NCTCOG iSWM Workshop

Integrated Design Criteria

Rules of Thumb / Lessons Learned

April 27, 2018

Richardson, TX

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Environment & Development

URBAN ECOPLAN

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Welcome and Introductions

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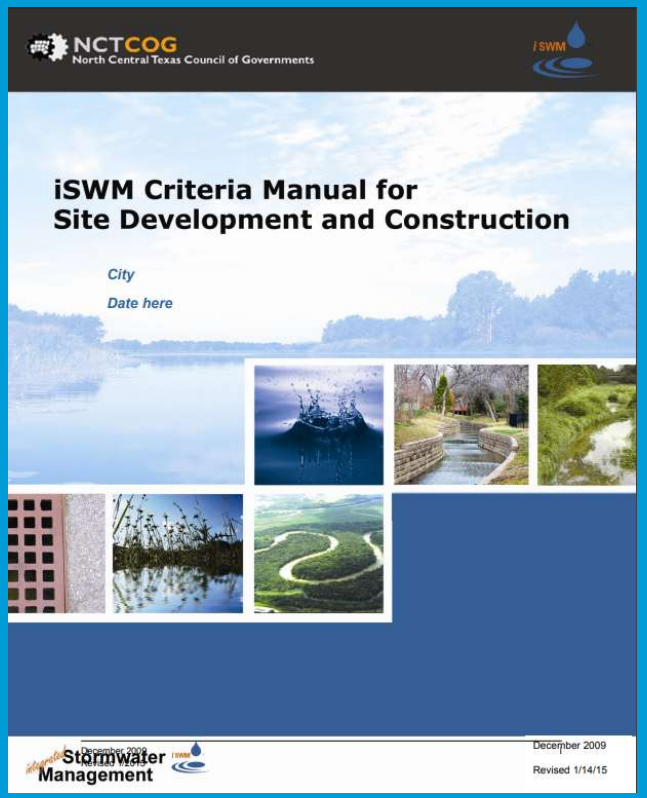
AGENDA

1. iSWM Overview and Resources
2. Hydrologic Methods
3. Water Quality protection
4. Acceptable downstream conditions
5. Streambank protection
6. Flood mitigation
7. Stormwater conveyance systems
8. Easements, plat, and maintenance agreements
9. Stormwater control selection / detention
10. Integrated construction criteria

EACH SECTION WILL REFERENCE TO THE ISWM CRITERIA MANUAL LOCATED HERE:

HTTP://ISWM.NCTCOG.ORG/DOCUMENTS/ISWM_CRITERIA_MANUAL_01142015.PDF



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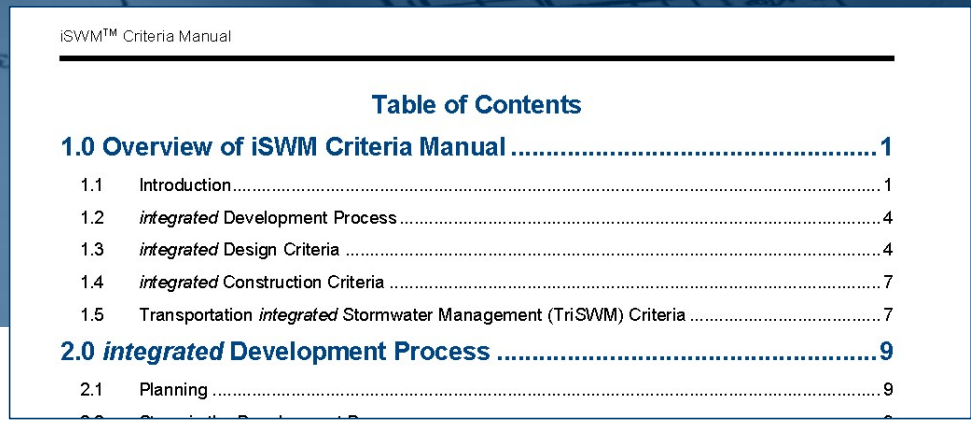
integrated Stormwater Management Program Overview & Resources



iSWM™ Criteria Manual

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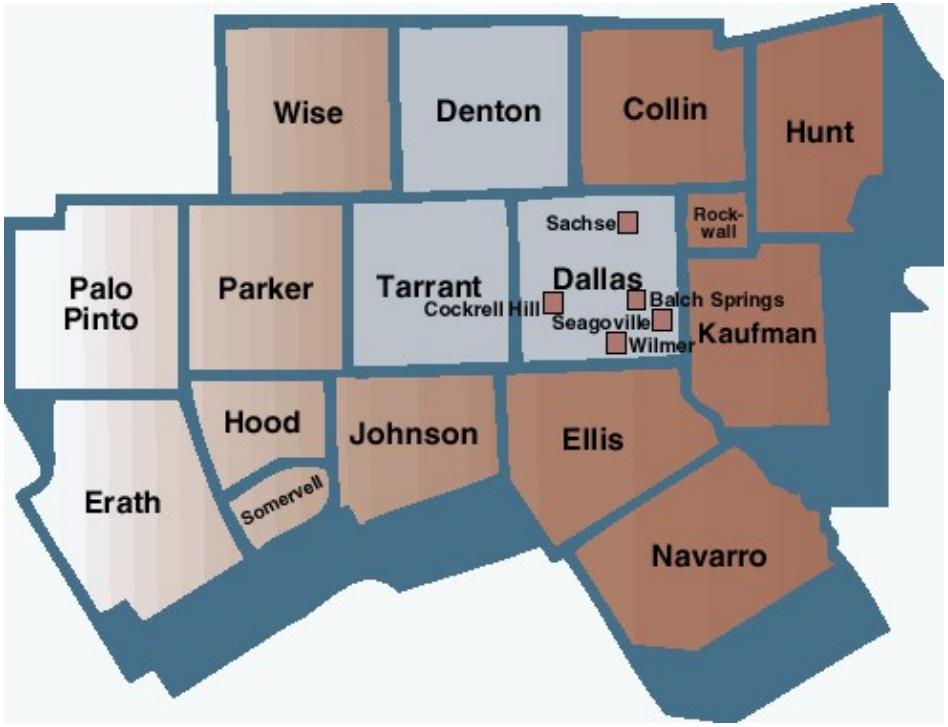
WHAT IS THE iNTEGRATED STORMWATER MANAGEMENT PROGRAM (iSWM)?

A regional program to assist local governments:

- Manage stormwater impacts
- Meet MS4 Permit requirements

Collaborative effort between:

- 60+ local governments
- iSWM Subcommittee
- Regional Public Works Council
- Consultant team led by Halff Associates



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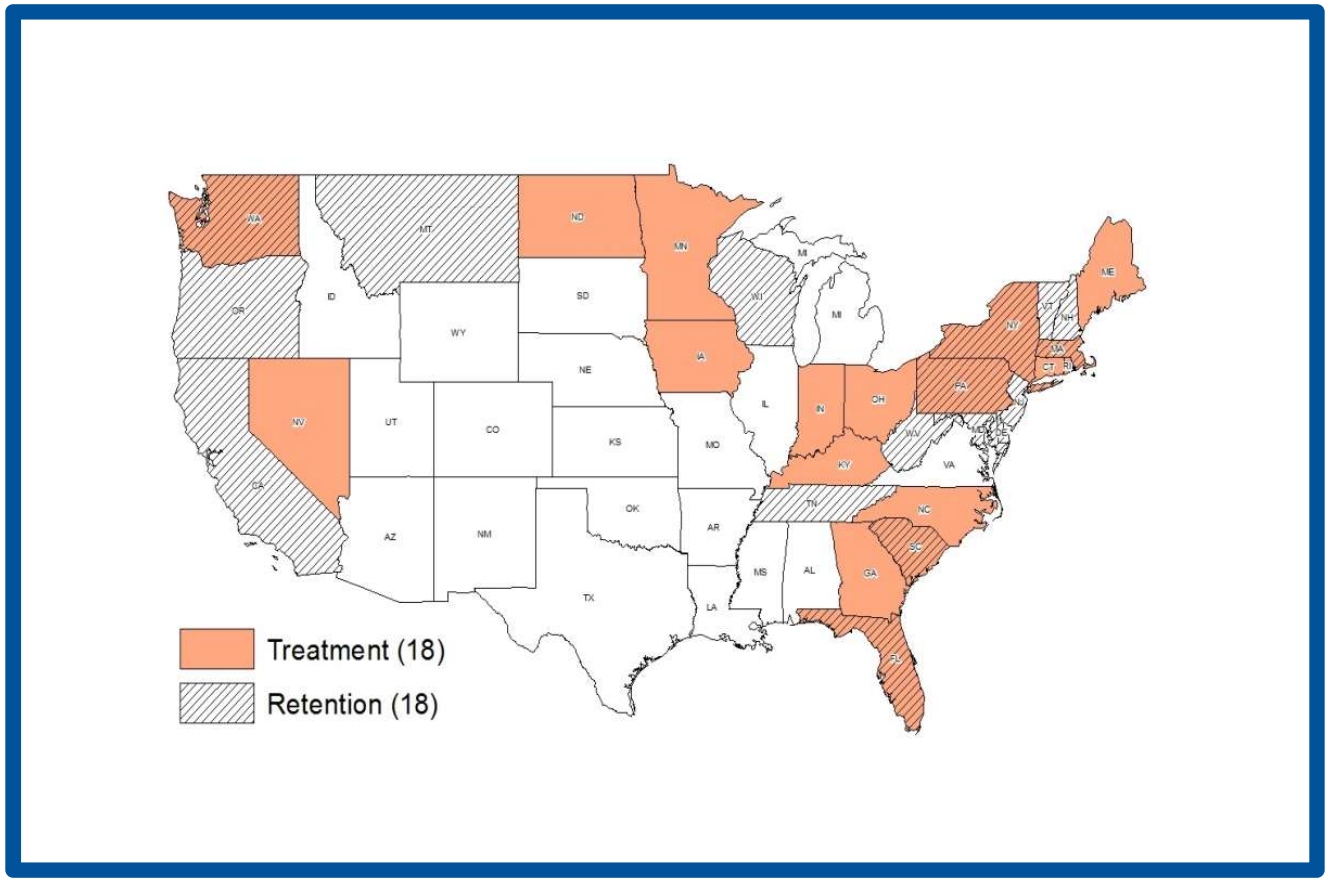
NATIONAL ISSUES

1. Clean Water Act
2. EPA Audits
3. EPA Rule Updates
4. National Requirements



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WHY iSWM?

- Increased runoff leads to flooding
- Streambank erosion
- Water quality concerns
- Stormwater regulations
- Loss of natural features
- Comprehensive approach needed
- Regional consistency

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iSWM BASICS

- Address stormwater early in the development process
- Design for multiple storm events
- Use integrated Site Design Practices
- Reduce downstream impacts
  - Water quality
  - Streambank erosion
  - Flooding
- Protect water quality during construction activities

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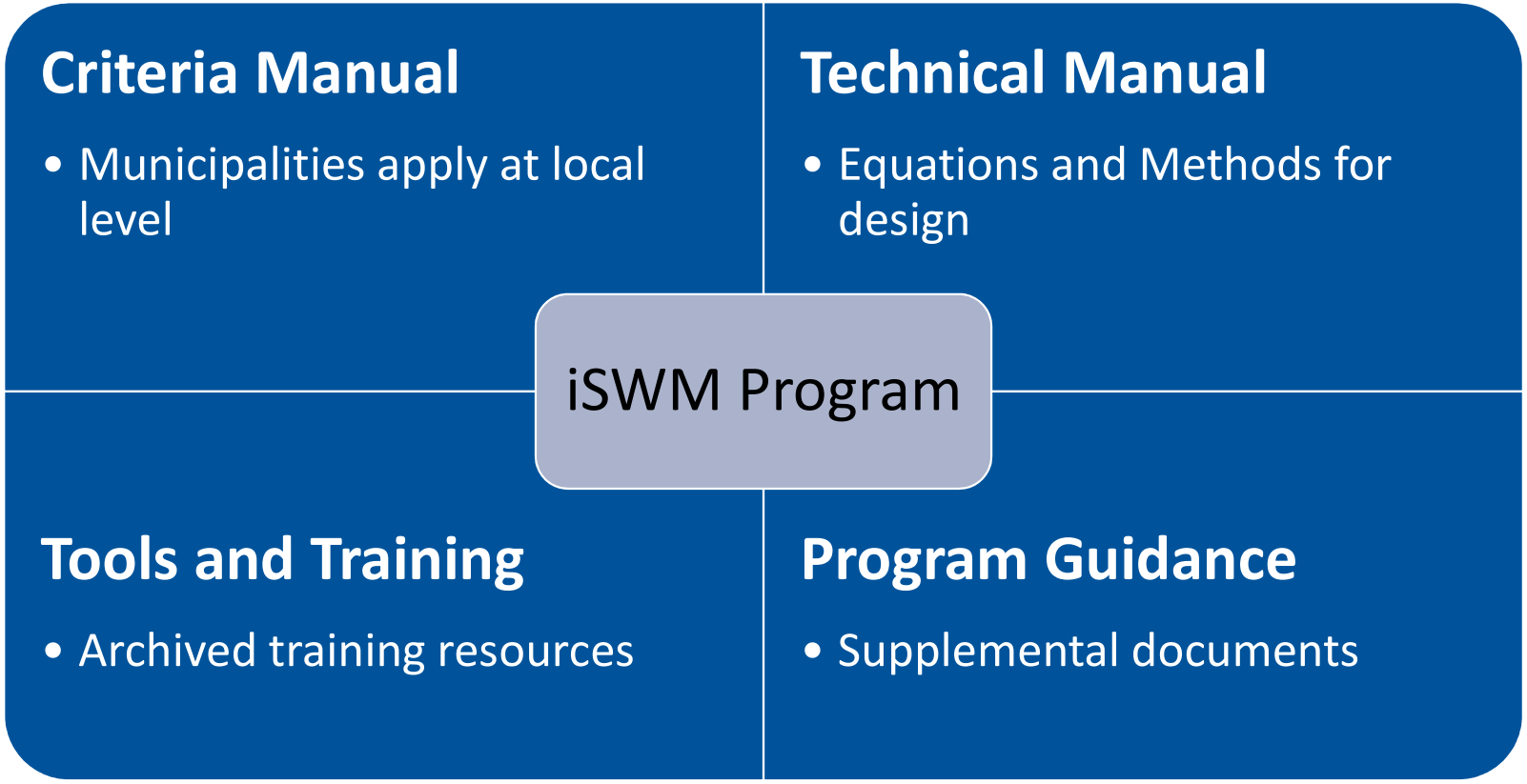
NCTCOG Resources



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iSWM COMMUNITIES

2006	2007	2008	2009	2010	2011	2012	2013	2014
Fort Worth	Roanoke	Benbrook	Dallas	Glenn Heights	Duncanville	Azle	Hurst	Outcome Focused Implementation
Grand Prairie	Southlake		Lakeside	Northlake	University Park			
			Mansfield					

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Hydrologic Methods

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HYDROLOGIC METHODS

APPLICABILITY OF HYDROLOGIC METHODS

Table 3.1 Applications of the Recommended Hydrologic Methods

Method	Rational Method	SCS Method	Modified Rational	Snyder's Unit Hydrograph	USGS / TXDOT Equations	iSWM Water Quality Volume Calculation
Water Quality Protection Volume (WQ_v)						✓
Streambank Protection Volume (SP_v)		✓		✓		
Flood Mitigation Discharge (Q_f)		✓		✓	✓	
Storage Facilities		✓	✓	✓		
Outlet Structures		✓		✓		
Gutter Flow and Inlets	✓					
Storm Drain Pipes	✓	✓		✓		
Culverts	✓	✓		✓	✓	
Bridges		✓		✓		
Small Ditches	✓	✓		✓		
Open Channels		✓		✓	✓	
Energy Dissipation		✓		✓		

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HYDROLOGIC METHODS

CONSTRAINTS OF HYDROLOGIC METHODS

- Consider pending modifications to the NRCS CN Method (Unit Hydrograph SCS)
  - https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=41604.wba

Table 3.2 Constraints on Using Recommended Hydrologic Methods

Method	Size Limitations[1]	Comments
Rational	0 – 100 acres	Method can be used for estimating peak flows and the design of small site or subdivision storm sewer systems.
Modified Rational[2]	0 – 200 acres	Method can be used for estimating runoff volumes for storage design.
Unit Hydrograph (SCS)[3]	Any Size	Method can be used for estimating peak flows and hydrographs for all design applications.
Unit Hydrograph (Snyder's)[4]	1 acre and larger	Method can be used for estimating peak flows and hydrographs for all design applications.
TXDOT Regression Equations	10 to 100 mi^2	Method can be used for estimating peak flows for rural design applications.
USGS Regression Equations	3 – 40 mi^2	Method can be used for estimating peak flows for urban design applications.
iSWM Water Quality Protection Volume Calculation	Limits set for each Structural Control	Method can be used for calculating the Water Quality Protection Volume (WQ_v).

