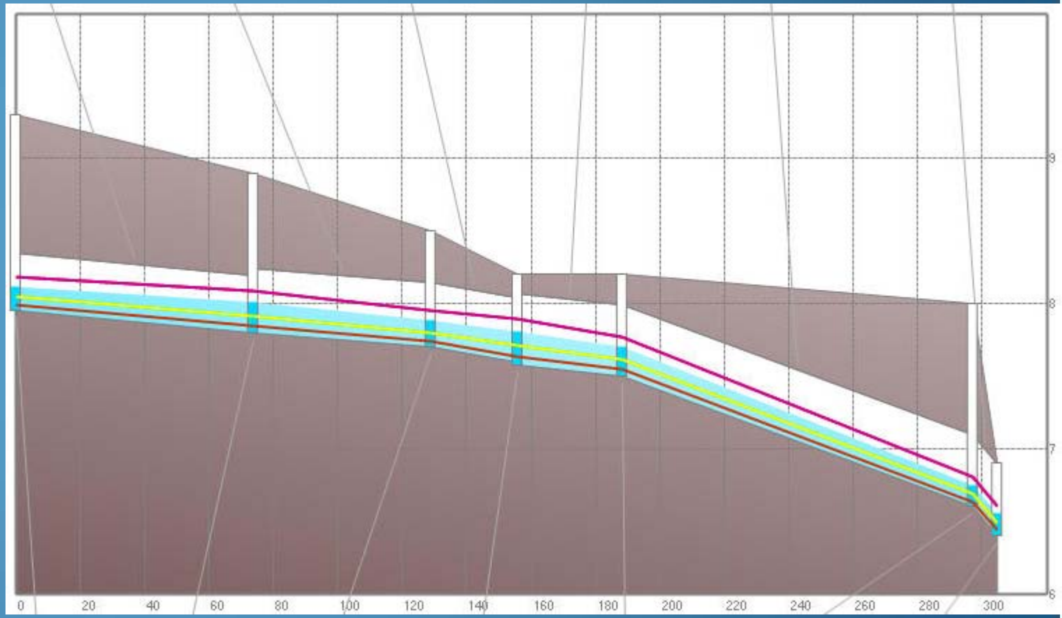
Urban Hydraulic Design

Presented By Audra Poehls

What will we cover?

- Hydraulic Design Basics
- Hydrologic Analysis
- Hydraulic Analysis
- Gutterflow
- Hydraulic Grade Line



HYDRAULIC DESIGN BASICS

Hydraulic Design Standards

- Complete a Hydraulic Review/Report
- What can be used for Hydraulic Design
  - NDDOT Design Manual Section V
  - Code of Federal Regulations
  - U.S. DOT Federal Highway Administration Hydraulic Engineering Circular No. 22 Urban Drainage Design manual
- Classify the Highway to determine the design flood frequencey
- Analyze the Water Surface Profile

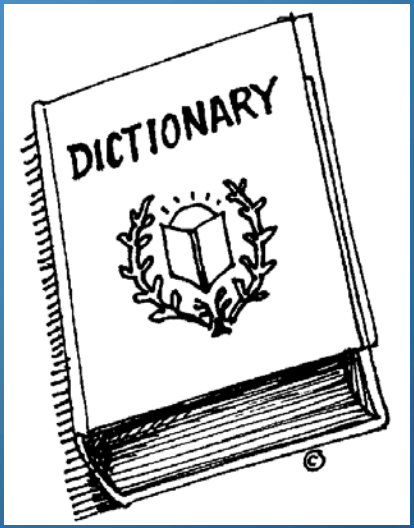
Why do we design storm drainage systems?

- "The objective of highway storm drainage design is to provide for safe passage of vehicles during the design storm event. The drainage system is designed to collect stormwater runoff from the roadway surface and right-of-way, and discharge it to an adequate receiving body without causing adverse on- or off-site impacts."

