The Challenge of Urban Flooding

Steven E. Eubanks, P.E., CFM
City of Fort Worth

Urban Flooding Awareness Bill

- Introduced into Congress in 2014 & 2015
- Based on Illinois law passed in 2014
- Study urban flooding, with “primary focus … on urban areas outside of special flood hazard areas”
- Never got out of committees

Urban Flooding Awareness Bill

- Adequacy of federal flood risk information
- Investigate causes:
  - global climate change;
  - increasing urbanization
  - undersized, deteriorating stormwater infrastructure
- Evaluate funding mechanisms
- Relevance of NFIP & CRS to urban flooding areas outside traditional floodplains

The Challenge of Urban Flooding

WHAT IS URBAN FLOODING?

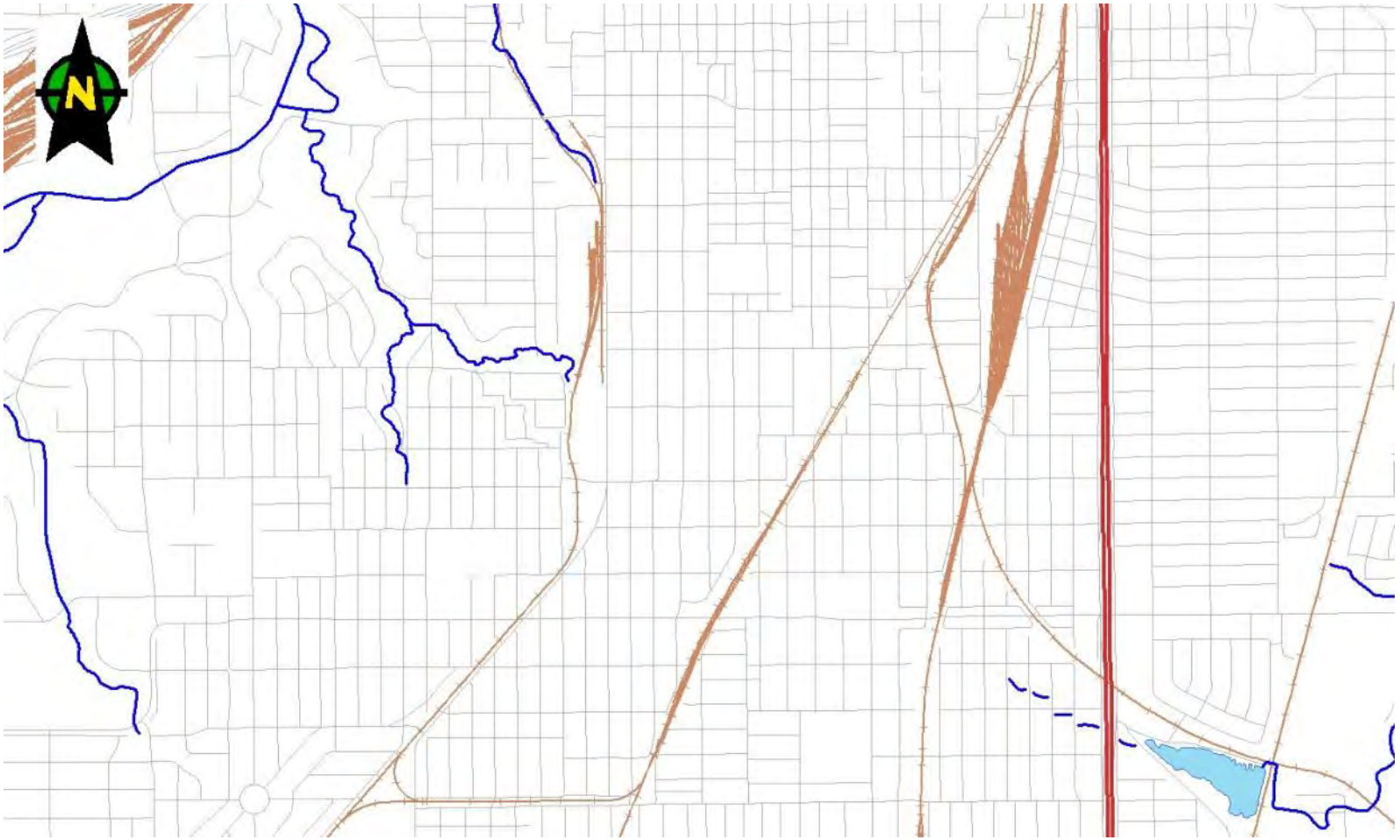
What Is Urban Flooding?

- Long-term chronic or nuisance flooding
- Typically older parts of town
- Small streams or storm drain system
- Happens fast: often gone in an hour
- Often only brief public attention
- Exacerbated by redevelopment activity

The Challenge of Urban Flooding

- Generally not addressed by NFIP
- Considered local problem only
- No affordable solutions available
- Low grant priority
- Flood risk and BFE's not mapped
- "Not floodplain"

Typical urban drainage patterns



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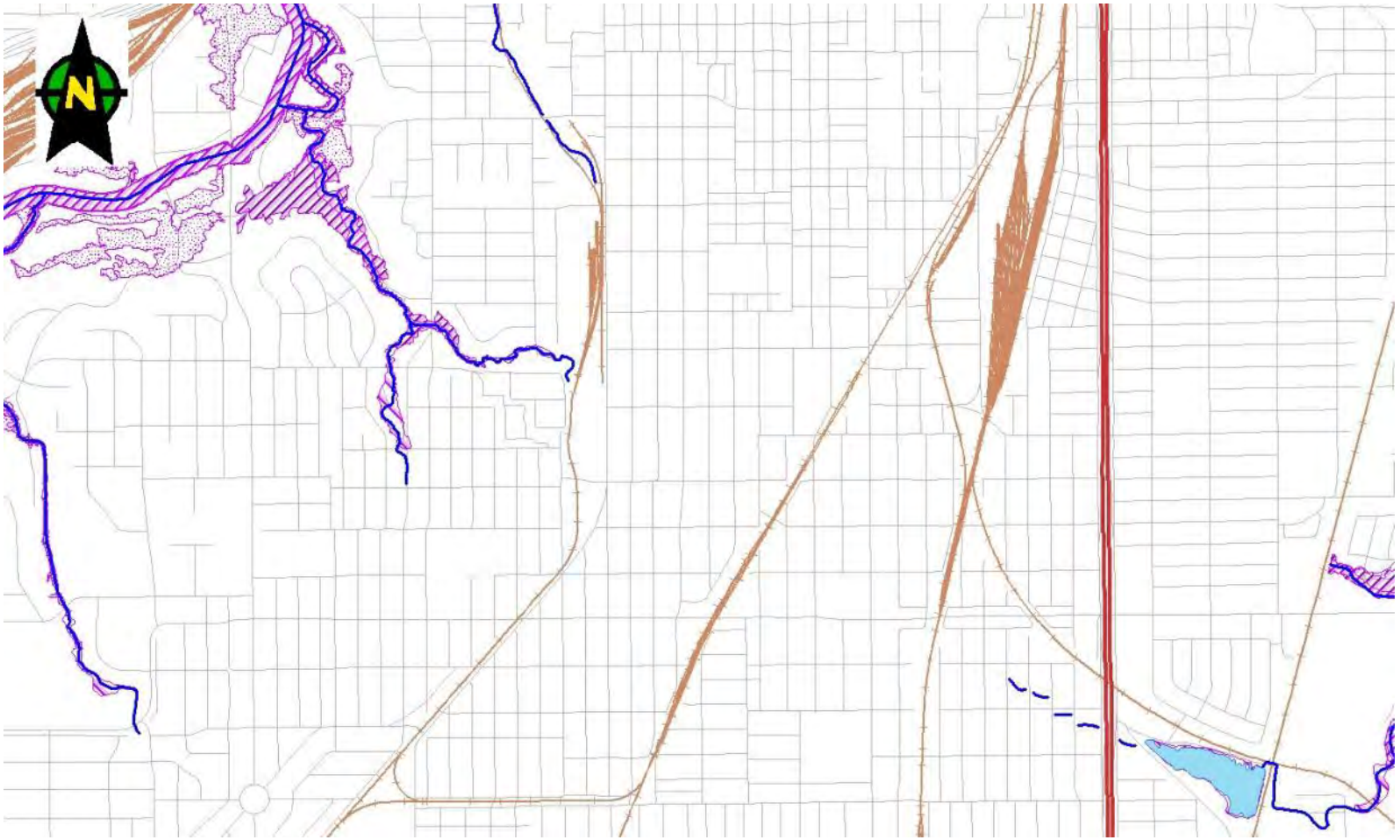
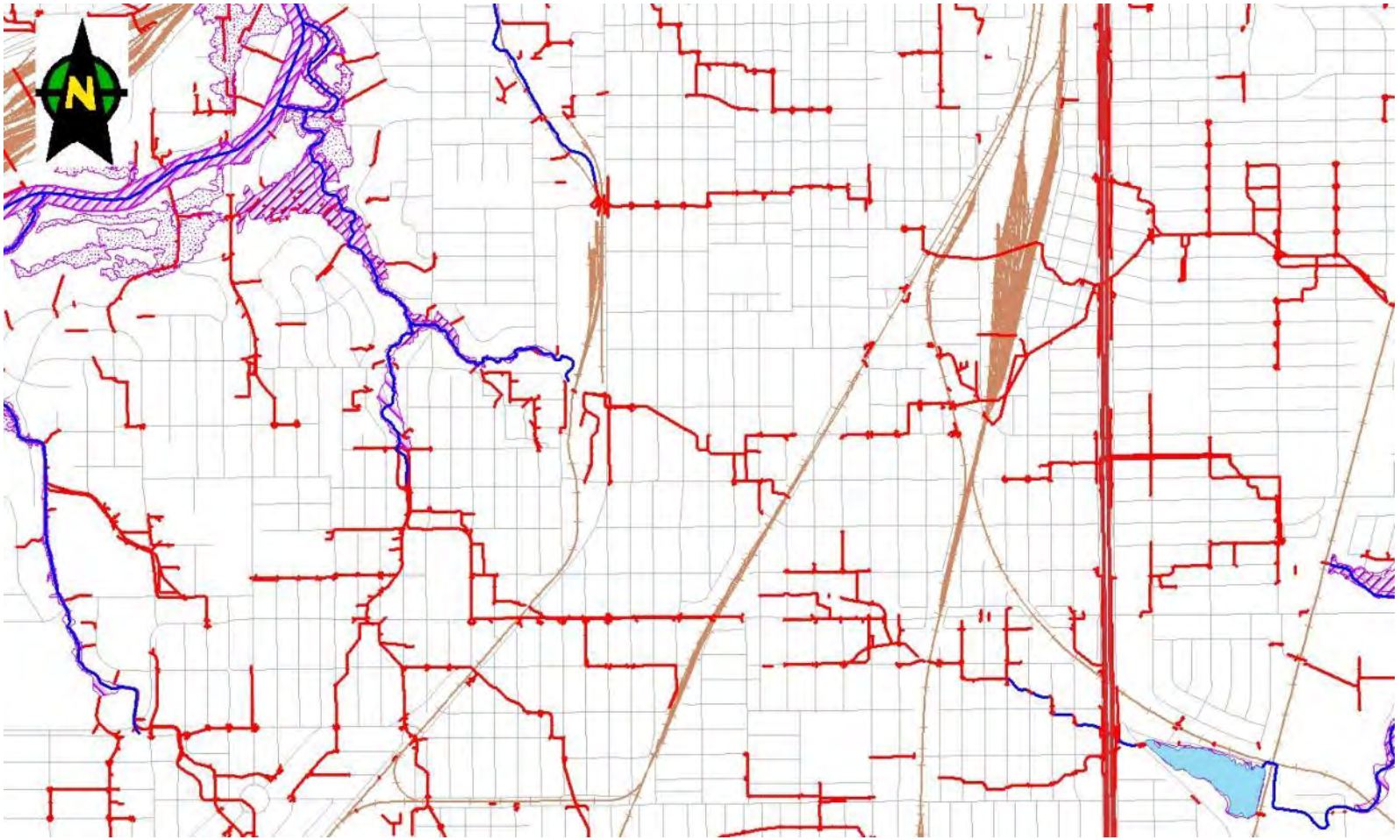


Typical urban drainage patterns



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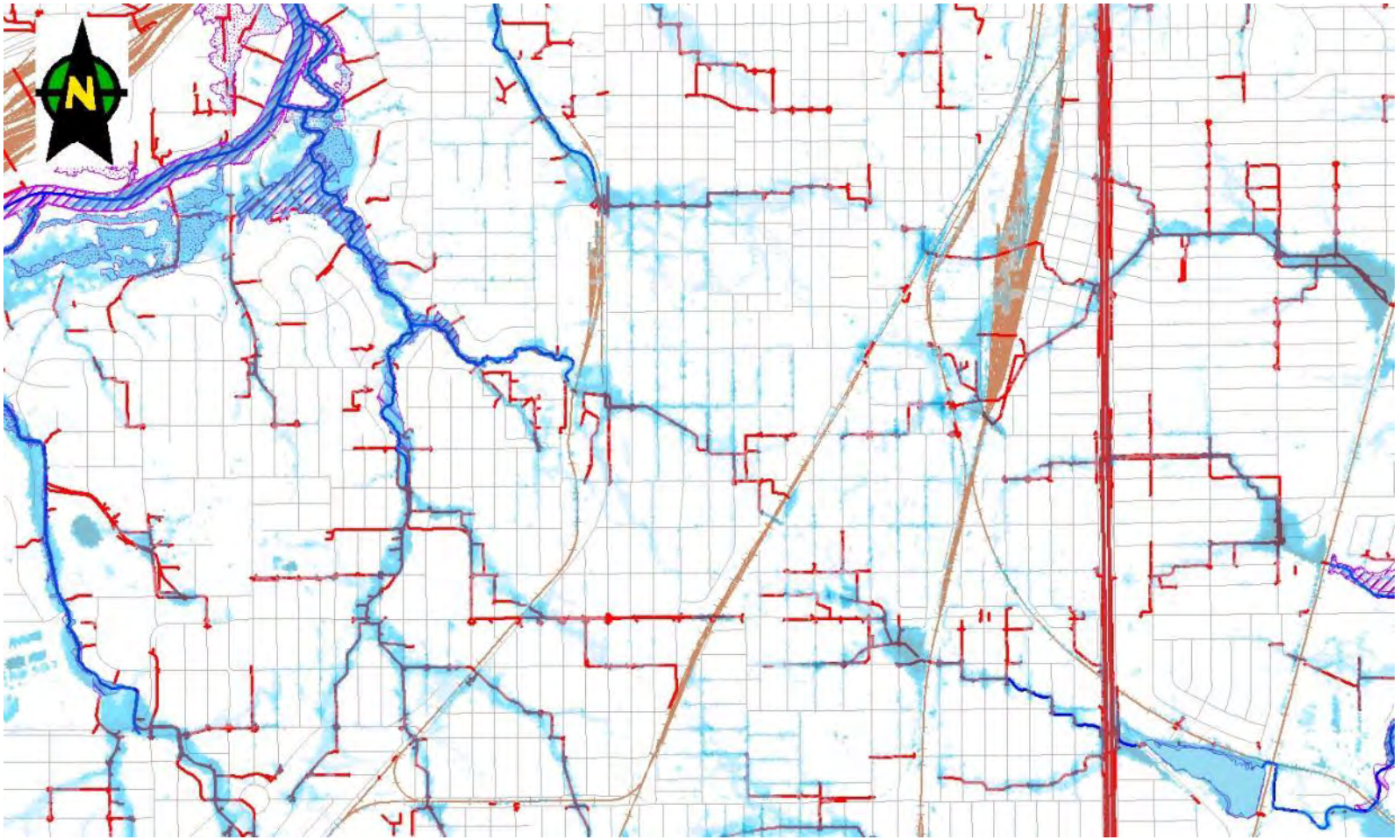


Main Causes of Urban Flooding

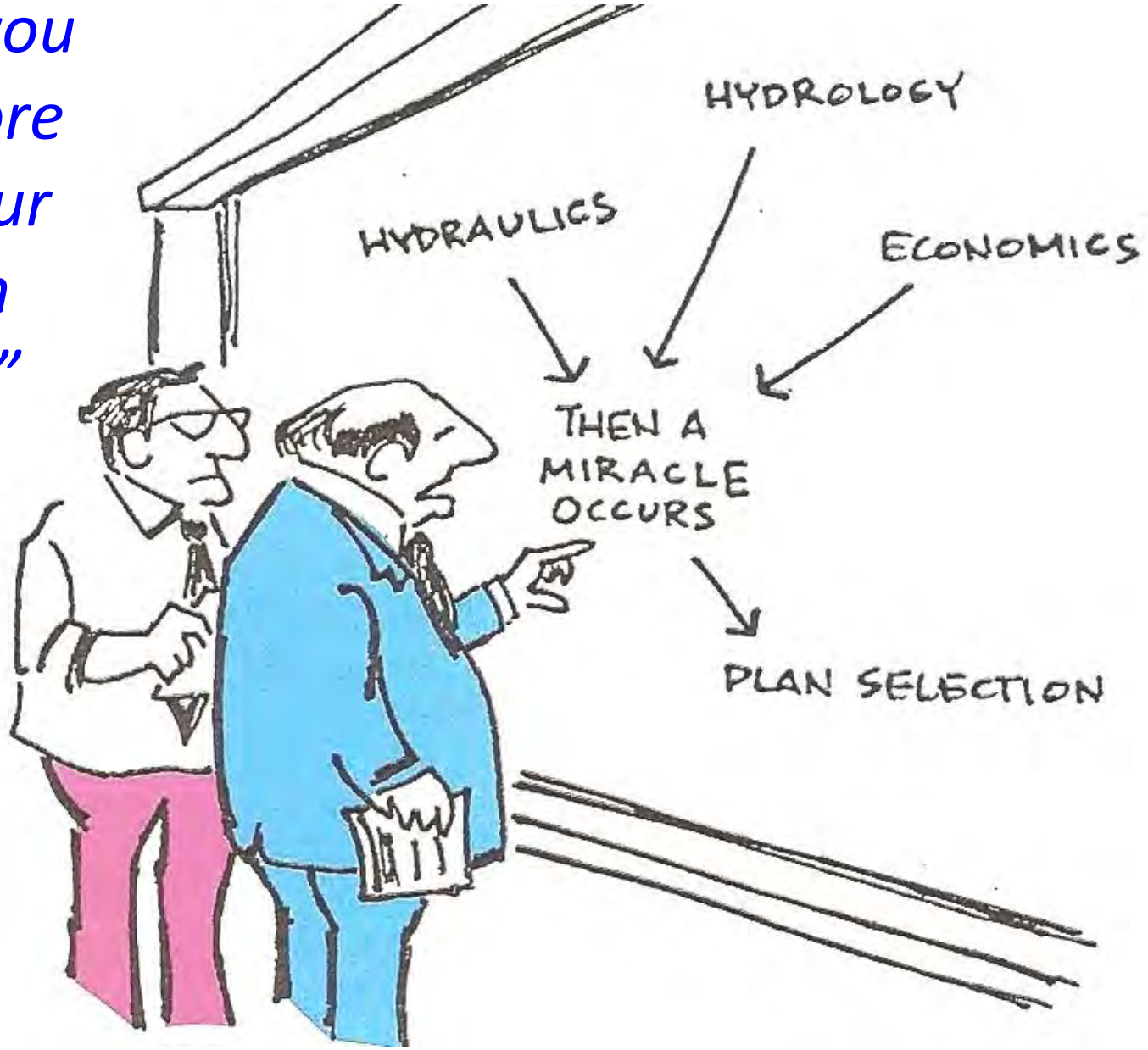
- Pre-1970, small creeks often enclosed in storm drains, usually severely undersized
- Street grid often ignored drainage patterns, leading to mid-block sumps
- Homes and buildings constructed over these creeks and storm drains, with overflow path running through them

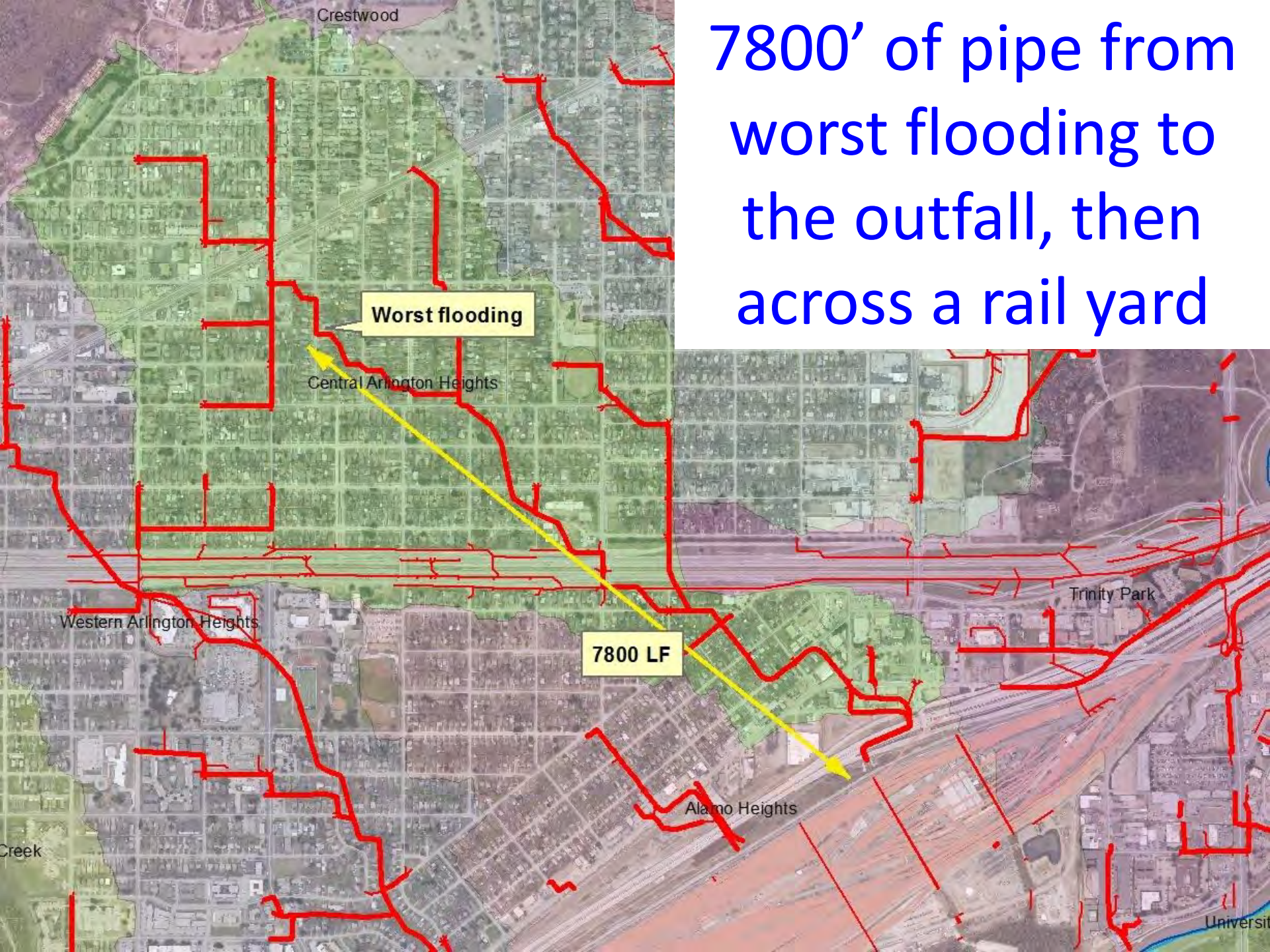
Typical Older Neighborhood

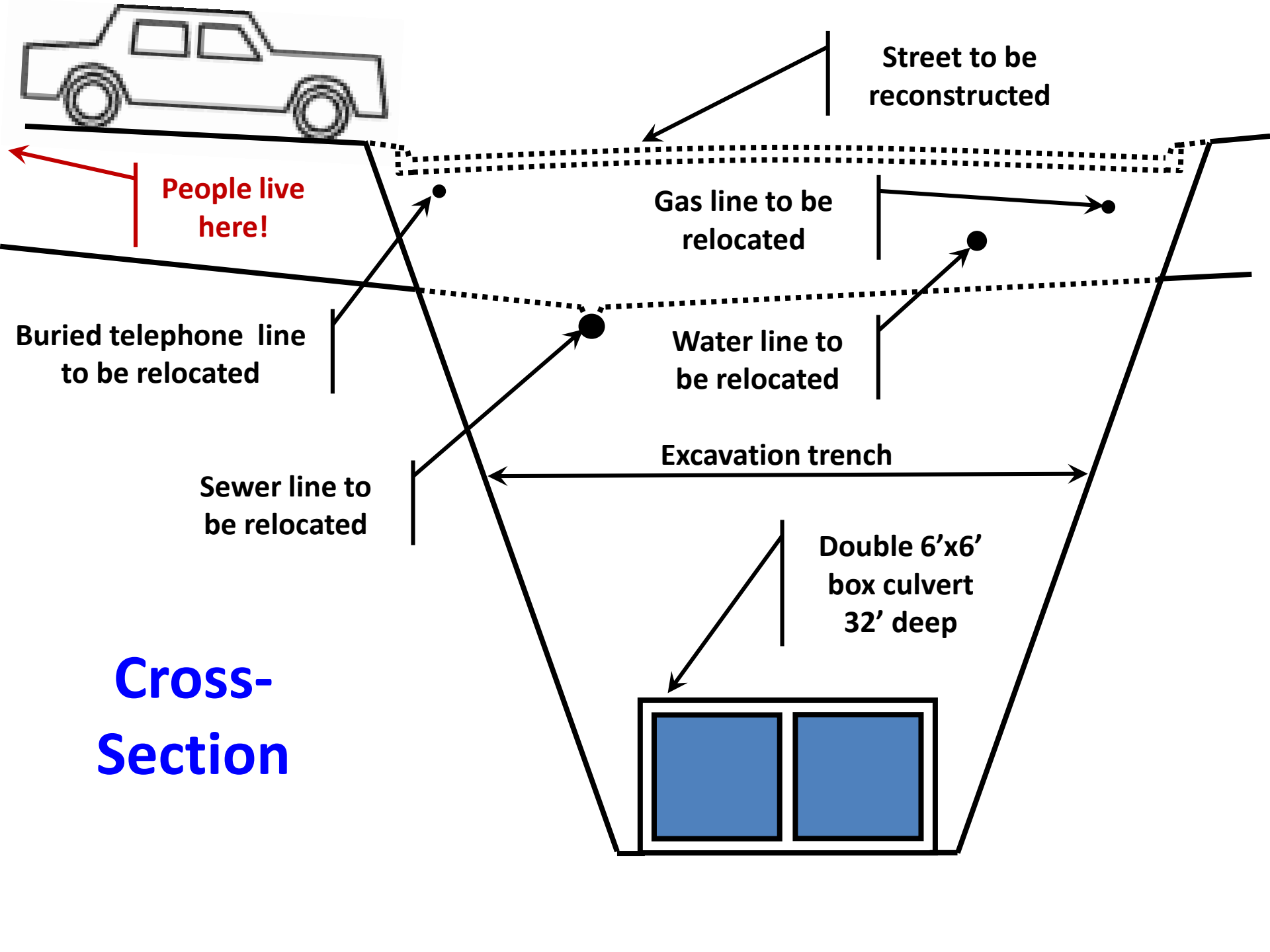
The Challenge of Urban Flooding

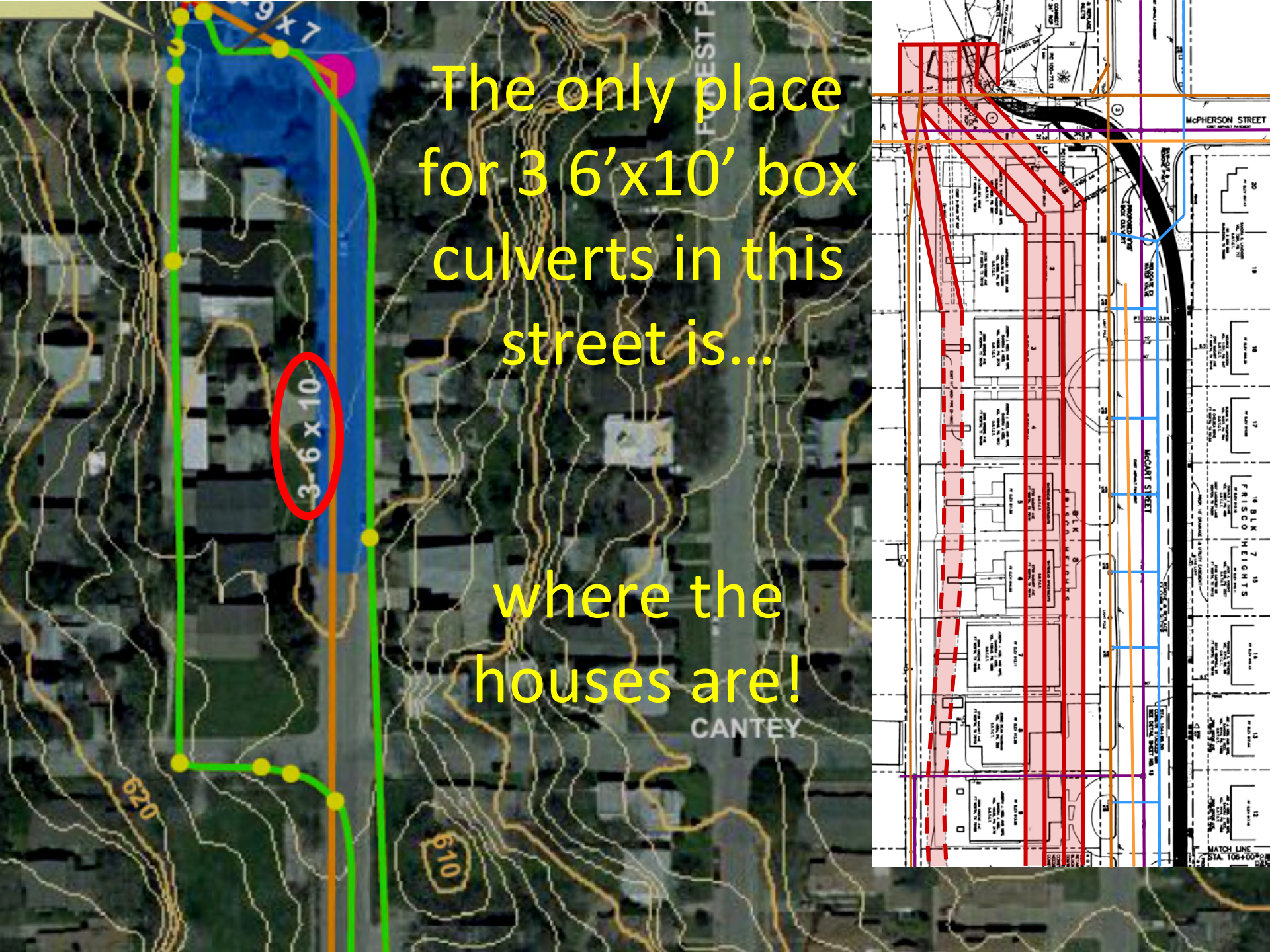
TRADITIONAL SOLUTIONS ARE NOT FEASIBLE

"I think that you should be more explicit in your explanation of this step."