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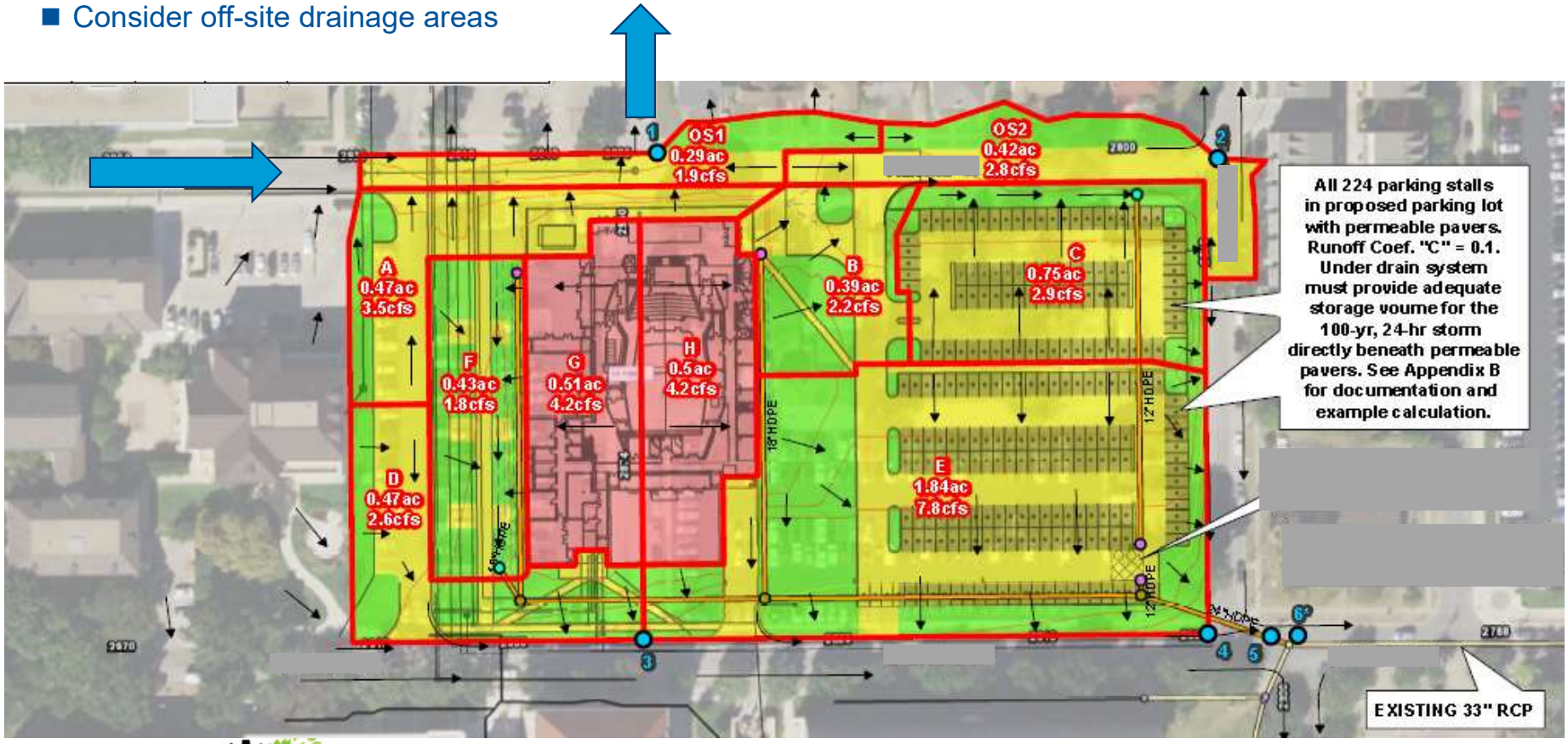
LESSONS LEARNED

Based on feedback preparing iSWM submittals and assisting in drainage reviews throughout the NCTCOG region where iSWM criteria has been adopted or iSWM design principles are being applied.

HYDROLOGIC METHODS – LESSONS LEARNED

OFFSITE DRAINAGE AREAS

- Consider off-site drainage areas



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HYDROLOGIC METHODS – LESSONS LEARNED

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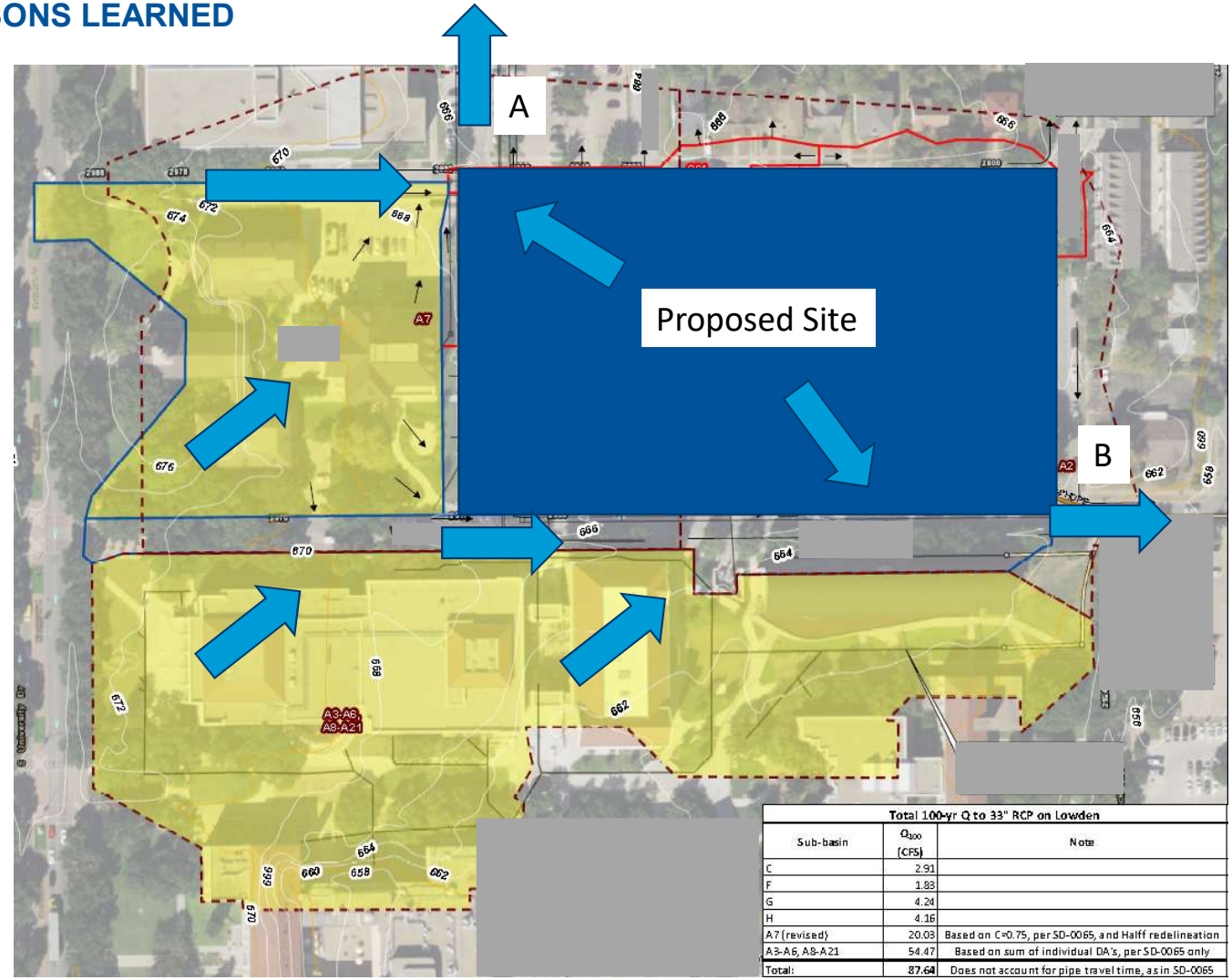
- Consider off-site drainage areas



Total 100-yr Q to 33" RCP on Lowden		
Sub-basin	Q_{100} (CFS)	Note
C	2.91	
F	1.83	
G	4.24	
H	4.16	
A7 (revised)	20.03	Based on C=0.75, per SD-0065, and Halff redelineation
A3-A6, A8-A21	54.47	Based on sum of individual DA's, per SD-0065 only
Total:	87.64	Does not account for pipe travel time, as in SD-0065

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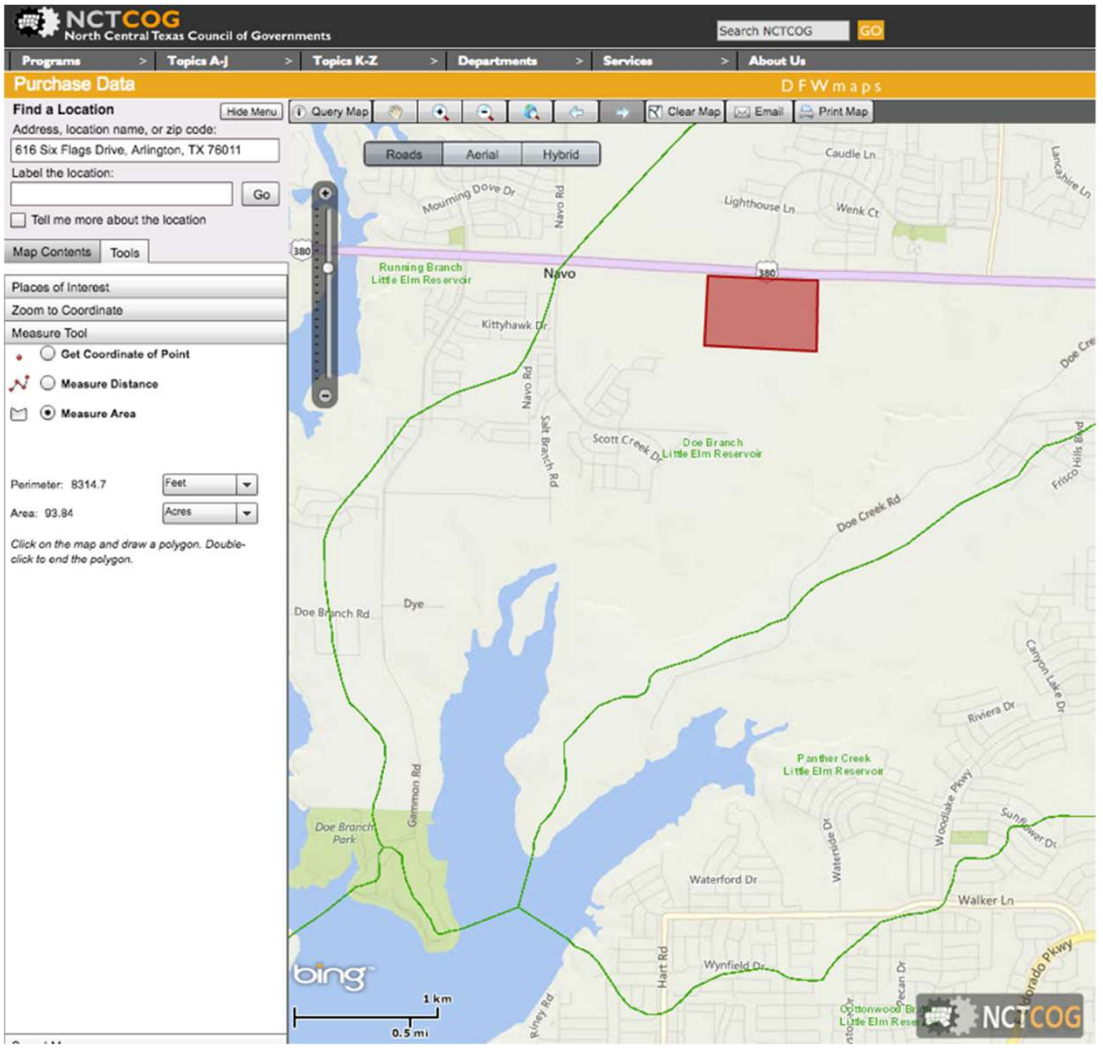
HYDROLOGIC METHODS – LESSONS LEARNED

OVERALL DRAINAGE AREA

- Consider how the site will interact with the overall watershed.
- Use DFWMaps.com
  - Map Contents tab includes HUC Watersheds



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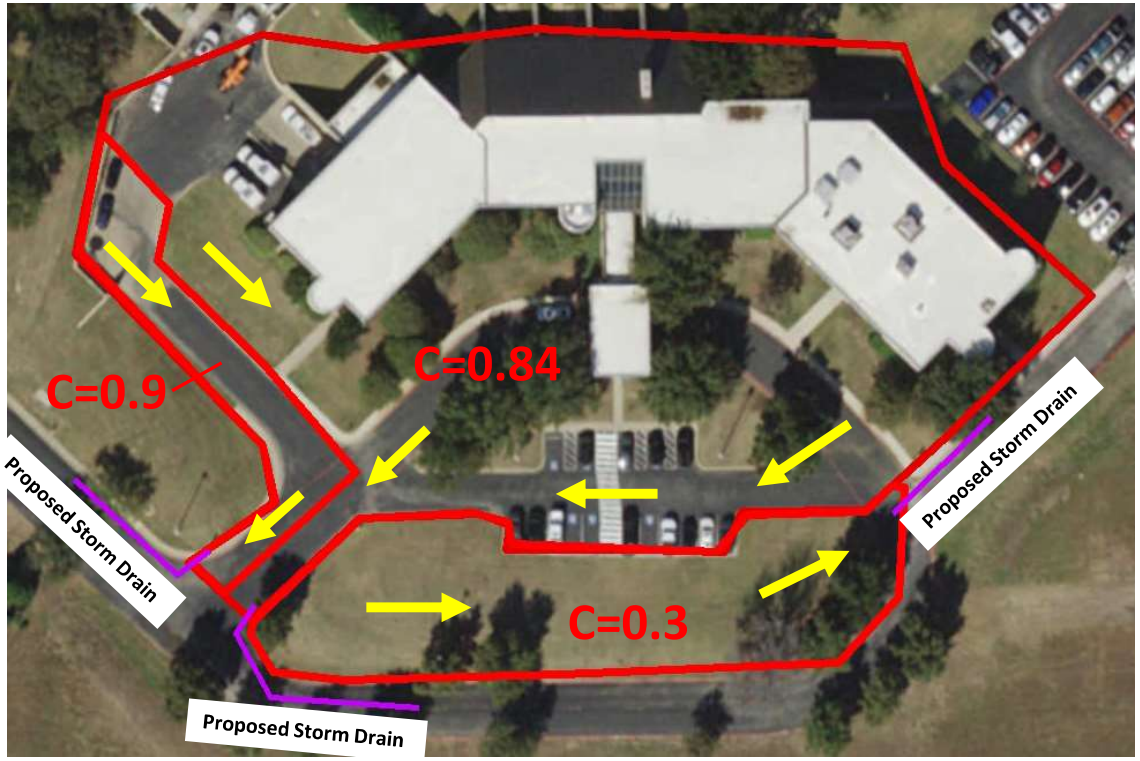
HYDROLOGIC METHODS – LESSONS LEARNED

IMPERVIOUS AREAS

- Use site specific impervious area calculations for proposed site.
- Need to recalculate time of concentration for proposed site.



