Urban Drainage System Analysis & Design

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Urban Drainage Systems

- Required for:
  - Flood Protection,
  - Surface Access,
  - Health & Sanitation (pest control),
  - Aesthetics

Urban Drainage Systems

- Types of Infrastructure
  - Open Channels,
  - Road Side Ditches,
  - Storm Sewer Systems,
  - Detention/Retention Facilities,
  - Pump Systems

Design Standards

- Typical Return Intervals for Capacity Analysis:
- Check Local Development Criteria in the area of the project

Type of Facility	Typical Design Storm Return Interval
Closed Conduit Storm Sewers	3-yr to 5-yr
Open Ditch Culverts (serving less than 100 ac)	5-yr
Open Ditch Culverts (serving 100 to 250 ac)	25-yr
Open Ditch Culverts (serving more than 250 ac)	50-yr
Major Ditches	100-yr
Bridges	100-yr
Detention Facilities	100-yr

Rational Method Analysis

- Rational Method:
  - Empirical Method
  - Applicable to sites < 200 ac
    - Intended to model overland response,
    - Basins > 200 ac likely to have significant channelization and hydrograph lag/attenuation,
    - Tends to overestimate peak flow for large basins, so use is restricted to smaller ones.
    - Practically, typical basin sizes are 0.1 to 10 ac.

Rational Method Analysis

$$Q = C*I*A$$

Where:

Q = Peak Flow Rate (cfs)

I = Design Storm Average Intensity (in/hr)

A = Basin Area (ac)

C = Rational Coefficient (ft3*hr/ac*in*sec)