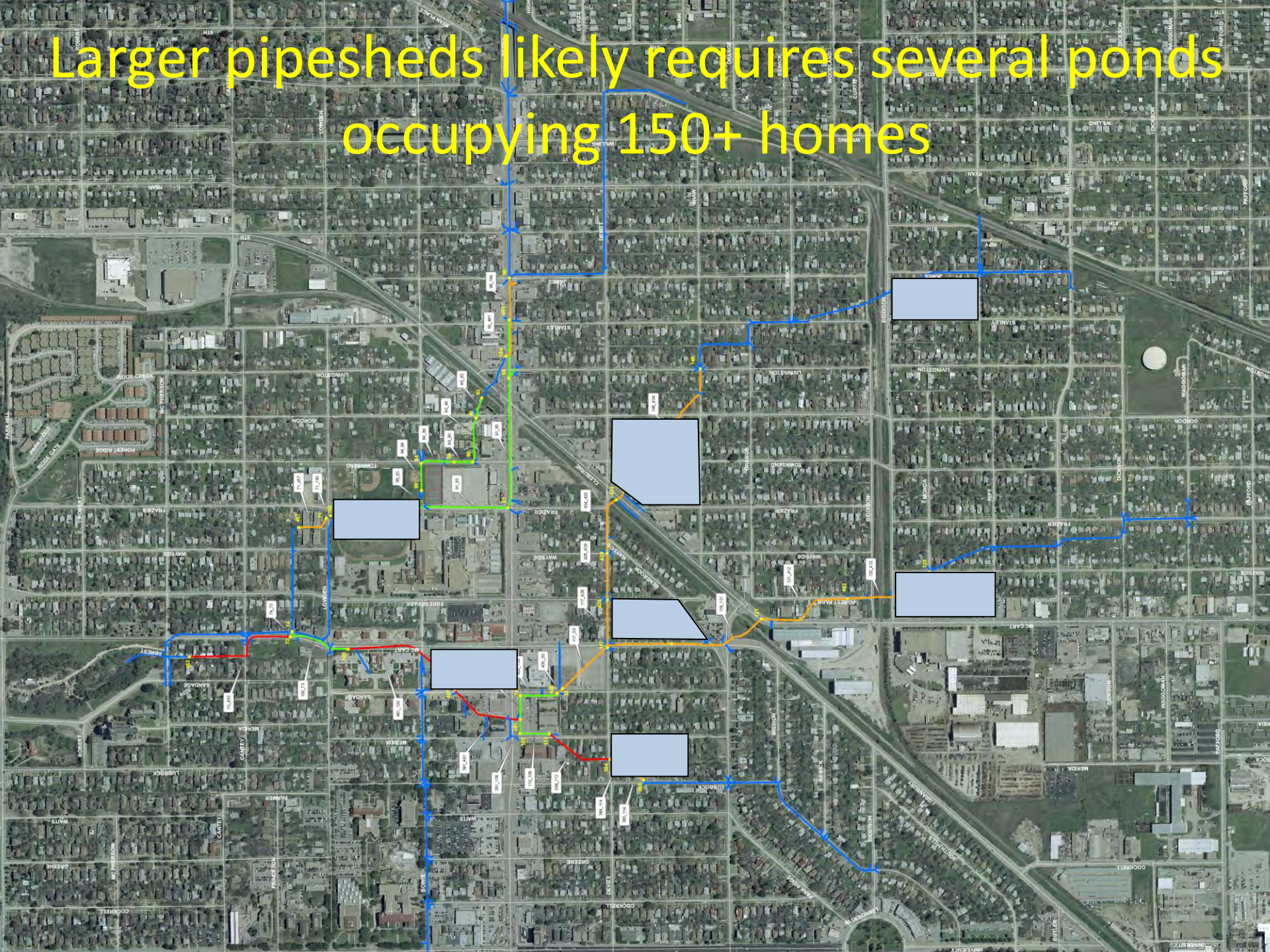

7800’ of pipe from worst flooding to the outfall, then across a rail yard
Crestwood
Worst flooding
Central Arlington Heights
Western Arlington Heights
7800 LF
Trinity Park
Alamo Heights
Creek

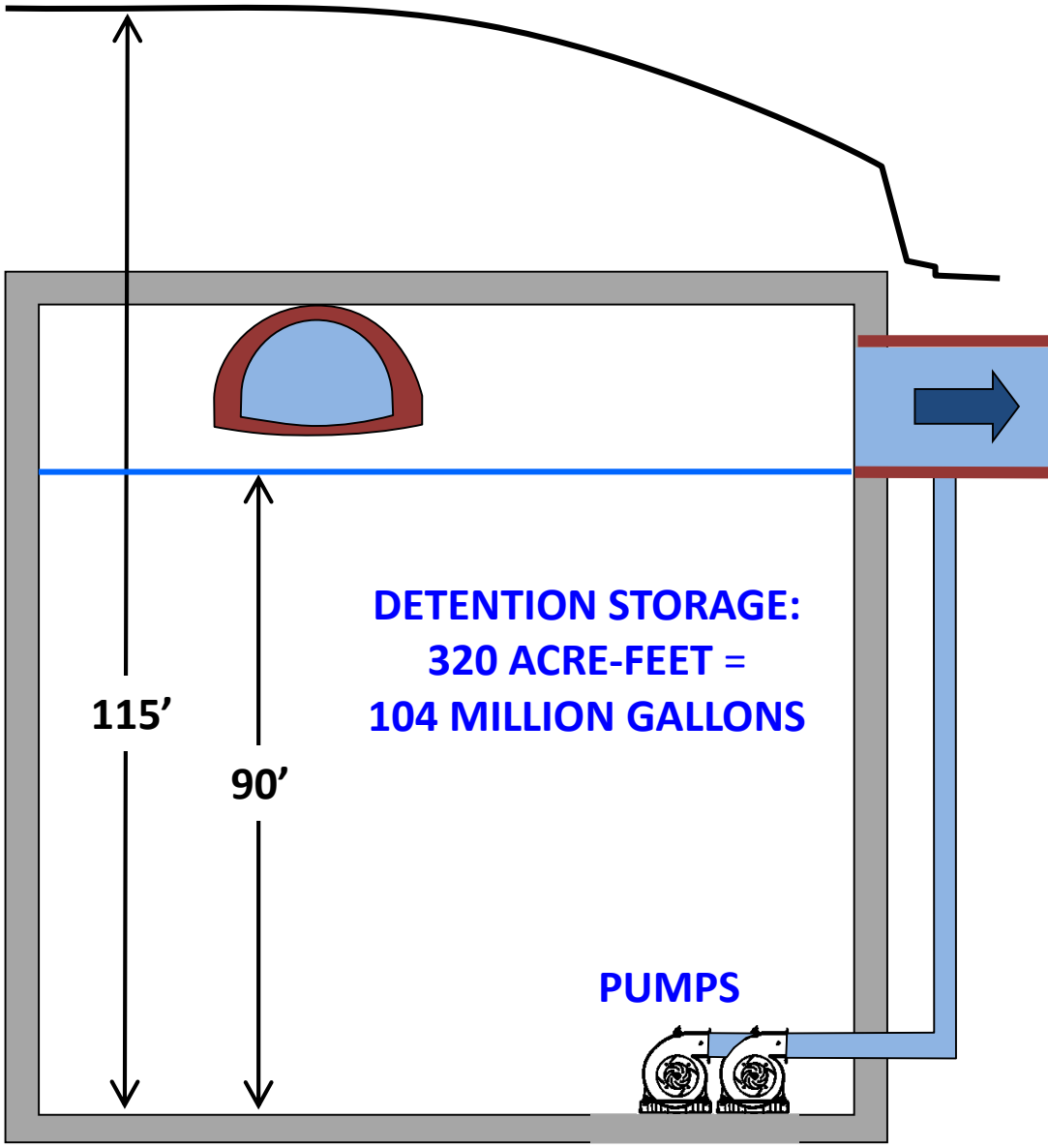

Street to be reconstructed
People live here!
Gas line to be relocated
Buried telephone line to be relocated
Water line to be relocated
Excavation trench
Sewer line to be relocated
Double 6'x6' box culvert 32' deep
Cross-Section


The only place for 3 6’x10’ box culverts in this street is…
where the houses are!
3-6 x 10
9 x 7
620
610
CANTEY
McPHERSON STREET
McCART STREET
BLK 8 FRISCO HEIGHTS
BLK 7 FRISCO HEIGHTS
MATCH LINE STA. 106+00


Tunneling preserves neighborhood
$30-50 million!
WESTERN
CARLETON
ASHLAND
TREMONT
BRYCE
EL CAMPO
PERSHING
CALMONT
LOCKE
South Hi Mount Elementary School
NATM TUNNEL BEGINS
RELOCATE OUTFALL
RAILROAD YARD
ALAMO
LISBON
CONCRETE
LANDERS
CHAMBERS
30 in.
48 in.
54 in.
60 in.
36 in.
Start 3 boxes 6 ft x 8 ft.
Legend
Points
Manhole
Junction Box
Access Shaft
Outfall
10 ft Contours
Conduits
Open Cut
Rehabilitate
Tunneling
Close and Abandon Pipe
0
750
1,500 Feet
Central Arlington Heights Watershed Planning Study
FORT WORTH
FIGURE
May 14, 2007
H:\exhibits\
FTW06134

Larger pipesheds likely requires several ponds occupying 150+ homes





Deep Detention with Pumps

Buyouts and Neighborhood Integrity

- Empty lots destroy neighborhood integrity
- Are linear parks greenways and pocket parks acceptable?

The Challenge of Urban Flooding

DOWNSTREAM CONSIDERATIONS

No Adverse Impact

- *"No Adverse Impact floodplain management takes place when the actions of one property owner are not allowed to adversely affect the rights of other property owners."* (ASFPM, 2008)

- Consistent with Texas Water Code §11.086 and similar laws in other states.

Texas Water Code §11.086

a) No person may divert or impound the natural flow of surface waters in this state, or permit a diversion or impounding by him to continue, in a manner that damages the property of another by the overflow of the water diverted or impounded.

b) A person whose property is injured by an overflow of water caused by an unlawful diversion or impounding has remedies at law and in equity and may recover damages occasioned by the overflow.

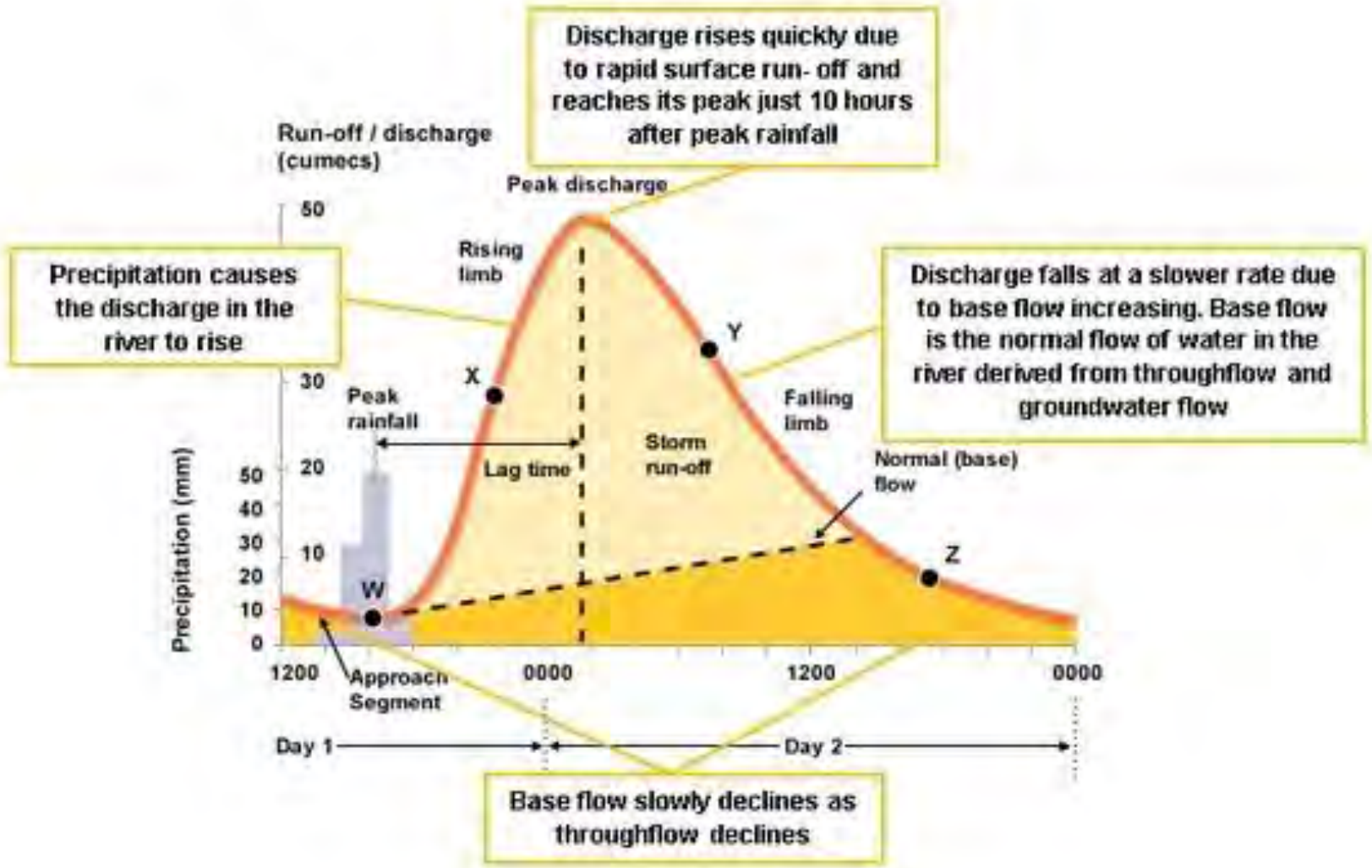
In other words: LAWSUITS!

Downstream Impacts Factors

- Increased runoff due to more impervious cover
- Increased runoff due to faster travel time in storm drains
- Increased runoff due to loss of valley storage (a/k/a “living room detention”)

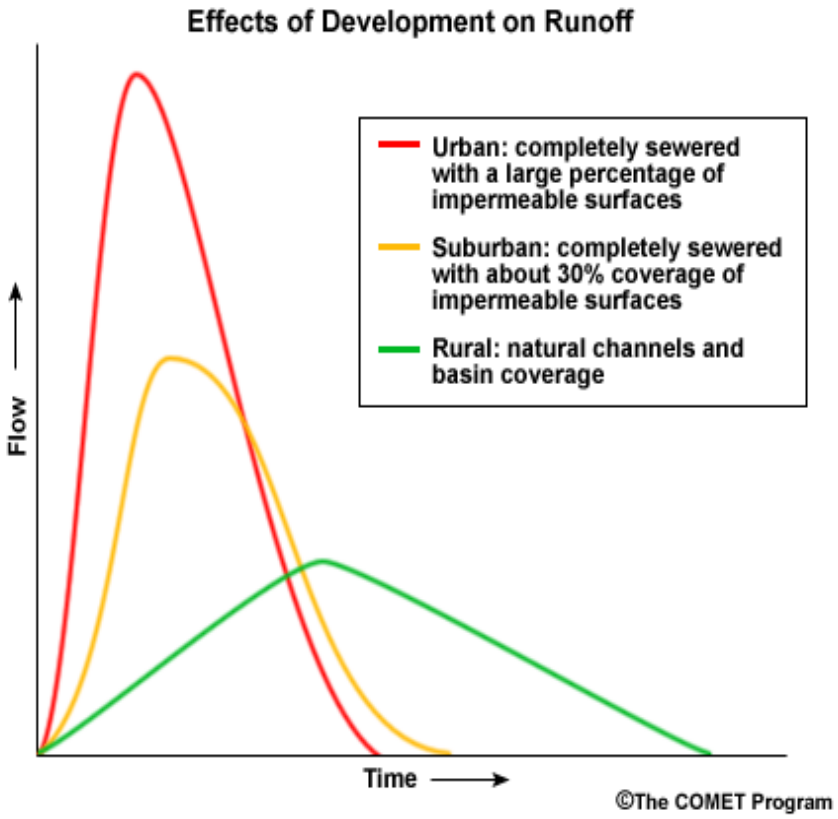
➢ Any solution has to consider these

Unit Hydrograph



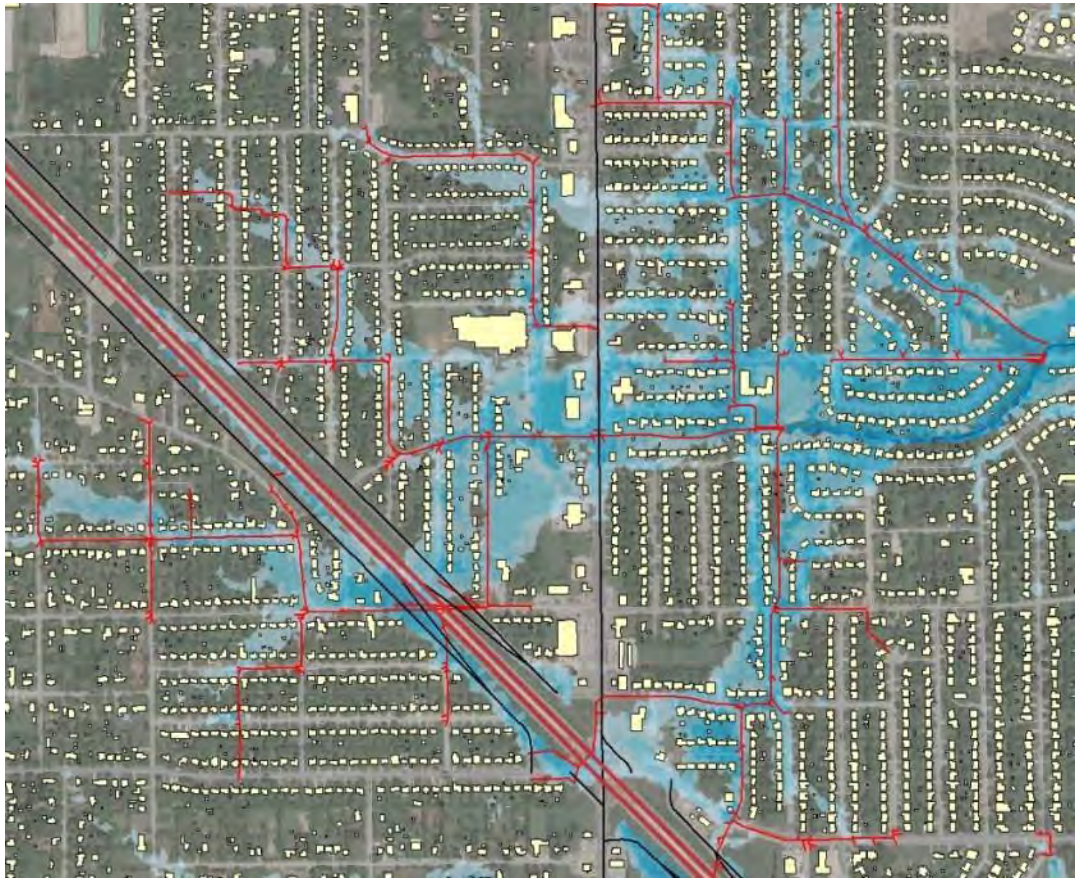
Effects of Urbanization

- Total Volume greater due to less infiltration
- Time to peak shorter due to faster flow on paving and in pipes
- Peak flow rate may be doubled or tripled



Volume Issues

Valley Storage: Undersized pipes cause floodwater to be stored in neighborhoods, decreasing the peak flows downstream.