  -HEC 22

What is Hydrology

- According to Dictionary.com Hydrology is the science dealing with the occurrence, circulation, distribution, and properties of the waters of the earth and it's atmosphere
- Hydrology in the NDDOT's application is better defined as estimating flood magnitudes as the result of precipitation

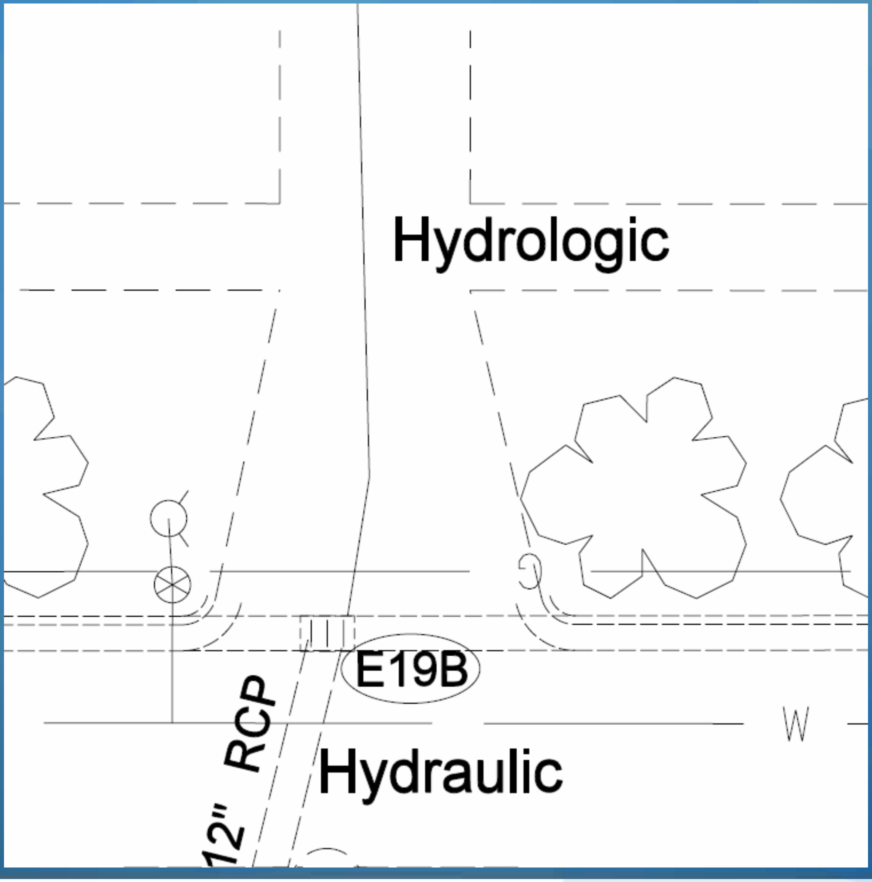


What does Hydrologic mean?

- According to FHWA's HEC 22 Urban Drainage Design Manual Hydrologic is defined as:
  - Losses of rainfall that do not contribute to direct runoff. These losses abstraction include water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration.

Hydrologic Vs. Hydraulic

- Hydrologic deals with rainfall while Hydraulic deals with flow of water in pipes



HYDROLOGIC ANALYSIS

Hydrologic Analysis

- Analysis Considerations
- Approved Methods
- Rational Method
  - Step 1
  - Step 2

Hydrologic Analysis

- Analysis Considerations
  - Drainage Basin Characteristics
    - Size
    - Slope
    - Land use
    - Soil Type
    - Surface Infiltration/cover
    - Storage

Hydrologic Analysis

- Analysis Considerations
  - Storage potential
    - Overbank
    - Reservoirs
    - Channels
    - Ditches
    - Etc.