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Water Quality Protection

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WATER QUALITY PROTECTION

OPTION 1 – INTEGRATED SITE DESIGN

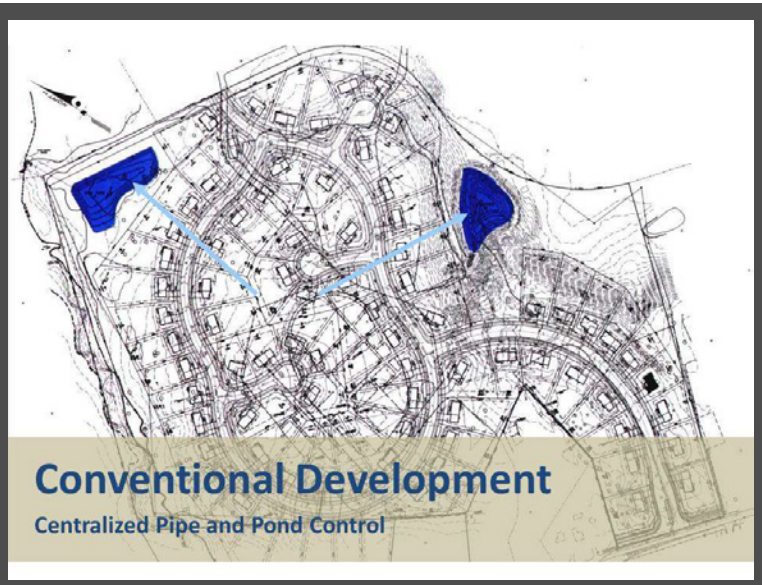
Use integrated Site Design Practices. Measured with a point system based on the percentage of natural features on a site and the percentage of practice utilized.

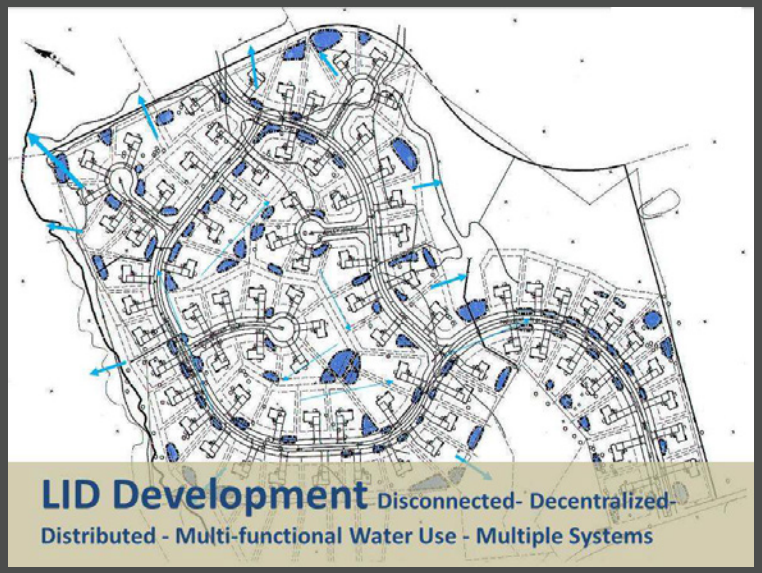
OPTION 2 – TREATMENT

Treat the runoff resulting from the rainfalls of up to 1.5 inches (85th percentile storm)

OPTION 3 – OFF-SITE TREATMENT

Assist in implementing off-site community stormwater pollution prevention programs/activities.





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WATER QUALITY PROTECTION

OPTION 1 – INTEGRATED SITE DESIGN

Undisturbed natural features are areas with one or more of the following characteristics:

- Unfilled Floodplain
- Stand of trees, forest
- Established vegetation
- Steep sloped terrain
- Creeks, gullies, and other natural stormwater features
- Wetland areas and ponds

Table 3.4 *integrated* Site Design Point Requirements

Percentage of Site(by Area) with Natural Features Prior to Proposed Development	Minimum Required Points for Water Quality Protection (WQP)	Additional Points Above WQP for Development Incentives
> 50%	50	10 points each
20 - 50%	30	10 points each
< 20%	20	10 points each

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iSWM Practice No.	Practice	Percent of Eligible Area Using Practice	Maximum Points	Actual Points Earned (% practice used * max. points)
Conservation of Natural Features and Resources				
1	Preserve/Create Undisturbed Natural Areas		8	
2	Preserve or Create Riparian Buffers Where Applicable		8	
3	Avoid Existing Floodplains or Provide Dedicated Natural Drainage Easements		8	
4	Avoid Steep Slopes		3	
5	Minimize Site on Porous or Erodible Soils		3	
Lower Impact Site Design				
6	Fit Design to the Terrain		4	
7	Locate Development in Less Sensitive Areas		4	
8	Reduce Limits of Clearing and Grading		6	
9	Utilize Open Space Development		8	
10	Incorporate Creative Design (e.g. Smart Growth, LEED Design, Form Based Zoning)		8	
Reduction of Impervious Cover				
11	Reduce Roadway Lengths and Widths		4	
12	Reduce Building Footprints		4	
13	Reduce the Parking Footprint		5	
14	Reduce Setbacks and Frontages		4	
15	Use Fewer or Alternative Cul-de-Sacs		3	
16	Create Parking Lot Stormwater "Islands"		5	
Utilization of Natural Features				
17	Use Buffers and Undisturbed Areas		4	
18	Use Natural Drainageways Instead of Storm Sewers		4	
19	Use Vegetated Swale Design		3	
20	Drain Runoff to Pervious Areas		4	
	Subtotal – Actual site points earned		**100**	
	Subtract minimum points required (Table 3.4)		-	
	Points available for development incentives			
	Add 1 point for each 1% reduction of impervious surface		+	
	Total Points for Development Incentives			

WATER QUALITY PROTECTION

OPTION 2 – TREATMENT

- Treat the 1.5 inch (85th Percentile) Rainfall Event
- Reduce TSS and other pollutants depending on BMPs used
- Reduce structural controls through the use of certain reduction methods

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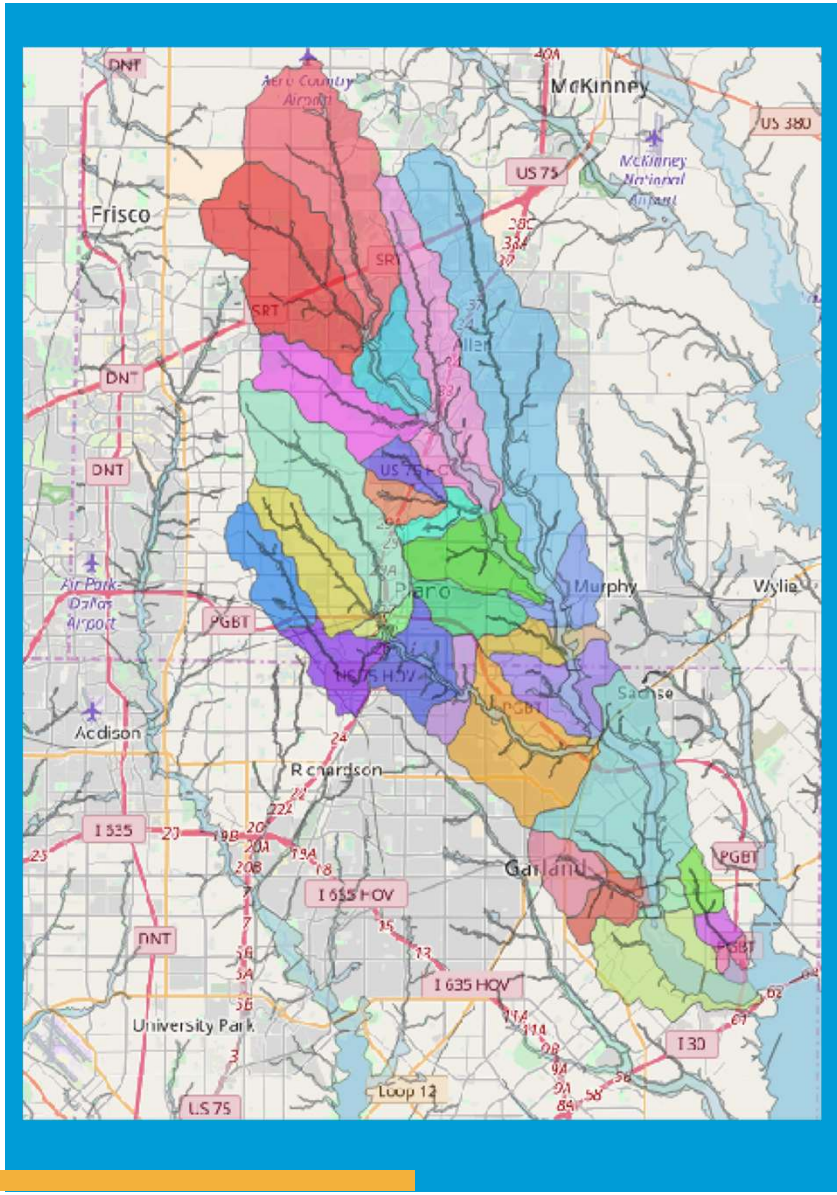
WATER QUALITY PROTECTION

OPTION 3 – REGIONAL APPROACH

- Participate in off-site pollution prevention programs (i.e. regional detention or linear enhanced bioretention/detention across multiple lots or across community boundary lines
- Program must be described in the city's Stormwater Management Program (SWMP) and/or city's approved watershed plan



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LESSONS LEARNED

Based on feedback preparing iSWM submittals and assisting in drainage reviews throughout the NCTCOG region where iSWM criteria has been adopted or iSWM design principles are being applied.

WATER QUALITY PROTECTION – LESSONS LEARNED

INTEGRATED SITE DESIGN

- Unpaved or pervious areas don't always count as natural areas.
- Counting Zone A areas as existing floodplain areas without reviewing actual site conditions.
- Identification of riparian areas can be done using available GIS data and site observations.
- Defining "Less Sensitive Areas"
- Conflicts between definitions of 'Open Space'
- Subjective interpretation of 'Creative Design'
- Definition of a Parking Lot Stormwater 'Island'
- Counting a trapezoidal channel as a 'natural drainageway'.
- Concentrating runoff to pervious areas versus lower energy sheet flow doesn't count.
- Take advantage of available resources at the site plan phase.

TREATMENT

- Existing swales and other surface drainage features can be modified to provide additional storage and treatment.
- Identify surface treatment opportunities during the site planning process for efficiency and cost savings.
- Utilize amenities, open spaces, and landscape areas to capture more volume.
- Design to facilitate and encourage consistent maintenance.

REGIONAL APPROACH

- Identify the major watershed that the site is located in.
- Is the receiving stream impaired or are there pollutants of concern? Review the TCEQ 303d lists or look up in water quality viewer.
- Collaboration within watershed management areas is essential.

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Acceptable Downstream Conditions

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DOWNSTREAM ASSESSMENT PURPOSE

- Protect downstream properties from flood or velocity increases caused by upstream development
- Provide defensible evidence that a proposed development does not impact downstream properties
- Potentially eliminate the need for detaining increased runoff caused by development
- Make better informed decisions

REFER TO TECHNICAL GUIDANCE AND TRAINING LOCATED HERE:

HTTP://ISWM.NCTCOG.ORG/TRAINING/VIDEO.HTML?PLAYLIST=DOWNSTREAM.XML

REFER TO HYDROLOGY TECHNICAL MANUAL SECTION 2.0 :

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DOWNSTREAM ASSESSMENT CONCEPT

- Detention doesn't always make things better….

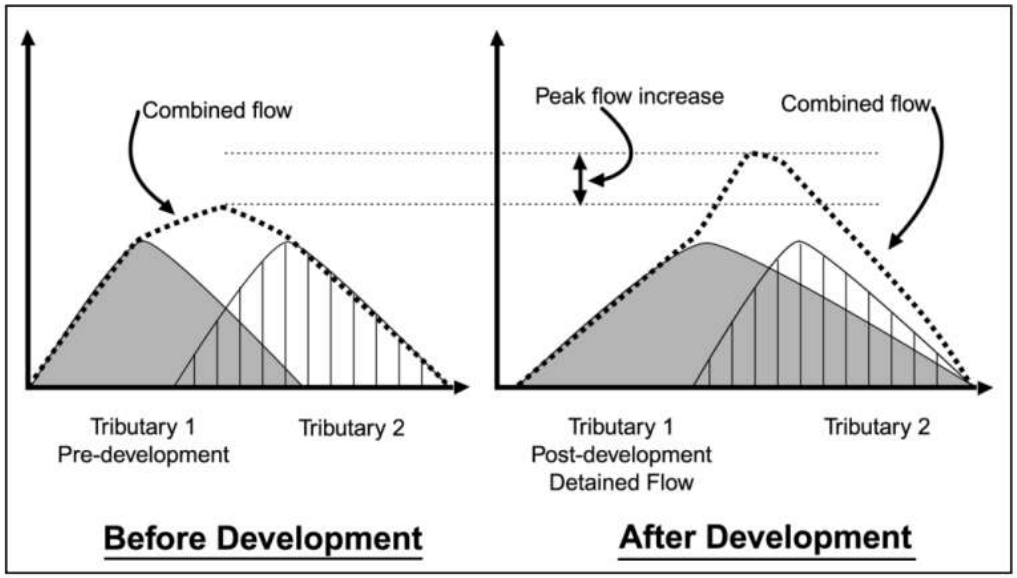
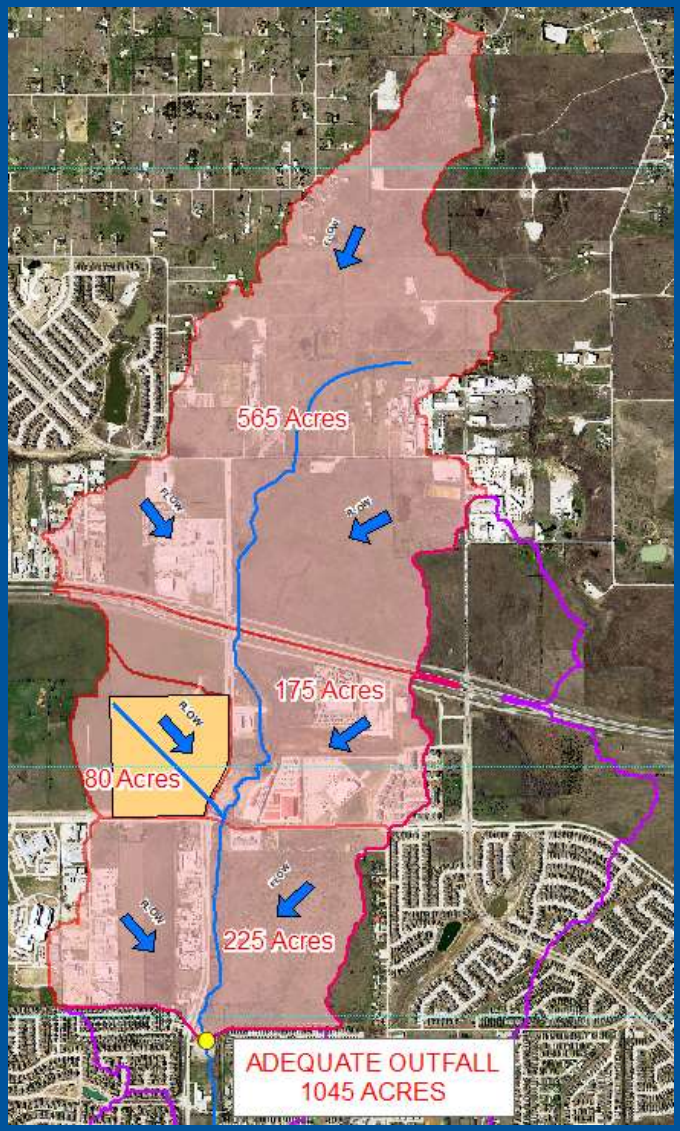


Figure 2.2 Effect of Increased Post-Development Runoff Volume with Detention on a Downstream Hydrograph



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DOWNSTREAM ASSESSMENT PROCESS

1. Identify outfalls
2. Data Collection (As-built plans and topography)
3. Determine the downstream limit of assessment
4. Perform Hydrologic Analysis
5. Analyze flood conditions

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DOWNSTREAM ASSESSMENT METHODS

1. ADEQUATE OUTFALL

   Location of an acceptable outfall that does not create adverse flooding or erosion conditions downstream

2. ZONE OF INFLUENCE

   A point downstream where proposed development no longer has significant impact on receiving stream.