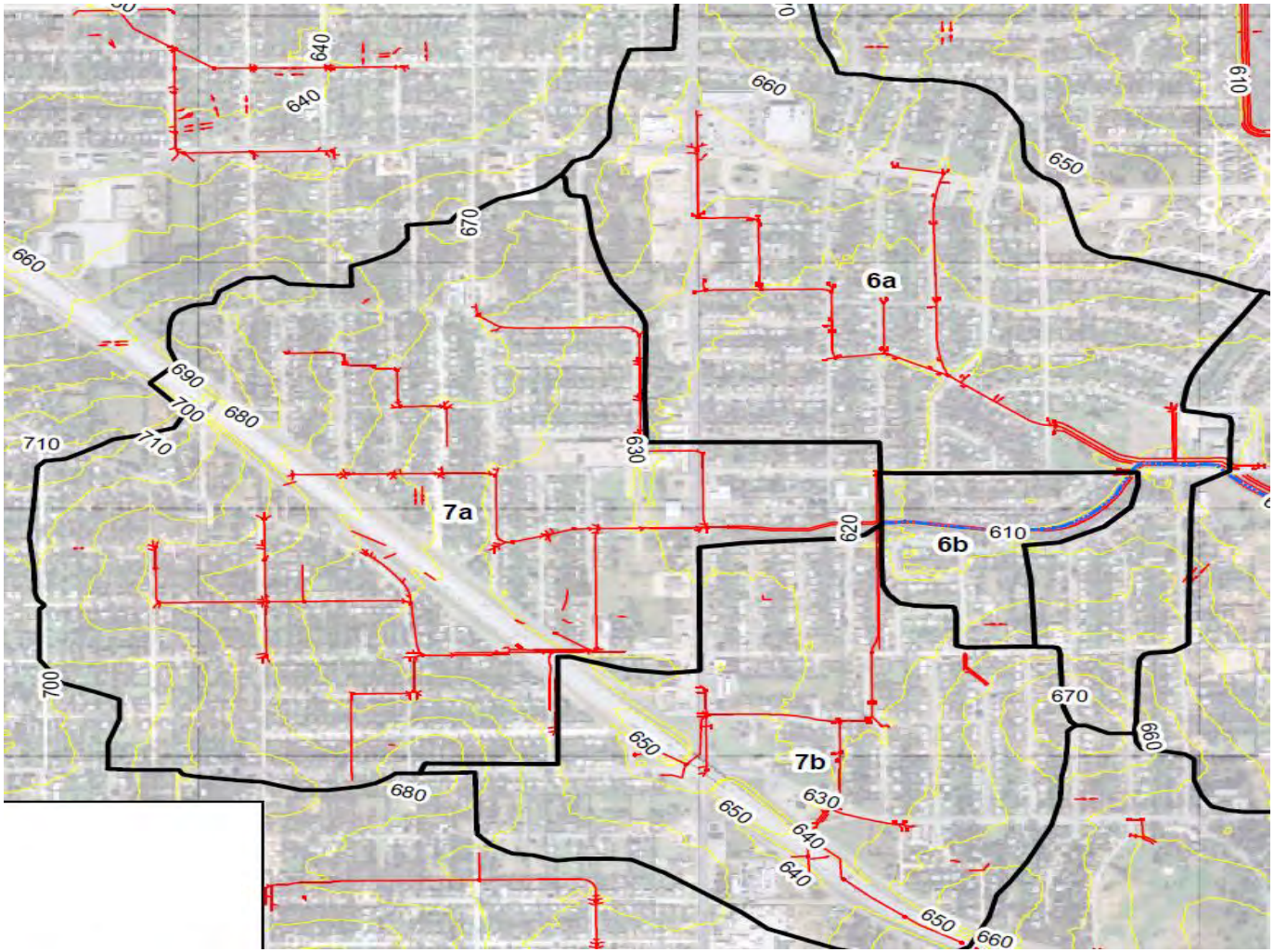
System Timing: A Case Study

EASTLAND CREEK

Eastland Creek – Eastern Fort Worth

Fort Worth Storm Water Management

- 800 acres
- Mostly Residential
- Extensive Storm Drain System in top 3 basins

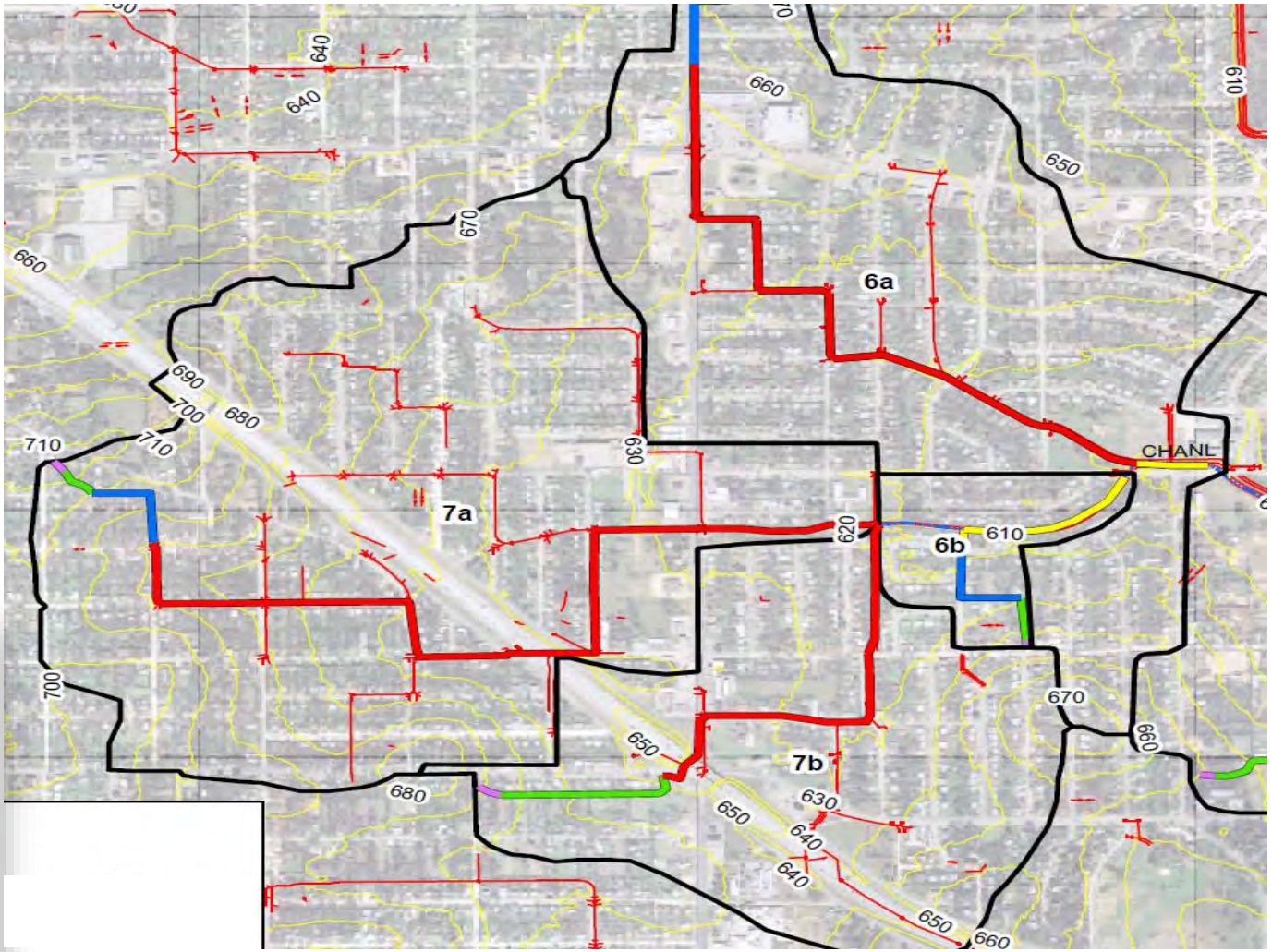


HDR

Storm Drain Flow Paths

Fort Worth Storm Water Management

- 18,000 Ft
- Average 4 ft/s Velocity



Legend

- Eastland Watershed Delineation

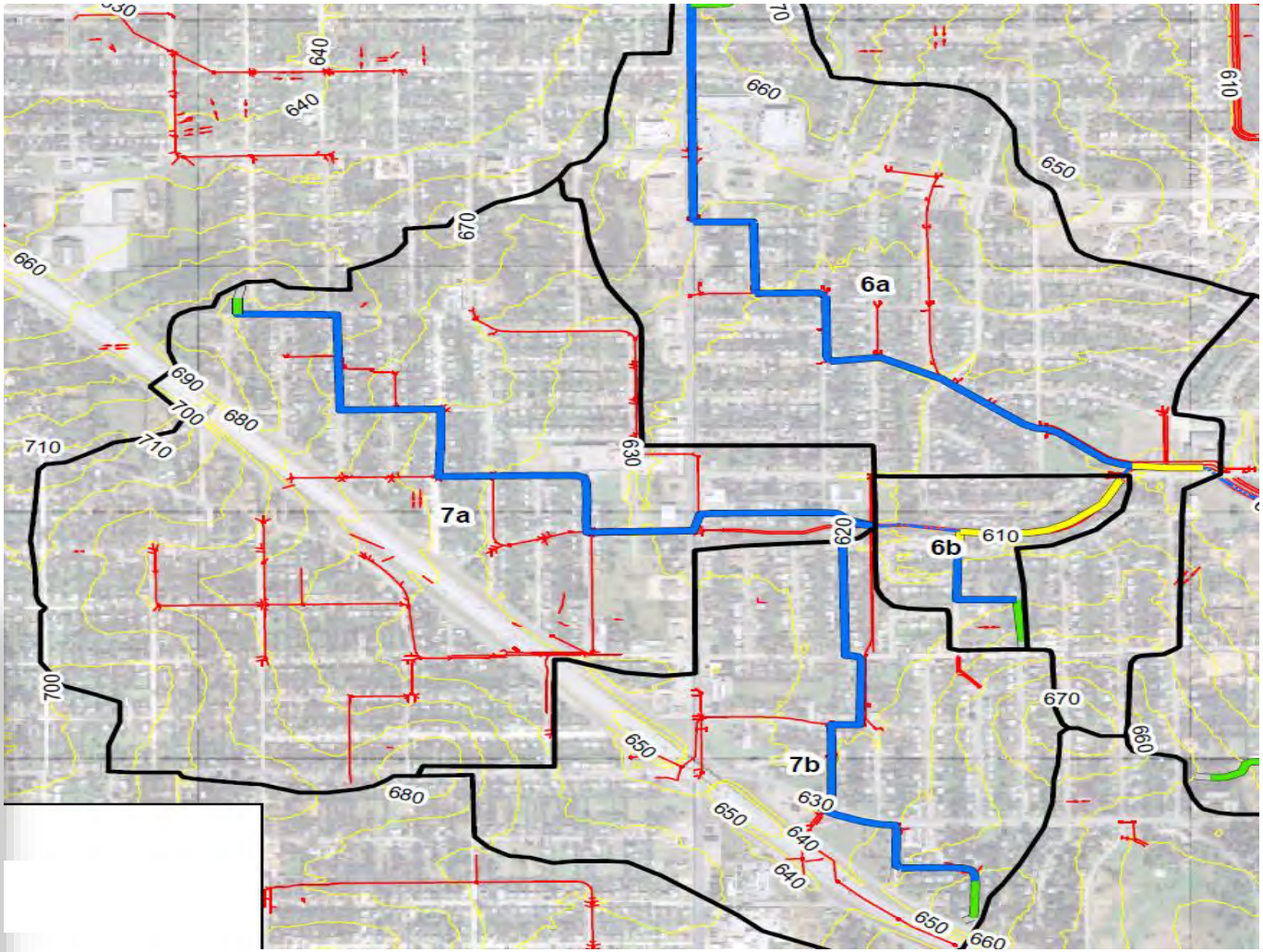
Tc Flow Type

- channel
- gutter
- pipe
- shallow
- sheet
- Eastland Creek
- Storm Sewer
- 2001 NCTCOG 10' Contours

HDR

Overland Flow Paths

- 17,000 Ft
- Average 1.5 ft/s Velocity



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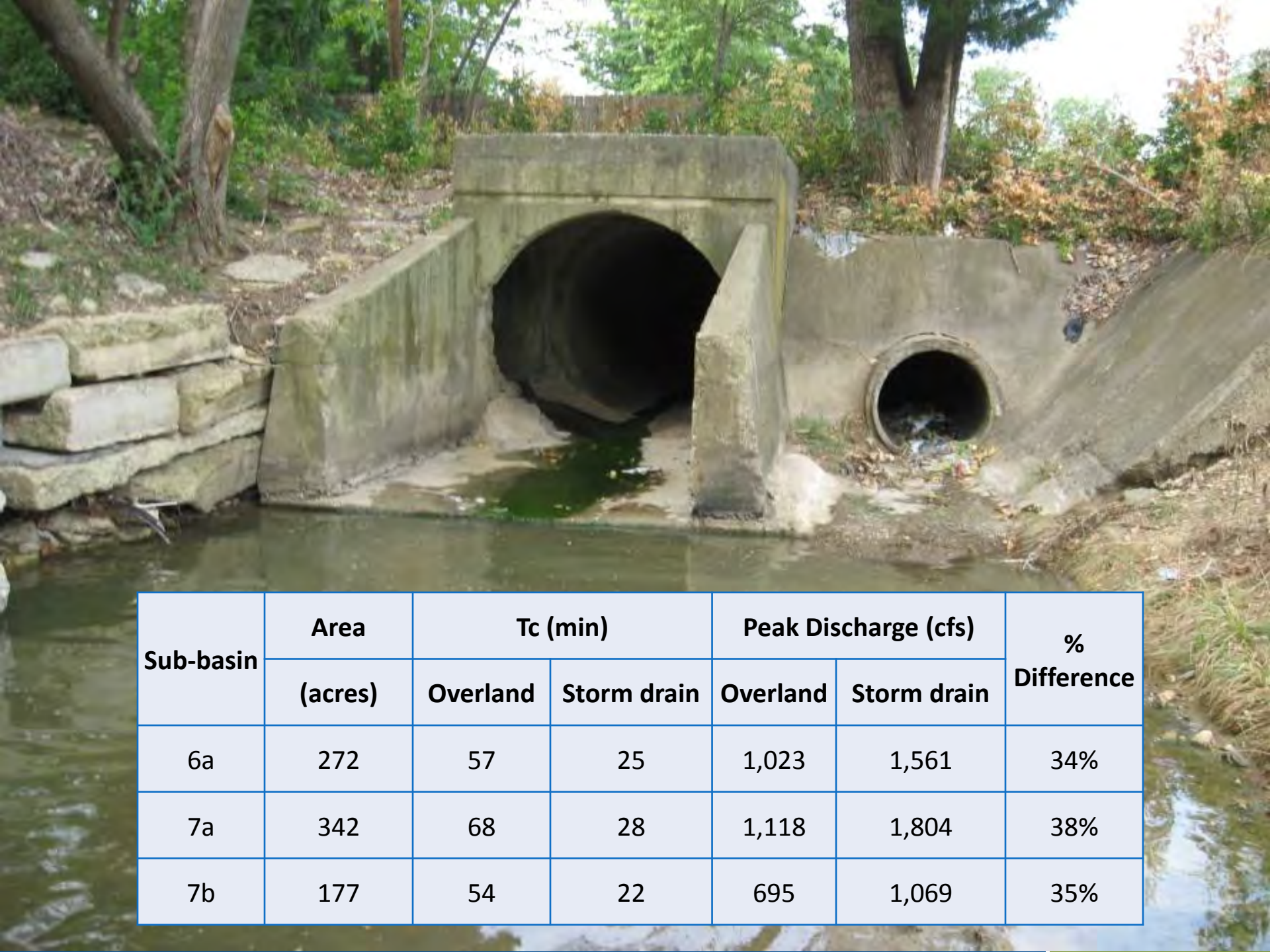
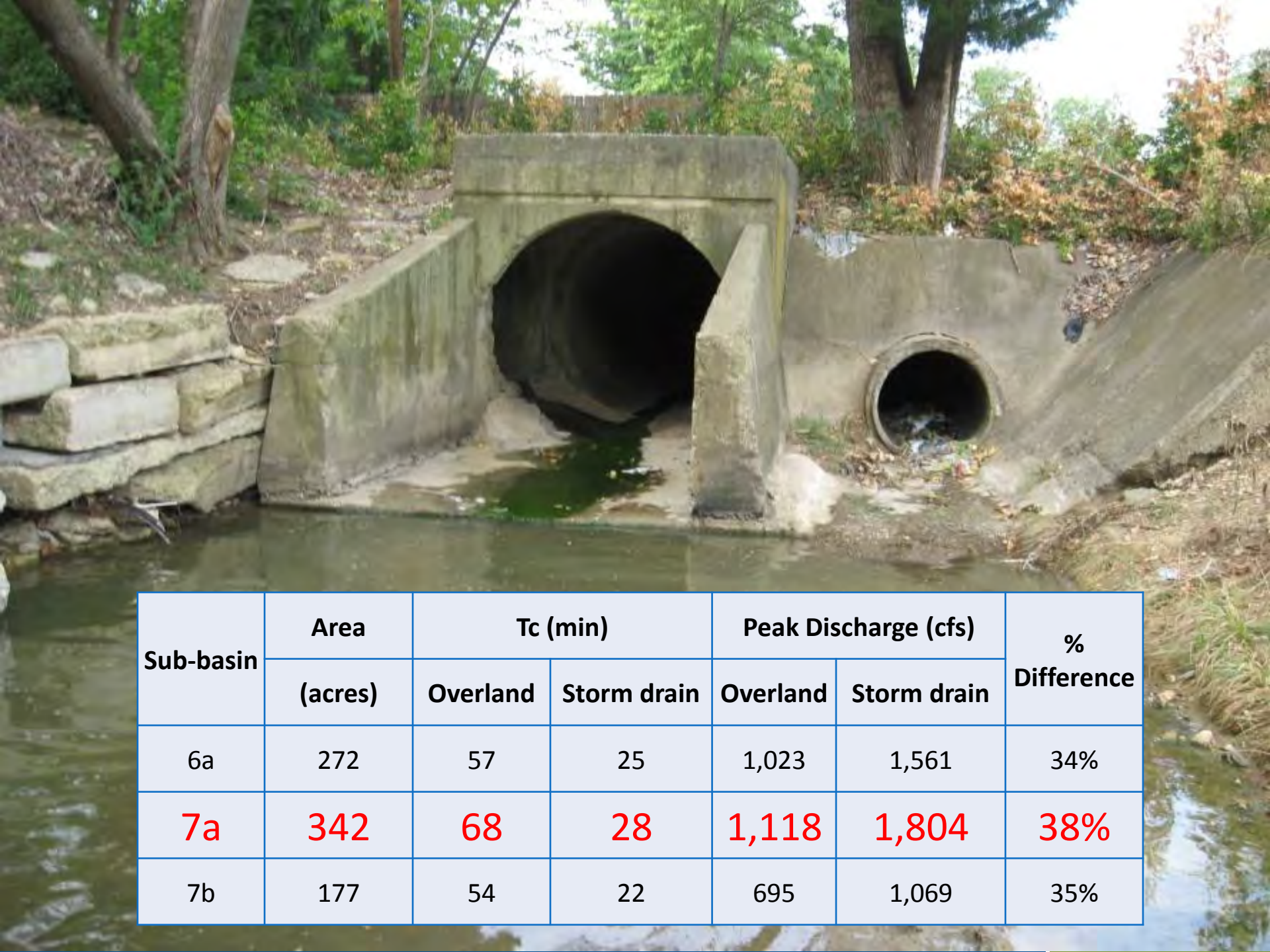


Sub-basin	Area	Tc (min)		Peak Discharge (cfs)		% Difference
	(acres)	Overland	Storm drain	Overland	Storm drain	
6a	272	57	25	1,023	1,561	34%
7a	342	68	28	1,118	1,804	38%
7b	177	54	22	695	1,069	35%



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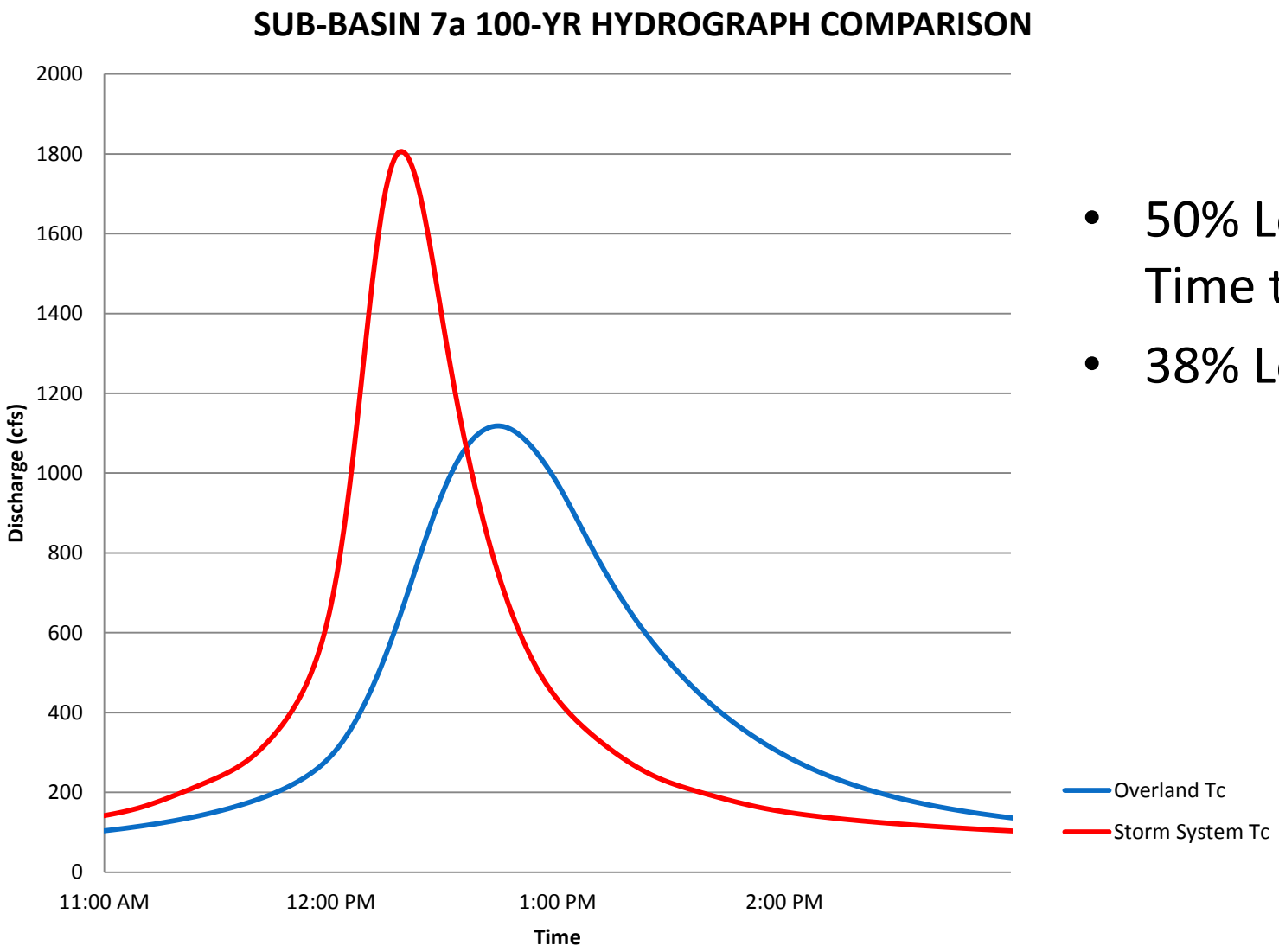
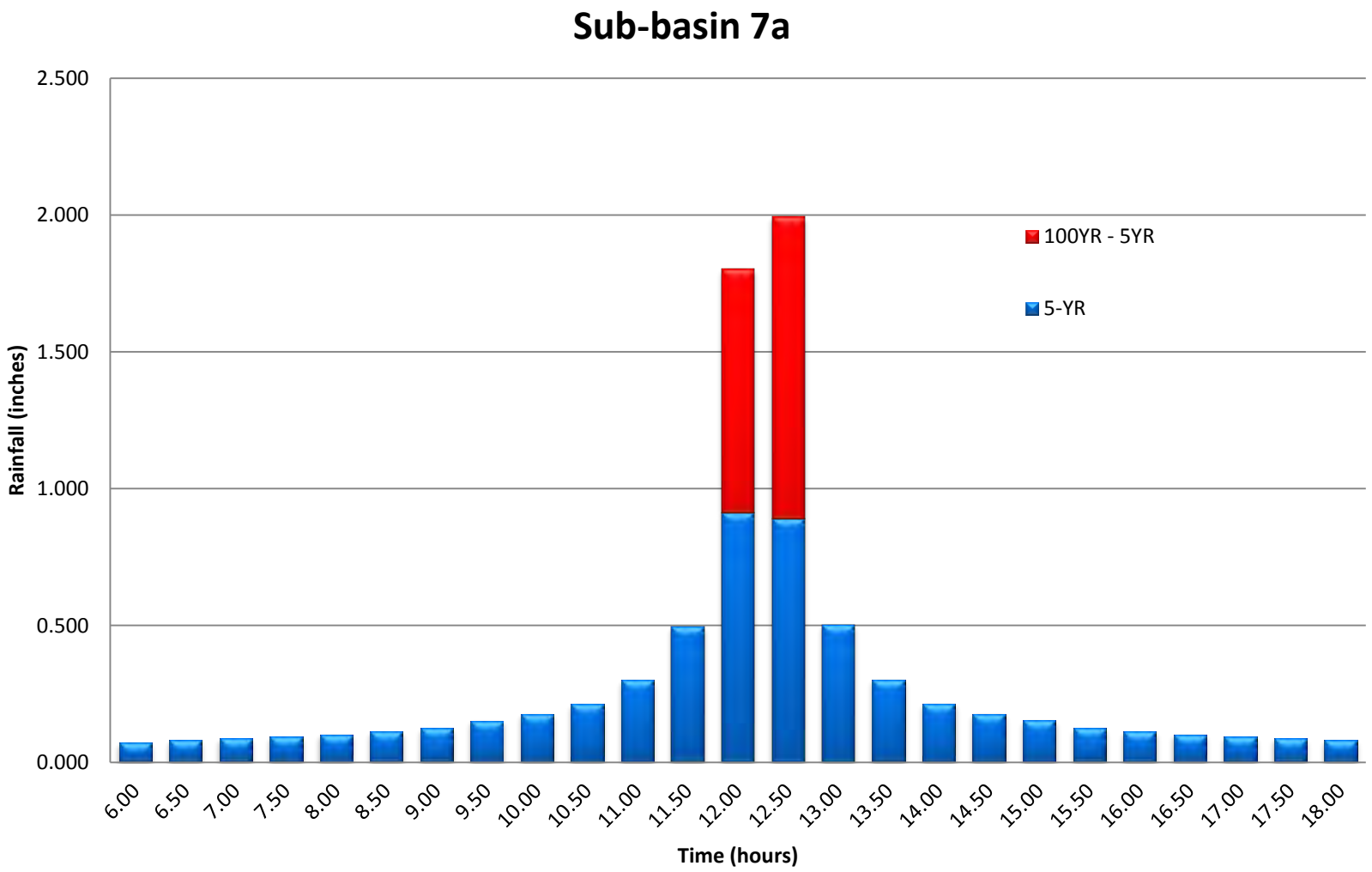
Hydrograph Comparison