Hydrologic Analysis

- Analysis Considerations
  - Type of Precipitation
    - Rain
    - Snow
    - Hail
    - Combination of the above

Hydrologic Analysis

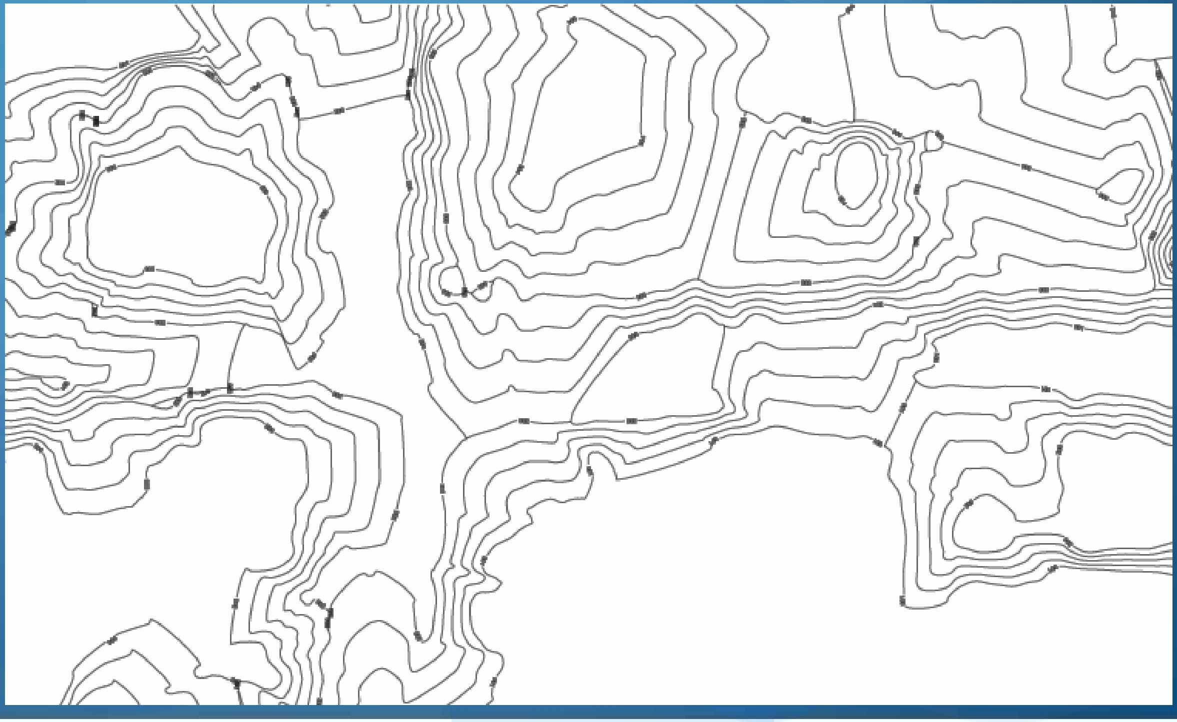
- Analysis considerations
  - Flood plain characteristics
  - Rainfall amount and storm distribution
  - Ground cover
  - Type of soil
  - Prior moisture condition
  - Watershed development
  - Terrain

Hydrologic Analysis

- There are many different approved methods
  - For urban drainage areas the method most generally used by NDDOT is the Rational Method
    - More detail to come
  - Other accepted methods for Hydrologic design
    - FHWA method
    - "Hydrology Manual for North Dakota" published by the Natural Resources Conservation Service
    - Suitable hydrograph methods may be used for routing calculations to decrease peak flows, after the peak flow has been determined

