HYDROLOGY
Factors Affecting Flood Runoff

- Drainage area size
- Slope of the terrain
- Land use
- Soil type
- Infiltration
- Storage
- Geology
Sources of Information

- Climatologic, Hydrologic, Rainfall
  - MN Climatology Working Group
  - NOAA
    - Hourly Precipitation Map
    - Interactive Weather
    - Precipitation Analysis
    - HDSC Precipitation Frequency Data Server
    - National Weather Service Forecast
  - NEXRAD Viewer
  - WSI Daily Radar-Based Precipitation Estimate

- Flooding
  - DNR Watershed Assessment Tool

- NOAA
  - North Central River Forecast

- US Army Corp of Engineers Water Control Center

- FEMA
  - Map Service Center
  - National Flood Hazard Layer for Arcmap
  - National Flood Hazard Layer for Google Earth

What procedure should I use

<table>
<thead>
<tr>
<th>FACILITY DESCRIPTION</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Analysis</td>
<td>Regression Equations</td>
</tr>
<tr>
<td>SCS Hydrograph</td>
<td>SCS Peak Discharge</td>
</tr>
<tr>
<td>Rational</td>
<td></td>
</tr>
<tr>
<td>Stream Flow, Channels, Bridges, &amp; Culverts Greater than 48&quot;</td>
<td>customary method</td>
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<tr>
<td>Culverts 48&quot; and Smaller</td>
<td>alternate method</td>
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<tr>
<td>Storm Drains, Roadside Ditches, &amp; Side Culverts</td>
<td>complex facilities or hydrograph needed</td>
</tr>
<tr>
<td>Detention Basins</td>
<td>customary method</td>
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</table>
Frequency Analysis

- Analysis of Stream Gage Data
- Log-Pearson Type III is used to analyze the data
- Need 10 years of continuous data for 10-year discharge estimates and 25-years for the 100-year estimate

Regression Equations

- Estimating peak flows at ungaged sites or sites with limited data
- Statistical method used to develop runoff equations
- \( Q = \alpha A^b S^c (St + 1)^d \)
- Done every 10 years by the USGS
http://water.usgs.gov/osw/streamstats/
Gage has 80 years of record

<table>
<thead>
<tr>
<th>Statistic Name</th>
<th>Value</th>
<th>Units</th>
<th>Citation Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area</td>
<td>1304.71</td>
<td>square miles</td>
<td>67</td>
</tr>
<tr>
<td>Main Channel Length</td>
<td>192.00</td>
<td>miles</td>
<td>31</td>
</tr>
<tr>
<td>Mean Basin Elevation</td>
<td>1100.00</td>
<td>feet</td>
<td>31</td>
</tr>
<tr>
<td>Mean Basin Slope &amp; per mi</td>
<td>4.739007</td>
<td>feet per mi</td>
<td>87</td>
</tr>
<tr>
<td>Percent Forest</td>
<td>1.2000</td>
<td>percent</td>
<td>31</td>
</tr>
<tr>
<td>Percent Storage</td>
<td>0.7000</td>
<td>percent</td>
<td>31</td>
</tr>
<tr>
<td>Soil Infiltration</td>
<td>3.1850</td>
<td>inches</td>
<td>31</td>
</tr>
<tr>
<td>Stream Slope &amp; 405 Method</td>
<td>6.0000</td>
<td>feet per mi</td>
<td>31</td>
</tr>
<tr>
<td>Percent Storage and 405 Alarm</td>
<td>2.594998</td>
<td>dimensionless</td>
<td>87</td>
</tr>
<tr>
<td>Percent Lakes and 405 Alarm</td>
<td>1.6</td>
<td>dimensionless</td>
<td>87</td>
</tr>
</tbody>
</table>

Streamflow Statistics:

Gage has 80 years of record
Hydrology is an “art”
Verify results with multiple methods
Don’t average your multiple results
Run your calculated flows through the inplace model. Does it give you sensible results.