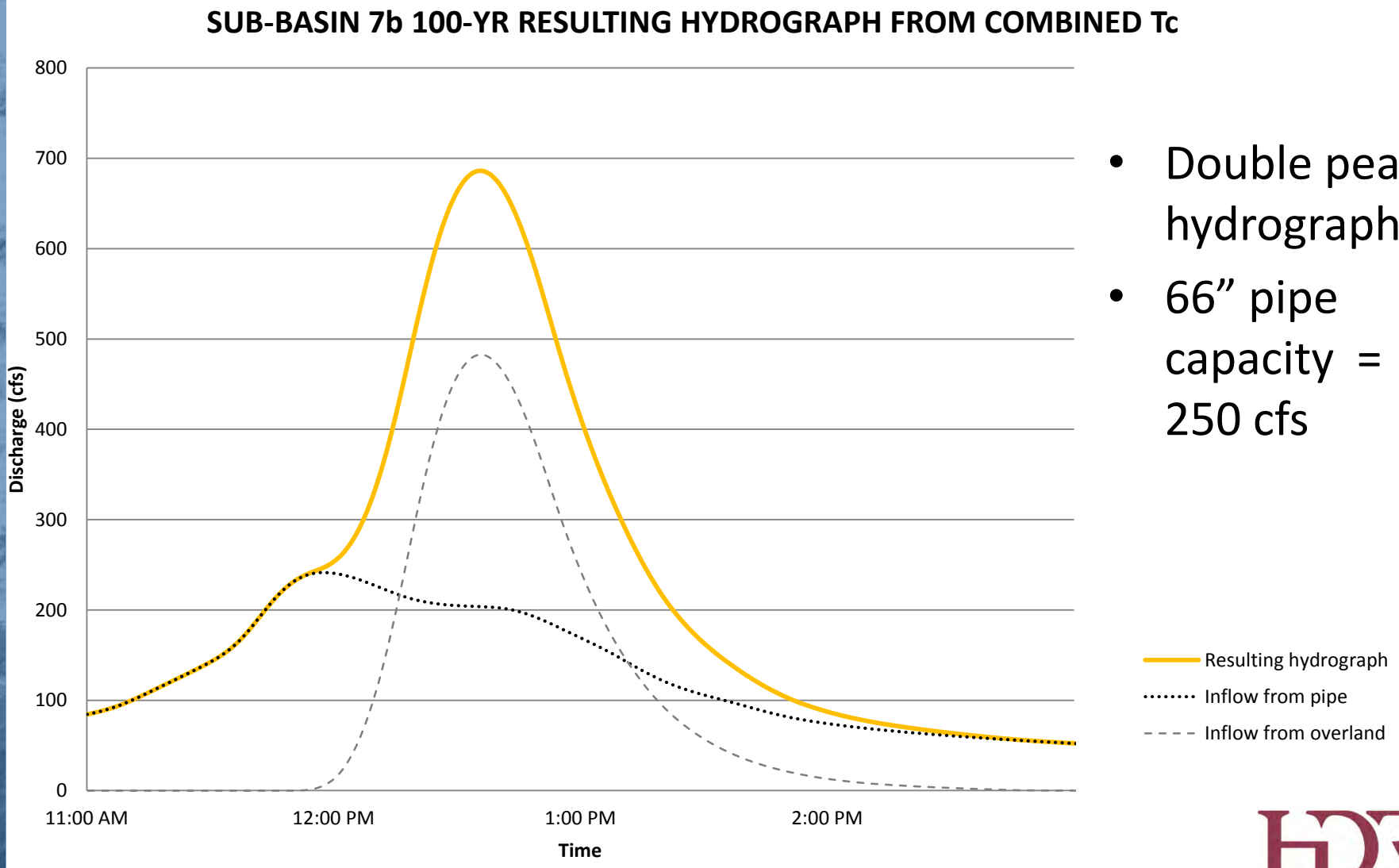


- 50% Longer Time to Peak
- 38% Lower Q

Hyetographs

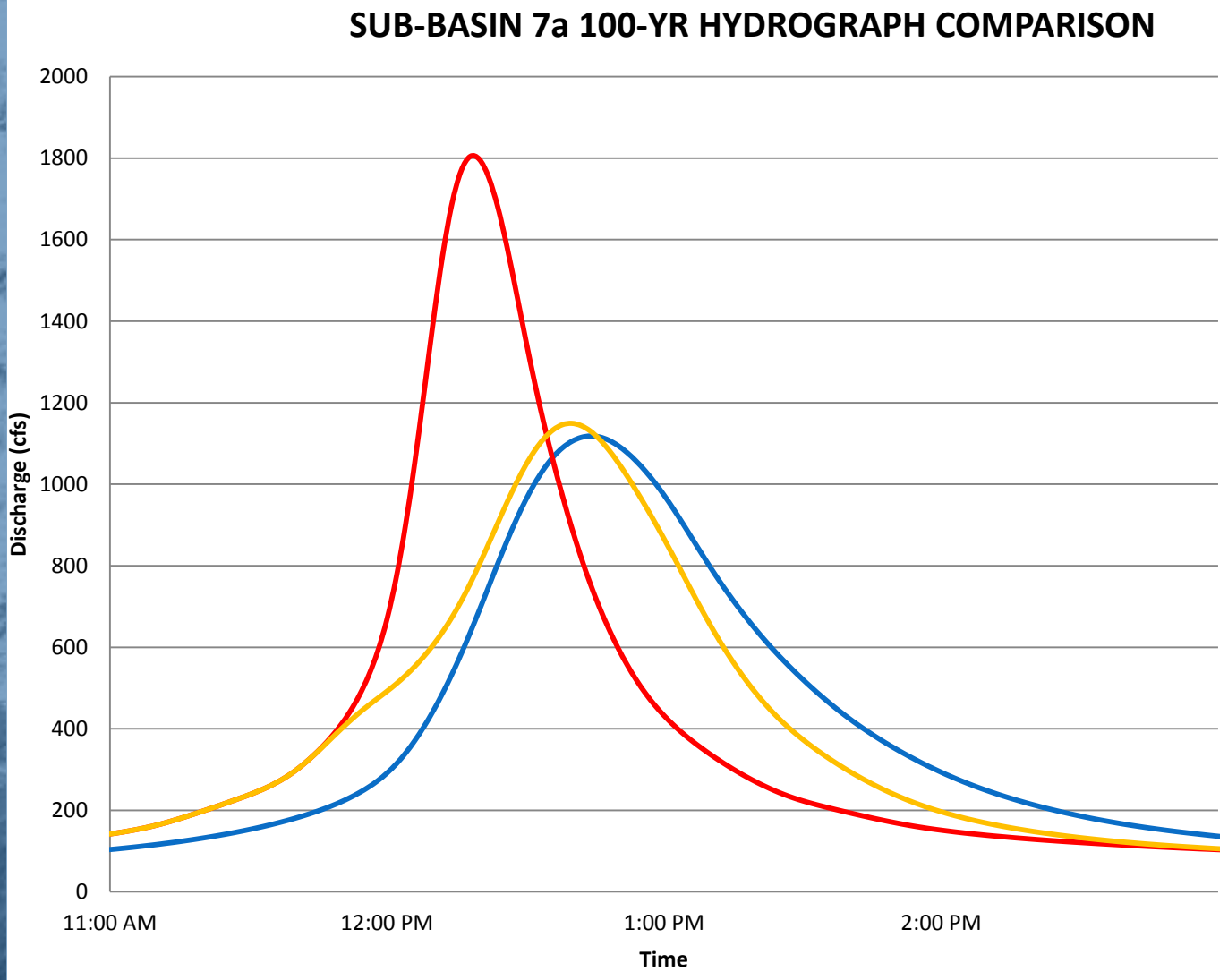


Combined Hydrograph



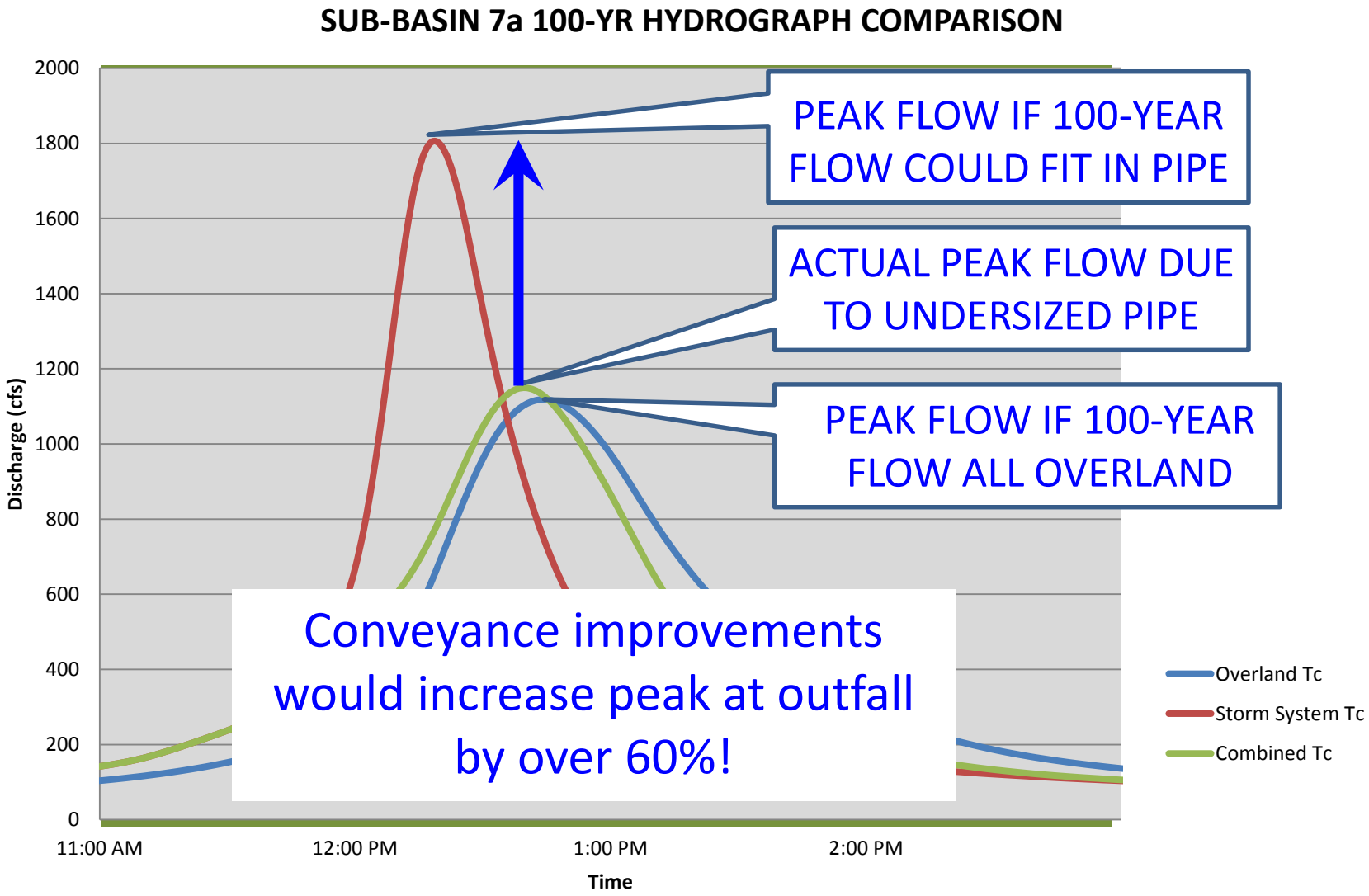
- Double peak hydrograph
- 66” pipe capacity = 250 cfs

Hydrograph Comparison



- Similar Time of Peak as Overland
- Q within 1% of overland
- Outfall is an 84” RCP & 36” RCP

Timing Issues: Summary



Increased Flooding Downstream

Downstream Impacts?

- Should FEMA floodplain be mapped based on existing storm drain constraints or potential capacity improvements?
- Should capacity improvements be considered an adverse impact?
- How do you prevent future downstream flooding as a policy?

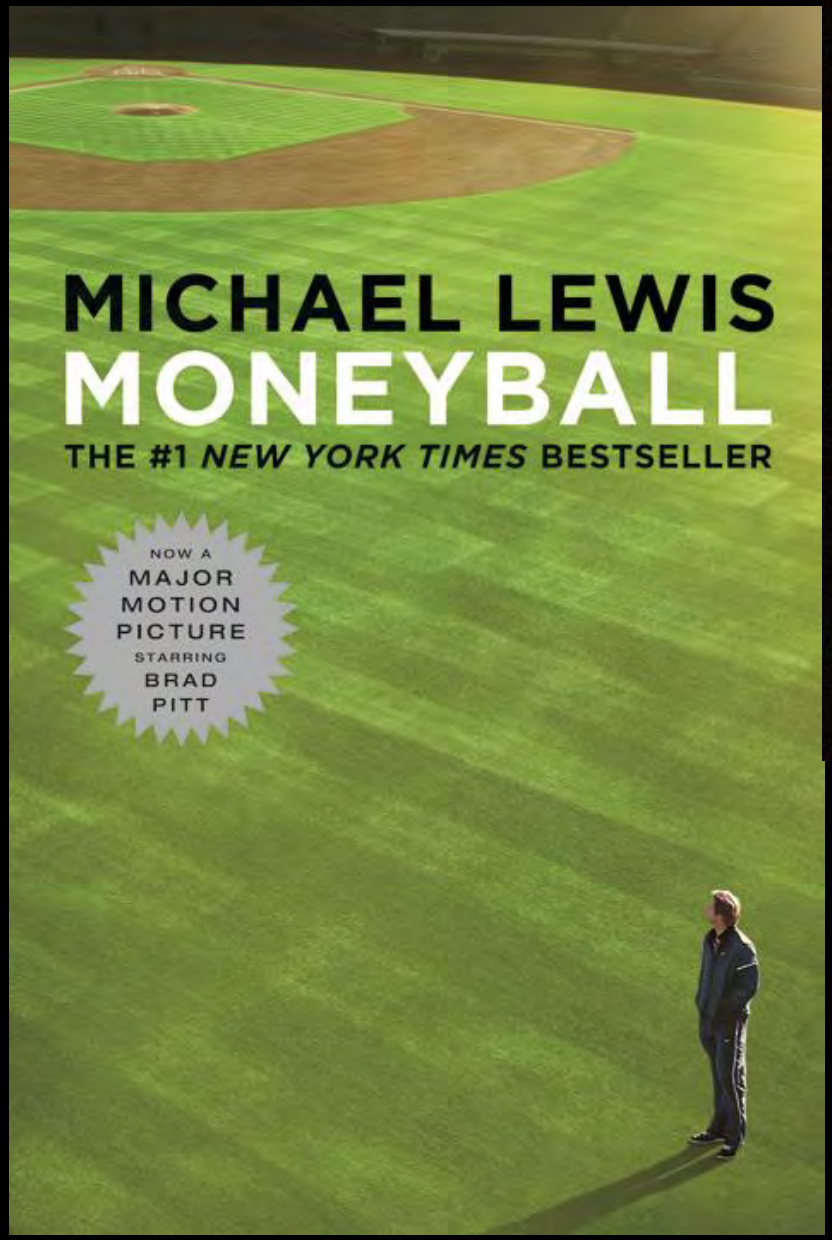
Downstream Impacts Summary

- Flooding upstream caused by undersized pipes reduces flooding downstream.
- Increased conveyance (larger pipes) is likely to move flooding downstream.
- "Managing flooding in place"
  - Detention and related solutions.
  - Downstream impacts are beneficial.

Issues in Urban (Zone X) Flooding

A DIFFERENT PARADIGM

A



New York Yankees
$114,457,768
vs
$39,722,689
Oakland Athletics

How do you compete?

- Challenge the conventional wisdom
- The numbers do not lie

Challenging the conventional wisdom

- Baseball teams have traditionally relied upon scouts who assess players based upon observations, biases, and prejudices
- Process never challenged or validated
- A “good ol’ boy” system
- A lot of bad investments

The numbers do not lie

- Sabremetrics – the search for objective knowledge about baseball
- Coined by Bill James, after Society for American Baseball Research
- Statistical measures to:
  - Question traditional measures of baseball evaluation
  - See true value in players (bargains)
  - Example: OBP >> AVG

Moneyball Example – 2002 A's

- After 2001, lost 3 best players to free agency
- Couldn't afford to replace with "all star" players
- Signed 3 players whose combined OBP equalled Damon and Giambi
- Won Division in 2002
- 20-game winning streak

What does this have to do with flood mitigation?

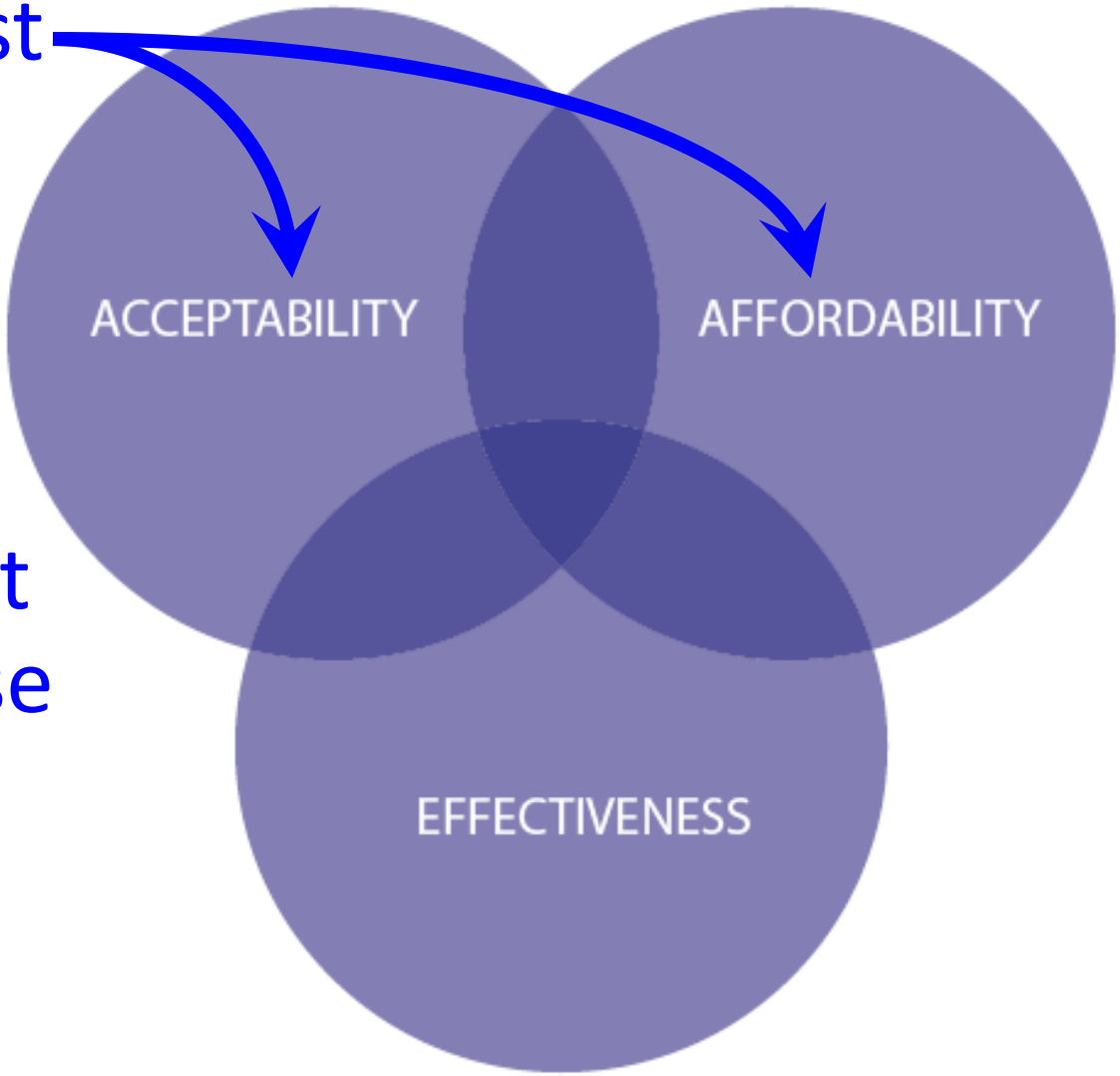
- You are the Oakland A's, not the Yankees!
  - Never enough funding
  - Your fans have high expectations
  - Must compete with higher profile funding expenditures (traffic, police, schools)
- Can we take a "sabremetric" approach to flood mitigation?
- Should we? YES!

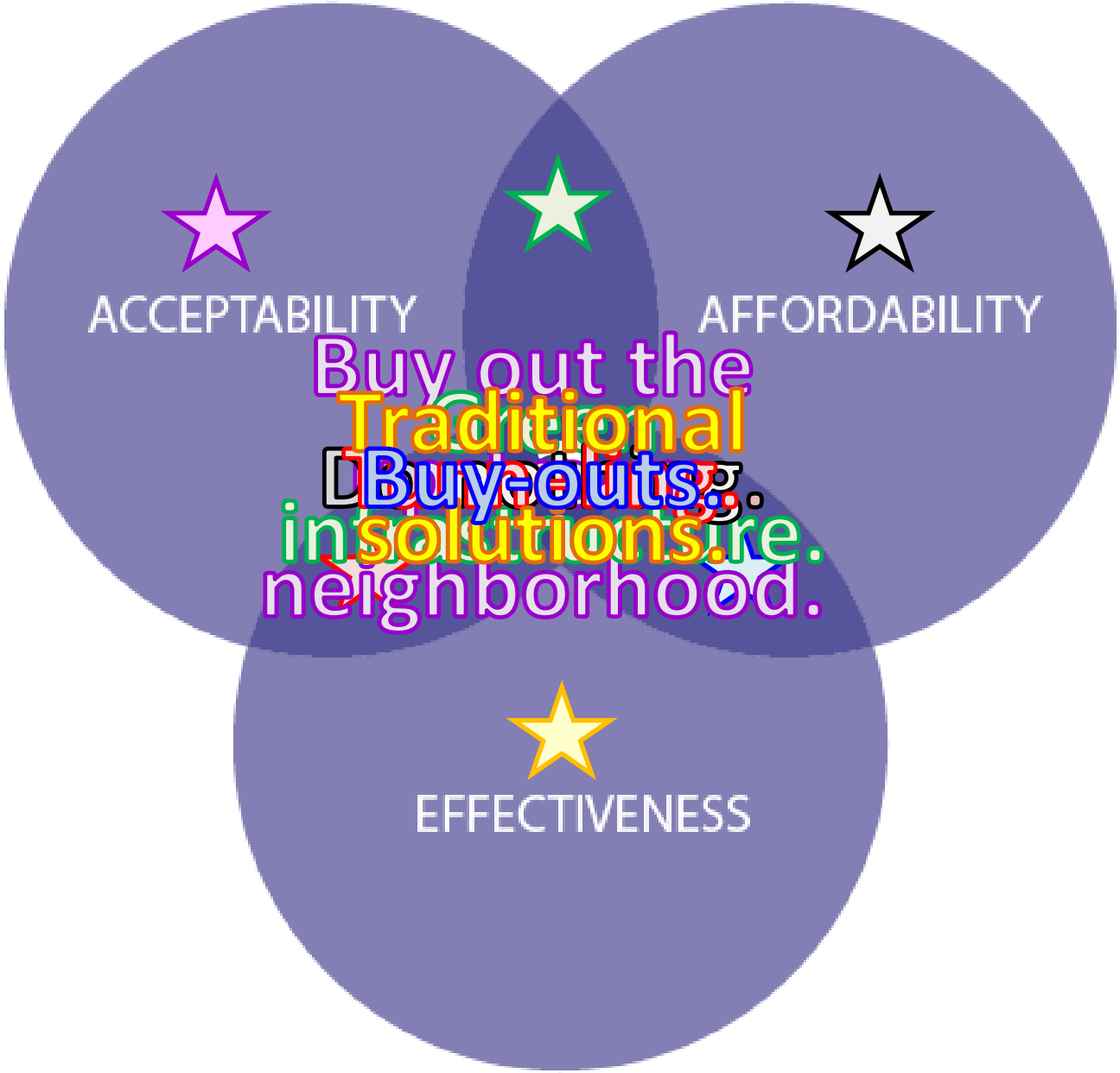
Understanding Risk

- Usually public safety not a major threat
- Zone X: nothing hinders rebuilding
- Chronic flooding vs. periodic flooding
- Manage flooding like other risks in life
- Flood risk management:
  - Avoidance: move out
  - Coping: minor prevention and repair
  - Insurance: limit economic losses

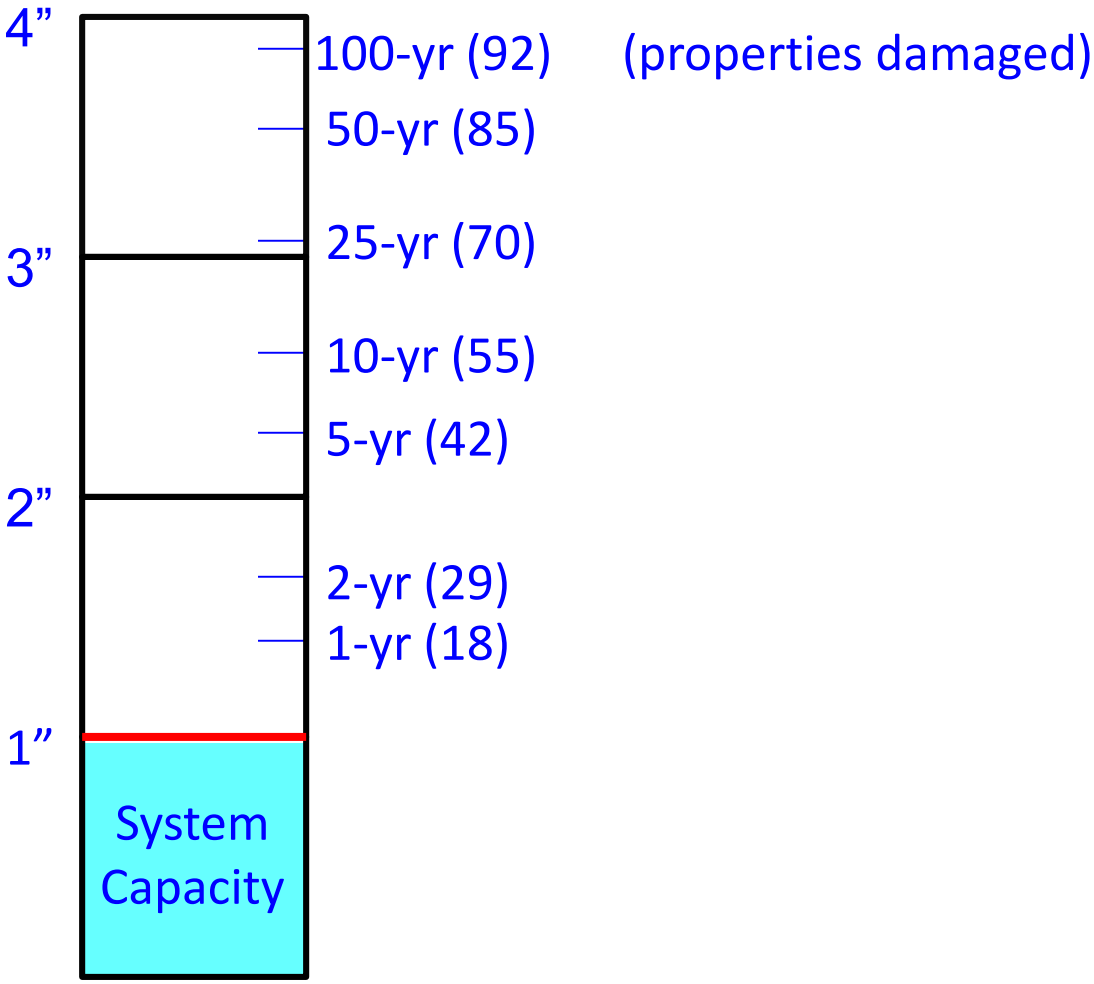
The Challenge

- More than just a technical challenge!
- In most situations we must find a bit of compromise in all three elements.

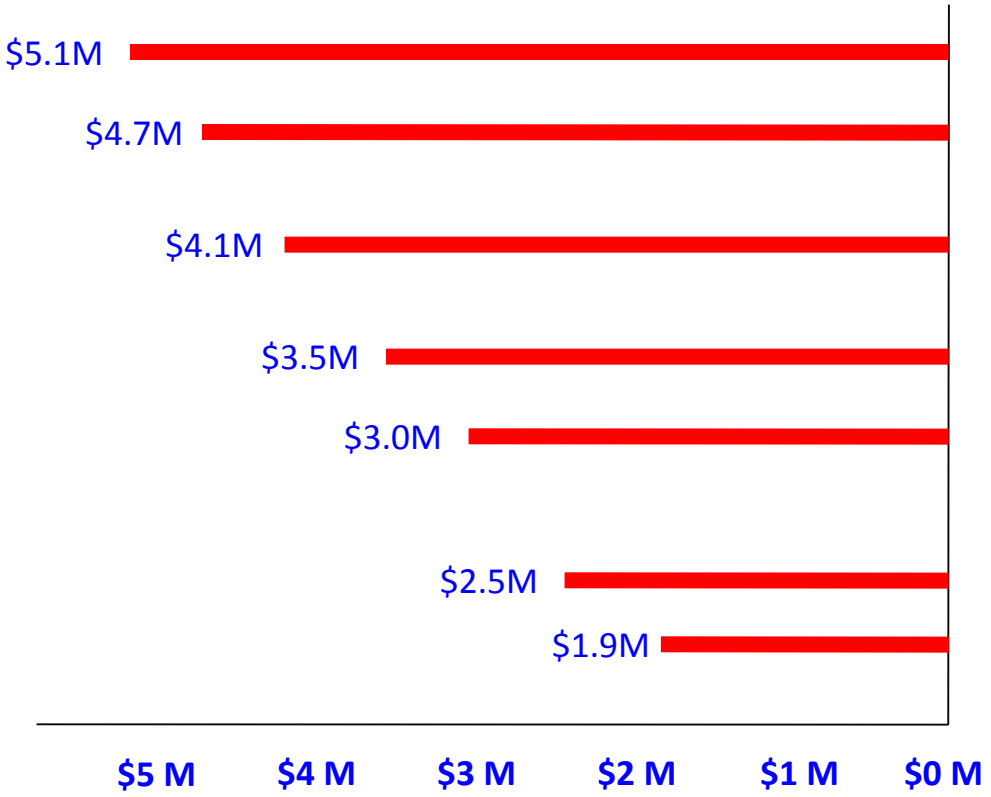



ACCEPTABILITY
AFFORDABILITY
EFFECTIVENESS
Buy out the
Traditional
Buy-outs.
in solutions.re.
neighborhood.

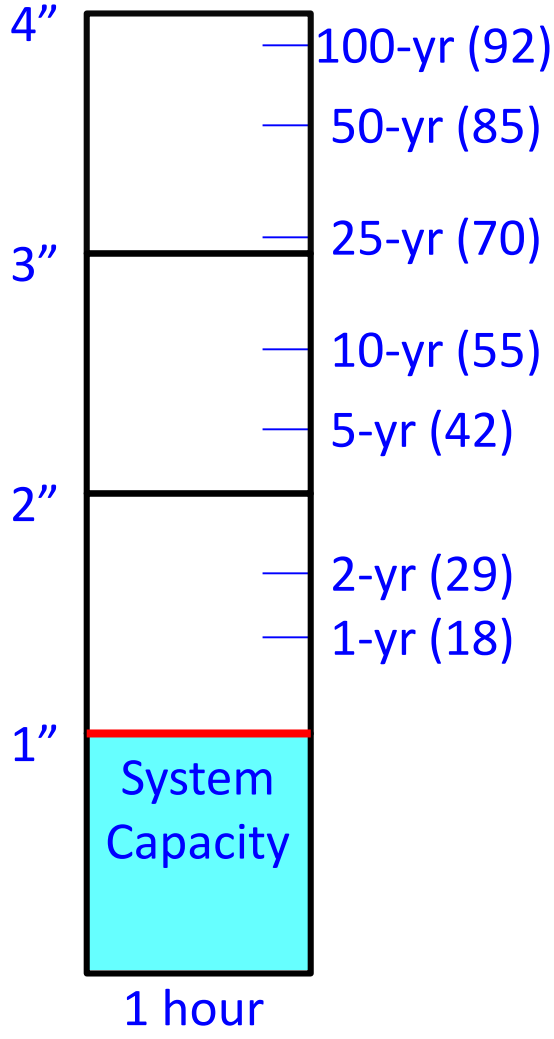
Let's think about a rain gage



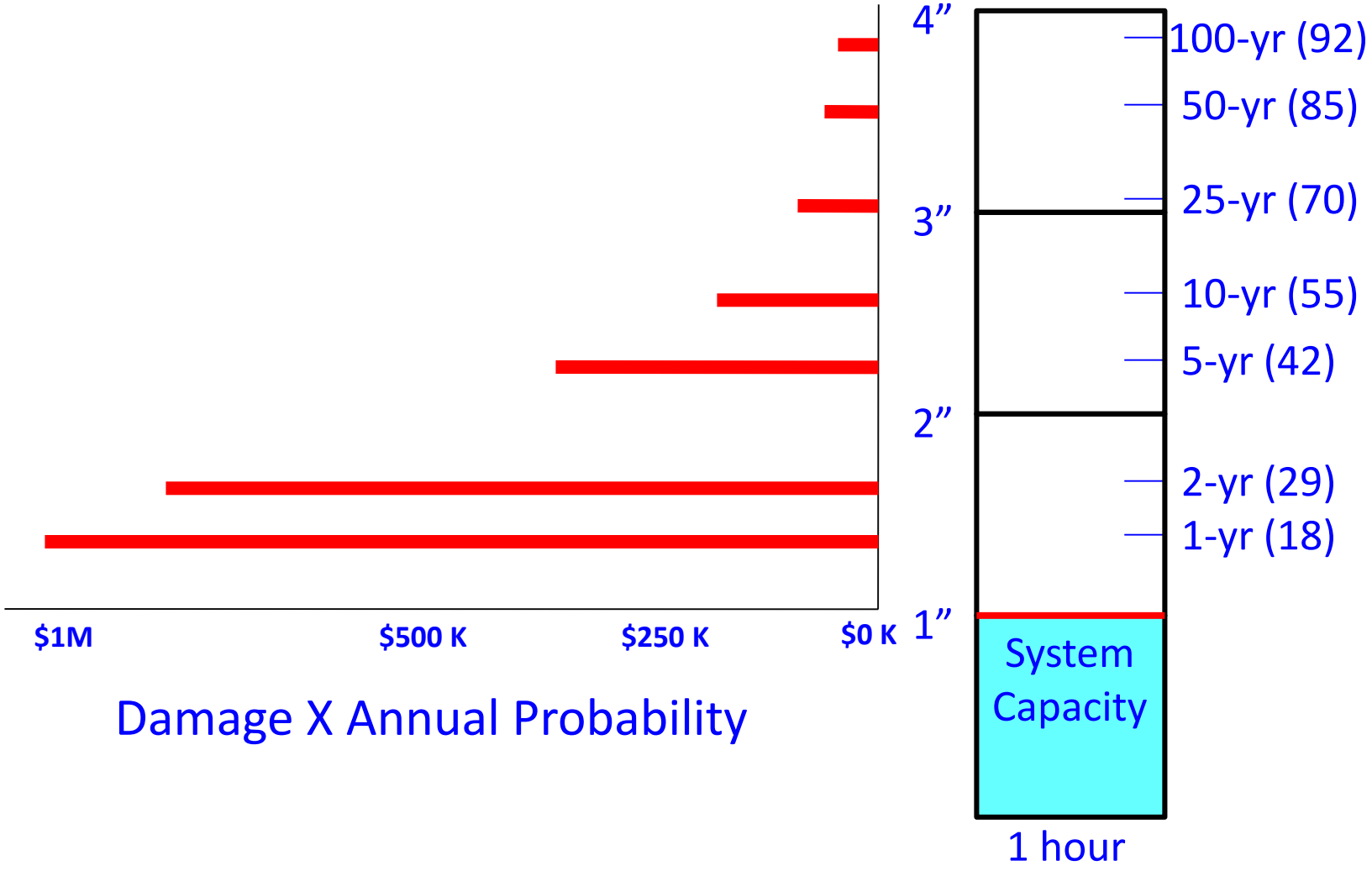
What if it rains more than 1”?