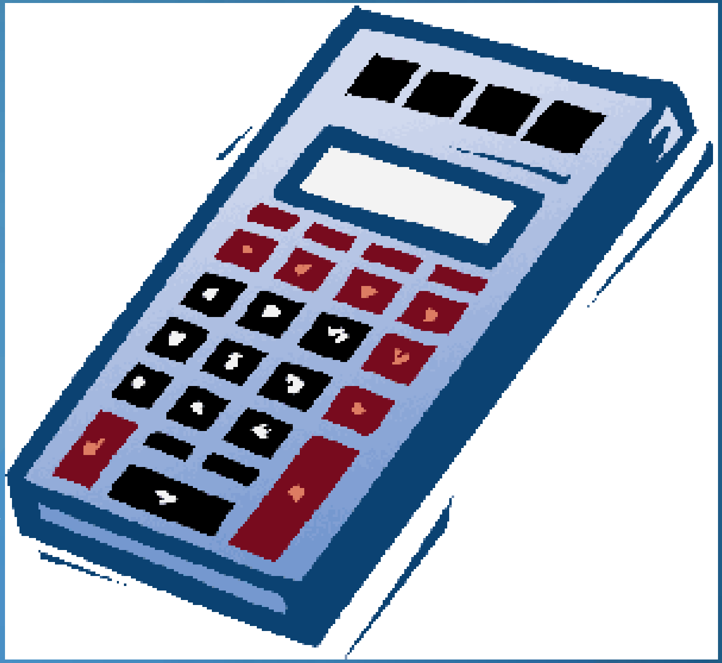
Rational Method

- Step 1 – Determine Contributing Drainage Area
  - Look at contour maps
  - Consider structures and manmade changes
  - Use your common sense and best engineering judgment



Rational Method

- Step 2 – Compute Runoff
  - Urban Design uses the rational method
    - Q=CIA
      - Q = maximum design rate of runoff, cfs
      - C = runoff coefficient representing a ratio of runoff to rainfall
        - See Design Manual Appendix V-03 A
      - I = Average rainfall intensity for a duration equal to the time of concentrations for a selected return period, in/he
        - See Design Manual Appendix V-03 C
      - A = drainage area tributary to the design location, acres