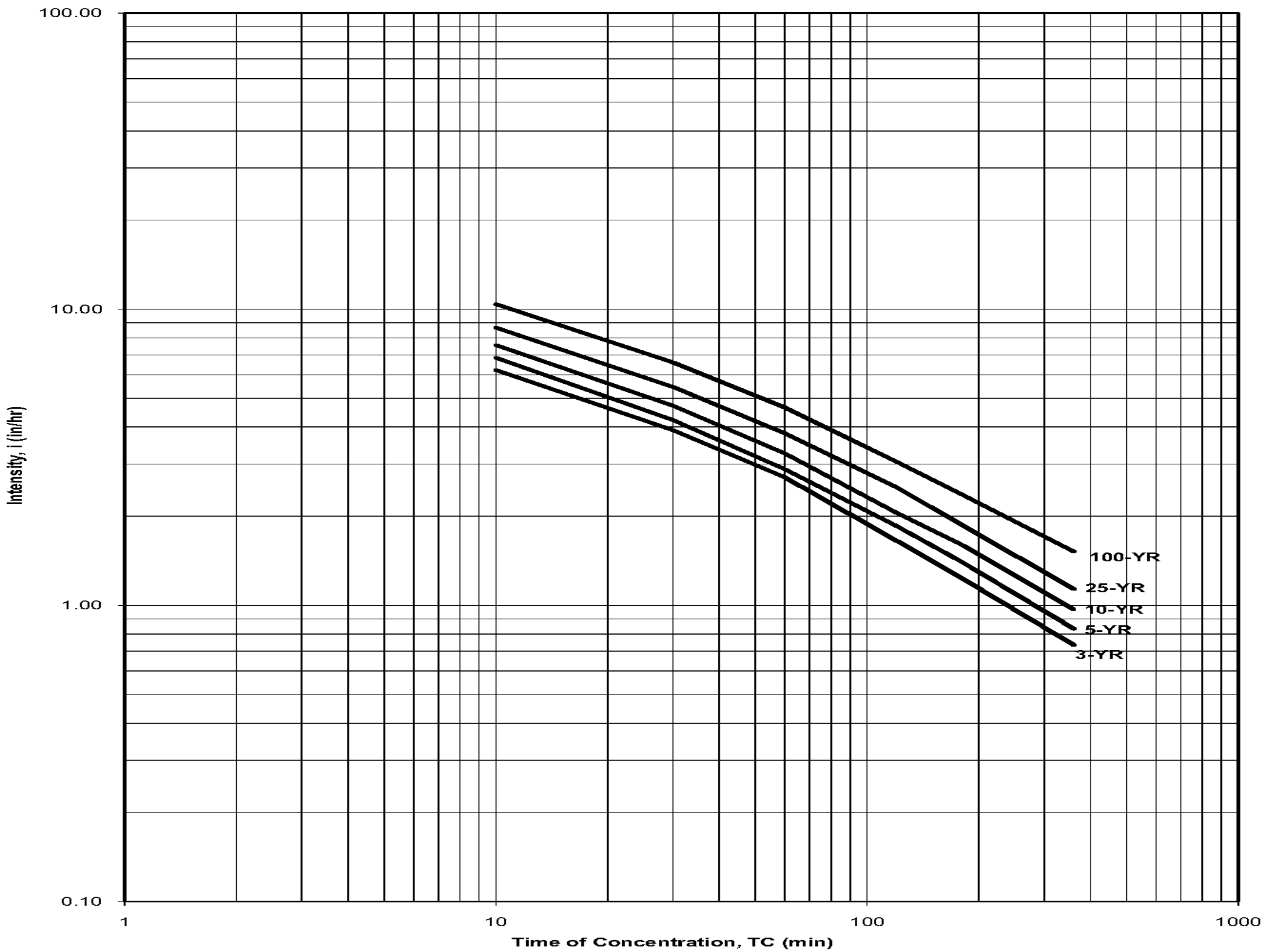
Design Storm Intensity

- Function of:
  - Regulatory Design Return Interval,
  - Basin Time of Concentration,
  - Geographic Location
- Regulators will likely specify required return interval based upon proposed facility being designed.

Design Intensity Tables

- Should be provided by the local regulator in the area of your project,
- Following example tables are from Galveston County (Texas Gulf Coast).

Figure 2-3: Brazoria Drainage District No. 4 Proposed IDF Curve
Rainfall Intensity Vs. Time of Concentration



Source: Brazoria County Drainage District No. 4 Design Manual

Design Intensity Tables

3-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	5.87
30 min	4.15
45 min	3.27
1 hour	2.72
3 hours	1.26
6 hours	0.75
12 hours	0.44
24 hours	0.26

100-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	9.83
30 min	6.93
45 min	5.51
1 hour	4.63
3 hours	2.29
6 hours	1.44
12 hours	0.90
24 hours	0.56

Source: Galveston County Drainage District No. 1 Design Manual

Design Intensity Equations

$$I = b/(Tc + d)^{e}$$

Where:

I = design storm average intensity (in/hr)

Tc = basin time of concentration (min)

b, d, & e are location and return interval specific

Design Intensity Equations

Storm Return Interval	b	d	e
3-year	77	11.9	0.782
5-year	66	7.6	0.739
25-year	85	7.6	0.727
50-year	88	7.6	0.704
100-year	85	7.8	0.690

Source: TxDOT Hydraulic Design Manual, values specific for Galveston County

Geographic Location

- Design storm intensities will vary from geographic location to location,
- Example, Houston's rainfall patterns are different than Denver's.
- Intensity Information can be provided as Intensity-Duration-Frequency (IDF) curves, Intensity Tables, or Intensity Equations.