Single-Event Damages

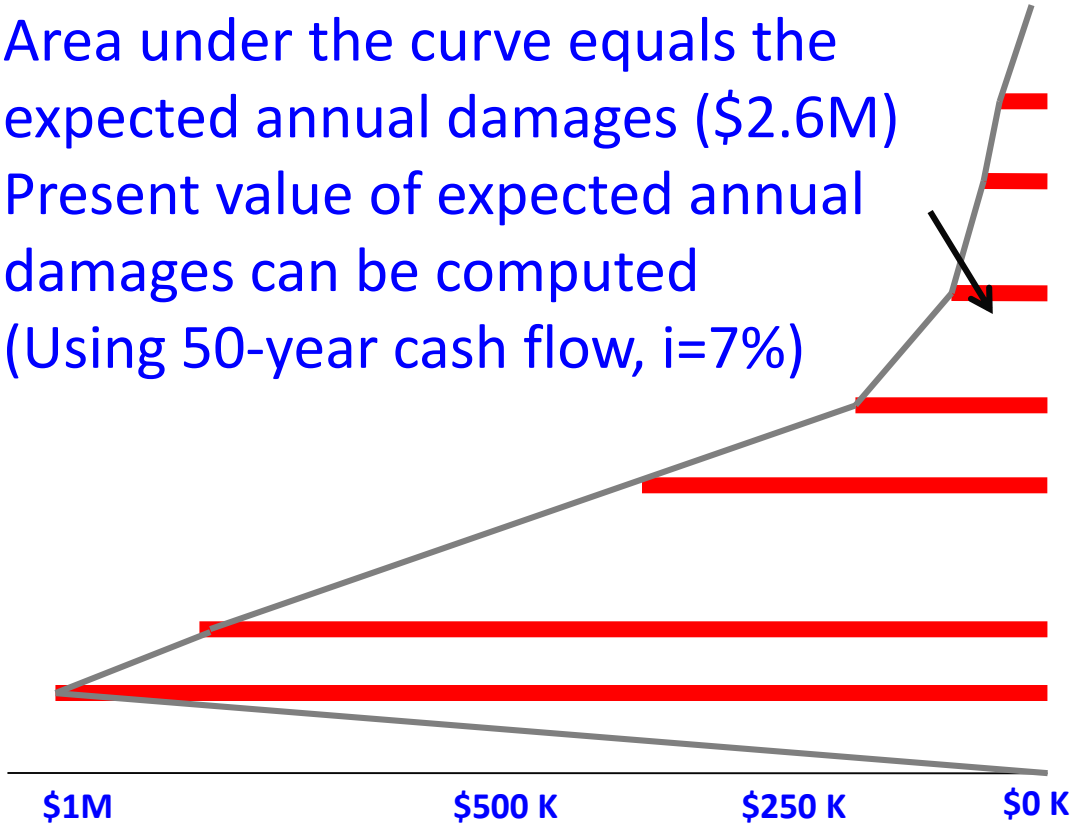


Damage X Annual Probability

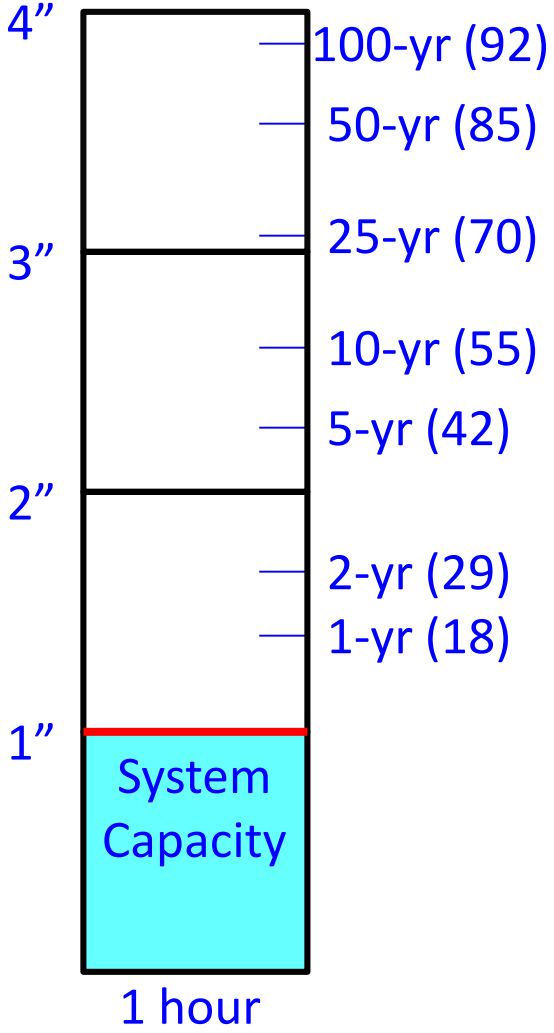


Expected Annual Damage

- Area under the curve equals the expected annual damages ($2.6M)
- Present value of expected annual damages can be computed (Using 50-year cash flow, i=7%)



Expected Annual Damages



Net Present Value = $36.5 million

Expected Annual Damage

Net Present Value =
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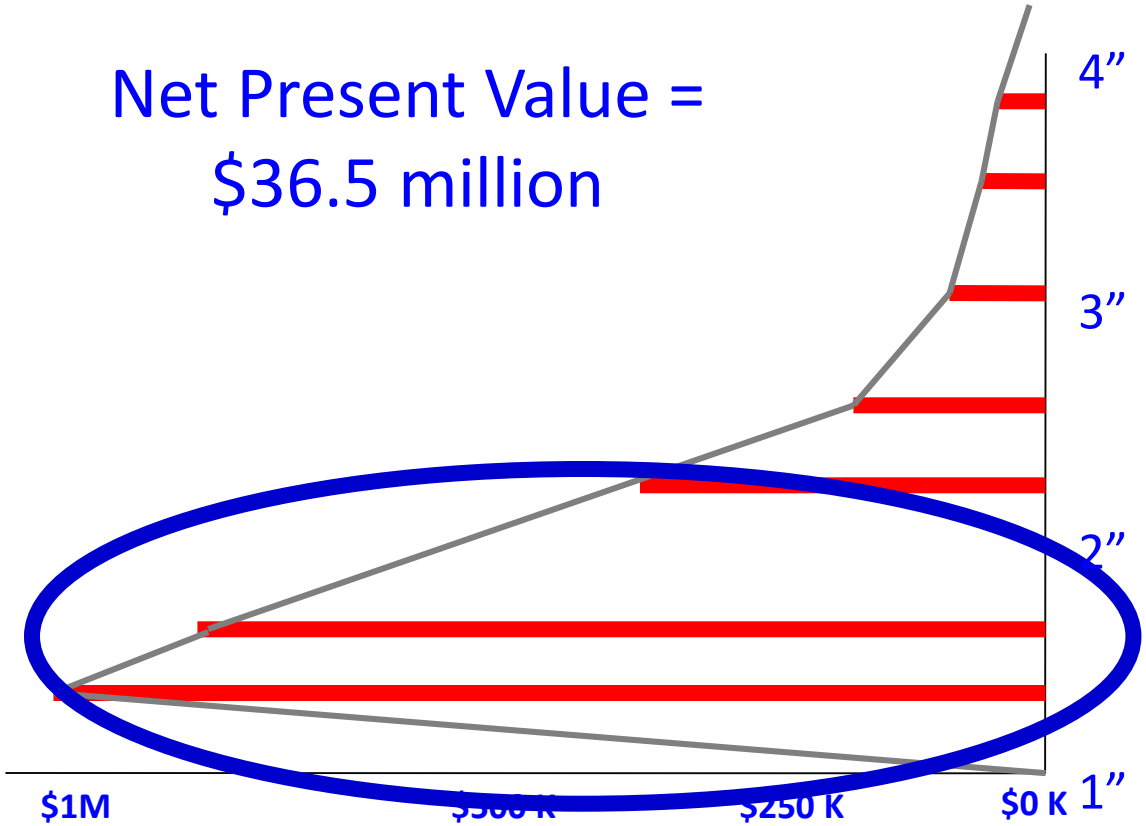
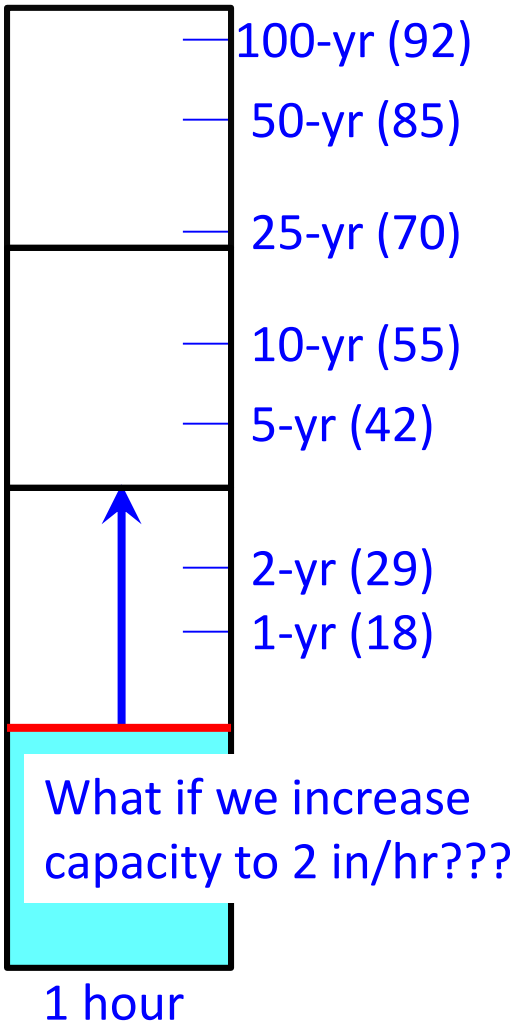
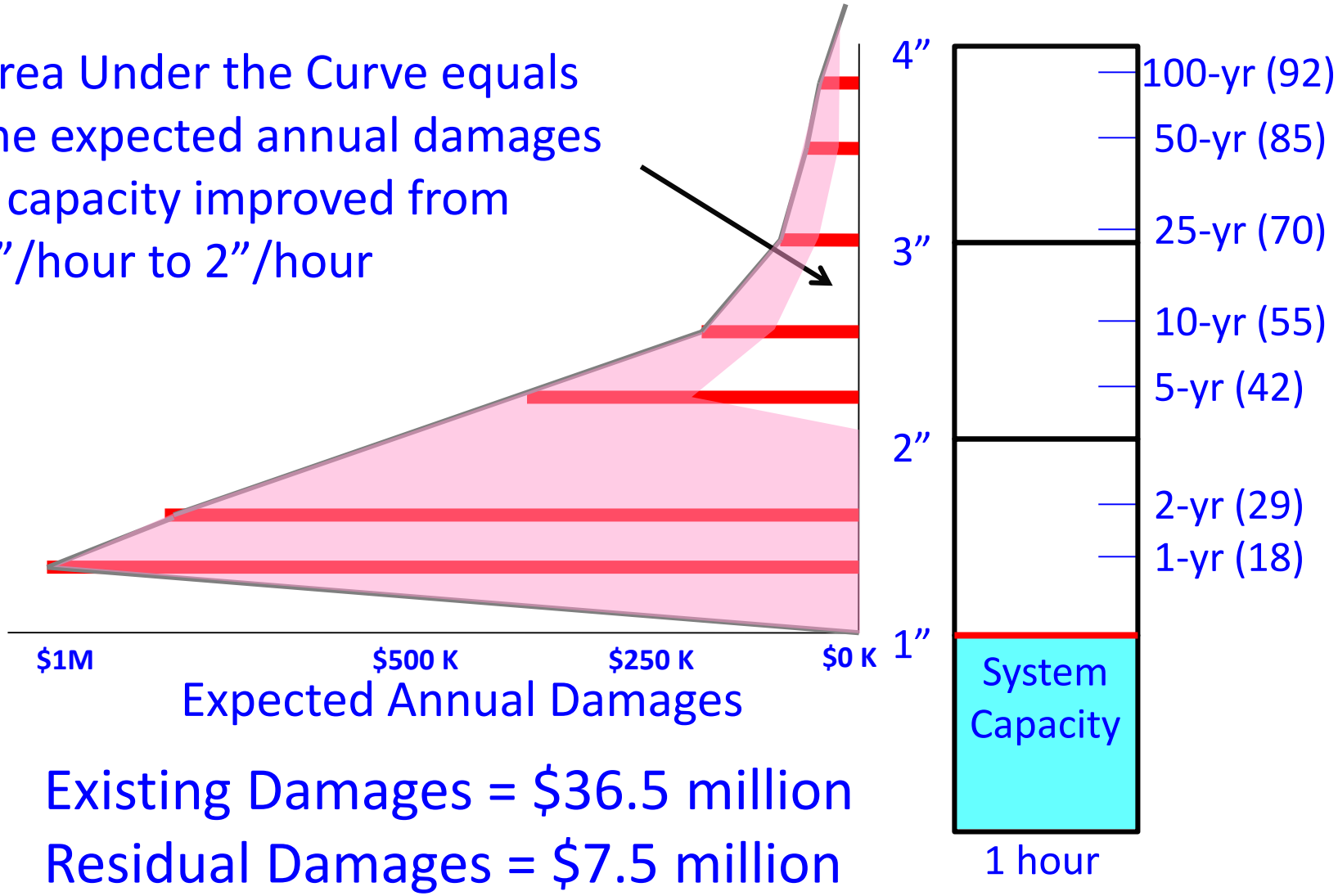


Expected Annual Damages



Net Present Value of Damages

Area Under the Curve equals the expected annual damages if capacity improved from 1”/hour to 2”/hour



Existing Damages = $36.5 million

Residual Damages = $7.5 million

Benefit = $29 million

The Challenge of Urban Flooding

MANAGING FLOODING IN PLACE

NOT THIS!

- Historically, detention viewed as fenced-off drainage facility
- Ends up as eyesores and wasted land

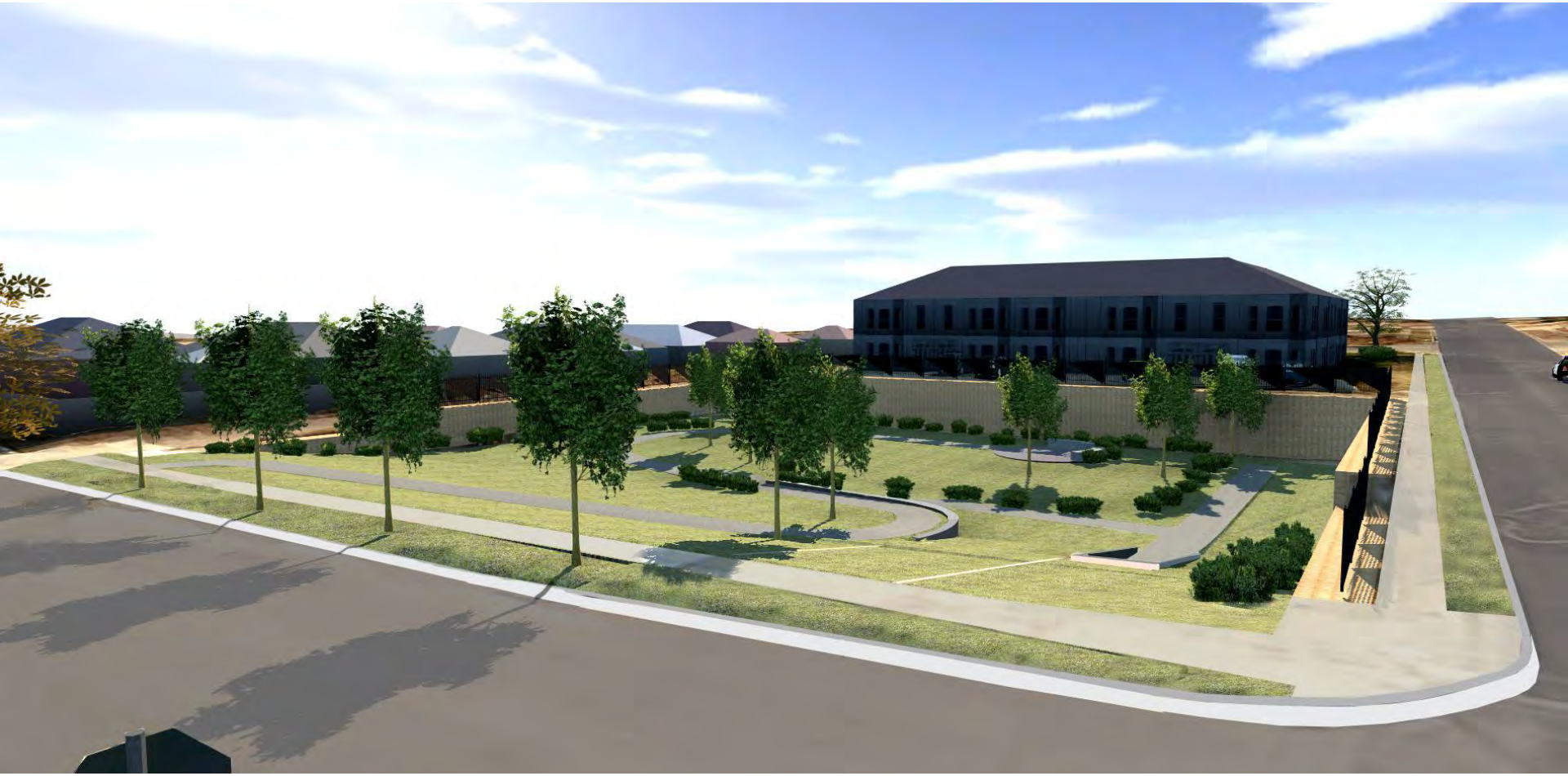
Multi-Use Detention

Detention areas can be used for aesthetics and water quality

Multi-Use Detention

Detention areas can be used for recreation and open space

Detention Basin—Neighborhood Park



Integrated with Urban Redevelopment

Daylighting Streams

Storm Drain with Overflow Swale

Linear Parks and Greenways

URBAN FLOODING

- Solutions must be **EFFECTIVE, AFFORDABLE & ACCEPTABLE**
- **NO ADVERSE IMPACT** principles require evaluating downstream effects
- **INCREMENTAL** improvements may be the only cost-effective option
- **MANAGING FLOODING IN PLACE** is likely to be most feasible solution

URBAN FLOODING

- It is receiving more attention.
- Handled differently than riverine flooding.
- Hydrodynamic modeling and citizen videos provide a better understanding.
- Major issues:
  - How to map it
  - How to enforce it
  - Who should regulate it

The Challenge of Urban Flooding

QUESTIONS?

City of Fort Worth
TPW Stormwater
Major Capital Projects

Steven E. Eubanks, P.E., CFM

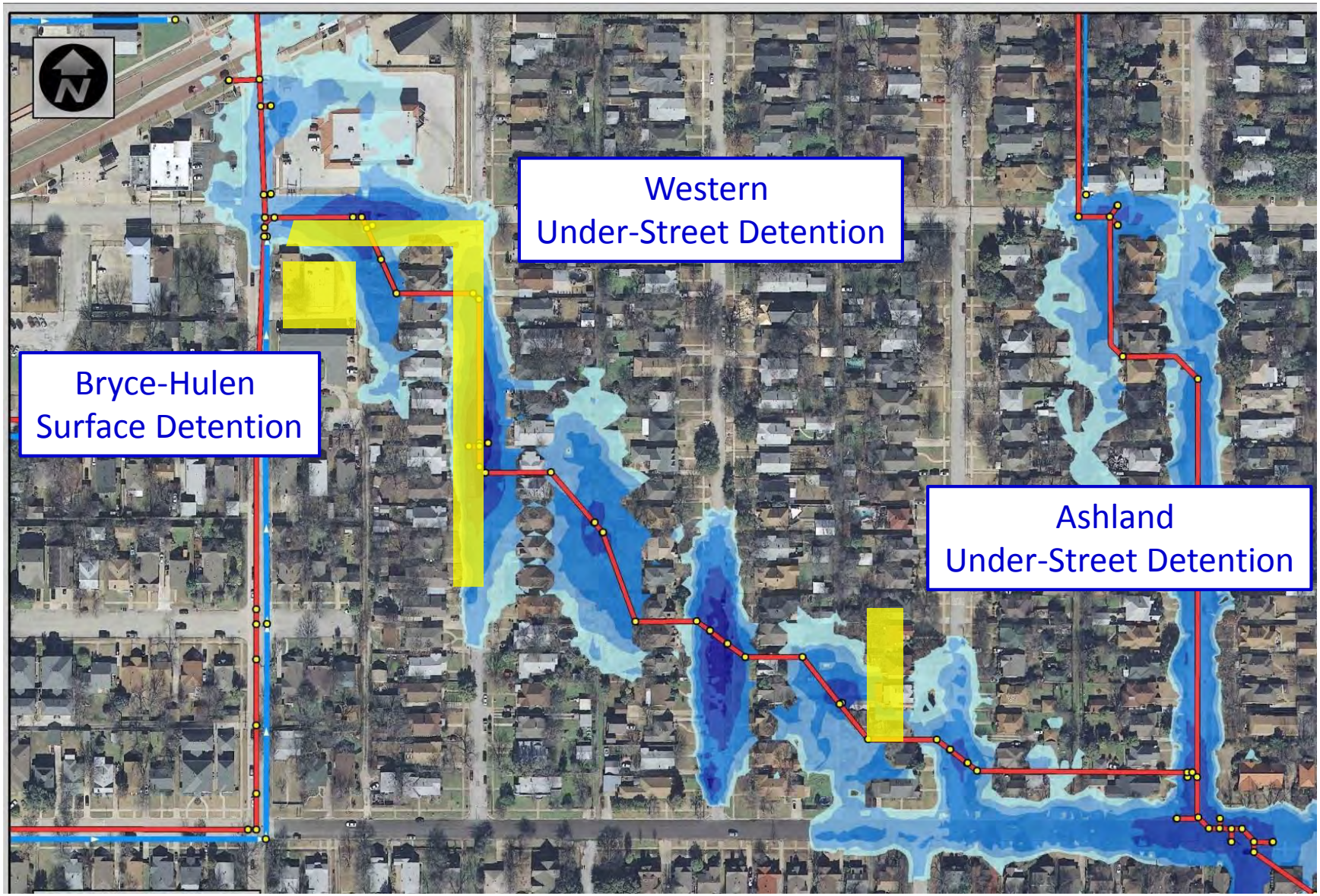
Major Projects

1. **Central Arlington Heights**

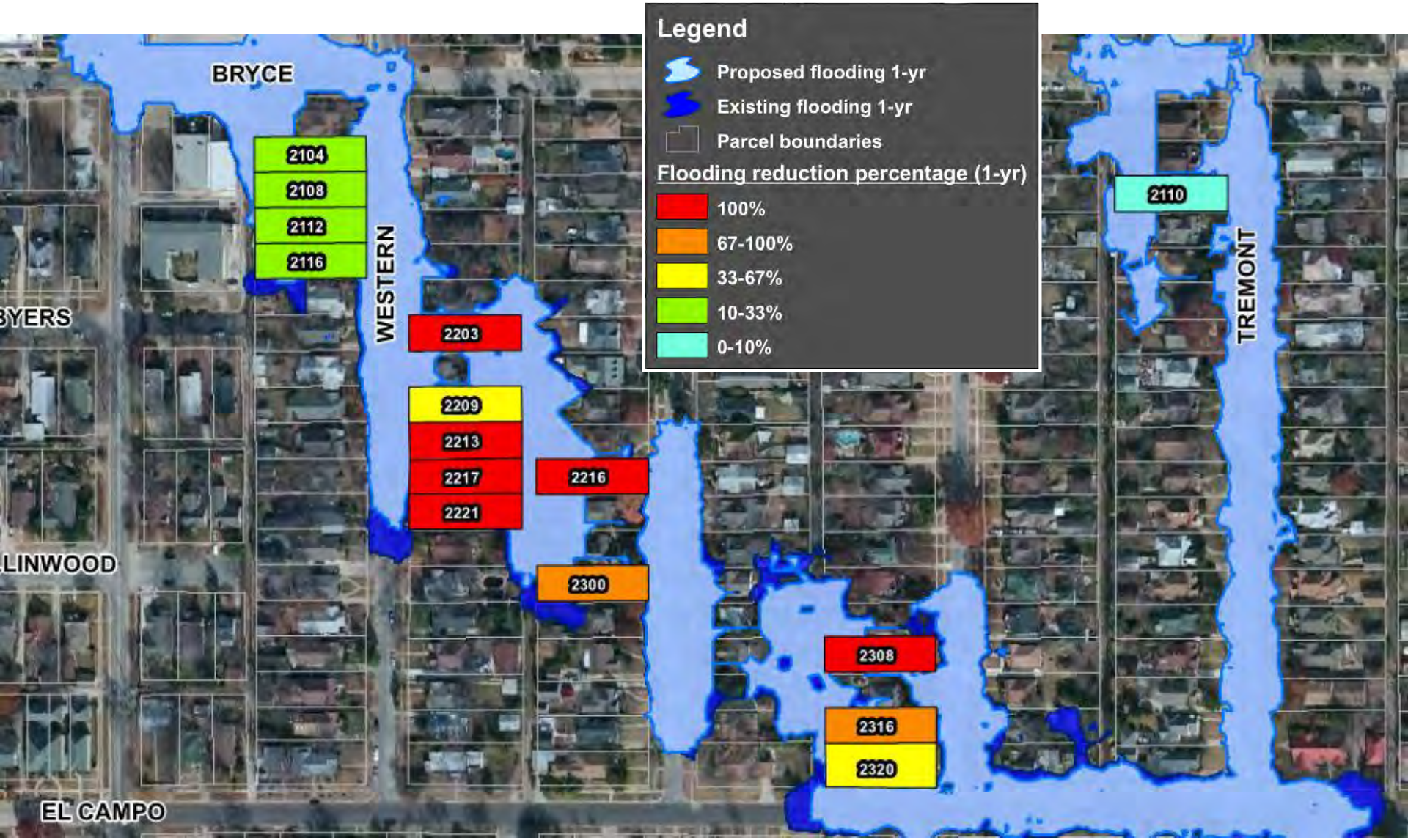
June 28, 2004 – Central Arlington Heights