Appendix V-03A Rational Method - Runoff Coefficients

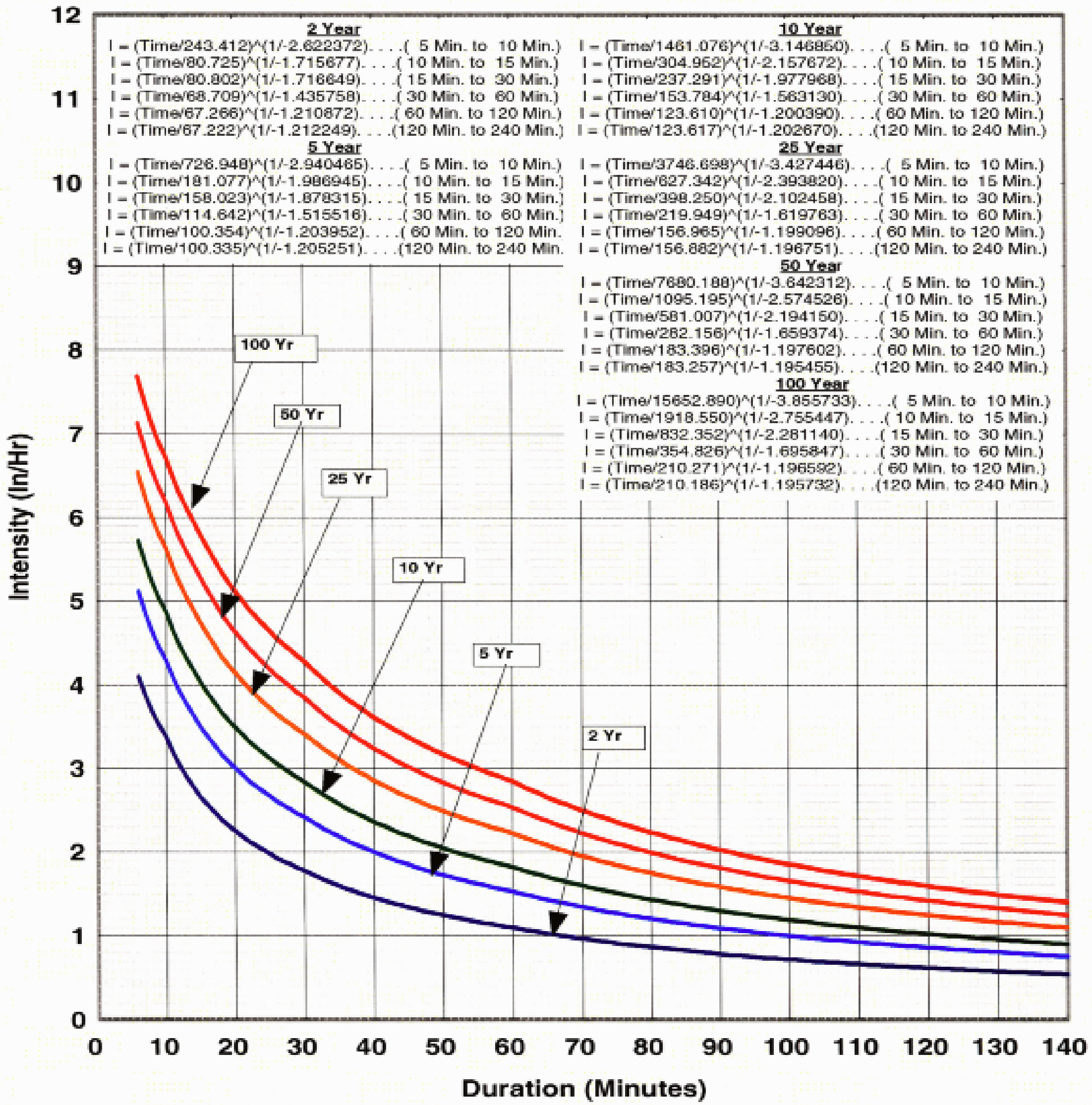
Description of Area	Runoff Coefficients
Business:	
Downtown Areas	0.70 to 0.95
Neighborhood Areas	0.50 to 0.70
Residential:	
Single-Family Areas	0.30 to 0.50
Multi-Units, Detached	0.40 to 0.50
Multi-Units, Attached	0.60 to 0.70
Residential (Suburban)	0.25 to 0.40
Apartment Dwelling Areas	0.50 to 0.70
Industrial:	
Light Areas	0.50 to 0.80
Heavy Areas	0.60 to 0.90
Unimproved Storage Areas	0.20 to 0.50
Parks, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad Yard Areas	0.20 to 0.35
Unimproved Areas	0.10 to 0.30
Streets:	
Concrete	0.80 to 0.95
Asphalt	0.70 to 0.95
Drives and Walks	0.75 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil:	
Flat, 2%	0.05 to 0.10
Average, 2-7%	0.10 to 0.15
Steep, >7%	0.15 to 0.25
Lawns, Heavy Soil:	
Flat, 2%	0.10 to 0.20
Average, 2-7%	0.15 to 0.25
Steep, >7%	0.25 to 0.35