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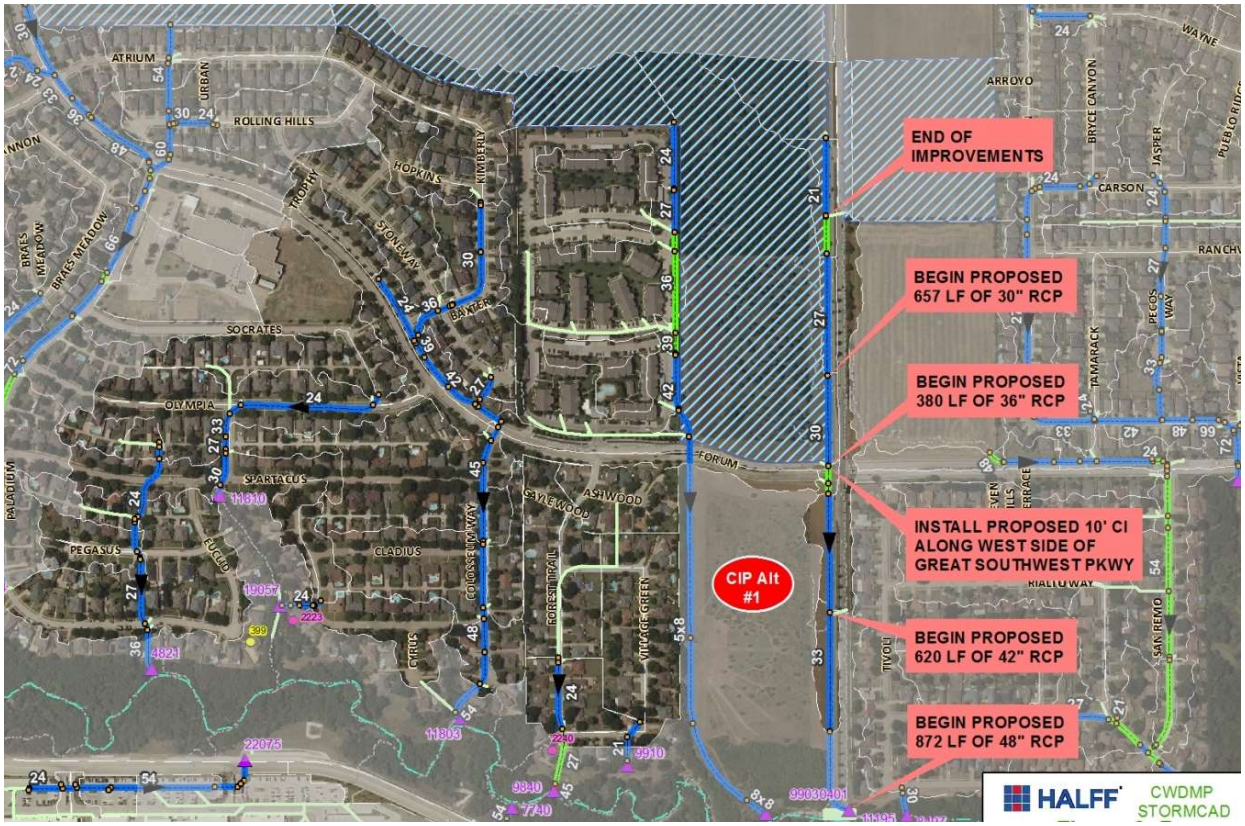
LESSONS LEARNED

Based on feedback preparing iSWM submittals and assisting in drainage reviews throughout the NCTCOG region where iSWM criteria has been adopted or iSWM design principles are being applied.

ADEQUATE OUTFALL – RULES OF THUMB



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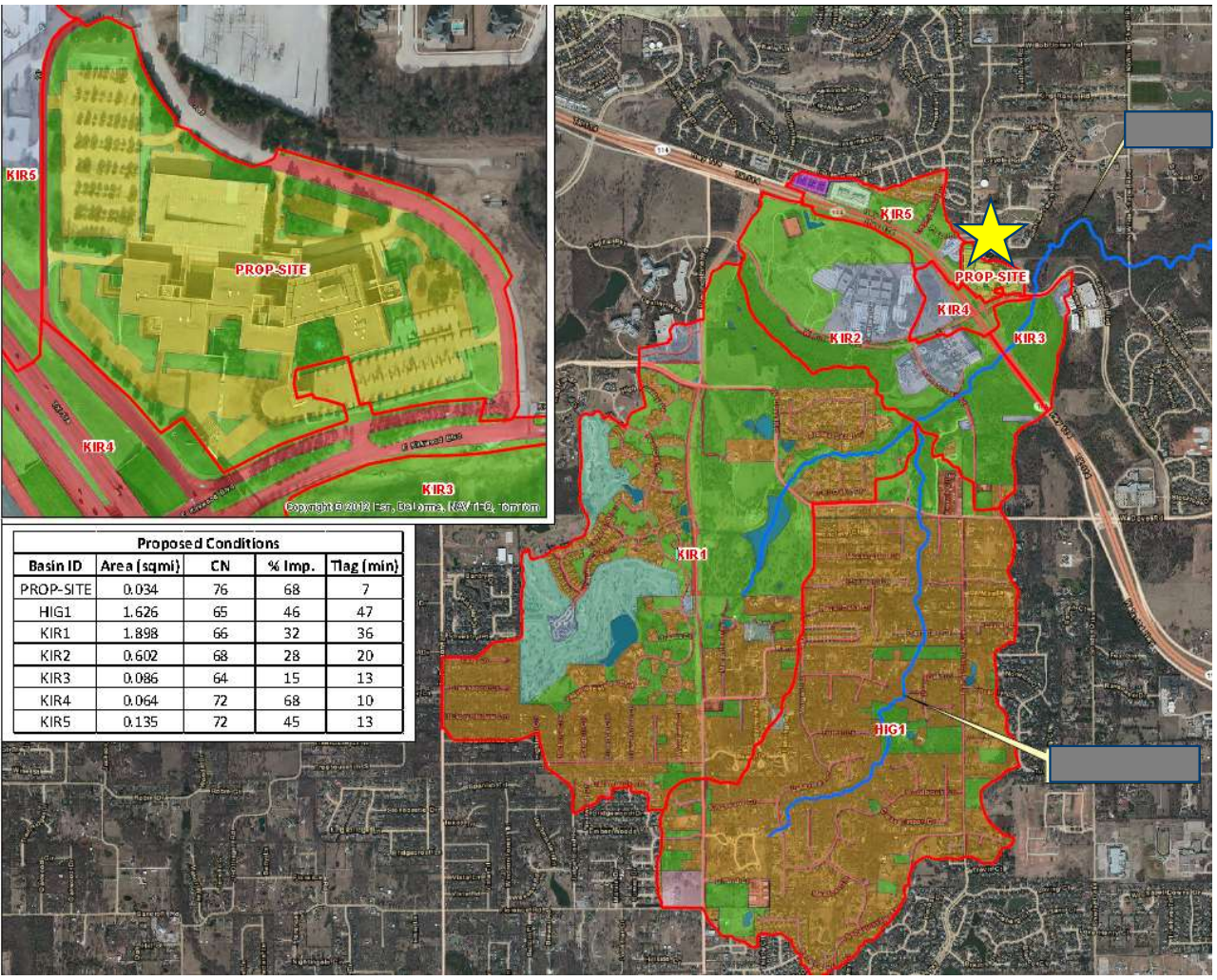
ADOPTEE DEFINED

1. FEMA FLOODPLAIN OR MAJOR STREAM
2. TRINITY RIVER
3. DESIGN PLANS FOR EXISTING SYSTEM
4. WATERS OF THE U.S.
5. CITY DEVELOPED MASTER PLAN

GREENFIELD - DOWNSTREAM ASSESSMENT



Proposed Conditions				
Basin ID	Area (sqmi)	CN	% Imp.	Tlag (min)
PROP-SITE	0.034	76	68	7
HIG1	1.626	65	46	47
KIR1	1.898	66	32	36
KIR2	0.602	68	28	20
KIR3	0.086	64	15	13
KIR4	0.064	72	68	10
KIR5	0.135	72	45	13

PROCESS

1. 10% RULE OF THUMB – POINT ON A RECEIVING STREAM WHERE THE DRAINAGE AREA IMPACTED BY THE SIZE COMPRISES LESS THAN 10% OF TOTAL DRAINAGE AREA.
2. HYDROLOGY ASSESSMENT
3. LIMITED SUBBASINS
4. NEED UNIT HYDROGRAPH METHOD TO EVALUATE TIMING

INFILL - DOWNSTREAM ASSESSMENT

PROCESS

1. 10% RULE STILL APPLIES
2. HYDRAULIC EVALUATION
3. OFTEN UTILIZES RATIONAL METHOD
4. FOCUS ON HYDRAULIC STRUCTURES AND KEY FEATURES MORE THAN WATERSHED SIZE
5. SAN ANTONIO UTILIZES 2,000 FT DOWNSTREAM

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Streambank Protection

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STREAMBANK PROTECTION

OPTION 1 – REINFORCE/STABILIZE DOWNSTREAM CONDITIONS

Bank protection methods including stone riprap, gabions, and bio-engineered methods constructed downstream through the areas of concern.

OPTION 2 – INSTALL STORMWATER CONTROLS TO MAINTAIN EXISTING DOWNSTREAM CONDITIONS

On-site controls to keep downstream post-development discharges at or below allowable velocity limits.

OPTION 3 – CONTROL RELEASE OF STORM EVENT

Twenty-four hours of extended detention provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event.

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LESSONS LEARNED

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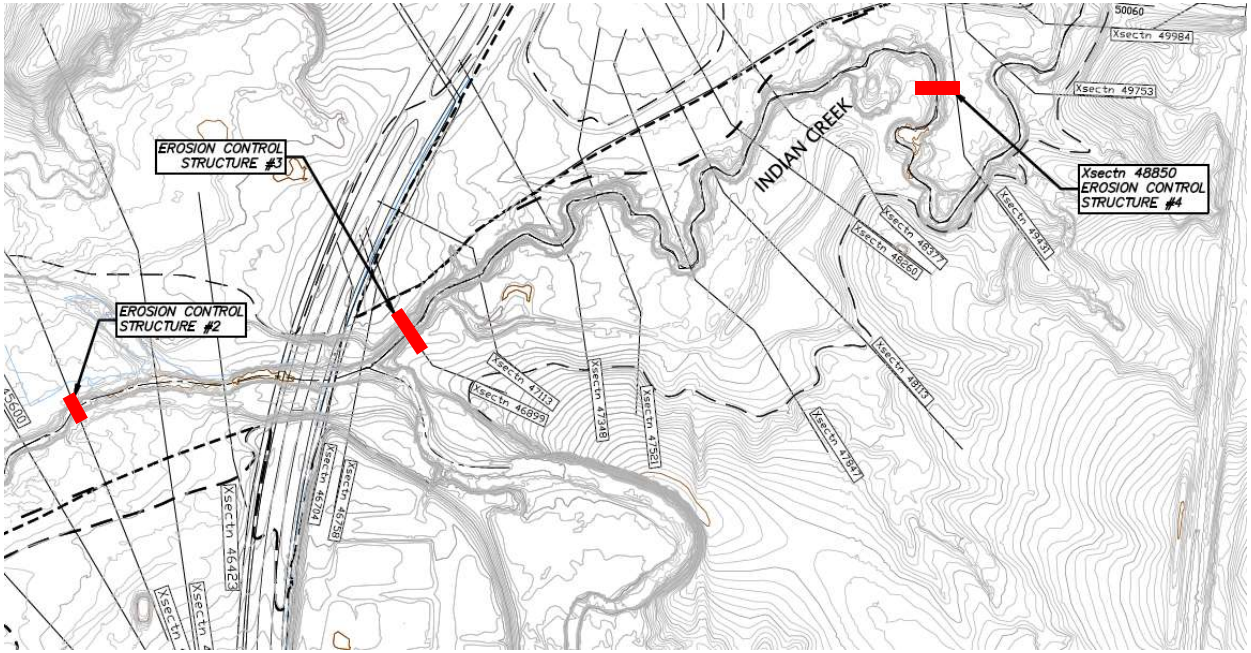
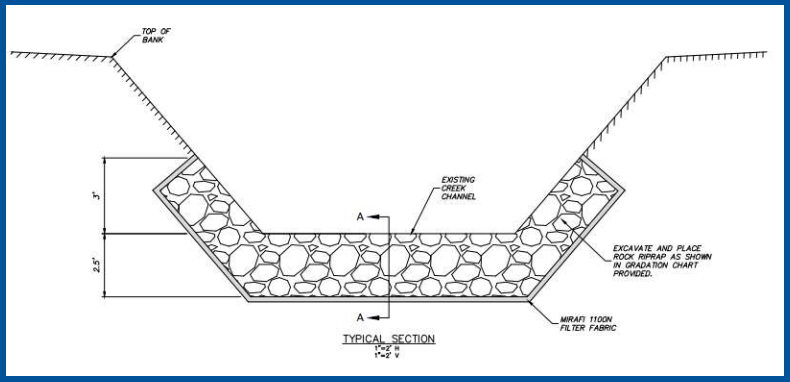
STREAMBANK PROTECTION – LESSONS LEARNED





STREAMBANK PROTECTION

1. **DOWNSTREAM CONDITIONS ARE OFTEN CHALLENGING TO MITIGATE**
2. **CAN REQUIRE MEASURES TO EXTEND THROUGH THE ZONE OF INFLUENCE**

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Flood Mitigation

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FLOOD MITIGATION

OPTION 1 – PROVIDE ADEQUATE DOWNSTREAM CONVEYANCE SYSTEMS

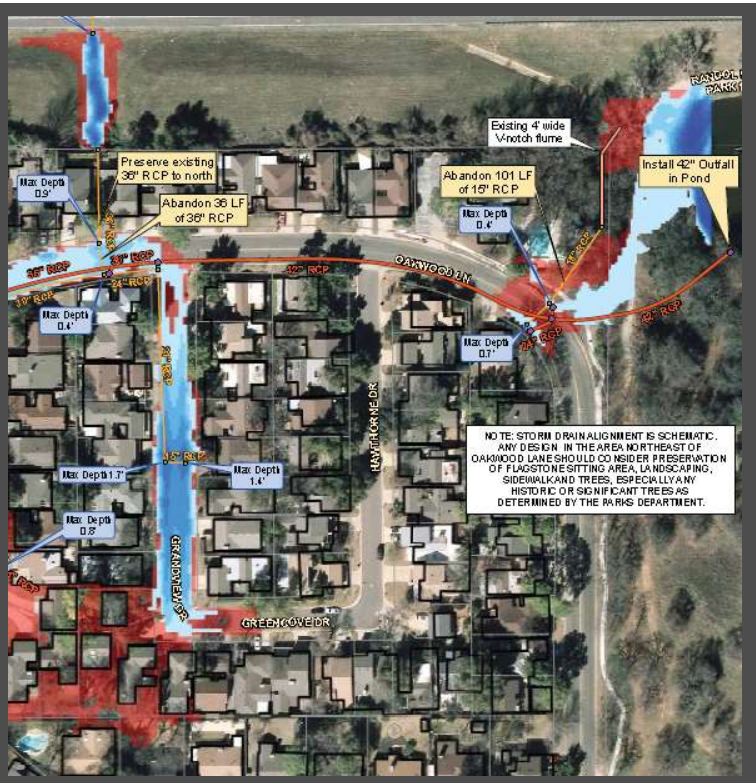
Improvement to downstream conveyance systems through the areas of impact.