Central Arlington Heights

Proposed Under-Street Detention



Modeled Flood Reduction



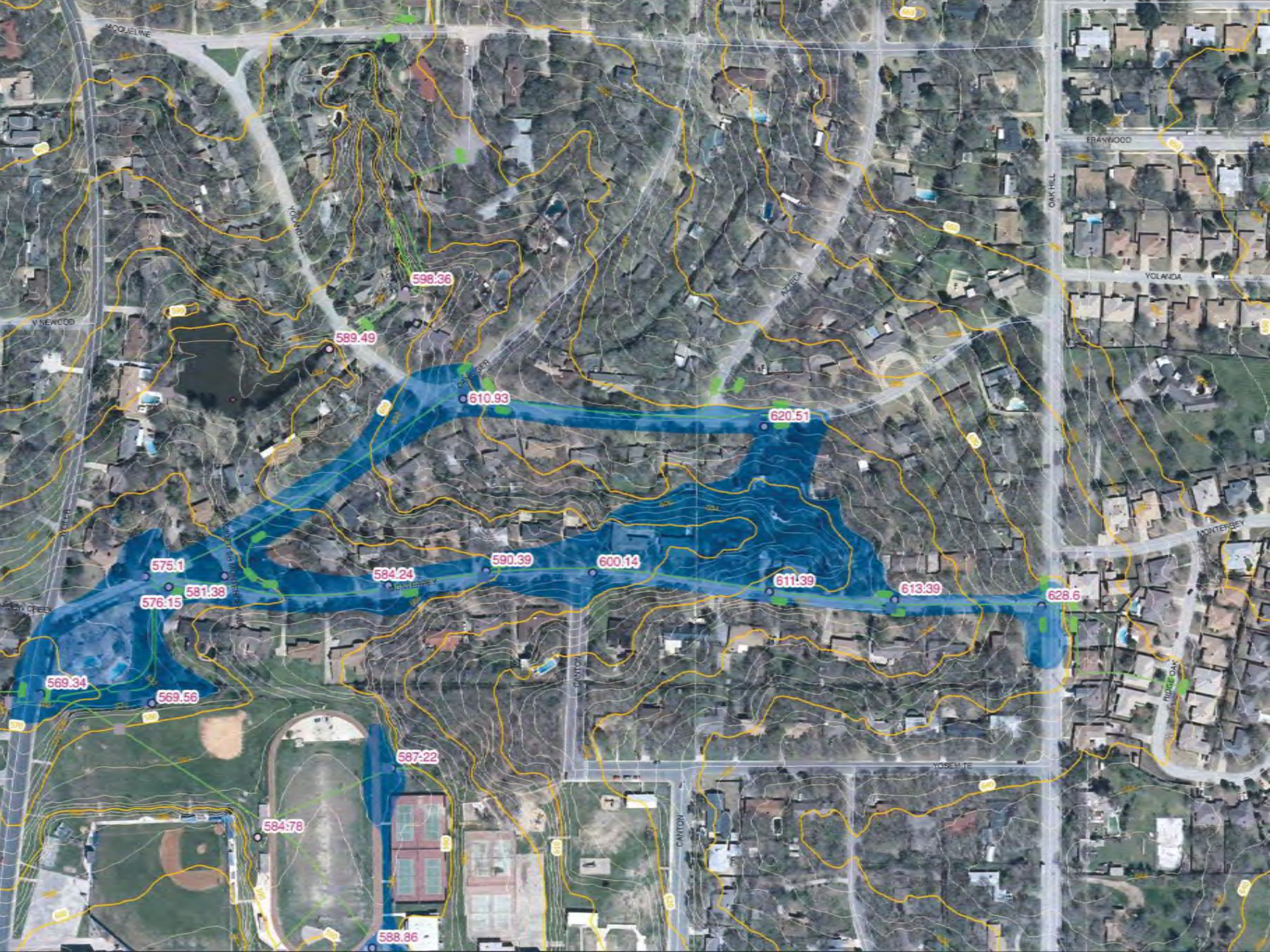
BCA for Planned Detention Projects

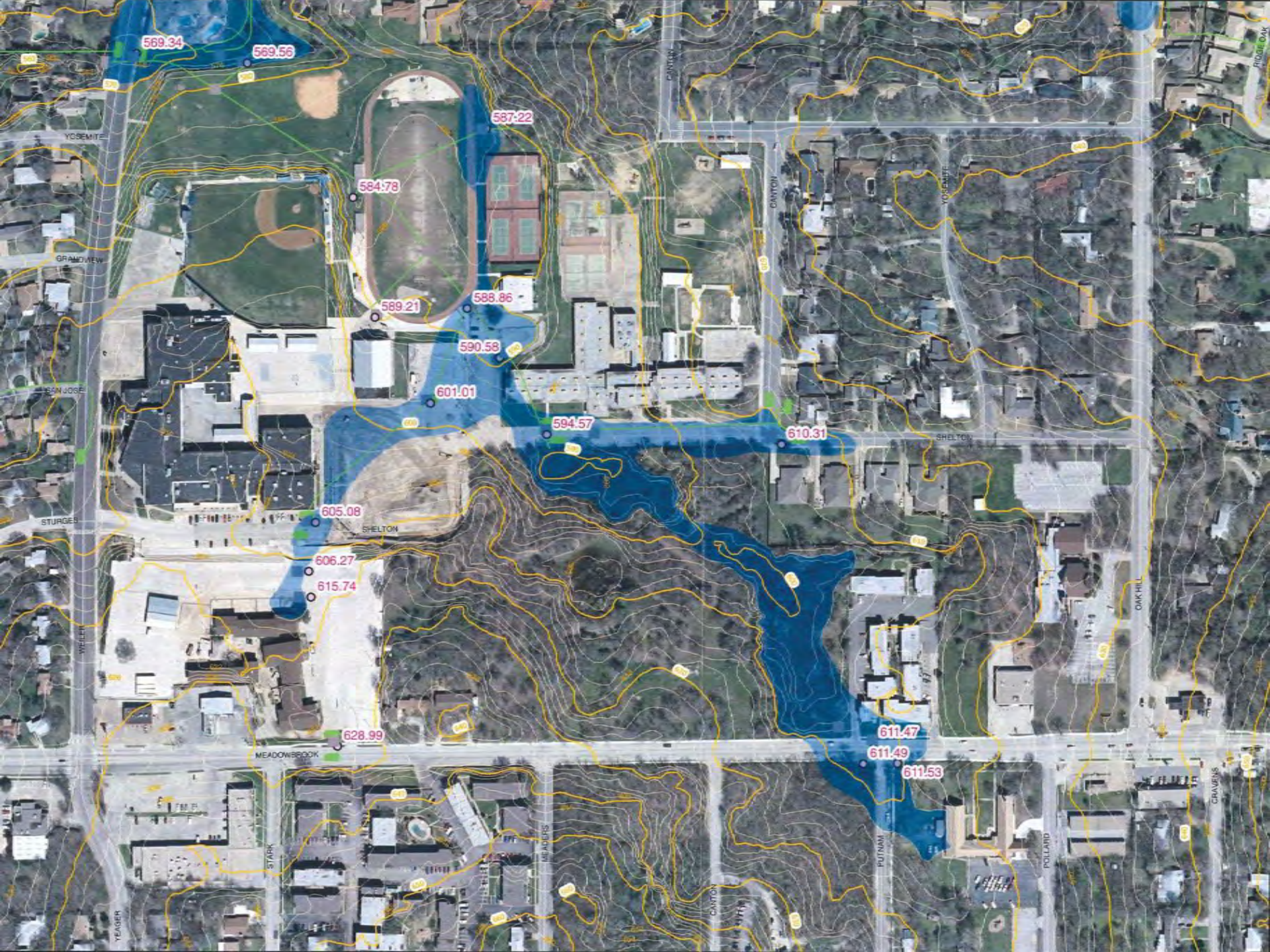
	Damages	Cumulative Benefits	Cumulative Cost	Cumulative BCR
Existing Conditions	$ 36,503,254	--	--	--
Ashland Detention	$ 35,220,075	$ 1,283,180	$ 975,000	**1.32**
Ashland Detention + Western Detention	$ 32,332,898	$ 4,170,356	$ 3,177,284	**1.31**
Ashland Detention + Western Detention + Hulen/Bryce Detention	$ 30,759,546	$ 5,743,708	$ 4,084,284	**1.41**

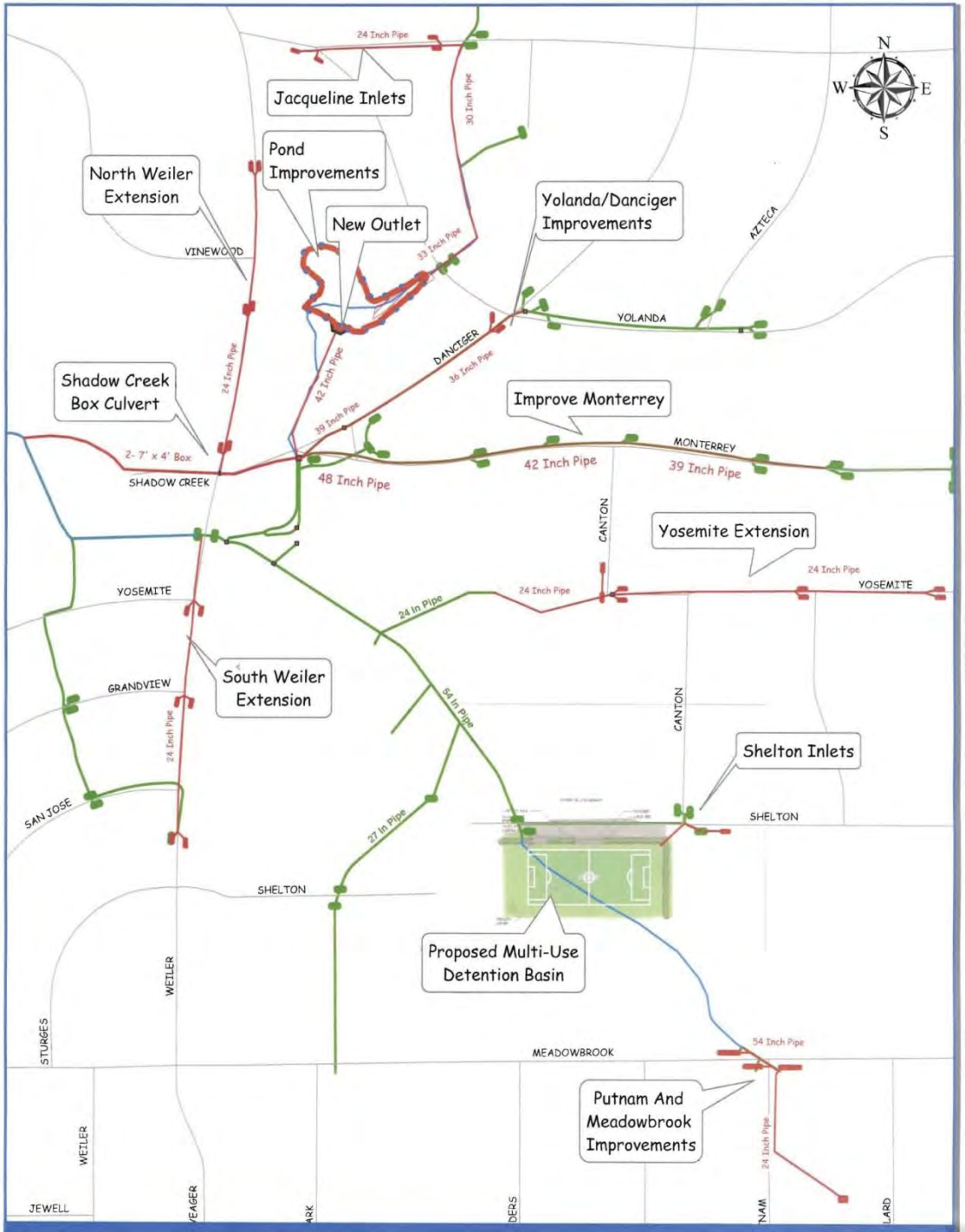

KOMATSU
WOODY CONST

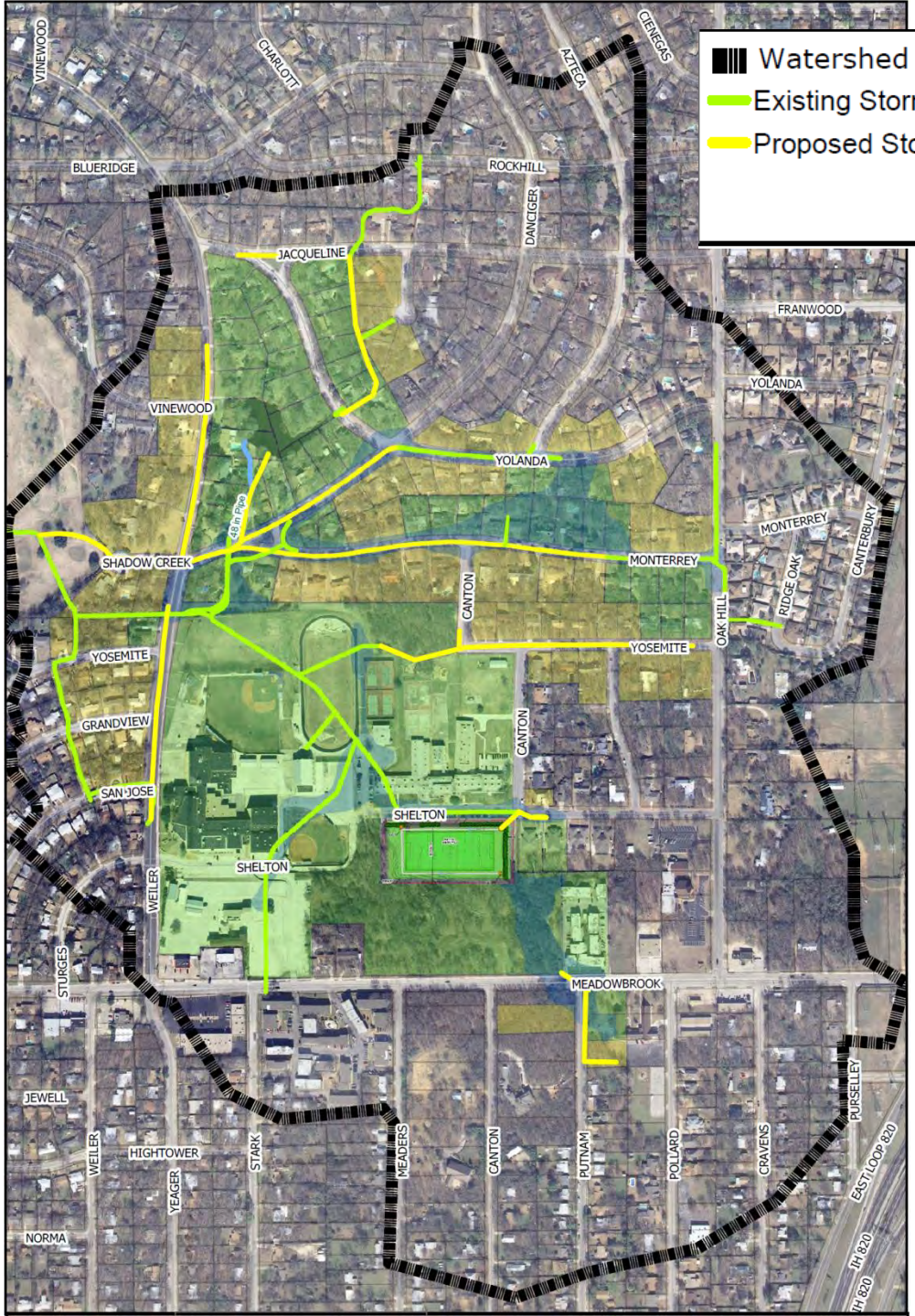
Major Projects

1. Central Arlington Heights
2. **Eastern Hills**


598.36
589.49
610.93
620.51
575.1
581.38
576.15
584.24
590.39
600.14
611.39
613.39
628.6
569.34
569.56
587.22
584.78
588.86
MONTEREY
CANYON
OAK HILL
YOLANDA
RIDGE OAK
YOSEMITE


569.34
569.56
587.22
584.78
589.21
588.86
590.58
601.01
594.57
610.31
605.08
606.27
615.74
628.99
611.47
611.49
611.53
YOSEMITE
GRANDVIEW
SAN JOSE
STURGES
SHELTON
MEADOWBROOK
CANTON
YOSEMITE
SHELTON
OAK HILL
RIDGEOAK
WELLS
STARK
YEAGER
MEADERS
CANTON
PUTNAM
POLLARD
CRAVENS


Jacqueline Inlets
24 Inch Pipe
30 Inch Pipe
Pond Improvements
North Weiler Extension
New Outlet
33 Inch Pipe
Yolanda/Danciger Improvements
VINEWOOD
AZTECA
YOLANDA
DANCIGER
36 Inch Pipe
42 Inch Pipe
24 Inch Pipe
Shadow Creek Box Culvert
2- 7' x 4' Box
SHADOW CREEK
39 Inch Pipe
Improve Monterrey
MONTERREY
42 Inch Pipe
39 Inch Pipe
48 Inch Pipe
CANTON
Yosemite Extension
24 Inch Pipe
YOSEMITE
24 In Pipe
24 Inch Pipe
YOSEMITE
GRANDVIEW
South Weiler Extension
24 Inch Pipe
54 In Pipe
CANTON
Shelton Inlets
SAN JOSE
27 In Pipe
SHELTON
SHELTON
Proposed Multi-Use Detention Basin
WETLER
STURGES
MEADOWBROOK
54 Inch Pipe
Putnam And Meadowbrook Improvements
24 Inch Pipe
WETLER
JEWELL
N
W
E
S



Watershed Boundary
Existing Storm Drain Lines
Proposed Storm Drain Lines
Directly Helped
Indirectly Helped

55

	Res	Com
Directly Helped	54	5
Indirectly Helped	82	0

1 inch equals 350 feet

N

FORT WORTH

Eastern Hills Watershed Study

City of Fort Worth 2004 CIP Watershed Planning Study

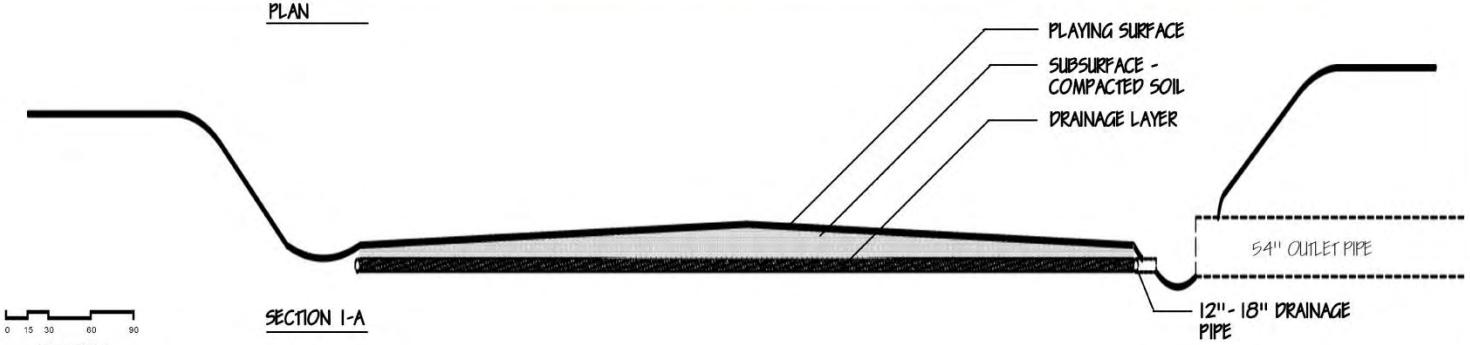
Eastern Hills Drainage System

Proposed Multi-Purpose Storm Water Detention Pond

Benefits include:

- Reduced flooding downstream
- Improved storm water quality
- Multi-sport athletic field

PLAN



SECTION 1-A

FORT WORTH

JE JACOBS Carter Burgess

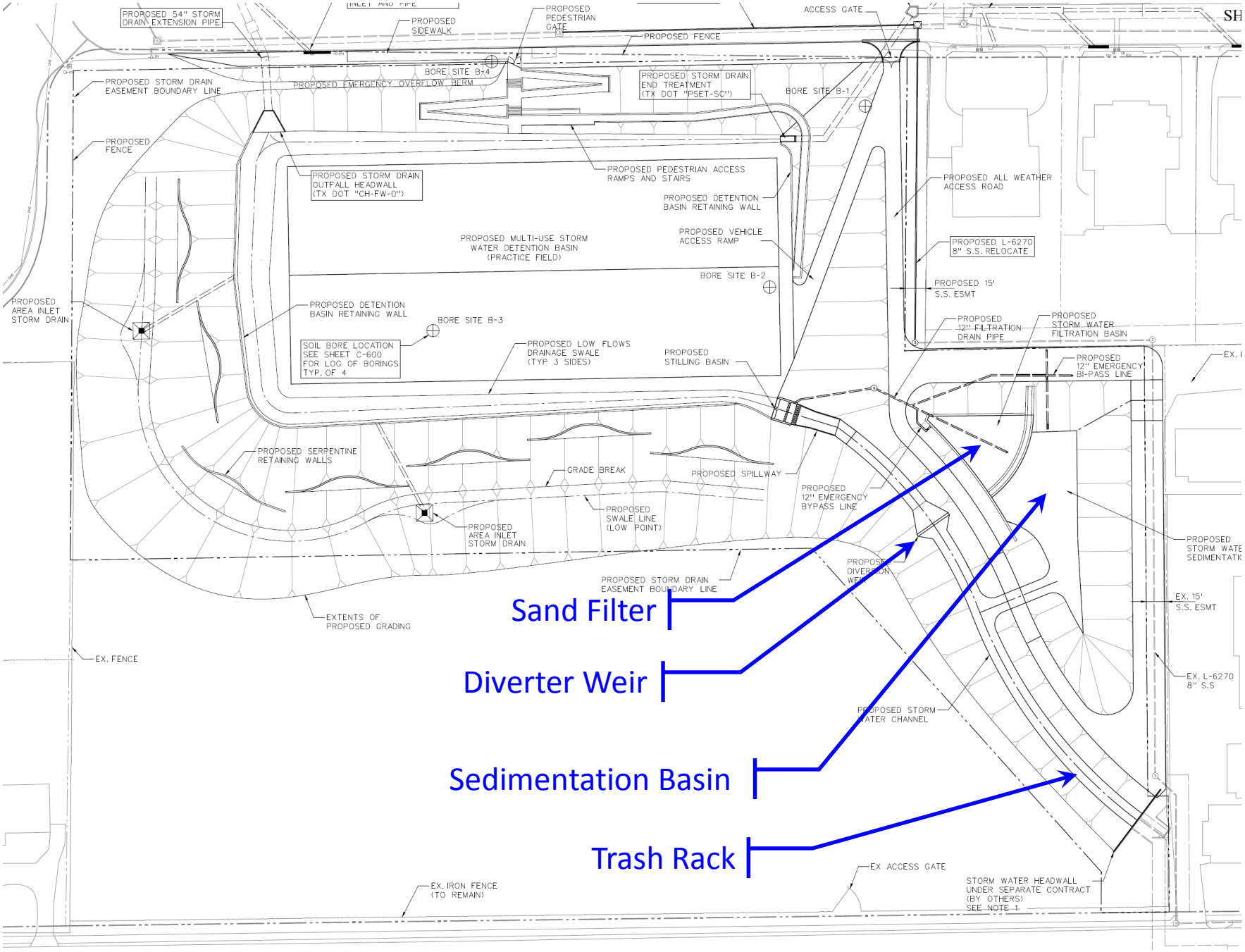
North

0 15 30 60 90

Scale: 1" = 30'-0"

CFW-FWISD Master Agreement

- FWISD grants easement at no cost
- City installs basin and some amenities: lighting, planting, irrigation, access, etc.
- City installs water quality features to keep trash from washing into basin
- Routine maintenance by FWISD
- WQ maintenance & major repairs by City

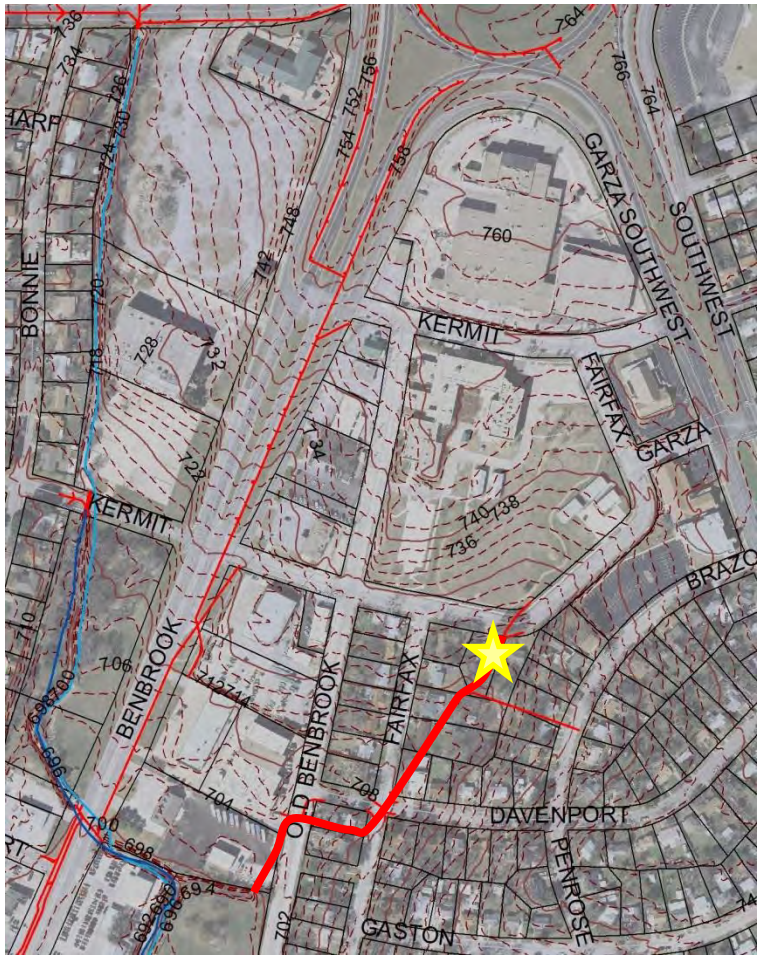

PROPOSED 54" STORM DRAIN EXTENSION PIPE
PROPOSED SIDEWALK
PROPOSED PEDESTRIAN GATE
ACCESS GATE
PROPOSED FENCE
PROPOSED STORM DRAIN EASEMENT BOUNDARY LINE
BORE SITE B-4
PROPOSED EMERGENCY OVERFLOW BERM
PROPOSED STORM DRAIN END TREATMENT (TX DOT "PSET-SC")
BORE SITE B-1
PROPOSED FENCE
PROPOSED STORM DRAIN OUTFALL HEADWALL (TX DOT "CH-FW-0")
PROPOSED PEDESTRIAN ACCESS RAMPS AND STAIRS
PROPOSED DETENTION BASIN RETAINING WALL
PROPOSED ALL WEATHER ACCESS ROAD
PROPOSED MULTI-USE STORM WATER DETENTION BASIN (PRACTICE FIELD)
PROPOSED VEHICLE ACCESS RAMP
PROPOSED L-6270 8" S.S. RELOCATE
BORE SITE B-2
PROPOSED 15' S.S. ESMT
PROPOSED AREA INLET STORM DRAIN
PROPOSED DETENTION BASIN RETAINING WALL
BORE SITE B-3
PROPOSED 12" FILTRATION DRAIN PIPE
PROPOSED STORM WATER FILTRATION BASIN
SOIL BORE LOCATION SEE SHEET C-600 FOR LOG OF BORINGS TYP. OF 4
PROPOSED LOW FLOWS DRAINAGE SWALE (TYP 3 SIDES)
PROPOSED STILLING BASIN
PROPOSED 12" EMERGENCY BI-PASS LINE
PROPOSED SERPENTINE RETAINING WALLS
GRADE BREAK
PROPOSED SPILLWAY
PROPOSED 12" EMERGENCY BYPASS LINE
PROPOSED SWALE LINE (LOW POINT)
PROPOSED AREA INLET STORM DRAIN
PROPOSED DIVERSION WEIR
PROPOSED STORM WATE SEDIMENTATIO
PROPOSED STORM DRAIN EASEMENT BOUNDARY LINE
EXTENTS OF PROPOSED GRADING
EX. 15' S.S. ESMT
EX. FENCE
EX. L-6270 8" S.S
PROPOSED STORM WATER CHANNEL
Sand Filter
Diverter Weir
Sedimentation Basin
Trash Rack
EX ACCESS GATE
EX. IRON FENCE (TO REMAIN)
STORM WATER HEADWALL UNDER SEPARATE CONTRACT (BY OTHERS) SEE NOTE 1