Appendix V-03 A

Bismarck

Rainfall Intensity-Duration-Frequency

Latitude 46º 48' N Longitude 100º 46' W



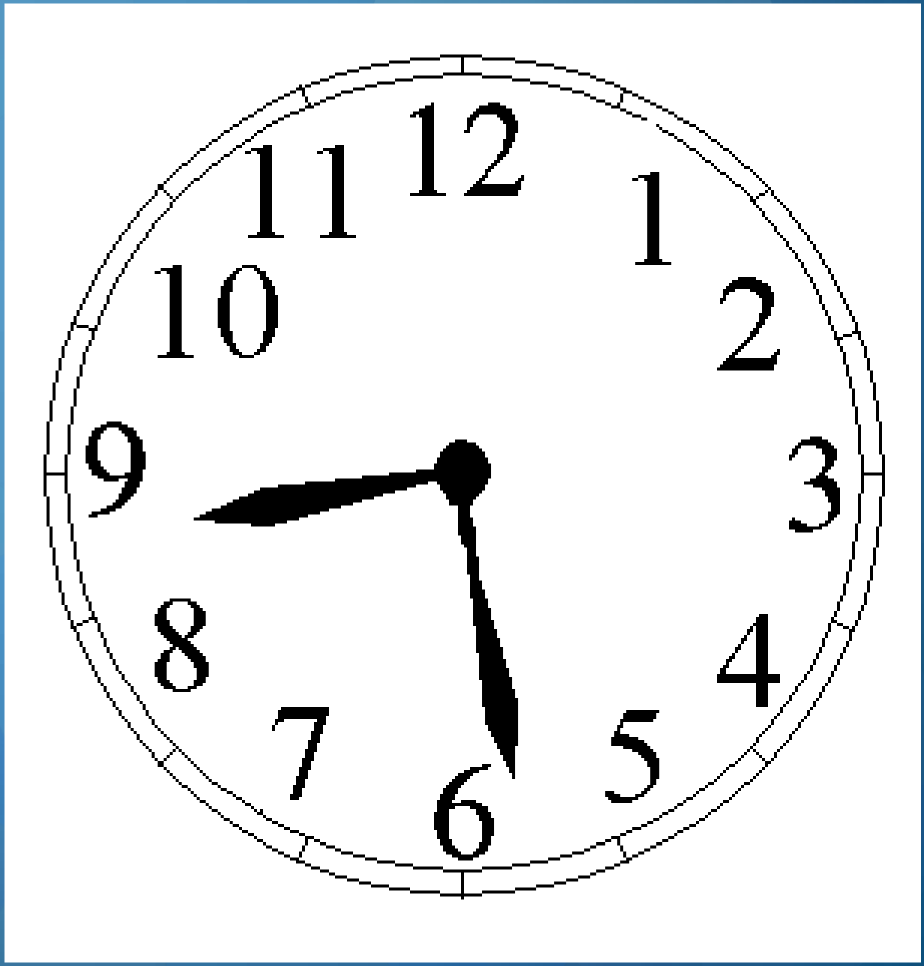
Source: HYDRAIN - Version 6.1 - March 1999
Integrated Drainage Design - Computer System
Data Base Source:
(1) National Weather Service (NWS) technical memorandum HYDRO-35
(2) National Oceanic and Atmospheric Administration (NOAA) Atlas 2 doc.

Rational Method

- Step 2- Compute Runoff (continued)
  - Rational method
    - The rational method is used to estimate peak discharges
      - Must use good engineering judgment

Rational Method

- Step 2 – Compute Runoff (continued)
  - Time of Concentration
    - Flow Type
      - Overland
      - Shallow Concentrated
    - Land Cover
      - Paved (OL)
      - Dense Grass (OL)
      - Short Grass (OL)
      - Grassed (SC)
      - Unpaved (SC)
      - Paved (SC)



Rational Method

- Step 2 – Compute Runoff (continued)
  - Time of Concentration
    - n or k
      - n- Manning's Roughness Coefficient for Overland Sheet Flow
        - Table 3-2 HEC 22
      - k – Intercept Coefficients for Velocity vs. Slope Relationship

Table 3-2. Manning's Roughness Coefficient (n) for Overland Sheet Flow.[6]

Surface Description	n
Smooth asphalt	0.011
Smooth concrete	0.012
Ordinary concrete lining	0.013
Good wood	0.014
Brick with cement mortar	0.014
Vitrified clay	0.015
Cast iron	0.015
Corrugated metal pipe	0.024
Cement rubble surface	0.024
Fallow (no residue)	0.05
Cultivated soils	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Range (natural)	0.13
Grass	
Short grass prairie	0.15
Dense grasses	0.24
Bermuda grass	0.41
Woods*	
Light underbrush	0.40
Dense underbrush	0.80

*When selecting n, consider cover to a height of about 30 mm. This is only part of the plant cover that will obstruct sheet flow.