OPTION 2 – INSTALL STORMWATER CONTROLS TO MAINTAIN EXISTING DOWNSTREAM CONDITIONS

On-site controls to keep downstream post-development discharges at or below allowable velocity limits.

OPTION 3 – IN LIEU OF A DOWNSTREAM ASSESSMENT, MAINTAIN EXISTING ON-SITE RUNOFF CONDITIONS

Provide supporting calculations and/or documentation that the on-site controls will be designed and constructed to maintain on-site existing conditions. This can result in construction of unneeded detention ponds. Will still need to consider potentially negative impacts of the detention pond.



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Stormwater Conveyance Systems

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HYDRAULIC DESIGN

GENERAL CONSIDERATIONS

- Existing Drainage Patterns
  - Maintaining Compatibility
  - Minimizing Interference
- Control Flooding
  - Property
  - Structures
  - Roadways
- Environment Impacts
  - Water quality
  - Erosion
  - Habitat
- Watershed Conditions
  - Fully Developed

Design Storms

Integrated design is based on the following four (4) storm events.

Table 1.2 Storm Events

Storm Event Name	Storm Event Description
"Water Quality"	Criteria based on a volume of 1.5 inches of rainfall, not a storm frequency
"Streambank Protection"	1-year, 24-hour storm event
"Conveyance"	25-year, 24-hour storm event
"Flood Mitigation"	100-year, 24-hour storm event

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HYDRAULIC DESIGN

STREETS & STORM WATER INLETS

- Depth of flow in streets
  - Conveyance Storm - Shall not exceed top of curb or maximum flow spread limits
  - Flood Mitigation Storm – Shall be contained within ROW or easement
- Flow Spread Limits
  - Conveyance Storm
  - Per Roadway Classification
- Parking Lots
  - Conveyance Storm – shall not exceed top of curb.
  - Max ponding 1’ in low points

Table 3.7 Flow Spread Limits

Street Classification	Allowable Encroachment
Collectors, Arterial, and Thoroughfares (greater than 2-lanes)	• 8 feet or one travel lane, both sides for a divided roadway
Residential Streets	• curb depth or maximum 6 inches at gutter

Residential Street Capacity (29' B-B)

n-value	Area (sq-ft)	Wetted Perimeter (ft)	R (ft)	Longitudinal Slope (ft/ft)	Street Capacity (cfs)
0.019	10.5	29	0.3621	0.0050	29.5
0.019	10.5	29	0.3621	0.0060	32.3
0.019	10.5	29	0.3621	0.0070	34.9
0.019	10.5	29	0.3621	0.0080	37.3
0.019	10.5	29	0.3621	0.0090	39.6
0.019	10.5	29	0.3621	0.0100	41.7

Residential ROW Capacity (29' B-B)

n-value	Area (sq-ft)	Wetted Perimeter (ft)	R (ft)	Longitudinal Slope (ft/ft)	Street Capacity (cfs)
0.019	18.69	50.05	0.3734	0.0050	53.6
0.019	18.69	50.05	0.3734	0.0060	58.7
0.019	18.69	50.05	0.3734	0.0070	63.4
0.019	18.69	50.05	0.3734	0.0080	67.8
0.019	18.69	50.05	0.3734	0.0090	71.9
0.019	18.69	50.05	0.3734	0.0100	75.8

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HYDRAULIC DESIGN

STORM DRAIN PIPE

- Pipe Design - Conveyance storm
  - HGL below inlet throat
- Velocity
  - Max – See Table 3.8
  - Min – 2.5 fps
- Slope
  - 0.5%
  - Or the slope that will produce velocity of 2.5 fps when flowing full
- Manhole Spacing
  - Maintenance access
  - Required at intermediate point along straight runs

Table 3.8 Desirable Velocity in Storm Drains

Description	Maximum Desirable Velocity
Culverts (All types)	15 fps
Storm Drains (Inlet laterals)	No Limit
Storm Drains (Collectors)	15 fps
Storm Drains (Mains)	12 fps

Table 3.9 Access Manhole Spacing Criteria
(HEC 22, 2001)

Pipe Size (inches)	Maximum Spacing (feet)
12-24	300
27-36	400
42-54	500
60 and up	1000

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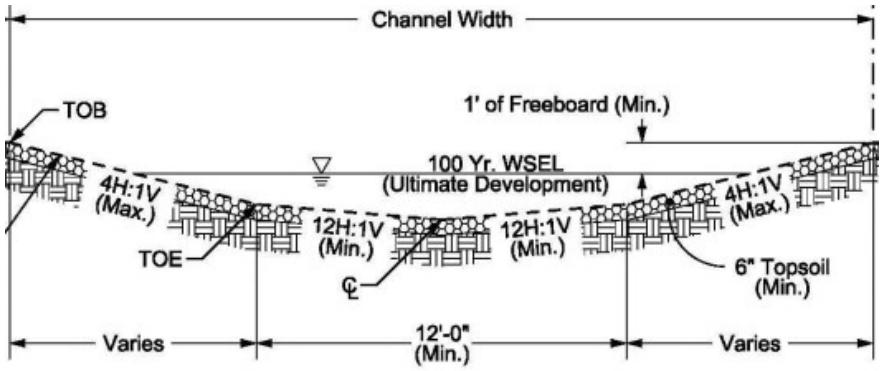
HYDRAULIC DESIGN

STRUCTURES – OPEN CHANNELS

- Design Frequency
  - Flood mitigation event
  - Multiple stages – Low Flow & High Flow sections
- Geometry
  - Trapezoidal or parabolic sections preferred
  - Bottom width
    - Min 6’ for trapezoidal
    - Need cross slope when greater than 6’
  - Side slope depends on channel material – generally 4:1 max
  - Roadside ditches 3:1 max slope
- Velocity
  - Max velocity for vegetative channels depends on grass type
  - Generally 6 fps max
- Analysis
  - HECRAS or similarly capable software for water surface profile computations



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HYDRAULIC DESIGN

STRUCTURES – CULVERTS/BRIDGES

- Culverts
  - Design Frequency
    - Flood Mitigation Storm
  - Roadway Type
  - Property/Structure Flooding
  - Tailwater
    - Free Outfall
    - Open Channel: Stage-Discharge Curve
    - Culverts in series
    - Lake/Pond
  - Freeboard
    - Min 12” from top of curb or pavement low point.
  - Property/Structure Flooding
  - Velocity Limitations
    - No specified max for RCP
    - Max 15 fps for CMP
    - Min 2.5 fps (ensure self-cleaning)
  - Slope Limitations
    - Max 10% for RCP
    - Max 14% for CMP
  - Minimum pipe diameter 18”
  - Erosion Protection

- Bridges
  - Cross drainage facility of 20’ or larger
  - 2’ freeboard from low chord
  - Erosion Protection

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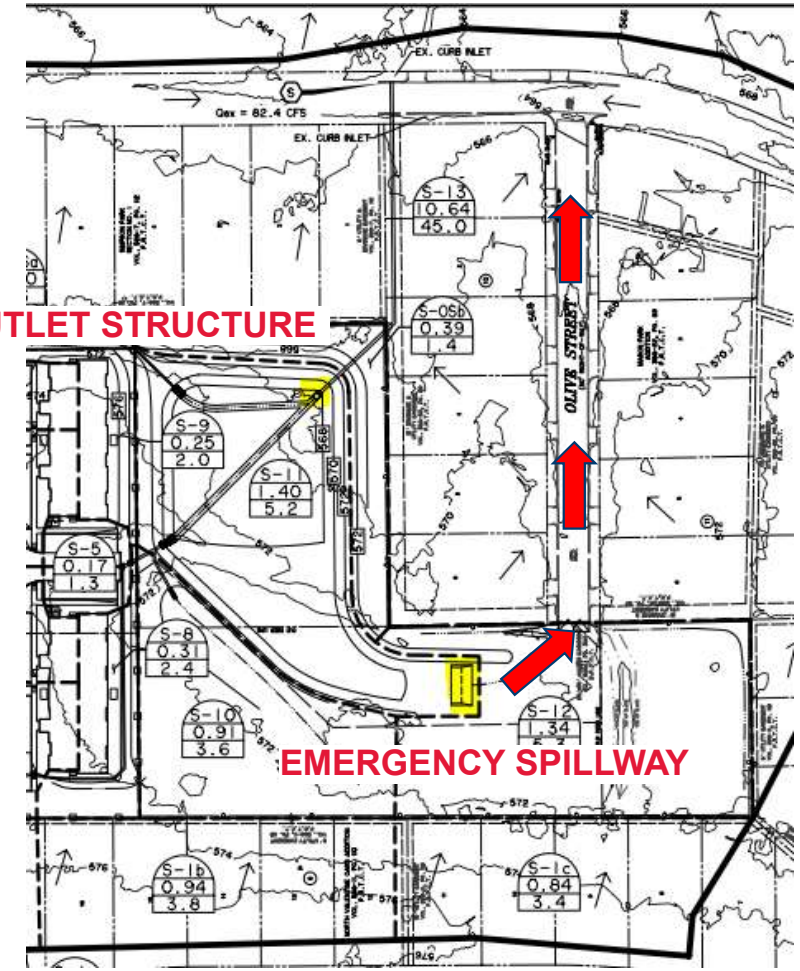
HYDRAULIC DESIGN

STRUCTURES – DETENTION

- Detention Ponds
  - Modified Rational Method (Adjustment Factors – Section 1.5.2, Hydrology)
  - Detailed Unit Hydrograph Method
  - Rated Outlet Structure
  - Emergency Spillway
  - Freeboard Requirements
  - Maintenance

★ MRM RULE OF THUMB ★

- Detention Volume Required
  - Undeveloped to Residential
    - 0.20 acre-feet per acre
  - Undeveloped to Commercial
    - 0.25 acre-feet per acre



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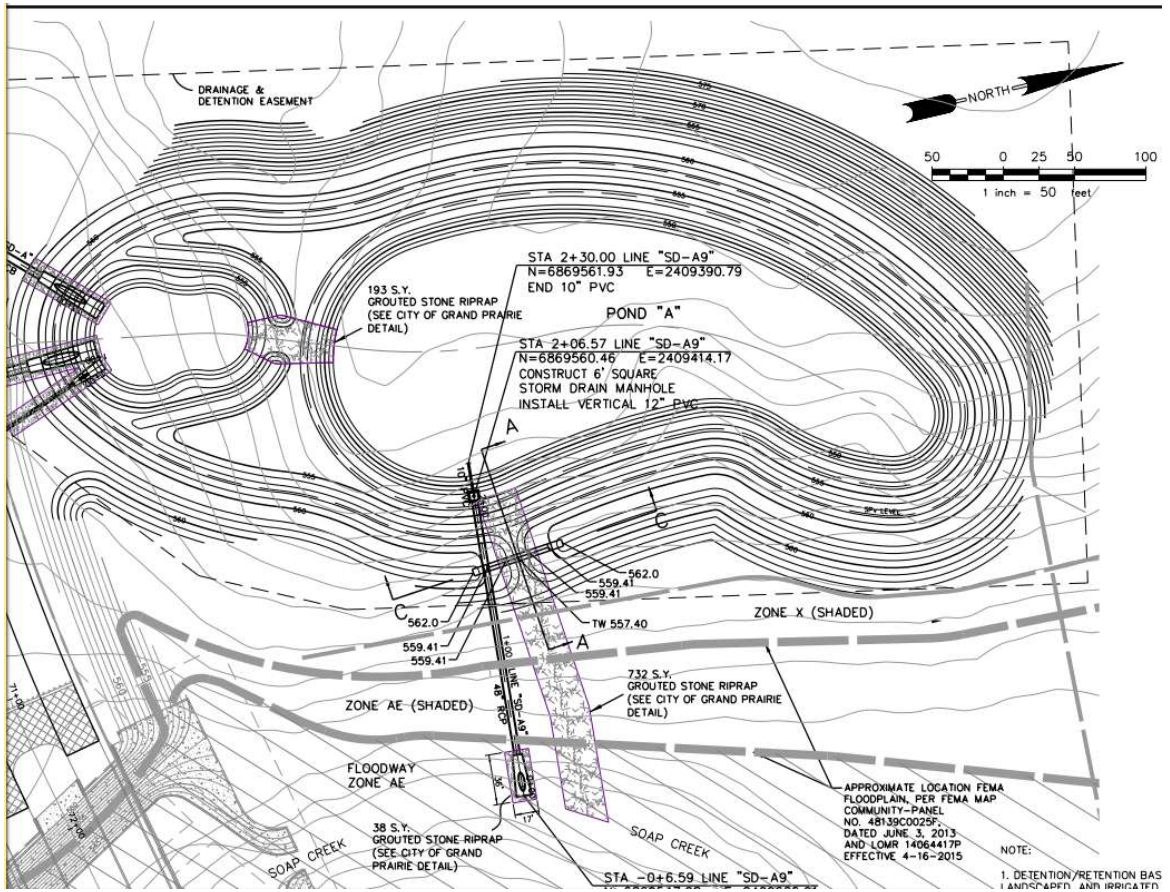
HYDRAULIC DESIGN – LESSONS LEARNED

STRUCTURES – DETENTION

- Using PondPack or proprietary model – please provide model to reviewer
- Include all applicable storm events
- Show final stage-storage-discharge tables to confirm that post-project flows do not exceed pre-project flow requirements
- Show stage-discharge elevations onto riser box/outfall detail
- Provide an emergency spillway