Check for other sources of hydraulic studies.
- Watersheds
- Flood Insurance Studies
- Ditch Authorities
Hydraulic Engineers vs. the Elements

Washed Up or Washed Out

A few weeks ago a local newspaper commented, "As far as the Minnesota Highway Department is concerned, this spring has been pretty much of a washout." To which we might add somewhat prophetically, it was the kind of spring that could well make a highway drainage engineer feel all washed up. With the floods of 1965 and the heavy storms of the past year still fresh in everyone's memory, it might be interesting to reflect on the occupational hazards of sizing culverts and bridge openings.

A drainage engineer in determining the amount of water which must be accommodated by a culvert or bridge invokes all kinds of hocus-pocus including records, charts, diagrams, and formulas. After deriving into variables, maxima, square roots, probabilities and various other functions, he crosses his fingers and predicts that a flow of so many cubic feet per second will not be exceeded oftener than once in 50 years. With a little bit of luck he'll be dead before nature proves him wrong. This is a facetious way of showing that a highway drainage engineer has to stick his neck out. He's structures wash out, he can well be washed up. Herein lies the hazard of the occupation.

Hydrology a Science

The science dealing with the problems which the highway drainage designer must attack is called "hydrology." The term is derived from the combination of two Greek words, "hydro" and "logos," the first meaning "water," and the second "reasoning." Thus hydrology has come to mean literally the science of water - its properties, laws and distribution upon the earth. The phase of hydrology important to the highway drainage engineer deals with the nature of the runoff of water from land surfaces. But no amount of hocus-pocus can account for all the vicissitudes of weather which may produce runoff from land surfaces so unpredictable. Nevertheless, experience has its applications. As an indication of what might happen in the future, we have to rely on past events. Therefore, recordkeeping of past events is paramount. The records themselves become valuable sources of information. And the longer the record the more reliable the data.

Records Valuable

Everyone is familiar with Weather Bureau records and predictions. Other agencies also collect data on water. One of these is the U.S. Geological Survey which maintains records on the runoff of rivers and streams at key locations throughout the country. Two key stations operated by the Geological Survey in Minnesota are the Mississippi River at St. Paul and the Minnesota River at Mankato. The St. Paul record goes back almost 100 years to 1867 and the Mankato record 62 years to 1903 with some additional supplementary information on the flow of 1881. With this extended record one would think that the probability of future flooding could be projected with confidence, but the flood of 1965 took care of the confident ones.

This spring the flood at St. Paul was 40 per cent greater than the previous high of record. And in Mankato it was estimated to be over 10 per cent greater than the flood of 1981. These earth-shaking statistics were repeated at other locations throughout the state, and hydrologists made a mud dash for their slide rules - the flood frequency curves needed to be recomputed.

Nature is always upsetting the applecart even on more or less predictably small streams. Last year on Labor Day weekend an intense rainstorm flooded streams crossing new Two Harbors, Duluth and Two Harbors. Practically all the culverts and bridges were washed out without undue stress, but an 7-foot-diameter concrete culvert used to be too small. The overflow surged across the highway and washed out part of the embankment on the downstream side. After considerable investigation, we have no logical explanation why the runoff on Schmidt Creek was proportionately greater than that of the surrounding streams. Perhaps it was a freak of nature, or perhaps it was just a bad hydrological guess.

Culvert Design Difficult

While records have been kept for many years on the larger rivers, little information is available on the culvert-size streams and channels which cross our highways. Drainage designers must rely on scanty and scattered observations of runoff from various sources or on formulas which at best provide questionable answers.

We were ill-prepared hydrologically to cope with culvert design for the interstate system. Taking it up from the old point of view, in 1956 the Highway Design Department in its 1956 entered into agreement with the Geological Survey to collect runoff data from usable sites along the trunk highway system. This "creed-stage-gage" program has been the basis of the maximum water elevations and the peak flows from runoff events. Many sites through the state. Currently there are 157 observation stations and ten are equipped with automatic water level recorders. The program now costs about $42,000 a year and trunk highway floods defy half the cost.

