24"	CRP	2945.27	2941.23	2941.89	25.8°Lt.	36	30	2	II	66												2				1	1	
Sideroad Sta. 231+00.08																														
Sideroad Sta. 50+66.62	℄	2.5 ft^2	CRP	2942.02	2938.32	2938.78	33°Rt.	30	28	2							58									2		1	1	
Sideroad Sta. 339+04.91																														
Sideroad Sta. 49+28.00	℄	24"	CRP	2904.60	2899.82	2900.12	30° Lt.	36	32	3	II			68										2				1	1	
Sideroad Sta. 50+71.00	℄	24"	CRP	2904.64	2900.28	2900.55	28° Lt.	29	31	2	II			60										2				1	1	
Sideroad Sta. 460+30.32																														
Sideroad Sta. 49+37.00	℄	30"	CRP	2875.14	2869.60	2870.07	30° Lt.	38	36	3	II				74										2			1	1	
Sideroad Sta. 50+65.00	℄	5.0 ft^2	CRP	2874.47	2869.63	2870.13	29° Lt.	33	31	2								64									2	1	1	
Sideroad Sta. 517+83.34																														
Sideroad Sta. 49+39.00	℄	24"	CRP	2853.45	2849.19	2849.38	30° Lt.	30	30	2	II			60										2				1	1	
Sideroad Sta. 548+14.00																														
Sideroad Sta. 49+31.00	℄	24"	CRP	2852.97	2847.79	2848.21	37° Rt.	39	41	3	II	80												2				1	1	
Sideroad Sta. 551+05.00																														
Sideroad Sta. 50+67.12	℄	24"	CRP	2851.67	2847.61	2847.55	25° Rt.	35	29	2	II			64										2				1	1	
Sideroad Sta. 578+11.43																														
Side Road Sta. 49+20.00	℄	2.5 ft^2	CRP	2837.34	2834.17	2833.91	0	29	23	2	II						52									2		1	1	
Sideroad Sta. 639+31.00																														
Sideroad Sta. 49+37.00	℄	24"	CRP	2835.08	2830.49	2830.72	28° Lt.	33	35	3	II			68										2				1	1	
Sideroad Sta. 50+58.00	℄	2.5 ft^2	CRP	2835.47	2831.54	2831.83	28° Lt.	29	31	2	II						60									2		1	1	
TOTALS												218		398	74	247	170	122	237	76	604	92	9	52	10	6	6			

◔ - See Pipe Culvert Summary Sheet for allowable End Section types.

STORM SEWER CONDUITS

LOCATIONS OF INSTALLATIONS: STATIONING	ROUTE	DISTANCE LEFT/RIGHT	CONSTRUCT OR INSTALL: TYPE OF CONDUIT SIZE	TYPE OF CONDUIT MATERIAL	LENGTH (FEET)	CONDUIT FLOWLINES: INFLOW ELEV.	OUTFLOW ELEV.	SEWER EXCAVATION: ROCK (Cu.Yd.)	COMMON (Cu.Yd.)	STORM SEWER PIPE (LIN. FT.) 5.0□' RCPHE	STORM SEWER PIPE (LIN. FT.)	REMARKS
601+40.00	US-83	32.37 Rt.	5.0□'	RCPHE	208'	2826.37	2826.01			208'		Connect to Box Ext. @ 603+19.15
TOTAL										208'		

DRAINAGE STRUCTURES - RCB's

STATION	SIDE	SIZE	TYPE	CROWN GRADE	FLOWLINE ELEVATION LEFT	FLOWLINE ELEVATION RIGHT	HORIZONTAL ROADWAY LEFT	HORIZONTAL ROADWAY RIGHT	DEGREE OF ROTATION	HEIGHT OF FILL (ft.)	EXTENSIONS (ft.) LEFT	EXTENSIONS (ft.) RIGHT	GRADE 4.0 CONC. (cu. yds.)	GRADE 4.0 (AE) CONC. (cu. yds.)	FOUNDATION STAB. (cu. yds.)	REINF. STEEL (GR.60) (lbs.)	REINF. STEEL (GR.60)(EPOXY) (lbs.)	BR. BACKWALL PROT. SYSTEM (sq.yds.)	GRANULAR BACKFILL) (cu.yds.)
115+25.95	℄	8' x 4'	RCB Ext.	2,948.79	2,941.96	2,941.97	44.25	44.25	0	2	35	5.5	25.3	10.5	13	1,160	3,310	48	24
177+94.46	℄	8' x 4'	RCB Ext.	2,941.65	2,934.91	2,934.87	44.10	44.40	0	2	35	5.5	25.3	10.5	13	1,160	3,310	48	24
286+82.74	℄	4' x 3'	RCB Ext.	2,914.70.	2,907.28	2,907.25	44.25	44.25	0	3	35.5	5	19.5		9	2,090			16
309+09.31	℄	7' x 3'	RCB Ext.	2,903.32	2,897.26	2,897.28	44.45	44.05	0	2	35.5	5	20.0	8.8	12	890	2,650	43	16
352+23.95	℄	4' x 3'	RCB Ext.	2,900.73	2,893.60	2,894.10	44.05	44.45	0	3	31	5.5	18.2		9	1,980			16
399+47.92	℄	7' x 4'	RCB Ext.	2,891.21	2,884.09	2,884.10	44.45	44.05	0	2	35.5	5.0	23.6	8.8	12	1,150	2,780	43	24
492+56.19	℄	7' x 3'	RCB Ext.	2,841.10	2,843.90	2,845.18	44.05	44.45	0	3	31	5.5	25.7		11	3,120			16
578+09.92	℄	10' x 3'	RCB Ext.	2,838.31	2,832.26	2,832.18	42.30	42.75	0	2	10	10	17.0	6.8	9	1,150	2,290	27	24
603+51.85	℄	6' x 3'	RCB Ext.	2,831.42	2,825.76	2,825.70	40.35	42.15	0	2	14.5	16	15.4	5.6	9	880	1,800	29	16
651+51.28	℄	4' x 3'	RCB Ext.	2,832.18	2,826.60	2,826.63	44.00	44.00	0	2	20	20	15.3	4.6	10	860	1,590	30	16
668+27.16	℄	4' x 4'	RCB Ext.	2,831.34	2,823.27	2,823.30	44.00	44.00	0	3	16	16	20.0		9	2,210			24
TOTALS													225.3	55.6	116	16,650	17,730	268	216