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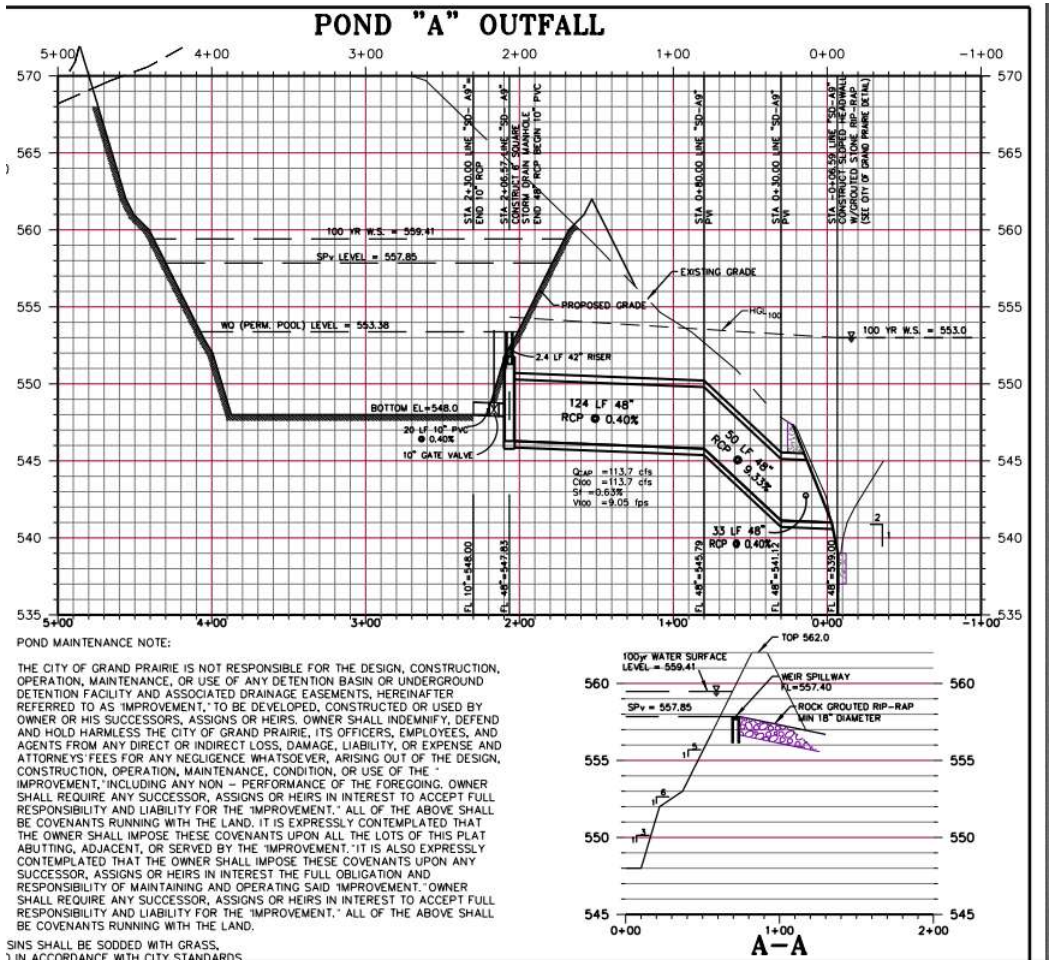
HYDRAULIC DESIGN – LESSONS LEARNED

STRUCTURES – DETENTION

- Provide landscape and irrigation plans if required by authority
- Provide a fence if required by authority
- If pond is constrained and walls are needed, ensure that structural design is provided
- Ensure pond bottom has a slope and conveys stormwater appropriately (flume, etc.)
- Provide maintenance plan
- Downstream conditions are taken into account. Free flowing or HGL downstream



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HYDRAULIC DESIGN – LESSONS LEARNED

MODIFIED RATIONAL METHOD

- Q allowable and Qout from outfall structure need to balance.
- Need to iterate until Qallowable, Qout, and required storage balance within acceptable tolerance.

Elevation (ft)	Storage (ac-ft)	Outflow (cfs)
819.2	0	0
820	0.06	8.16
821	0.41	19.5
822	1.94	22.1
823	2.56	26.3
824	3.29	32.5
825	**5.05**	**35.0**
826	5.5	42

- Concentrated flow to creek

MODIFIED RATIONAL METHOD

Existing Runoff Coefficient	0.3		Proposed Runoff Coefficient	0.9	
Area	20	Acres	Area	20	Acres
Time of Concetration	15	Min.	Time of Concetration	10	Min.
1 Year Runoff	19.92	CFS	1 Year Runoff	73.09	CFS
5 Year Runoff	29.17	CFS	5 Year Runoff	103.38	CFS
100 Year Runoff	47.86	CFS	100 Year Runoff	166.40	CFS

$Q_{a,\ 1\ yr}$=	19.92	CFS
$Q_{a,\ 5\ yr}$=	29.17	CFS
$Q_{a,\ 100\ yr}$=	47.86	CFS

Table 5.15: Tarrant County Rainfall Data	For 1 Yr Return Period: e =0.8217, b =43.653, d =8 For 5 Yr Return Period: e =0.8142, b =71.154, d =12 For 100 Yr Return Period: e =0.7798, b =110.202, d =14

T_{d1}=	34.80	Min.
T_{d5}=	44.58	Min.
T_{d100}=	52.48	Min.

Table 1.18 Rainfall Factors	For 1 Yr Return Period: a =95.84, b =13.43 For 5 Yr Return Period: a =170.81, b =19.44 For 100 Yr Return Period: a =322.07, b =24.39

P_{td1}=	1.16	in.	$P_{180\text{-}1}$=	1.77	in.
P_{td5}=	1.98	in.	$P_{180\text{-}5}$=	2.95	in.
P_{td100}=	3.65	in.	$P_{180\text{-}100}$=	5.44	in.

$V_{Preliminary1}$=	47918.82	Cu.Ft	V_{Max1}=	73468.18	Cu.Ft
$V_{Preliminary5}$=	80710.13	Cu.Ft	V_{Max5}=	120507.17	Cu.Ft
$V_{Preliminary100}$=	147776.70	Cu.Ft	V_{Max100}=	219877.51	Cu.Ft

5.05 ac-ft

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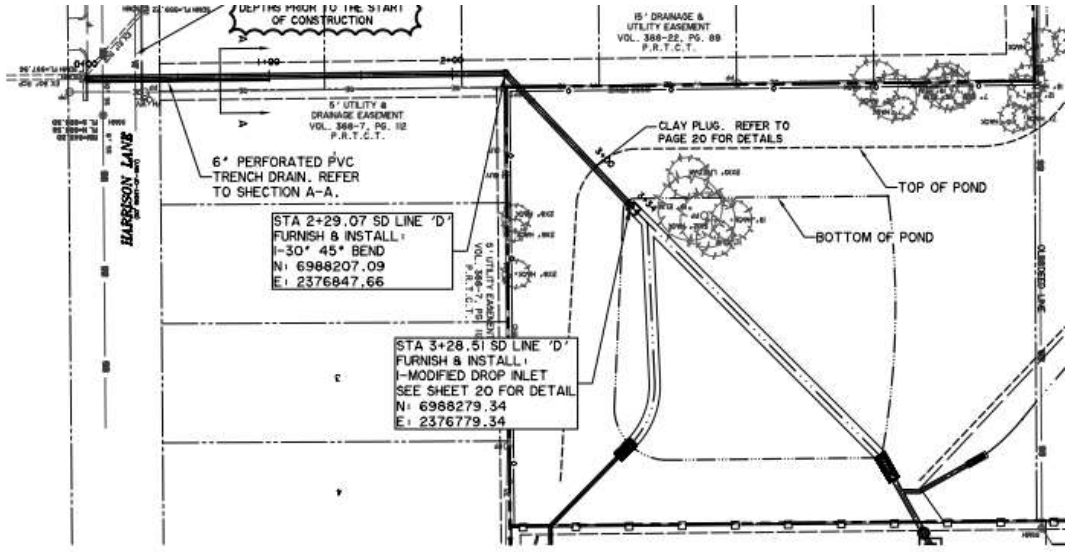
HYDRAULIC DESIGN – LESSONS LEARNED

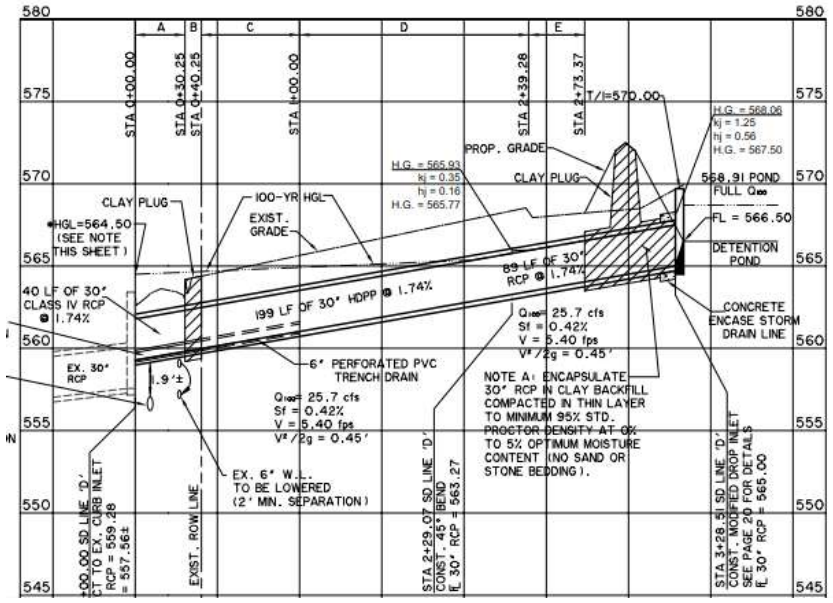
TAILWATER

- Backwater Impacts
- Coincident Tailwater
- Detention Pond Design

Table 1.10 Frequencies for Coincidental Occurrences
(TxDOT, 2002)

Area ratio	50-year design		100-year design	
	Main Stream	Tributary	Main Stream	Tributary
10,000:1	2	50	2	100
	50	2	100	2
1,000:1	5	50	10	100
	50	5	100	10
100:1	10	50	25	100
	50	10	100	25
10:1	25	50	50	100
	50	25	100	50
1:1	50	50	100	100
	50	50	100	100

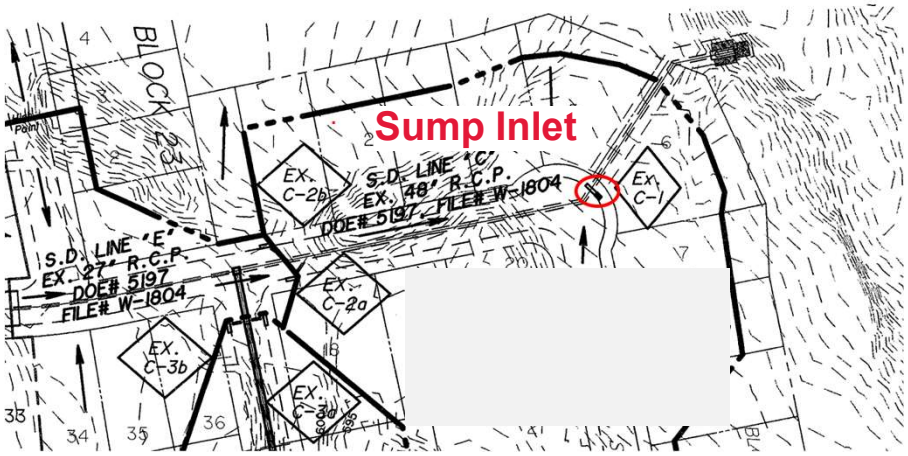




HYDRAULIC DESIGN – LESSONS LEARNED

CURB INLETS

- On Grade Inlets – Generally 1 cfs per linear foot of opening
- Sump Inlets – Generally 2 cfs per linear foot of opening
  - Weir/Orifice flow threshold



100-YR SUMP INLET DESIGN CALCULATIONS

Inlet No.	Gutter Slope So (ft/ft)	Crown or Slope of Pvmt. (ft/ft)	Gutter Flow Qo (cfs)	Depth of Gutter Flow Yo (ft)	Depth of Depression (ft)	Depth of Flow at Opening Y (ft)	Capacity of Inlet per Foot of Length Q/L (cfs/ft)	Length of Inlet Opening L or P (ft)	Capacity of Inlet Q (cfs)	Carryover into Over Flow (ft/ft)	Percent Q100 Captured by Inlet
Ex. C-1	0.0006	0.02	44.4	0.78	0.42	1.20	3.94	15	59.2	0.00	100.0

3.94 cfs/lf

WM™ Technical Manual — Hydraulics

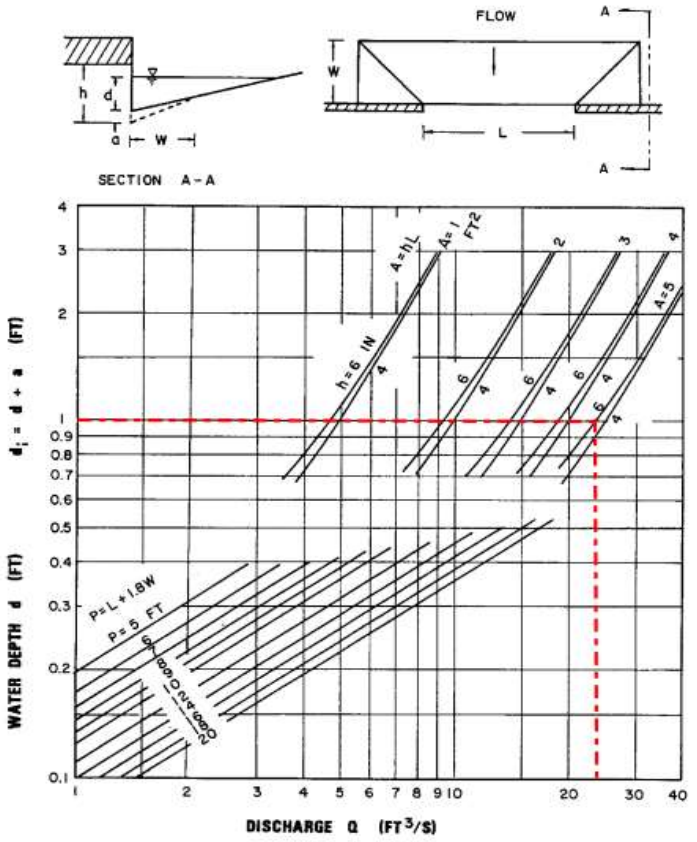


Figure 1.10 Depressed Curb-Opening Inlet Capacity in Sump Locations
(Source: AASHTO Model Drainage Manual, 1991)

Approximately 2.4 cfs/lf at ROW capacity depth

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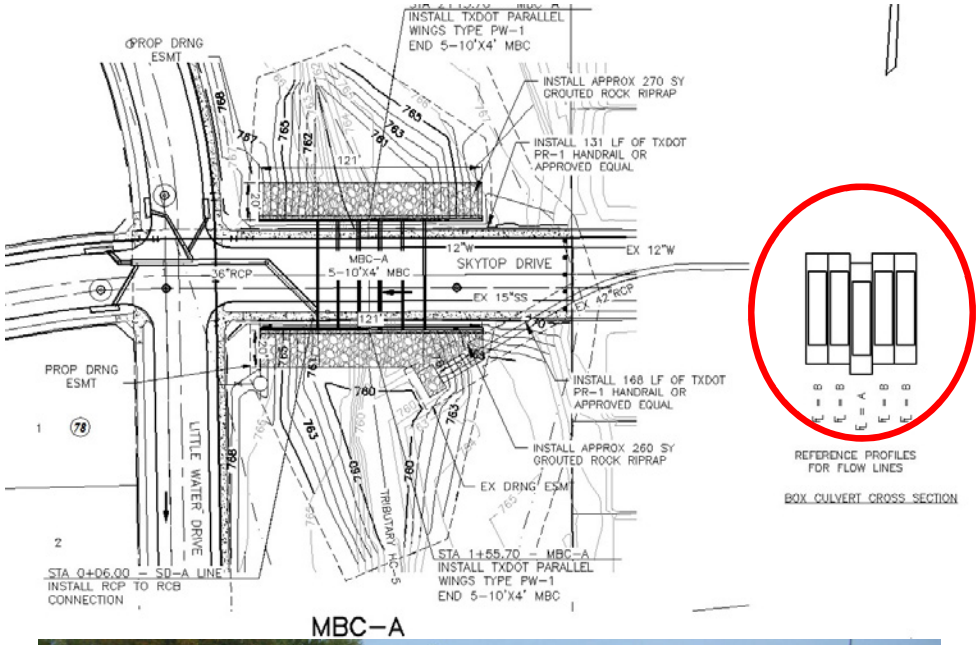
HYDRAULIC DESIGN – LESSONS LEARNED