In addition, the cooperative program with the Geological Survey gives the Department the privilege to order special surveys and flood flow determinations whenever floods occur on vulnerable locations along the trunk highway system. For example, shortly after the program commenced, we designed a triple box culvert to replace a bridge at Willow Creek on TH 63 south of Rochester. Before the contractor started construction a flash flood washed out the old bridge. By special survey the Geological Survey determined that the flood flow was almost twice the capacity of the proposed box culvert. Fortunately, we were able to increase the size of the structure through a supplemental to the construction contract.

Perhaps the average person is apt to ask, Why all this fuss over culverts and bridge openings? Why not make them large enough and shut the people out of the way? This is a simple philosophy but an expensive one. With drainage facilities, exclusive of bridges accounting for 8 to 10 cents of every highway construction dollar, integrity and precision of design is a challenge to the highway drainage engineer. If he fails to meet the challenge, he could well be both washed out and washed up.
## HYDROLOGY

### INTRODUCTION

Analysis of peak rate of runoff, volume of runoff, and time distribution of flow is fundamental for design of highway drainage facilities. Most drainage facility designs require determination of a peak flow rate while others require a runoff hydrograph that provides an estimate of runoff volume. Peak flow rates are most often used for design of bridges, culverts, roadside ditches, and small storm sewer systems. Drainage systems involving detention storage, pumping stations and large or complex storm sewer systems require the development of a runoff hydrograph to estimate volume of runoff.

The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex, and too little data is available on the factors influencing the rainfall-runoff relationship to expect exact solutions. Any hydrologic analysis is only an approximation, though an error in the estimate of peak runoff effects the design. Under prediction of the peak runoff can result in a structure that is undersized and may contribute to flooding while over predicting the peak runoff may lead to an oversized drainage facility that costs more than necessary.


### Definition

Hydrology is a science dealing with the interrelationship and movement of various forms of water on and under the earth surface and in the atmosphere. For the purpose of this manual, hydrology will deal with estimating flood magnitudes as the result of precipitation. In the design of highway drainage structures, floods are measured in terms of peak runoff or hydrograph having a discharge in cubic feet per second (cfs). Structures designed to control volume of runoff, like detention storage facilities, or situations where flood routing is used, the entire discharge hydrograph will be of interest.