Rational Method

- Step 2 – Compute Runoff (continued)
  - Time of concentration
    - I – The rainfall intensity determined from NDDOT graphs in Appendix V-03 C pages 1 through 15.
      - The graphs are for 15 major cities in North Dakota

Rational Method

- Step 2 – Compute Runoff (continued)
  - Time of concentration
    - After imputing other basic information with the assistance of Microsoft Excel you can do some iteration to determine the time of concentration

HYDRAULIC METHOD

Hydraulic Methods

- Using Time of Concentration and the rest of the information equated through the rational method and begin to compute the flow of water in the inlet and pipes.
- This portion is determined by examining the elevations of inlets, the slopes and parts full for each pipe section as well as the pipe sizing to determine the most efficient and cost effective design options

GUTTER FLOW

Gutter Flow

- Gutter Flow is unique in the fact that you must use hydrologic as well as hydraulic methods of analyzing
- Spread on Pavement
- Gutter Velocity/Slope

Gutter Flow

- Interception
  - If an inlet is on grade you must determine how much of the flow it will intercept
  - Another analysis that you might need to do is determine how much of the flow you want to intercept at the specific inlet and then depending on your surrounding constraints adjust your inlet to meet the desired intercept

Gutter Flow

- Flow into the inlet
  - The easiest way to determine how water will flow, at what rate, and how much is by using the hydrologic methods that were previously discussed specifically the rational method

Gutter Flow

- Spread on the pavement
  - What is Spread?
    - A measure of the transverse lateral distance from the curb face to the limit of the water flowing on the roadway
  - Drain inlets are sized and located to limit the spread of surface water onto travel lanes

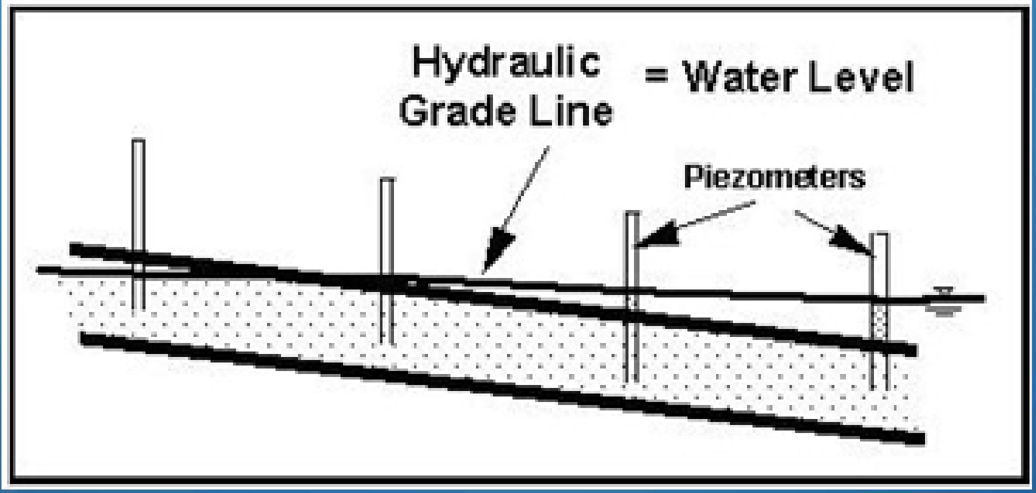
Gutter Flow

- Gutter Velocity/Slope
  - Gutter Velocity is directly related to determining the flow time in a gutter which is essential to urban drainage design.
  - To determine gutter flow and velocity Mannings equations is used.

HYDRAULIC GRADE LINE

Hydraulic Grade Line

- Up to this point of Hydraulic Design you have analyzed the movement of the water before and once it gets to the pipe.
- Now the level of the water within the pipe itself must be analyzed.



Hydraulic Grade Line

- What is Hydraulic Grade Line?
  - According to HEC 22 hydraulic Grade Line is:
    - A line coinciding with the level of flowing water at any point along an open channel.
    - For purposes of storm drain design Hydraulic Grade Line is used to determine the acceptability of a proposed storm drainage system by establishing the elevation to which water will rise when the system is operation under design conditions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