MULTI-BARREL BOX CULVERTS

- Low Flow Barrel
- Reduce debris/sediment accumulation



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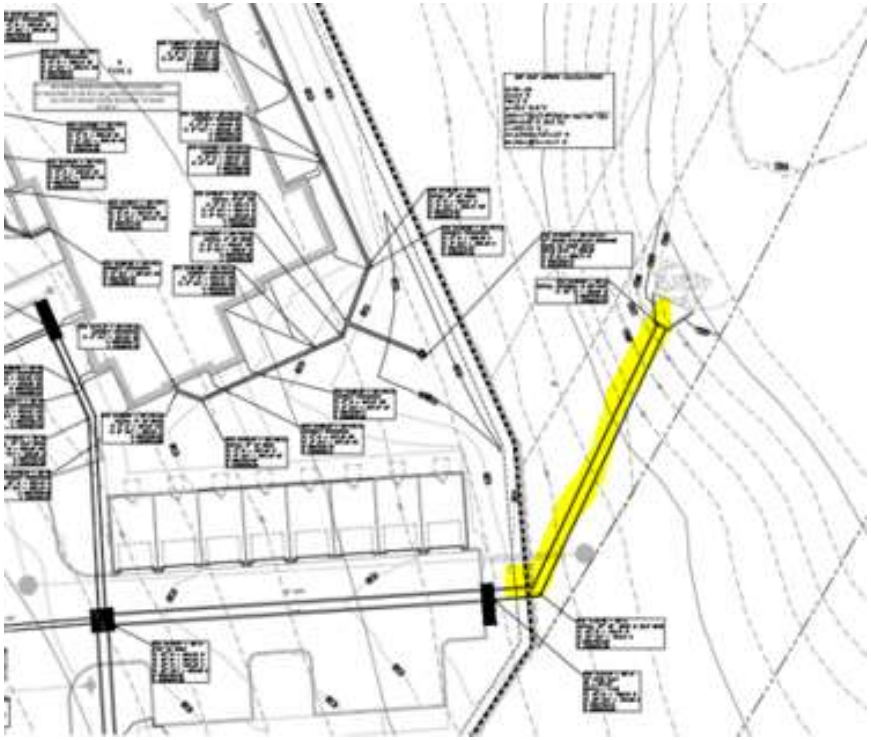
HYDRAULIC DESIGN – LESSONS LEARNED

OUTFALLS

- Existing site sheet flows adjacent to creek
- Concentrated discharge over bank

- Concentrated flow to creek



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Easements, Plats, and Maintenance Agreements

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EASEMENTS, PLATS, AND MAINTENANCE AGREEMENTS

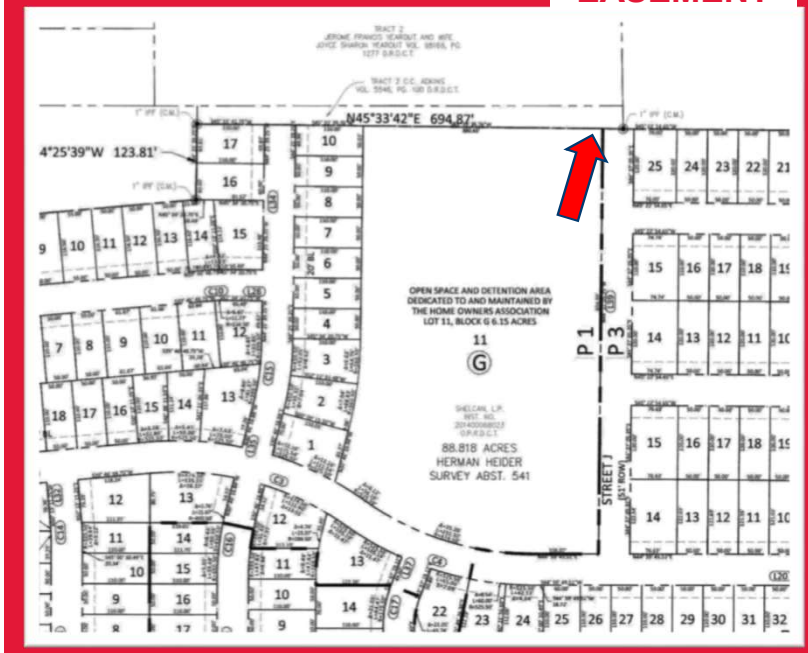
EASEMENTS

- Drainage easements for on-site and off-site improvements
- Floodplain easements for FEMA Special Flood Hazard Areas
- Temporary drainage easements with municipality approval
- Allow for access and maintenance
- Easements for detention ponds and permanent stormwater controls vary by municipality.
- Minimum easements for pipes as follows (municipalities vary):

Table 3.14 Closed Conduit Easements

Pipe Size	Minimum Easement Width Required
39" and under	15 Feet
42" through 54"	20 Feet
60" through 66"	25 Feet
72" through 102"	30 Feet

NO OFF-SITE EASEMENT



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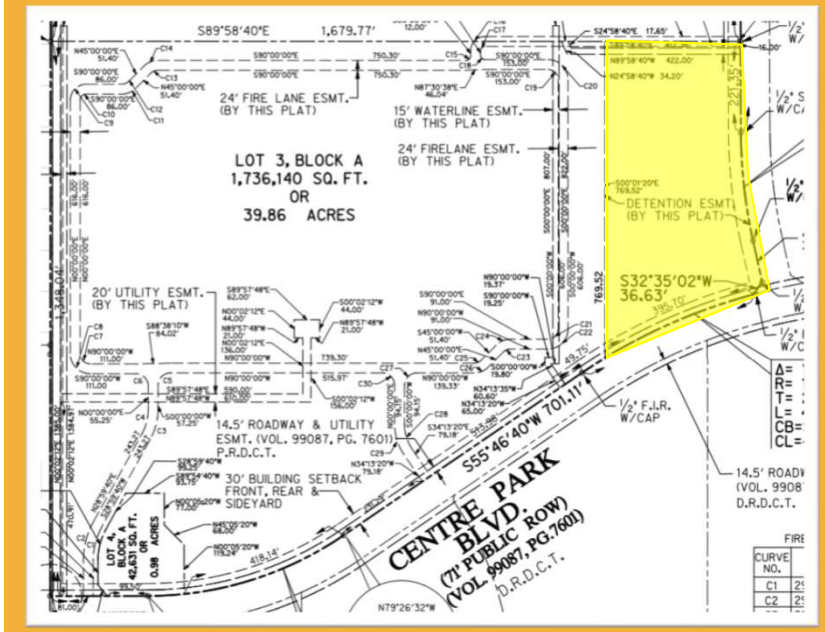
EASEMENTS, PLATS, AND MAINTENANCE AGREEMENTS

PLATS

Plats should include the following information:

- Public and Private easements
- Easements to be recorded by separate instrument
- All floodplain easements
- Legal disclosure for drainage provisions upon sale or transfer
- Documentation of maintenance responsibilities and agreements including transfer of responsibility upon sale of the property



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EASEMENTS, PLATS, AND MAINTENANCE AGREEMENTS

MAINTENANCE AGREEMENTS AND PLANS

For drainage improvements and permanent structure controls

- Responsible parties
- Required maintenance activities
- Frequency of inspections
- Maintenance agreement should remain in force upon sale or transfer

MAINTENANCE AGREEMENT EXAMPLE

THE CITY OF X IS NOT RESPONSIBLE FOR THE DESIGN, CONSTRUCTION, OPERATION, MAINTENANCE, OR USE OF ANY DETENTION BASIN AND ASSOCIATED DRAINAGE EASEMENTS TO BE DEVELOPED, CONSTRUCTED OR USED BY OWNER OR HIS SUCCESSORS, ASSIGNS OR HEIRS. OWNER SHALL INDEMNIFY, DEFEND AND HOLD HARMLESS THE CITY OF X, ITS OFFICERS, EMPLOYEES, AND AGENTS FROM ANY DIRECT OR INDIRECT LOSS, DAMAGE, LIABILITY, OR EXPENSE AND ATTORNEYS' FEES FOR ANY NEGLIGENCE WHATSOEVER, ARISING OUT OF THE DESIGN, CONSTRUCTION, OPERATION, MAINTENANCE, OR ANY NON-PERFORMANCE OF THE FOREGOING. OWNER SHALL REQUIRE ANY SUCCESSOR, ASSIGNS OR HEIRS IN INTEREST TO ACCEPT FULL RESPONSIBILITY AND LIABILITY FOR THE "IMPROVEMENT." IT IS EXPRESSLY CONTEMPLATED THAT THE OWNER SHALL IMPOSE THESE COVENANTS UPON ALL THE LOTS OF THIS PLAT ABUTTING, ADJACENT, OR SERVED BY THE "IMPROVEMENT." IT IS ALSO EXPRESSLY CONTEMPLATED THAT THE OWNER SHALL IMPOSE THESE COVENANTS UPON ANY SUCCESSOR, ASSIGNS OR HEIRS IN INTEREST THE FULL OBLIGATION AND RESPONSIBILITY OF MAINTAINING AND OPERATING SAID "IMPROVEMENT." OWNER SHALL REQUIRE ANY SUCCESSOR, ASSIGNS OR HEIRS IN INTEREST TO ACCEPT FULL RESPONSIBILITY AND LIABILITY FOR THE "IMPROVEMENT." ALL OF THE ABOVE SHALL BE COVENANTS RUNNING WITH THE LAND.

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LESSONS LEARNED

Based on feedback preparing iSWM submittals and assisting in drainage reviews throughout the NCTCOG region where iSWM criteria has been adopted or iSWM design principles are being applied.

EASEMENTS, PLATS, AND MAINTENANCE AGREEMENTS – LESSONS LEARNED

PREVENT DRAINAGE THROUGH ADJACENT PROPERTIES WITHOUT EASEMENT

- Flow from one property through another typically requires a drainage easement and analysis
- Multiple properties draining through another property without an easement often result in issues

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Stormwater Control Selection

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DESIGN FOCUS AREA – SECTION 1.3 OF THE iSWM CRITERIA MANUAL

- Water Quality Protection
- Streambank Protection
- Flood Mitigation and Conveyance

DESIGN FOCUS AREA – TABLE 1.2 OF THE iSWM CRITERIA MANUAL

- Table 1.2 - Design Storms
  - Water Quality – Criteria based on a volume of 1.5 inches of rainfall, not a frequency
  - Streambank Protection – 1-year, 24-hour storm event
  - Conveyance – 25-year, 24-hour storm event
  - Flood Mitigation – 100-year, 24-hour storm event
- Note: If a development causes no adverse impacts to existing conditions downstream, then it is possible that little or no mitigation would be required

3.8.1 – CONTROL SCREENING PROCESS

- Four criteria for evaluation – To treat water quality volume or water quantity control
  - Stormwater Management Suitability
  - Relative Water Quality Performance
  - Site Applicability
  - Implementation Considerations
- Specific criteria - three additional factors for evaluation
  - Physiographic Factors
  - Soils
  - Special Watershed or Stream Considerations
- Consider environmental regulations in regards to where a structural control is located
- Presented as seven matrices in the Stormwater Control Selection chapter

3.8.1 – CATEGORIES OF STORMWATER CONTROLS

- Bioretention Areas
- Channels
- Chemical Treatment
- Conveyance System Components
- Detention
- Filtration
- Hydrodynamic Devices
- Infiltration
- Ponds
- Porous Surfaces
- Proprietary Systems (i.e. Stormceptors)
- Re-Use (i.e. Rain barrels)
- Wetlands

TABLE 3.15 – STORMWATER MANAGEMENT SUITABILITY

- Matrix showing capability of each structural control option (primary and secondary)
  - Water Quality Treatment
    - Bioretention Areas
    - Filtration & Infiltration systems
    - Ponds and Wetlands
    - Proprietary Systems
  - Downstream Streambank Protection
    - Energy Dissipators
    - Detention & Ponds
    - Wetlands
  - Flood Control
    - On-Site – Channels, Conveyance systems, Detention, Ponds, Stormwater Wetlands
    - Downstream – Conveyance systems, Detention, Ponds, Stormwater Wetlands

TABLE 3.16 – WATER QUALITY PERFORMANCE

- Matrix showing overview of pollutant removal performance for structural controls
  - Ability to provide TSS and Sediment Removal
    - Bioretention, Filtration, Infiltration, Ponds, Green Roofs, Wetlands
  - Ability to provide Nutrient Treatment
    - Chemical Treatment, Green Roofs, Modular Porous Paver Systems
  - Ability to provide Bacteria Removal
    - Chemical Treatment, Infiltration, Detention, Ponds, Wetlands
  - Ability to accept Hotspot Runoff
    - Bioretention, Chemical Treatment, Detention, Ponds
    - Wetlands

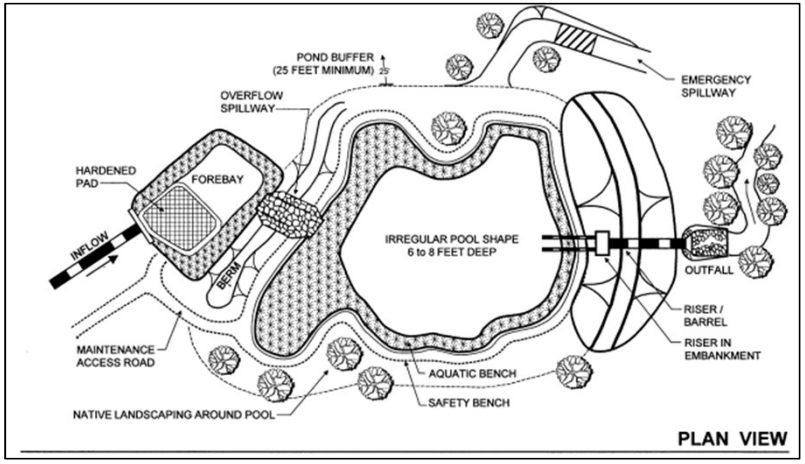

TABLE 3.17 – SITE APPLICABILITY

- Matrix showing site specific conditions for a structural control to be suitable
  - Drainage Areas
    - Min/Max limits are guidelines and can be flexible based on site, soil and project conditions
  - Space Required
    - How much space a structural control typically consumes at a site
    - Approximate area required as a percentage of the impervious area draining to the control
  - Site Slope
    - Refers to how flat the area where the facility can be installed
    - How steep contributing drainage area or flow length can be
  - Minimum Head Required
    - Estimate of minimum elevation difference needed to allow for gravity operation of control
  - Depth to Water Table
    - Indicates minimum depth to seasonally high water table to floor of a control structure

TABLE 3.18 – IMPLEMENTATION CONSIDERATIONS

- Matrix showing additional considerations for applicability of each structural control
  - Residential subdivision use
    - Not recommended: Most Filtration systems, Porous Surfaces
  - Ultra-Urban
    - Not recommended: Channels, Dry Detention, Ponds, Stormwater wetlands
  - Construction Cost
    - High / Moderate / Low – Capital Costs
  - Maintenance
    - High / Moderate / Low – Maintenance Burden
- Note: All structural controls require routine inspection and maintenance