### Concept Definitions

The following terms will be important in a hydrologic analysis. These concepts will be used throughout the remainder of this chapter in dealing with different aspects of hydrologic studies.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antecedent Moisture Conditions</td>
<td>Antecedent moisture conditions are the soil moisture conditions of the watershed at the beginning of a storm. These conditions affect the volume of runoff generated by a particular storm event. Notably they affect the peak discharge only in the lower range of flood magnitudes. Antecedent moisture has a rapidly decreasing influence on runoff as the flood recurrence interval becomes longer.</td>
</tr>
<tr>
<td>Depression Storage</td>
<td>Depression storage is the natural depressions within a watershed which store runoff. Generally after the depression storage is filled runoff will commence.</td>
</tr>
<tr>
<td>Drainage Area (A)</td>
<td>The area draining into a stream at a given point along the stream.</td>
</tr>
<tr>
<td>Frequency</td>
<td>Frequency is the number of times a flood of a given magnitude or greater can be expected to occur on average over a long period of time. Frequency analysis is the</td>
</tr>
</tbody>
</table>
estimation of peak discharges for various recurrence intervals. Another way to express frequency is with probability. Probability analysis seeks to define the flood flow with a probability of being equaled or exceeded in any year.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic Roughness</td>
<td>Hydraulic roughness is a composite of the physical characteristics which influence the flow of water across the earth's surface, whether natural or channelized. It affects both the time response of a watershed and drainage channel as well as the channel storage characteristics.</td>
</tr>
<tr>
<td>Hydrograph</td>
<td>The hydrograph is a graph of the time distribution of runoff from a watershed.</td>
</tr>
<tr>
<td>Hydrologic Soil Group</td>
<td>A group of soils having the same runoff potential under similar storm and cover conditions.</td>
</tr>
<tr>
<td>Hyetographs</td>
<td>The hyetograph is a graph of the time distribution of rainfall over a watershed.</td>
</tr>
<tr>
<td>Infiltration</td>
<td>Infiltration is a complex process of allowing runoff to penetrate the ground surface and flow through the upper soil surface. The infiltration curve is a graph of the time distribution at which this occurs.</td>
</tr>
<tr>
<td>Interception</td>
<td>Storage of rainfall on foliage and other intercepting surfaces during a rainfall event is called interception storage.</td>
</tr>
<tr>
<td>Lag Time</td>
<td>The lag time is defined as the time from the centroid of the excess rainfall to the peak of the hydrograph.</td>
</tr>
<tr>
<td>Peak Discharge</td>
<td>The peak discharge, sometimes called peak flow, is the maximum rate of flow of water passing a given point during or after a rainfall event or snowmelt.</td>
</tr>
<tr>
<td>Rainfall Excess</td>
<td>The rainfall excess is the water available to runoff after interception, depression storage and infiltration have been satisfied.</td>
</tr>
<tr>
<td>Rainfall Intensity (I)</td>
<td>Amount of rainfall occurring in a unit of time, converted to its equivalent in inches per hour.</td>
</tr>
<tr>
<td>Recurrence Interval</td>
<td>The average number of years between occurrences of a discharge or rainfall that equals or exceeds the given magnitude.</td>
</tr>
<tr>
<td>Runoff (Q)</td>
<td>The part of the precipitation which runs off the surface of a drainage area after all abstractions are accounted for.</td>
</tr>
<tr>
<td>Runoff Coefficient</td>
<td>A factor representing the portion of runoff resulting from a unit rainfall. Principally dependent on terrain, topography, slope, land use and soil type.</td>
</tr>
<tr>
<td>Time of Concentration</td>
<td>The time of concentration is the time it takes a drop of water falling on the hydraulically most remote point in the watershed to travel through the watershed to the point under investigation.</td>
</tr>
<tr>
<td>Ungaged Stream Sites</td>
<td>Locations at which no systematic records are available regarding actual stream flows.</td>
</tr>
<tr>
<td>Unit</td>
<td>A unit hydrograph is the direct runoff hydrograph resulting from a rainfall event which</td>
</tr>
</tbody>
</table>
Hydrograph has a specific temporal and spatial distribution and which lasts for a unit duration of time. The ordinates of the unit hydrograph are such that the volume of direct runoff represented by the area under the hydrograph is equal to one inch of runoff from the drainage area.

Factors Affecting Flood Runoff
In the hydrologic analysis for a drainage structure, there are many variable factors that affect floods. Some of the factors which need to be recognized and considered on an individual site by site basis are such things as:

· Drainage basin characteristics
  – drainage area size,
  – drainage area shape,
  – drainage area orientation,
  – slope of terrain,
  – land use; consider watershed development potential,
  – geology,
  – soil type,
  – surface infiltration,
  – storage,
  – antecedent moisture condition, and
  – storage potential: overbank, ponds, wetlands, reservoirs, channel, etc.

· Stream channel characteristics
  – channel slope,
  – channel geometry,
  – channel configuration,
  – natural and artificial controls,
  – channel modification,
  – aggradation/degradation, and
  – ice and debris.

· Flood plain characteristics
  – type of soil, and
  – ground cover.

· Meteorological characteristics
  – precipitation amount,
  – time rate of precipitation, hyetograph,
  – storm cell size,
  – storm cell distribution,
  – storm direction, and
  – type of precipitation: rain, snow, hail, or combinations thereof.

Sources of Information
The type and source of information available for hydrologic analysis will vary from site to site. It is the responsibility of the designer to determine what information is available and applicable to a particular analysis.