Time of Concentration

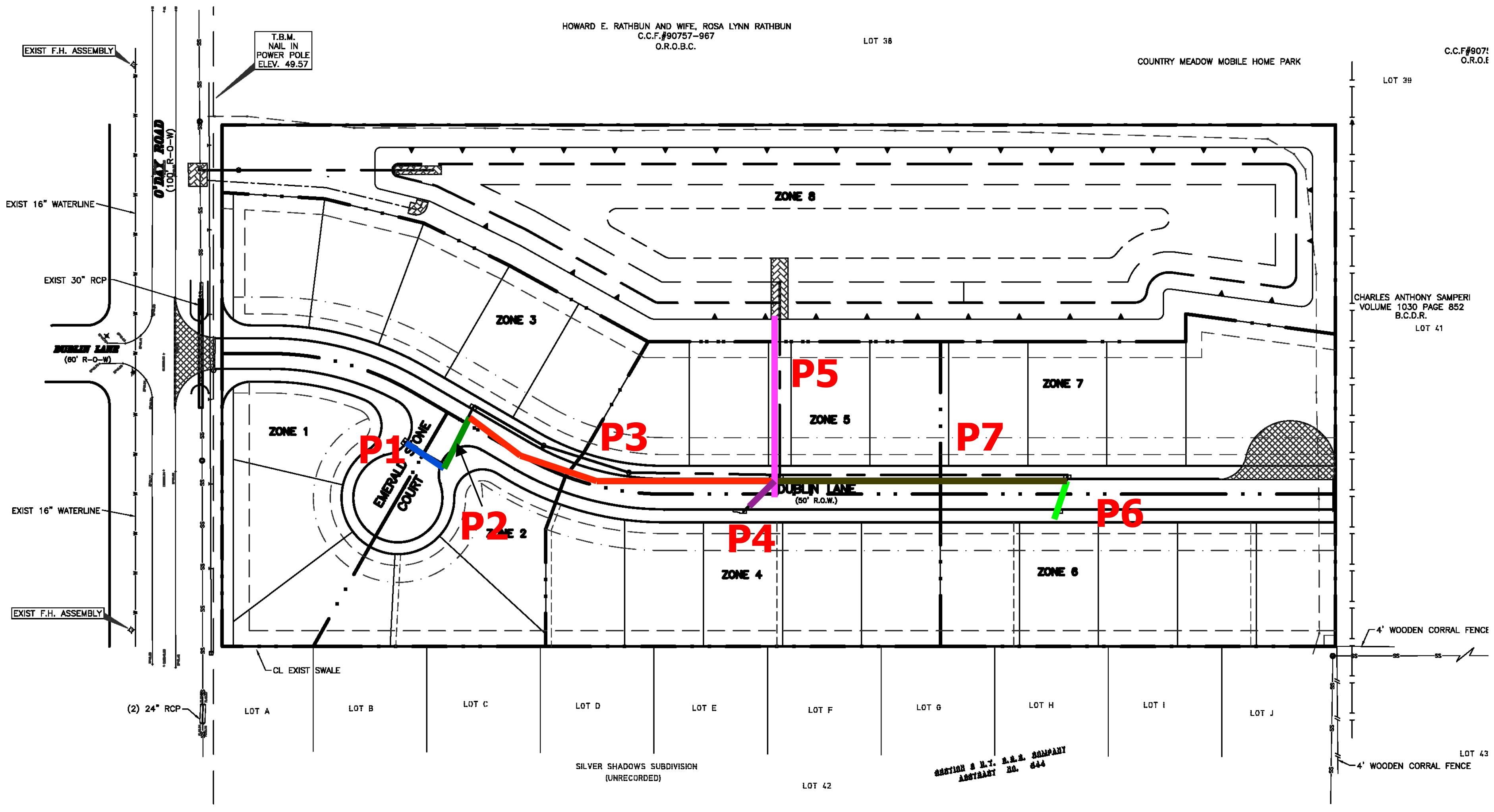
- Defined as the time it takes a drop of water to travel from the most hydraulically remote part of the basin to the outfall.
- Can be estimated directly (overland method),
- Can be estimated indirectly (empirical method).

Time of Concentration Estimate

- Overland Flow Method:
  - Determine path to most remote location of the basin,
  - Divide the path into segments based on flow characteristics,
  - $Tc = \sum d_i/v_i + 10$,
  - Units are minutes (you must convert velocities)

Flow Characteristic	Representative Velocity
Shallow overland flow in undefined channels (i.e., flow across lawn)	0.25 to 0.50 fps
Flow in street gutter or road ditches	0.75 to 1.25 fps
Flow in shallow ditches	1.5 to 3.0 fps
Flow in larger channels	2.0 to 4.0 fps
Flow in closed conduit sewers	3.0 to 5.0 fps

Overland Tc Example



Time of Concentration Estimate

- Empirical Method:
  - Quicker method allowed in some jurisdictions,
  - Reasonable results for Texas Gulf Coast area, need to confirm applicability to other locations & soil types

$$Tc = 10*A^{0.1761} + 15$$

Where:

Tc = Time of Concentration (min),

A = Contributing Basin Area (ac)

Rational Coefficients

- Empirical Coefficient
- Function of:
  - Storm Return Interval
  - Land Use
  - Percent Surface Impermeability
  - Soil Type
  - Drainage Infrastructure

Rational Coefficients

- What does it mean?
  - The Rational Coefficient is a rating of the basin's capability to shed runoff.
  - Value ranges from 0.20 to 1.0.
  - It is proportional to percent imperviousness, but not equal to it.
  - The larger the coefficient, the quicker it drains

Rational Coefficients

Land Use or Land Cover	Rational Coefficient
Raw, undeveloped land	0.20
Improved undeveloped land (i.e., mowed, filled, graded, etc.)	0.30
Park Land	0.40
Residential - > 1 ac lots	0.40
Residential - 0.5 to 1 ac lots	0.45
Residential - less than 0.5 ac lots	0.55
Multi-family	0.75
Commercial/Industrial	0.90

Rational Coefficients

Can be approximated by:

$$C = 0.2 + 0.8*PI$$

Where:

C = Rational Coefficient

PI = Percent Imperviousness (as a decimal)