TABLE 3.19 – SPECIFIC CRITERIA: PHYSIOGRAPHIC FACTORS

- Low relief areas (very flat)
  - Primarily located east of the Dallas metropolitan area
  - Need special consideration because many structural controls require a hydraulic head to move stormwater runoff through the facility
- High relief areas (steep and hilly)
  - Primarily located west of the Fort Worth metropolitan area
  - May limit the use of some structural controls that are made for low relief areas
  - May impact dam heights to the point that a structural control becomes infeasible
- Karst terrain
  - Limited to portions of Palo Pinto, Erath, Hood, Johnson, Somervell
  - Infiltration of polluted waters into underground streams ~ prohibited
  - Ponding areas may not reliably hold water

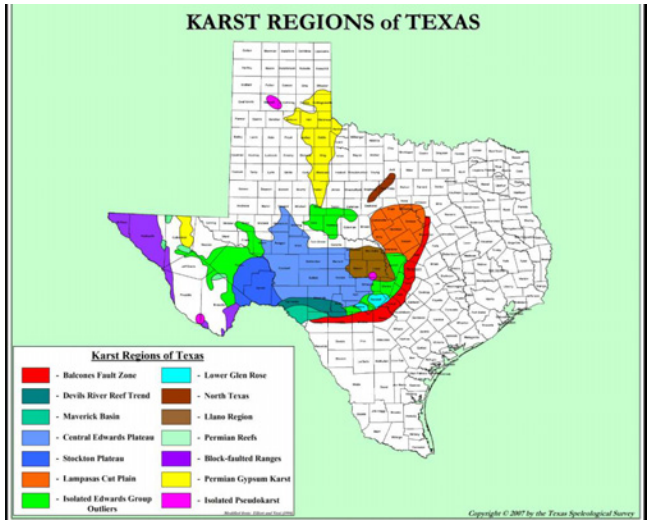

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TABLE 3.20 – SPECIFIC CRITERIA: SOILS

- Review NRCS hydrologic soil groups data for your location
- Additional detailed geotechnical tests may be required
  - Infiltration feasibility
  - Confirm permeability
  - Slope stability analysis

TABLE 3.21 – SPECIFIC CRITERIA: SPECIAL WATERSHED OR STREAM CONSIDERATIONS

- Review project with appropriate authority to determine if additional structural control criteria is needed for the watershed of your location
  - Could have an adopted local watershed plan
  - Special provisions for the watershed could be in place (more stringent criteria)
- May need to consider
  - High Quality Streams – streams with a watershed impervious cover less than approximately 15%
  - Wellhead/Aquifer protection – for areas that recharge existing public water supply wells
  - Reservoir or drinking water protection – watersheds that deliver surface runoff to a public supply reservoir or impoundment may require additional treatment

TABLE 3.22 – LOCATION AND PERMITTING CHECKLIST

- Restrictions
  - Locating a structural control within an area when expressly prohibited by law
  - Locating a structural control within an area that is strongly discouraged
    - Applicant will have to justify locating the stormwater control within the regulated area
    - Obtain local, state, and/or federal permits first
  - Structural stormwater controls must be set back a fixed distance from a site feature

TABLE 3.22 – LOCATION AND PERMITTING CHECKLIST

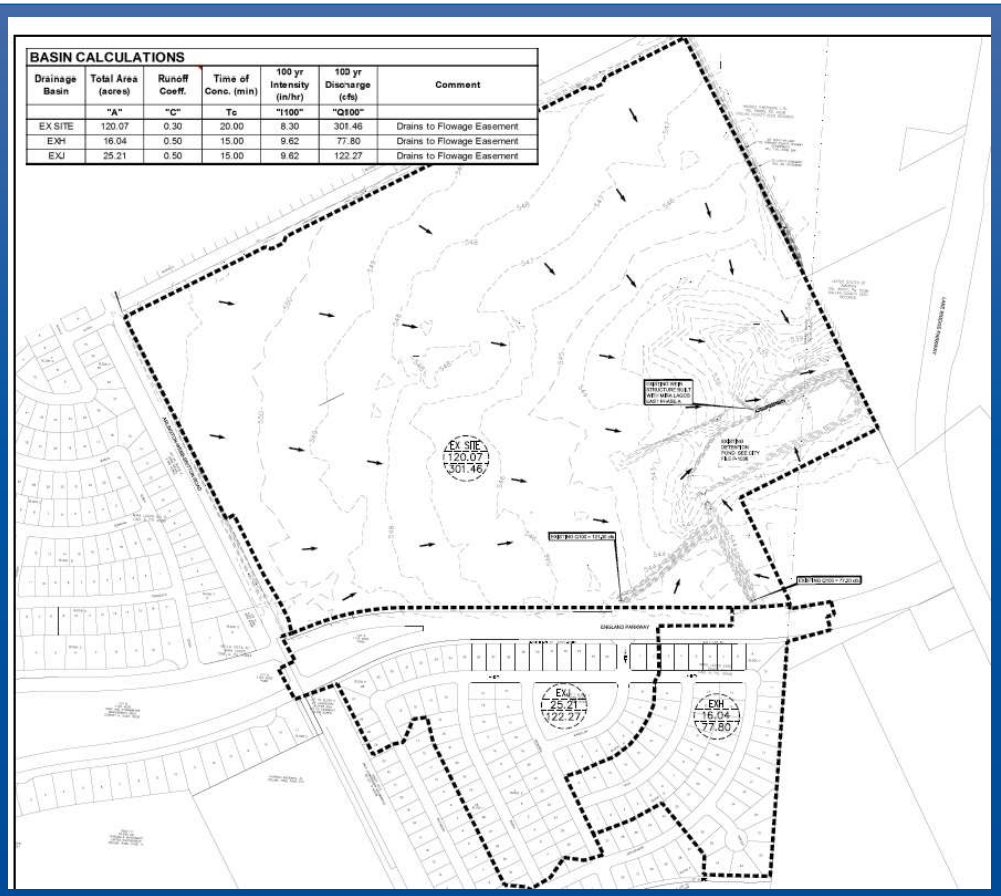
- Jurisdictional Wetlands – Waters of the U.S.
- Stream Channels – Waters of the U.S.
- Water Quality Certification – TCEQ
- Impaired Water Bodies – TCEQ
- Groundwater Management Areas – TCEQ
- Floodplain Areas – NFIP/FEMA/Local Floodplain Administrator
- Stream Buffer – Local Authority
- Utilities – Local Authority
- Roads – TxDOT, Local Authority (Department of Public Works)
- Structural Control Setbacks – Local Authority/Franchise Utilities
- Septic Drain Fields – Local Authority (50-foot setback from drain field edge)
- Water Wells – Local Authority

EXAMPLE – STORMWATER CONTROL SELECTION

- *Undeveloped site in NCTCOG region*
- *Planned Residential Subdivision*
- *Site slope is 10%-12%*
- *Major utility line crossing the site*
- *Downstream assessment shows detention is required*
- *Municipality has stormwater quality criteria*
- *Jurisdictional Waters of the U.S. are located on-site*
- *Downstream receiving stream is stable*

EXAMPLE – STORMWATER CONTROL SELECTION

- *Pre-Project Site*



BASIN CALCULATIONS

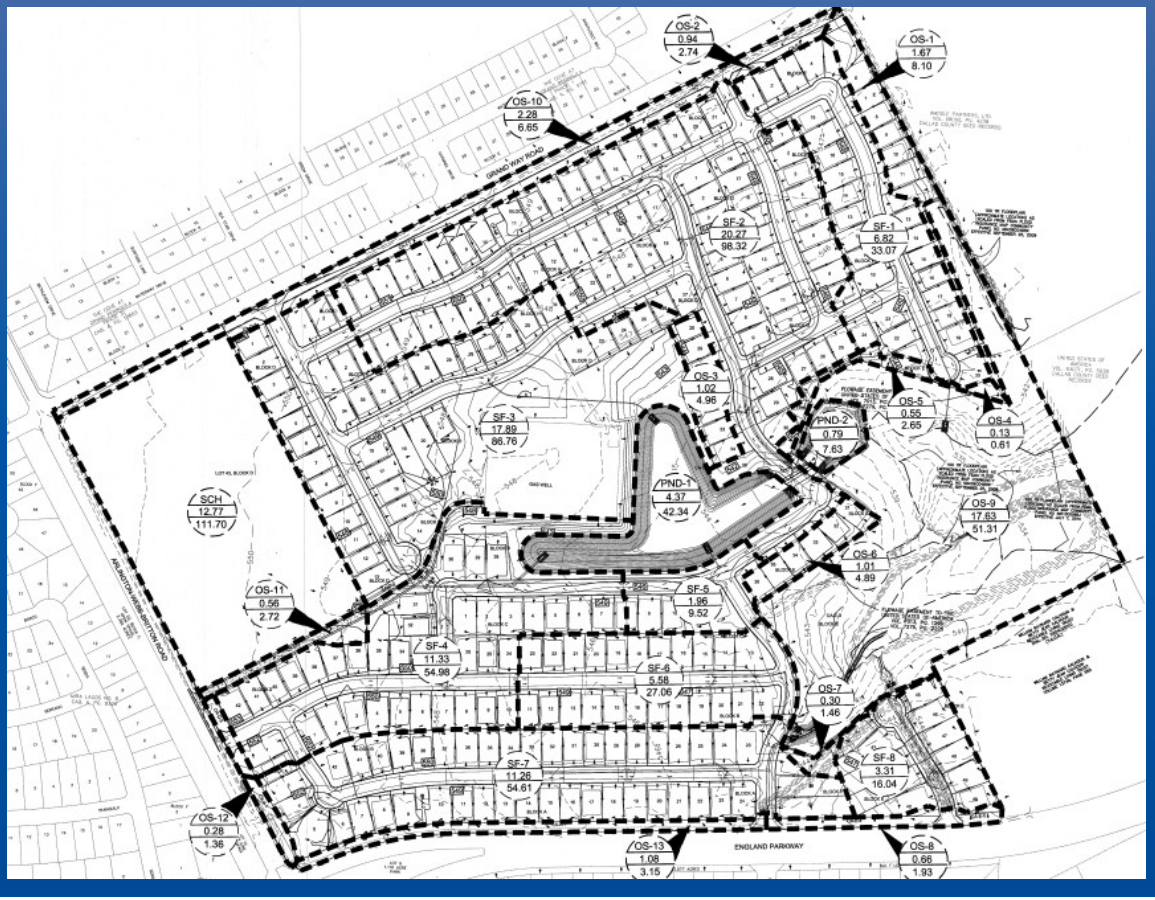
Drainage Basin	Total Area (acres)	Runoff Coeff.	Time of Conc. (min)	100 yr Intensity (in/hr)	100 yr Discharge (cfs)	Comment
	"A"	"C"	Tc	"I100"	"Q100"	
EX SITE	120.07	0.30	20.00	8.30	301.46	Drains to Flowage Easement
EXH	16.04	0.50	15.00	9.62	77.80	Drains to Flowage Easement
EXJ	25.21	0.50	15.00	9.62	122.27	Drains to Flowage Easement

STORMWATER CONTROL SELECTION EXAMPLE

- **Table 3.15 – Stormwater Treatment Suitability**
  - Ponds and Wetlands are Primary Control Structures for Water Quality and Flood Control
  - Detention – only a secondary control for Water Quality
  - Could have a combination Dry Detention and pond/wetland if site allows
- **Table 3.16 – Water Quality Performance**
  - Ponds and Wetlands have 80% TSS/Sediment Removal Rate
- **Table 3.17 – Site Applicability**
  - Ponds – Site slope max is 15% ✓
  - Wetlands – Site slope max is 8% ✘
- **Table 3.18 – Implementation Considerations**
  - Ponds – Allow for Residential Subdivision Use
  - Multiple ponds can be used for water quality volume and water quantity control

EXAMPLE – STORMWATER CONTROL SELECTION

- *Proposed Development*



STORMWATER CONTROL SELECTION EXAMPLE

- **Table 3.19 – Physiographic Factors**
  - Low to medium relief area
  - Upstream pond has 8 feet of normal pool depth (amenity & water quality)
  - Most downstream pond has 4 feet of pool depth (flood control)
- **Table 3.20 – Soils**
  - NRCS Data shows “C” and “D” type soils – pond liner most likely not required
  - Geotechnical study is still performed that provides recommendations
- **Table 3.21 – Special Watershed Considerations**
  - Downstream receiving stream is not considered a high quality stream
  - No Aquifer protection is required

STORMWATER CONTROL SELECTION EXAMPLE

- **Location and Permitting Considerations**
  - Jurisdictional Waters of the U.S. are located on-site
    - Intermittent stream
  - Stormwater Control Ponds are located away from stream but tie-in
  - Pre-Construction Notification is filed with USACE
- **Major utility line crossing (with easement)**
  - Stormwater Control Ponds are designed to be outside of utility easement and connections between ponds are ensured to have proper clearance with existing utility line
  - Local authority permits have been obtained to perform work in utility line easement
- **Stormwater Controls determined using matrices from Chapter 3.8 ✓**
- **Permits obtained and project construction commences ✓**

Integrated Construction Criteria

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INTEGRATED CONSTRUCTION CRITERIA

APPLICABILITY

Temporary construction controls are required for:

- Land disturbing activity of one acre or more
- Land disturbing activity of less than one acre, where the activity is part of a common plan of development that is one acre or larger

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WHY ARE CONSTRUCTION SITES SO REGULATED?

"Construction activity can contribute more sediment to streams than would be naturally deposited over several decades." - EPA

INTEGRATED CONSTRUCTION CRITERIA

WHY ARE CONSTRUCTION SITES SO REGULATED?

Sediment is #1 Pollutant by volume in the world

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WHAT IS AN iSWM CONSTRUCTION PLAN?

- Erosion Controls
- Sediment Controls
- Material and Waste Controls

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EROSION CONTROLS

Measures used to retain soil in place

- Limits of Disturbance – Minimize disturbed area
- Slope Protection – Protect steep or erodible slopes
- Channel Protection - Energy Dissipaters, Turf Reinforcement Mats, etc.
- Temporary Stabilization – Required for disturbed areas where work stops for 14 days or more.
- Final Stabilization – Established vegetation and BMPs meeting contract requirements

SEDIMENT CONTROLS

Measures used to trap sediment after broken loose

- Sediment Barriers - Linear controls, sediment basins, etc.
- Perimeter Controls – Linear BMP at all down slope boundaries
- Inlet Protection
- Construction Access Controls
- Dewatering Controls – all pumped water should be discharged through a BMP prior to leaving site

INTEGRATED CONSTRUCTION CRITERIA

MATERIAL AND WASTE CONTROL

- Sanitary Facilities
- Trash and Debris
- Chemical and Hazardous Material
- Fuel Tanks
- Concrete Wash-out
- Water Line Disinfection Water
- Equipment Wash Water
- Soil Stabilizers (Lime)
- Concrete Saw-cutting water

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LESSONS LEARNED

Based on feedback preparing iSWM submittals and assisting in drainage reviews throughout the NCTCOG region where iSWM criteria has been adopted or iSWM design principles are being applied.

INTEGRATED CONSTRUCTION CRITERIA – LESSONS LEARNED

HOW IS THIS DIFFERENT THAN TYPICAL EROSION CONTROL PLANS?

- **BMP Calculations** - Drainage Area and calculations for each BMP (Design Criteria is included in iSWM).
- **Material and Waste Controls**
- **Maintenance Requirements**
- **More Plan Sheets** –
  - Existing site conditions
  - Any major construction sequences
  - Final site conditions

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Conclusion

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