All hydrologic analysis shall consider the flood history of the area and the effect of these historical floods on existing and proposed structures. The flood history shall include the historical floods and the
flood history of any existing structures. Files should be reviewed for documentation of relevant communications, studies and investigations. Surveys should be conducted to provide enough field data for analysis. Typical data that is obtained in such surveys or studies are: topographic maps, aerial photographs, streamflow records, historical highwater elevations, flood discharges, and locations of hydraulic features such as reservoirs, water projects, and designated or regulatory flood plain areas.

Interagency coordination is necessary since many levels of government plan, design, and construct highway and water resource projects which might have an affect on each other. Agencies can share data and experiences within project areas to assist in the completion of accurate hydrologic analysis. Agencies include: Department of Natural Resources (DNR), U. S. Fish and Wildlife Service, U. S. Army Corps of Engineers (USACE), Watershed District & Management Organizations, Counties, Cities, Pollution Control Agency (PCA), Natural Resources Conservation Service (NRCS) previously Soil Conservation Service (SCS) and U. S. Geologic Survey (USGS).

HYDROLOGIC PROCEDURE SELECTION

Streamflow measurements are usually unavailable for determining flood frequency relationships at a site. In such cases, it is accepted practice to estimate peak runoff rates and hydrographs using statistical or empirical methods. The design discharge for other structures on the stream and historical data should be reviewed, and consideration given to previous studies and Flood Insurance Studies. Mn/DOT's practice shall be to use the discharge that best reflects local project conditions with the reasons documented.

Peak Flow Rates or Hydrographs
Determination of peak runoff rates for design conditions is generally adequate for conveyance systems such as storm drains or open channels. However, if the design includes storage basins or complex conveyance networks, a flood hydrograph is usually required. The development of runoff hydrographs is usually accomplished using computer programs.

Hydrologic Procedures Options
The recommended hierarchy for selecting a method of computing discharge for design of highway structures in Minnesota and the circumstances for their use are listed below and shown in Table 3.3. Where feasible, the hydrologic model should be calibrated to local conditions and tested for accuracy and reliability. Consider design discharges for other structures in the area and historical data for the area. In general the results from different hydrologic models should not be averaged.

- Minnesota USGS regression equations should be used for routine designs of bridges and culverts with 54" or larger widths and in accordance with the other limitations of the regression equations, unless there is gaging station data or historical evidence suggesting other alternatives.
- Log Pearson III analyses of stream gaging station data should be used for all routine designs with gaging station data, provided there is at least 10 years of continuous record for 10-year discharge estimates and 25 years for 100-year discharge estimates.
- Rational method shall be used only for drainage areas less than 200 acres, and preferably only for developed areas.
- The SCS unit hydrograph method contained in TR-20 should be used for storage routing or storage design.
- Both the graphical peak discharge and tabular hydrograph method available in TR-55 are simplified procedures are derived from TR-20.
• The TR-55 graphical method may be used for small rural watersheds (1 - 2000 acres).
• TR-55's tabular hydrograph method can be applied to larger watershed areas by splitting a non-homogenous watershed into homogenous subareas.
• Suitable computer programs such as HEC HMS, TR-20, TR-55, and HYDRAIN may be used for hydrologic calculations. Other computer programs that incorporate the recommended methodology may also be used. Output from all programs must be reviewed to see that the answers are reasonable.
• The 100-year discharges specified in the FEMA flood insurance study shall be used to analyze impacts of a proposed crossing on a regulatory floodway. However, if these discharges are deemed to be outdated, discharges based on current methods may be used subject to receipt of necessary regulatory approvals.

Rainfall vs. Flood Frequency
Drainage structures are designed for a designated flood frequency. However, certain hydrologic procedures use rainfall and rainfall frequency as the basic input. Thus it is commonly assumed in most cases that the 10-year rainfall will produce the 10-year flood. In general, rainfall is used to design storm drains and culverts with small drainage areas. The rational method and SCS methods use the assumption that a rainfall of a certain frequency will produce a flood of the same frequency.