Major Projects

1. Central Arlington Heights
2. Eastern Hills
3. **Luella Merrett**

Luella Merrett Detention Basin

- Flooding due to small pipe at mid-block sump
- Lots of impervious area in watershed
- Pipe capacity improvements $2 million +



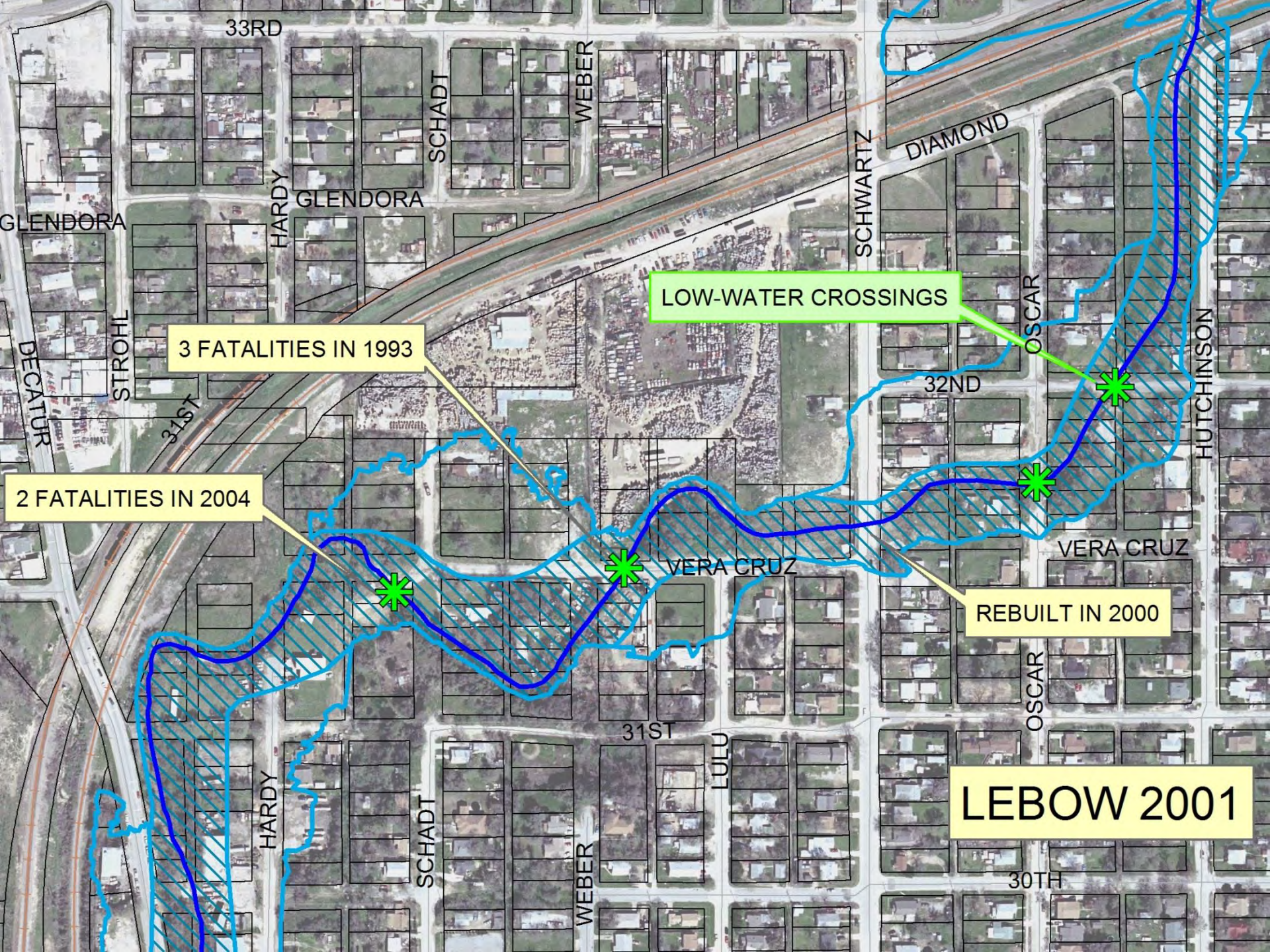
Luella Merrett Detention Basin

- Sloping play field at school suitable for detention
- Principal liked idea because of success of Eastern Hills

Major Projects

1. Central Arlington Heights
2. Eastern Hills
3. Luella Merrett
4. **Lebow Channel**

Lebow Low-Water Crossings


33RD
SCHADT
WEBER
DIAMOND
SCHWARTZ
HARDY
GLENDORA
GLENDORA
STROHL
DECATUR
31ST
LOW-WATER CROSSINGS
3 FATALITIES IN 1993
OSCAR
32ND
HUTCHINSON
2 FATALITIES IN 2004
VERA CRUZ
VERA CRUZ
REBUILT IN 2000
OSCAR
31ST
LULU
HARDY
SCHADT
WEBER
30TH
LEBOW 2001

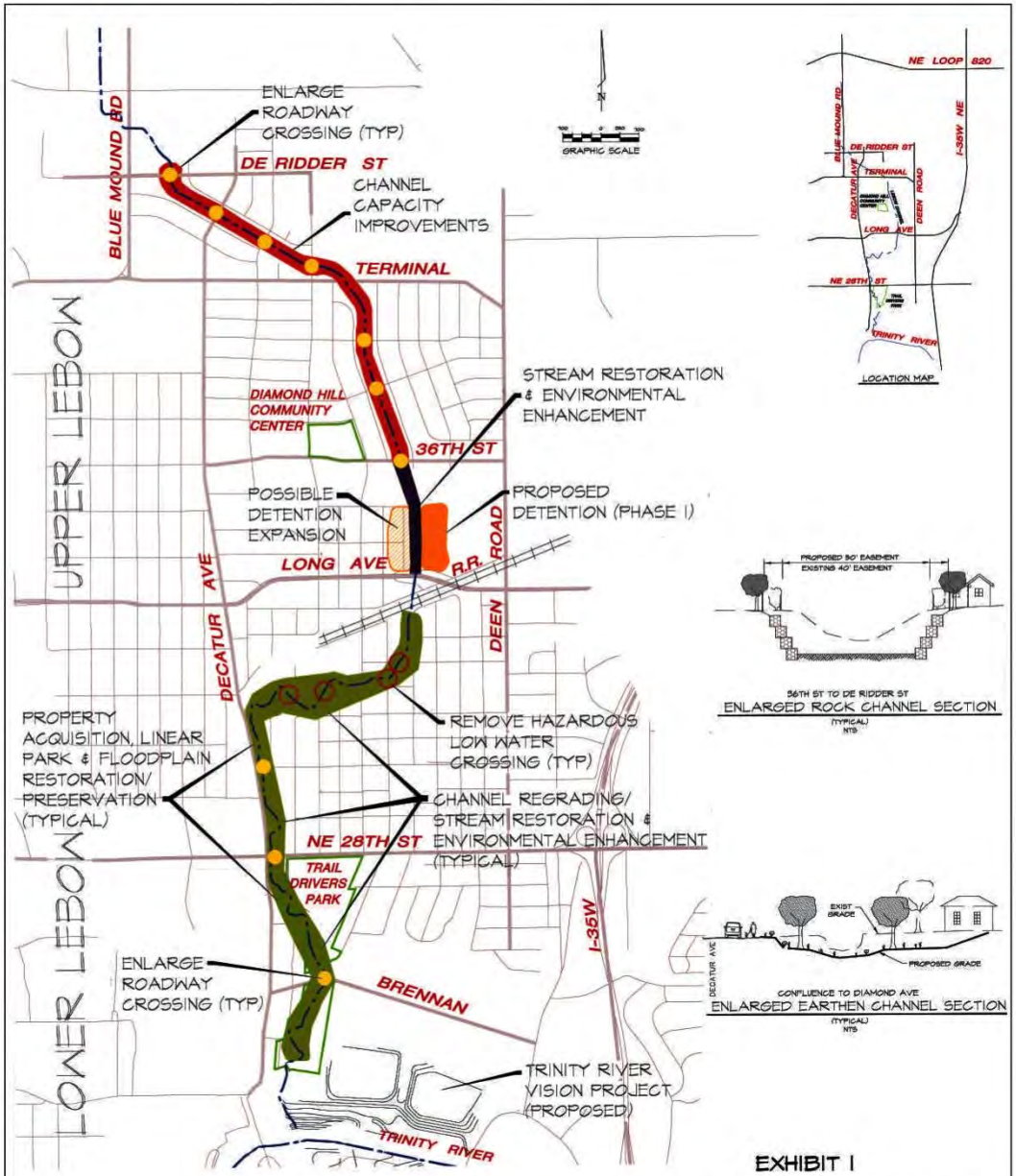


EXHIBIT I

RECOMMENDED IMPROVEMENT PLAN FOR THE LEBOW WATERSHED

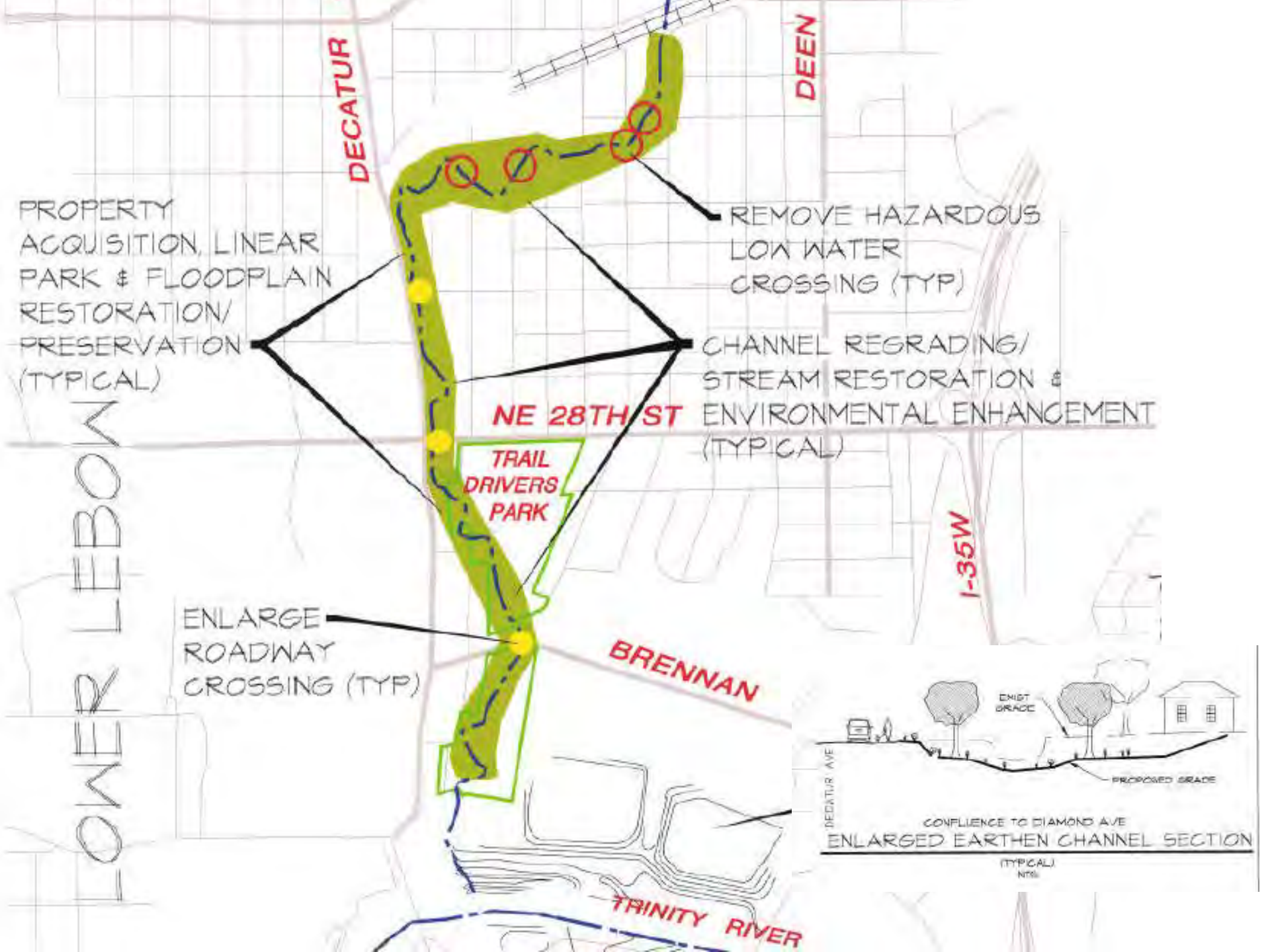
CITY OF FORT WORTH, TEXAS

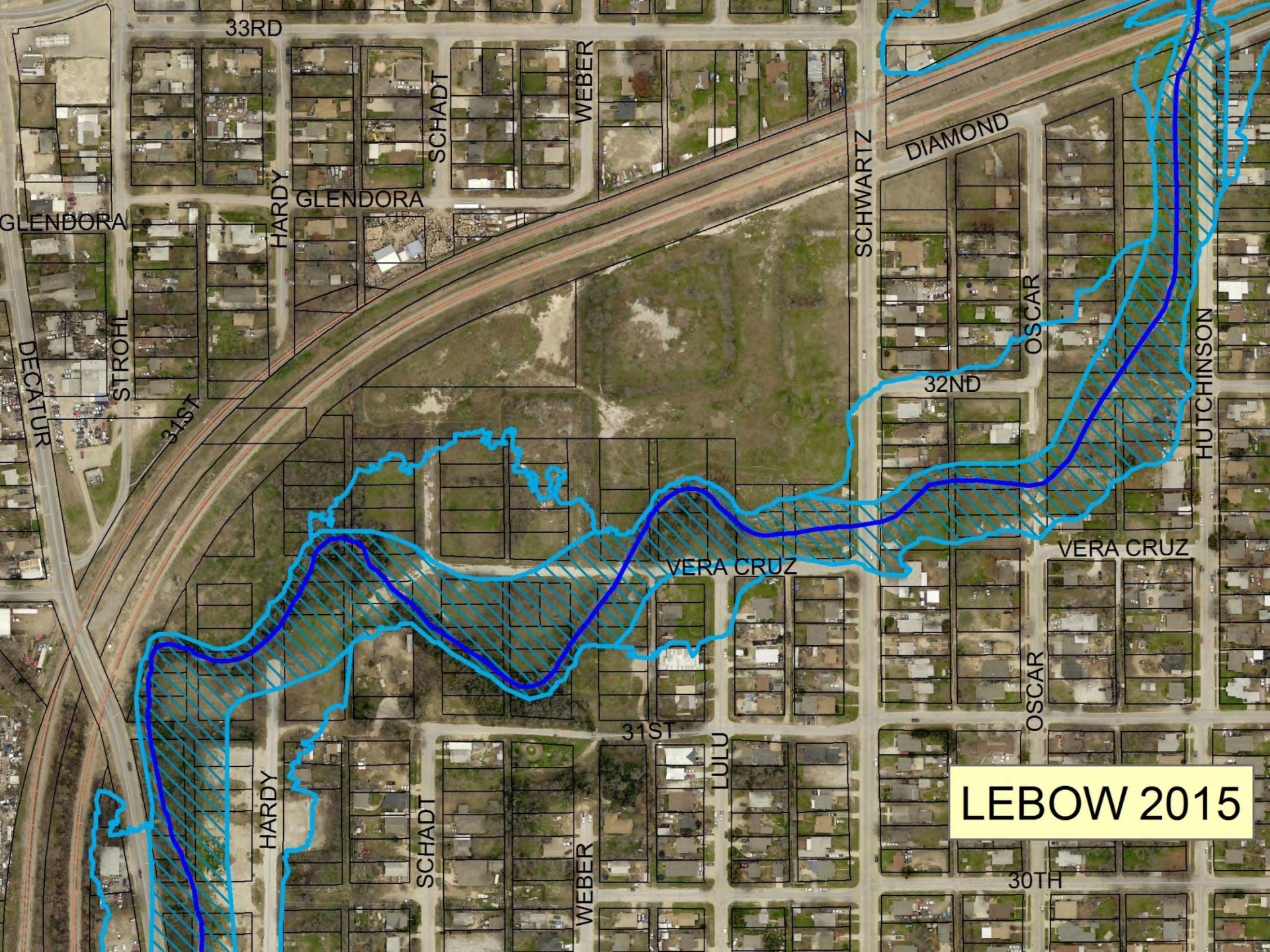
DECEMBER 8, 2006

TEAGUE NALL AND PERKINS INC.
ENGINEERS • SURVEYORS • CONSULTANTS
1100 Macon Street
Fort Worth, Texas 76102
(817) 336-5773

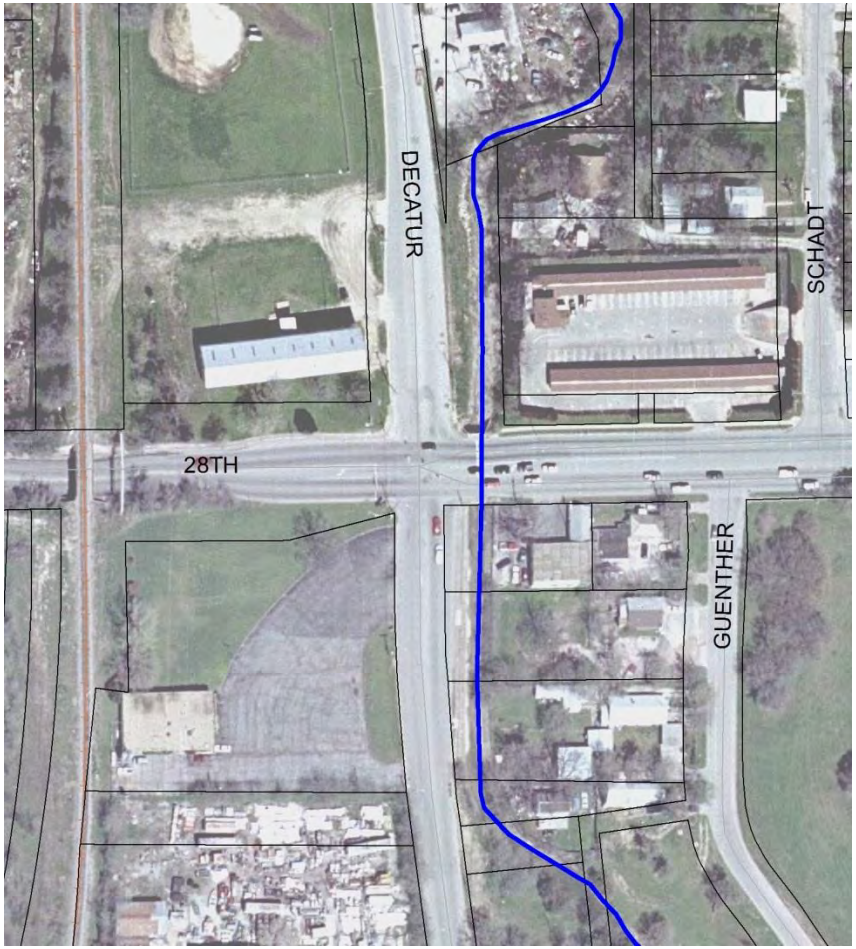
FORT WORTH


BLUE MOUND RD
ENLARGE ROADWAY CROSSING (TYP)
DE RIDDER ST
CHANNEL CAPACITY IMPROVEMENTS
TERMINAL
UPPER LEBOW
DIAMOND HILL COMMUNITY CENTER
STREAM RESTORATION & ENVIRONMENTAL ENHANCEMENT
36TH ST
POSSIBLE DETENTION EXPANSION
PROPOSED DETENTION (PHASE I)
LONG AVE
R.R.
ROAD
AVE
PROPOSED 50' EASEMENT
EXISTING 40' EASEMENT
36TH ST TO DE RIDDER ST
ENLARGED ROCK CHANNEL SECTION
(TYPICAL)
NTS


DECATUR
DEEN
PROPERTY ACQUISITION, LINEAR PARK & FLOODPLAIN RESTORATION/ PRESERVATION (TYPICAL)
REMOVE HAZARDOUS LOW WATER CROSSING (TYP)
CHANNEL REGRADING/ STREAM RESTORATION & ENVIRONMENTAL ENHANCEMENT (TYPICAL)
NE 28TH ST
TRAIL DRIVERS PARK
I-35W
ENLARGE ROADWAY CROSSING (TYP)
BRENNAN
LOWER LEBOW
TRINITY RIVER
EXIST GRADE
PROPOSED GRADE
DECATUR AVE
CONFLUENCE TO DIAMOND AVE
ENLARGED EARTHEN CHANNEL SECTION
(TYPICAL)
NTS


33RD
SCHADT
WEBER
DIAMOND
SCHWARTZ
GLENDORA
HARDY
GLENDORA
STROHL
DECATUR
31ST
OSCAR
32ND
HUTCHINSON
VERA CRUZ
VERA CRUZ
OSCAR
31ST
LULU
HARDY
SCHADT
WEBER
30TH
LEBOW 2015

NE Twenty-Eighth Street Crossing



NE 28th St. Crossing

Major Projects

1. Central Arlington Heights
2. Eastern Hills
3. Luella Merrett
4. Lebow Channel
5. **Westcliff**

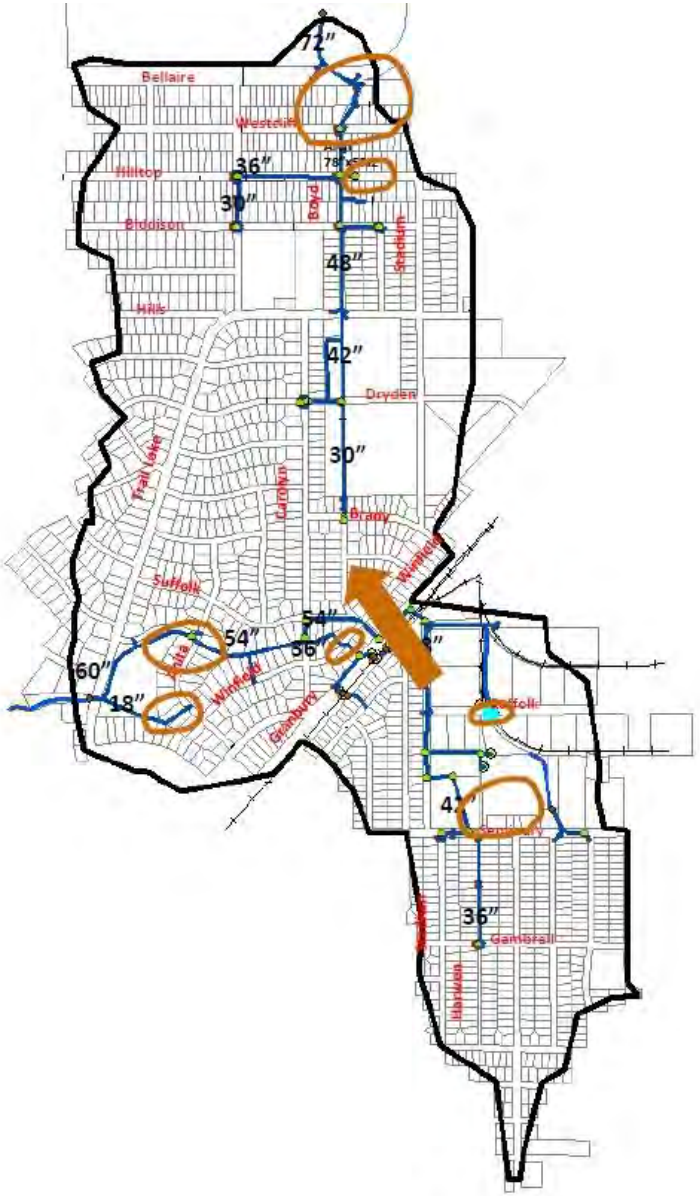
Westcliff Manor Apts., 6/28/04 (31 units flooded)