NO.	DATE	REVISIONS	BY	APP'D
3				
2				
1				

KANSAS DEPARTMENT OF TRANSPORTATION

SUMMARY OF DRAINAGE STRUCTURES

~~RD049~~

FHWA APPROVAL 5-28-08		APP'D. James O. Brewer	
DESIGNED	DETAILED	QUANTITIES	TRACED B.N.B.
DESIGN CK.	DETAIL CK.	QUAN.CK.	TRACE CK. S.W.K.

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Drawn By : jhobelman   Plotted : 04-AUG-2016 11:01
File : Figure 9-5-2-2 Summary of Quantities.dgn

1.5.4 RCB Culverts and Extensions

Standard detail sheets for RCB culverts and RCB extensions may be obtained from the KDOT Automated RCB System. Designers external to KDOT may obtain the RCB detail sheets for KDOT projects by completing the "Standard RCB/RFB Detail Request Application" and submitting it to the appropriate KDOT unit within the Division of Engineering and Design. See Section 16.6 for additional information on how to obtain RCB/RFB detail sheets. The appropriate standard detail sheets for RCB's, RFB's, and their extensions should be included in the plans. A contour map may also be required. A summary of quantities table is included in the automated RCB drawing. The summary table shows the length, size, skew, rotation, end treatment, concrete quantity, and steel quantity for each RCB and RCB extension. Information provided to the external designer should be checked by the external designer.

1.5.5 Detention-Storage Structures

The plans and supporting documents should include the pertinent information regarding detention requirements that impact construction. This information may include, but is not limited to, watershed area, basin volume, storage runoff, peak discharge, maximum water surface elevation, normal pool elevation, low pool elevation, freeboard, length of retention, permanent drainage easement, and storm return period. The designer may choose to include this information in tabular form.

1.5.6 Road Ditches

Ditches are shown on the plan-profile sheets. See the Design Manual, for instructions. The plan set should include the appropriate standard drawings for aggregate ditch lining and concrete ditch lining.

1.5.7 Storm Sewers

The plan set should include a standard Schedule of Storm Sewer Conduits, a standard Schedule of Storm Sewer Installations, and a standard Schedule of Inlets and Manholes.

1.5.8 Precast Structures

Many drainage structures are available as prefabricated units. If a precast structure is allowed and an appropriate KDOT standard drawing is available, the standard drawing should be included in the plans. If no standard details are available, shop drawings from a precast manufacturer should be submitted for the designer's review for general conformity to the plans. The designer may need to request the Bureau of Structures and Geotechnical Services to review shop drawings for some structures such as 10'-20' structures. See Section 2.6.4 "Precast Structures," for additional information regarding the use of precast structures.

1.5.9 Pipe Liners

Several options, including pipe liners, are available for the maintenance or repair of an existing pipe culvert. Installing a pipe liner generally consists of inserting a new liner inside of an existing distressed culvert as an alternative to total replacement. This method typically takes less time to complete; however, may be more expensive than replacement of the culvert.

There are many factors that need to be considered before it is determined to repair a culvert versus total replacement. Some of these factors include location, section loss and upstream/downstream impacts. The selection of the type of liner may depend on whether the pipe is located in an urban or rural area. Cured in Place Pipe (CIPP) is one type of pipe liner that has been used for medians and other locations. Section loss or reduction in pipe opening may have an impact on headwater depth and /or outlet velocity. These impacts need to be evaluated with regard to buildings or other structures located upstream or downstream of the pipe. The need for permanent erosion control should be considered if the velocity is increased.

The determination to repair a pipe culvert with a liner as opposed to replacing it should be coordinated with the Area Engineer. The designer will need to request the Area Engineer to complete a KDOT Form No. 252, "Existing Culvert Inspection" for each pipe that is being considered for a liner. The information included on the form may be used to determine if the pipe culvert can be lined and the type of liner used. Additional information regarding culvert rehabilitation and pipe liners may be found in of AASHTO's Highway Drainage Guidelines.

1.6 COMPUTER PROGRAMS

Numerous computer programs are available for various aspects of drainage design. A computer program is considered acceptable if it can be used to perform design calculations in accordance with the requirements in this manual. Certain computer programs for drainage design incorporate methods, assumptions, or approximations that are inconsistent with KDOT requirements. These programs are unacceptable. The designer is responsible for developing a design that meets the requirements specified in this manual. The designer should only use computer programs for which the methods, assumptions, and approximations are fully documented as being consistent with the recommendations in this manual.

1.7 REFERENCES

Young, C.B., McEnroe, B.M. Gamarra, R., Luo, Y., and Lurtz, M., (2014), *Estimating the Discharge for Ordinary High Water Levels in Kansas*, Report No. K-TRAN KU-13-1.

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