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USGS REGRESSION EQUATIONS

Regional regression equations are a commonly accepted method for estimating peak flows at ungaged sites or sites with insufficient data. Regression studies are statistical practices used to develop runoff equations. These equations are used to relate peak flow at a specified recurrence interval to the watershed's physiographic, hydrologic and meteorological characteristics. The U.S. Geological Survey (USGS) developed the regression equations for Minnesota and published them in *Techniques for Estimating Magnitude and Frequency of Floods in Minnesota* (Guetzkow, 1977). Since then regression analysis was redone and new equations developed and published twice. Once with the same title *Techniques for Estimating the Magnitude and Frequency of Floods in Minnesota* (Jacques and Lorenz, 1988) developed in 1987 and published in 1988, and also as *Techniques for Estimating Peak Flow on Small Streams in Minnesota* (Lorenz, Carlson and Sanocki, 1997).

Regression analyses use stream gage data to define hydrologic regions. These are geographic regions having very similar flood frequency relationships and, as such, commonly display similar characteristics. Separate regression analysis were performed and equations developed at 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals for each hydrologically similar region. The most significant characteristic of the equations is the drainage area size above the point of interest. Additional basin characteristics such as main channel slope, lake storage, total storage and mean annual runoff are included as independent variables when they were determined to be statistically significant.

**Application**
The USGS Regression Equations may be used to design culverts and bridges in Minnesota. The USGS Regression Equations, obtained from multiple-regression analyses of gaging-station data in each hydrologic region, can be used to obtain flood-frequency estimates for ungaged sites on unregulated streams. Peak discharges for selected recurrence intervals can be computed from the empirical equations that relate flood magnitude to basin characteristics. Historical observations and other methods, should be used to evaluate the results. Where there is stream gage data, the findings from a Log Pearson III method should govern, provided there is at least 10 years of stream gage record. Reasonable and prudent judgment along with consideration of the standard regression error shall be used in reaching a design decision. Typical regression equation format:

\[
Qi = \alpha A^b S^c (St + 1)^d
\]

Where: 
- \(Qi\) = flood frequency estimate for recurrence interval \(i\)
- \(A\) = drainage area in square miles
- \(S\) = main channel slope in feet per mile
- \(St\) = percent of drainage area occupied by lakes, ponds or wetlands
- \(a, b, c, d\) = variables

The regression equations, hydrologic region boundaries, variable definitions, procedures for use and discussion on accuracy and limitations are provided in the USGS reports.

**Limitations**
The basin characteristics of the stream being analyzed should be within the limits of those used to develop the equations. Each USGS report has a table showing the upper and lower limits for basins characteristics used in the regression analysis; care should be exercised using equation outside of the specified limits. The regression equations are intended to be used on streams which are not significantly
affected by manmade regulation, urbanization, or diversion. The equations should not be used immediately downstream of a lake or ponding area, but may be used to determine the peak inflow to be routed through an impoundment.

Procedure
There are three sets of equations that can be applied to a particular site. These include the 1997 regression equations developed by Lorenz, Carlson and Sanocki; 1987 regression equations developed by Jacques and Lorenz; and the 1977 regression equations developed by Guetzkow. Although the later equations were intended to supersede earlier equations, it is advisable to compute the discharge using multiple methods, and compare to other historical data or methods. The 1987 procedure divides the state into 4 hydrologic regions, where the 1977 procedure used 8 different hydrologic regions in the state and the 1997 procedures use 6 regions. Although the later reports used gaging stations with longer periods of records and more stations, it is valid to use the earlier 1977 and 1987 equations as a check. Problems related to hydrologic boundaries may occur in selecting the appropriate regression equation. Because of the distance between stream gages, the regional boundaries cannot be considered as precise. The watershed of interest may lie partly within two or more hydrologic regions or it may lie totally within a hydrologic region, but close to a hydrologic region boundary. In these instances care must be exercised in using regression equations. A field visit is recommended to first collect all available historical flood data as well as to compare the project's watershed characteristics with those of the abutting hydrologic regions. For drainage areas near regional divides, the equations for both regions should be evaluated and the results compared. The coefficients in the equations can also be used to transfer flood flows from a gaged site to an ungaged site on the same stream. The regional boundaries generally follow watershed basin divides.