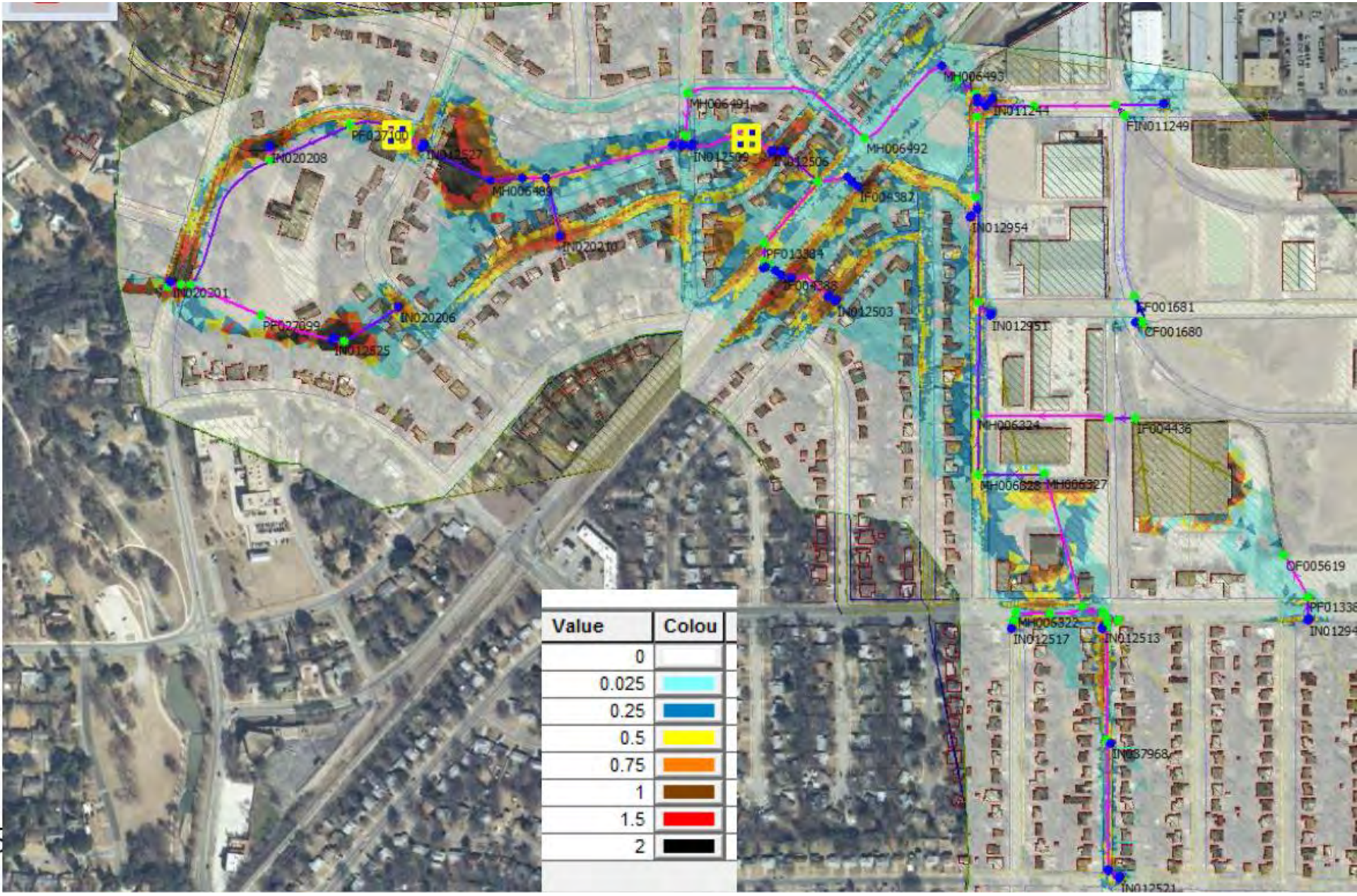
Home flooding on Boyd

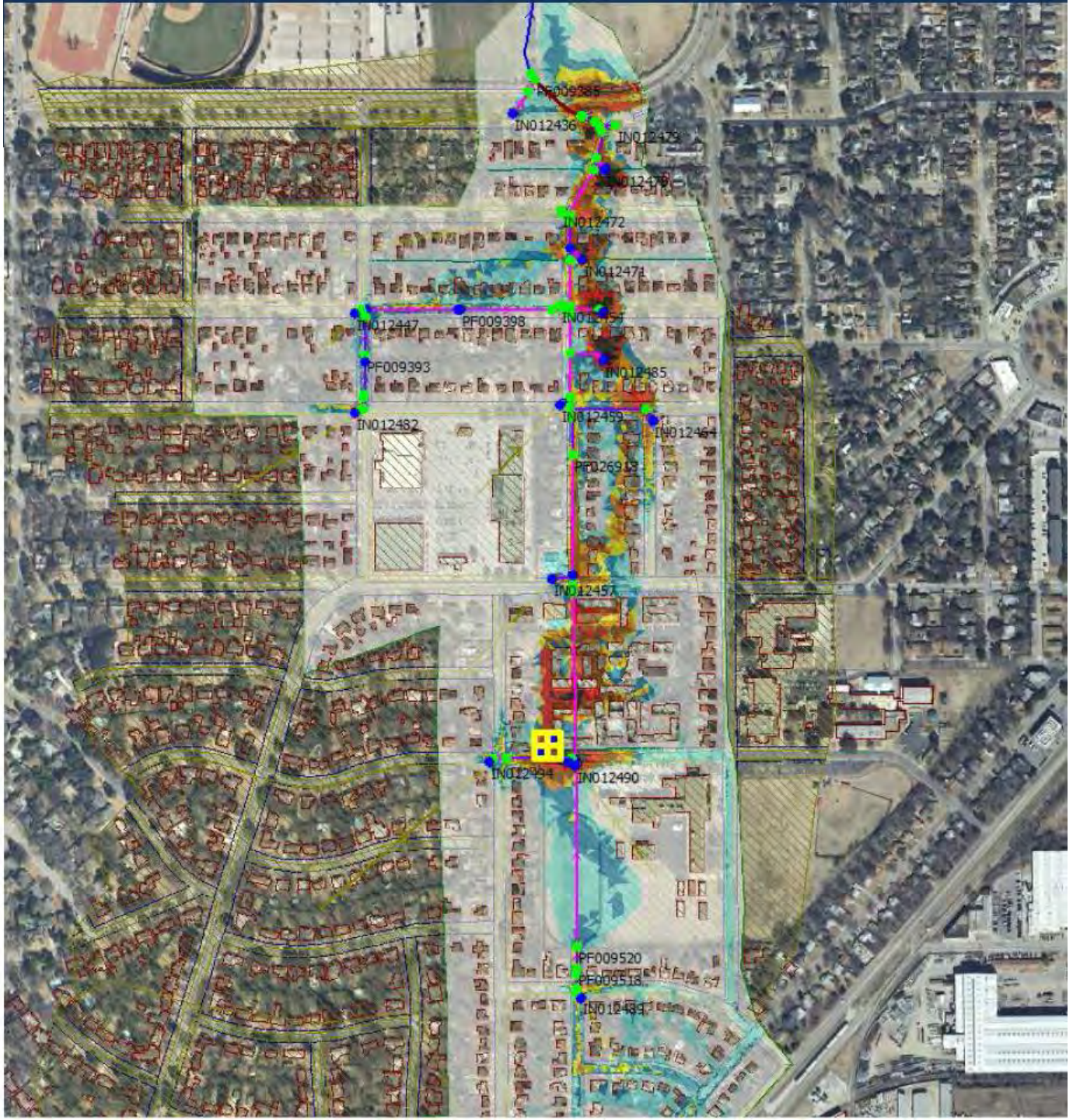
Surface Flooding

Transfer of Flow

Storm Sewer System Capacity



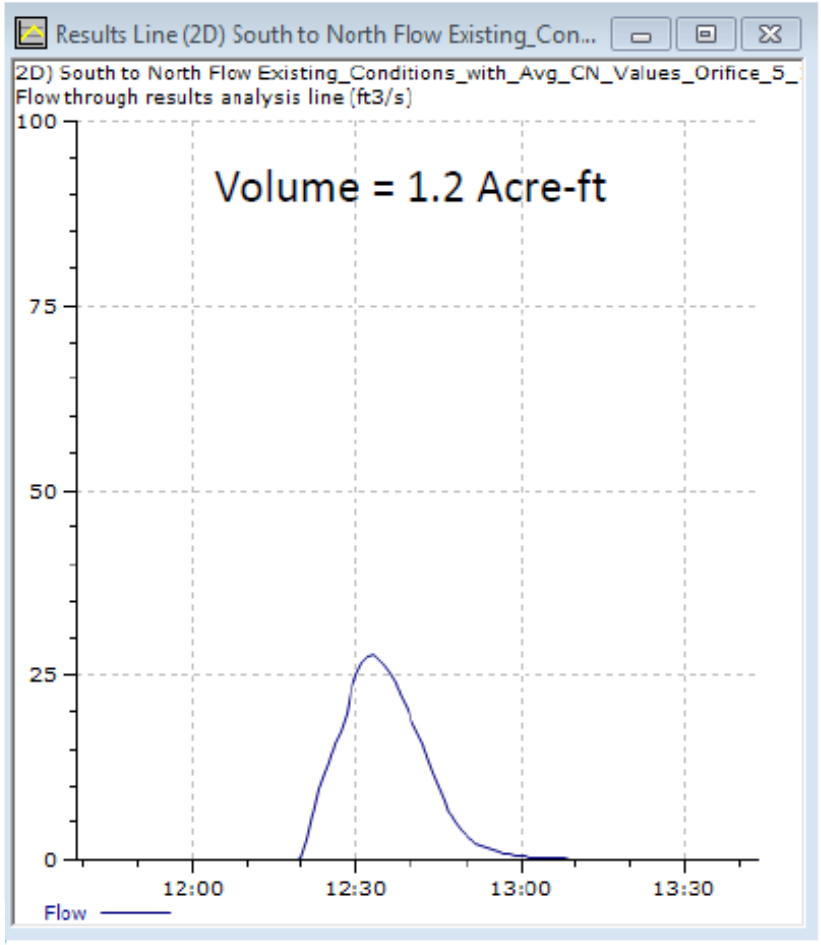

MH006493
IN011243
FIN011249
MH006491
PF027100
IN020208
IN012527
IN012509
IF012505
MH006492
MH006489
IF004387
IN012954
IN020210
PF013384
IF004438
IN020201
IN020206
PF027099
IN012525
IN012503
IN012951
CF001681
CF001680
MH006324
IF004436
MH006328
MH006327
CF005619
PF01338
IN01294
MH006322
IN012517
IN012513
IN037968
IN012521
Value
Colou
0
0.025
0.25
0.5
0.75
1
1.5
2



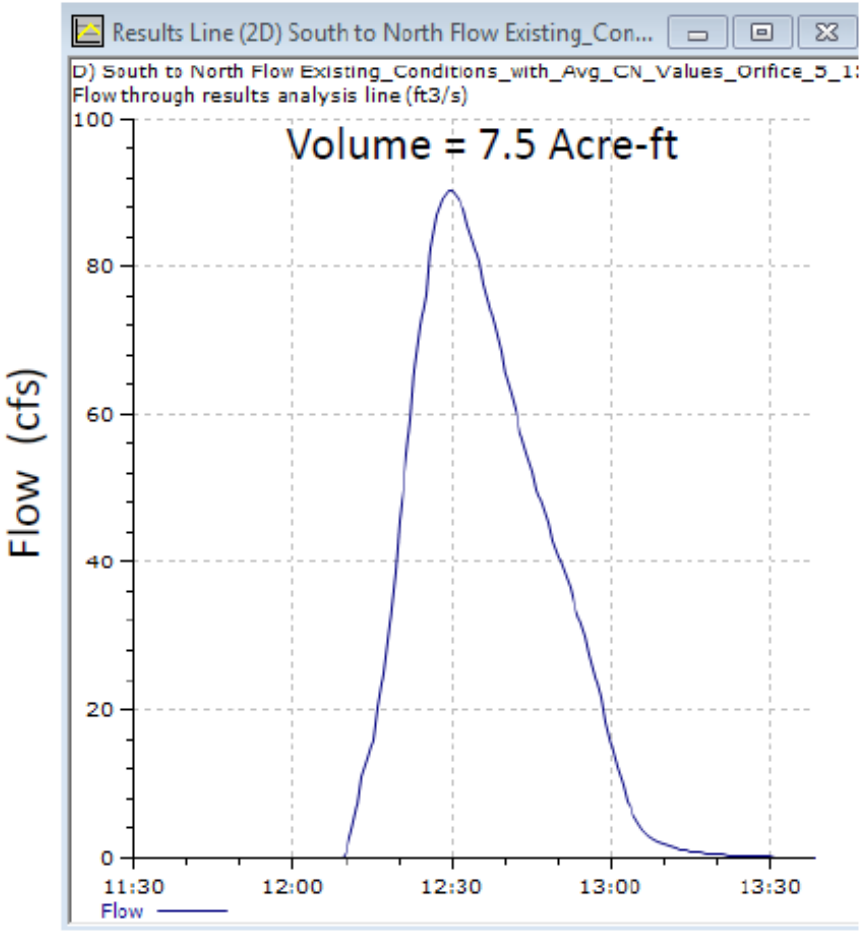
Value	Colou
0	
0.025	
0.25	
0.5	
0.75	
1	
1.5	
2	

Hydrograph of Spillover Flow

5 Year 24 Hour



100 Year 24 Hour



Flooded Structures

Summary of Flooded Structures and Estimated Depth of Flood for the 100 Year and 5 Year 3 Hour Design Events
Based on InfoWorks SD Model Design Strom Simulations

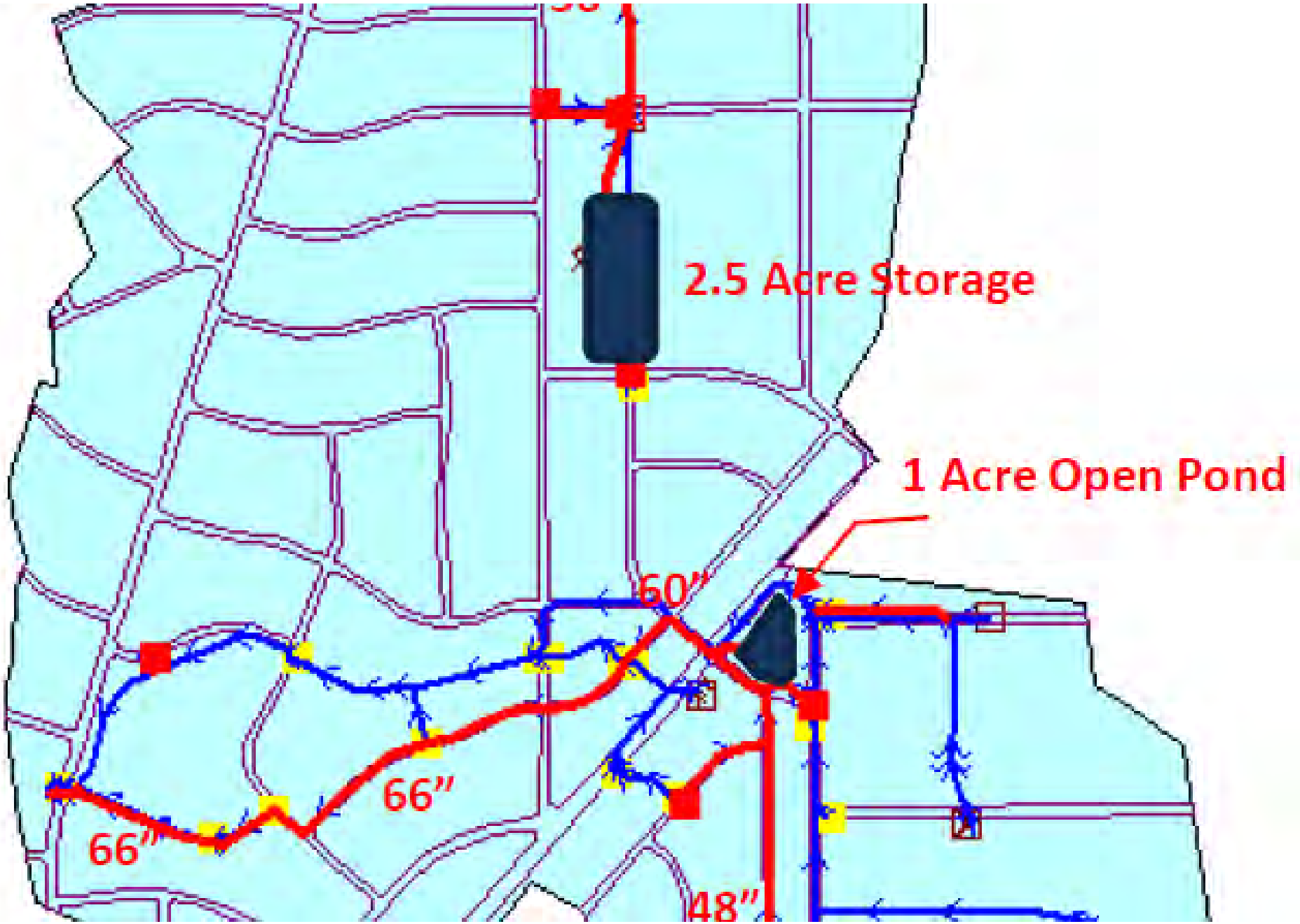
Address	District	Approx. Ground Elevation (IW SD Model)	Assumed FFE Above Ground Elev. (ft)	Approx. FFE	100 Year 3 Hour Design Storm		5 Year 3 Hour Design Storm	
					Simulated Max Water Elev. (IW SD Model)	Water Depth Above FFE (ft)	Simulated Max Water Elev. (IW SD Model)	Water Depth Above FFE (ft)
3328 W SEMINARY DR	WC South	713.4	0.5	**713.9**	714.0	0.1		
3328 W SEMINARY DR	WC South	712.0	0.5	**712.5**	713.0	0.5		
3328 W SEMINARY DR	WC South	711.8	0.5	**712.3**	712.9	0.6	712.3	0.0
3328 W SEMINARY DR	WC South	710.4	0.5	**710.9**	711.7	0.8	711.2	0.3
3328 W SEMINARY DR	WC South	707.5	0.5	**708.0**	708.5	0.5		
3250 W SEMINARY DR	WC South	708.0	0.5	**708.5**	709.9	1.3		
4100 SURREY ST	WC South	688.9	1	**689.9**	690.0	0.1		
4205 SURREY ST	WC South	698.1	1	**699.1**	699.1	0.0		
4124 CHEROKEE TR	WC South	689.8	1	**690.8**	691.1	0.2		
4141 WINFIELD AVE	WC South	684.6	1	**685.6**	685.7	0.1		
4201 WINFIELD AVE	WC South	681.6	1	**682.6**	682.7	0.1		
4159 CAROLYN RD	WC South	684.3	1	**685.3**	685.7	0.4		
4121 ANITA AVE	WC South	669.6	1	**670.6**	672.8	2.3	671.1	0.5
4121 ANITA AVE	WC South	670.1	1	**671.1**	672.6	1.5		
4125 ANITA AVE	WC South	669.7	1	**670.7**	672.9	2.2	671.1	0.5

Impacted Structures 15 4

Summary of Flooded Structures and Estimated Depth of Flood for the 100 Year and 5 Year 3 Hour Design Events
Based on InfoWorks SD Model Design Strom Simulations

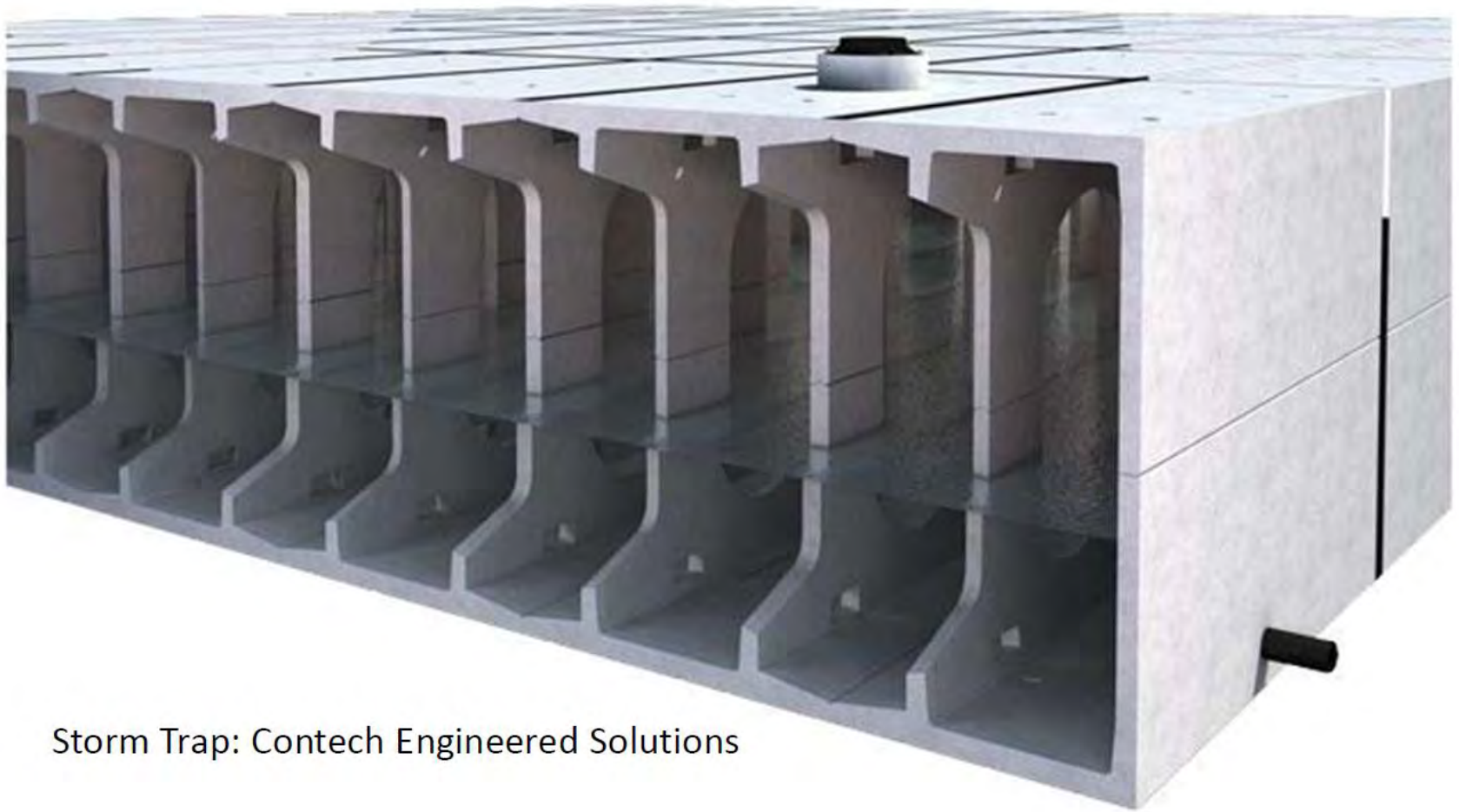
Address	District	Approx. Ground Elevation (IW SD Model)	Assumed FFE Above Ground Elev. (ft)	Approx. FFE	100 Year 3 Hour Design Storm		5 Year 3 Hour Design Storm	
					Simulated Max Water Elev. (IW SD Model)	Water Depth Above FFE (ft)	Simulated Max Water Elev. (IW SD Model)	Water Depth Above FFE (ft)
3737 CAROLYN RD	WC North	668.0	1	669.0	669.3	0.3		
3415 SOUTH HILLS AVE-1	WC North	667.0	0.5	667.5	668.6	1.1		
3415 SOUTH HILLS AVE-2	WC North	666.7	0.5	667.2	668.3	1.1		
3415 SOUTH HILLS AVE-3	WC North	667.6	0.5	668.1	668.2	0.1		
3415 SOUTH HILLS AVE-4	WC North	665.4	0.5	665.9	666.9	1.0		
3415 SOUTH HILLS AVE-5	WC North	664.9	0.5	665.4	666.7	1.2	665.5	0.1
3415 SOUTH HILLS AVE-6	WC North	664.9	0.5	665.4	666.7	1.3	665.4	0.0
3415 SOUTH HILLS AVE-7	WC North	665.3	0.5	665.8	666.7	0.8		
3415 SOUTH HILLS AVE-8	WC North	665.9	0.5	666.4	666.7	0.3		
			0.5	665.9	666.6	0.8		
			0.5	665.3	666.7	1.4	665.5	0.2
			0.5	665.3	666.6	1.3	665.4	0.1
			0.5	665.9	666.5	0.6		
			0.5	665.3	666.5	1.1		
			0.5	665.3	666.3	1.1	665.3	0.1
			0.5	665.8	666.4	0.6		
			0.5	665.8	666.0	0.2		
			0.5	665.1	666.3	1.2	665.3	0.1
			0.5	664.4	665.0	0.6		
			0.5	666.2	666.2	0.0		
			0.5	664.3	665.0	0.7		
			0.5	663.7	664.9	1.2	663.9	0.2
			0.5	663.3	664.7	1.5	663.5	0.2
			0.5	659.4	659.4	0.1		
			0.5	659.8	660.6	0.8		
			0.5	660.0	660.7	0.6		
			1	655.6	655.6	0.0		
			1	656.2	656.5	0.4		
			1	657.0	657.1	0.1		
			1	658.1	658.6	0.4		
			1	658.2	658.8	0.6		
			1	659.4	659.5	0.1		
			1	659.6	659.6	0.0		
			1	652.0	652.4	0.4		
			1	651.6	652.7	1.0		
			1	651.6	652.7	1.0		
			1	645.3	646.1	0.8		
			1	645.7	646.5	0.8		
3429 HILLTOP RD	WC North	646.9	1	647.9	649.0	1.1		
3432 HILLTOP RD	WC North	644.7	1	645.7	646.4	0.7		
3422 WESTCLIFF RD S	WC North	634.9	1	635.9	637.6	1.7	636.3	0.4
3426 WESTCLIFF RD S	WC North	634.9	1	635.9	637.6	1.7	636.3	0.4
3429 WESTCLIFF RD S	WC North	640.1	1	641.1	641.8	0.7		
3433 WESTCLIFF RD S	WC North	639.5	1	640.5	641.9	1.4		
3501 BELLAIRE DR S	WC North	634.9	1	635.9	636.2	0.3		

Impacted Structures 45 10


2.5 Acre Storage
1 Acre Open Pond
60"
66"
66"
48"

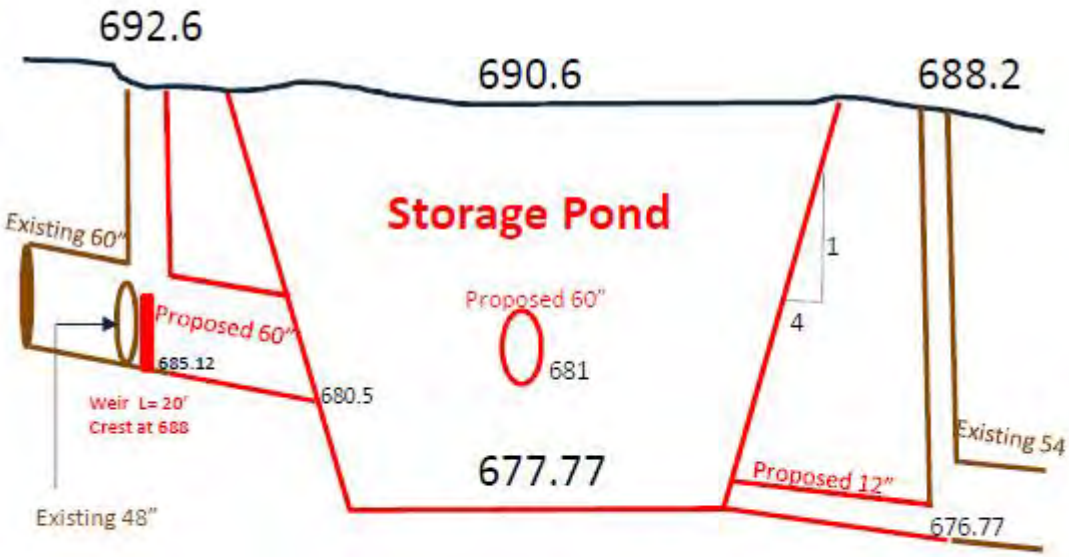
North Storage Structure Conceptual Layout

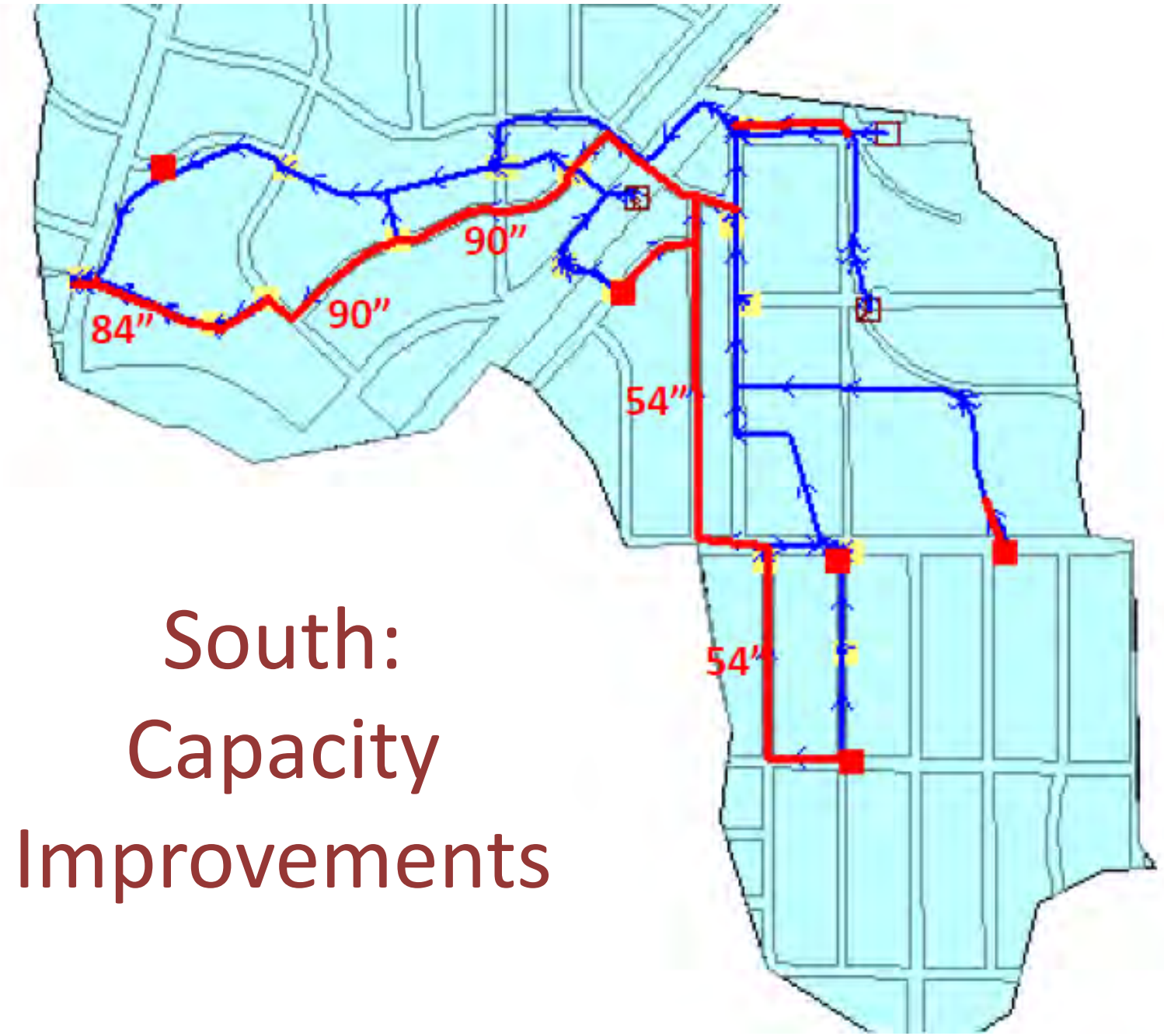
North Storage Structure – Potential Construction Method 1



Storm Trap: Contech Engineered Solutions

South 1 Storage Pond Conceptual Layout





South: Capacity Improvements

Fort Worth Stormwater Capital Projects

QUESTIONS?