ANALYSIS OF STREAM GAGE DATA
Many gaging stations exist throughout Minnesota where data can be obtained and used for hydrologic studies. If a project is located near one of these gages and the gaging record is of sufficient length of time, a frequency analysis may be made. The most important aspect of applicable station records is the series of annual peak discharges. It is possible to apply a frequency analysis to that data for the derivation of flood-frequency curves. Such curves can then be used in several different ways.

- If the subject site is at or very near the gaging site and on the same stream and watershed, the discharge for a specific frequency from the flood-frequency curve can be used directly.
- If the facility site is nearby or representative of a watershed with similar hydrologic characteristics, transposition of frequency discharges is possible.
- If the flood-frequency curve is from one of a group of several gaging stations comprising a hydrologic region, then regional regression relations may be derived. Regional regression relations are usually furnished by established hydrologic agencies and the designer will not be involved in their development.

Application
Mn/DOT may use a frequency analysis of stream gage data at appropriate locations when there is sufficient years of measured stream gage record. The preferred method of estimating flood frequency curves from stream gage data is a statistical method, which makes use of the Log Pearson Type III frequency distribution.

The analysis of gaged data permits an estimate of the peak discharge for the desired return period at a particular site. Experience has shown that statistical frequency distributions may be more representative
of naturally occurring floods and can be reliable when used for prediction. Although several different distributions are used for frequency analysis, experience has shown the Log-Person Type III distribution to be one of the most useful. The Log-Pearson III distribution and the process of fitting it to a particular data sample are described in detail in Water Resources Council Bulletin 17B, *Guidelines for Determining Flood Flow Frequency*, (WRC, 1981). Special handling of outliers, historical data, incomplete data, and zero flow years is covered in detail in Bulletin 17B.

There are two alternative methods for determining the value of the skew coefficient to be used in calculating the Log-Pearson Type III curve fit. The value of skew that is calculated directly from the gage data using the above formula is called the station skew. This value may not be a true representation of the actual skew of the data if the period of record is short or if there are extreme events in the period of record. Often, the station skew and the generalized skew can be combined to provide a better estimate for a given sample of flood data.

**Transferring Gaged Data**

Gaged data may be transferred to an ungaged site on the same river as the gaged site provided such data are nearby, within the same hydrologic region, and there are no major tributaries or diversions between the gage and the site of interest. These procedures make use of the constants obtained in developing the regression equations. To transfer discharge data from a gaged site to an ungaged site on the same stream:

\[
Q_u = Q_g \left(\frac{A_u}{A_g}\right)^B
\]

Where:
- \(Q_u\) = flood frequency estimate to ungaged site
- \(Q_g\) = flood frequency estimate for gaged site
- \(A_u\) = drainage area for ungaged site
- \(A_g\) = drainage area for gaged site
- \(B\) = exponent for drainage area from the appropriate regression equation

This transfer relation can be used where drainage area size differs by no more than 50%. If other basin characteristics differ significantly, they should also be included by taking the ratio of the parameters raised to the power given in the regression equation. If the period of record at the gaged site is short, a weighted average of the results of the transfer equation and regression equation should be used.

The transposition of design discharges from one basin to another basin with similar hydrologic characteristics is accomplished by multiplying the design discharge by the direct ratio of the respective drainage areas raised to the drainage area exponent given in the appropriate regression equation. Thus on streams where no gaging station is in existence, records of gaging stations in nearby hydrologically similar watersheds may be used. The discharge for such an ungaged stream may be determined by the transposition of records using a similar procedure. This procedure is repeated for each available nearby watershed and the results are averaged to obtain a value for the desired flood frequency relationships in the ungaged watershed.