The Challenge of Urban Flooding

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FORT WORTH


STOP


10/21/2009

The Challenge

- Typically older parts of town
- Long-term chronic or nuisance flooding
- No affordable solutions available
- Happens fast: gone in an hour or so
- Often only brief public attention
- Damages may be intangible

The Challenge

- Generally not addressed by NFIP
- Flood risk not mapped
- Considered local problem only
- No established recovery process
- Low grant priority
- “Not floodplain” = (?) Not important

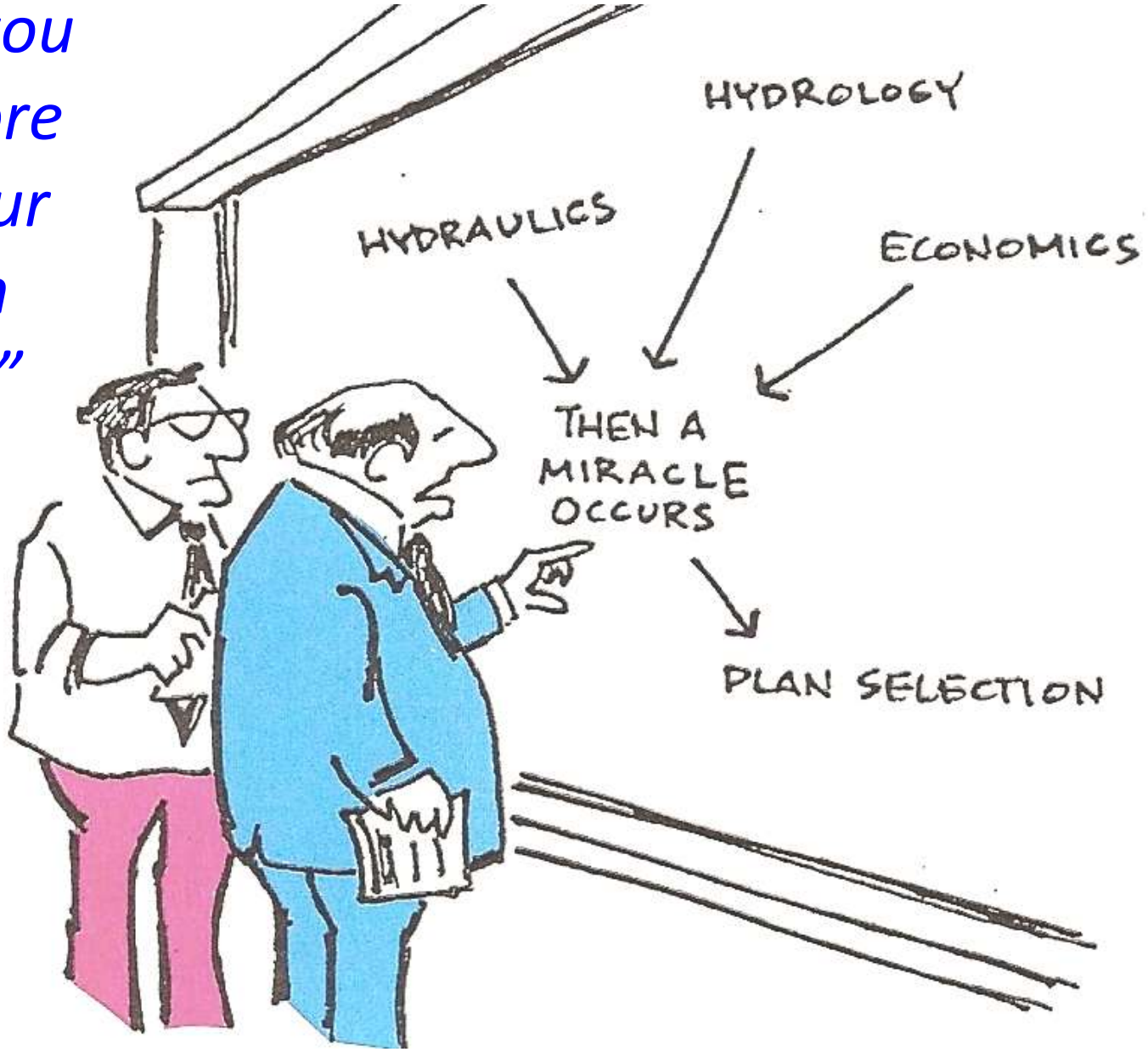
Urban Flooding Awareness "Act" (Bill)

- 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"
- Still in assigned committees

Urban Flooding Awareness "Act" (Bill)

- Inadequacy 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

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



Issues in Urban (Zone X) Flooding

GENERAL CONSIDERATIONS

(1) Water Law

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.

—Texas Water Code §11.086

In other words: LAWSUITS!

(2) 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. The adverse effects or impacts can be measured in terms of increased flood peaks, increased flood stages, higher flood velocities, increased erosion and sedimentation, or other impacts the community considers important."

—ASFPM, 2008

(3) Hydrodynamic Modeling

- Need to track overland flow as well as pipe capacity
- Too complex for traditional modeling and calculations
- Need fully dynamic flow modeling and complex software

(3) Hydrodynamic Modeling

- Dynamic wave modeling looks at effects of water rising, peaking and dropping, not just a steady flow rate
- Storage and routing built into the analysis
- Momentum and continuity expressed as non-linear differential equations

St. Venant Equations

(1) The continuity equation

$$v\frac{\partial A}{\partial x} + A\frac{\partial v}{\partial x} + b\frac{\partial h}{\partial t} = 0$$

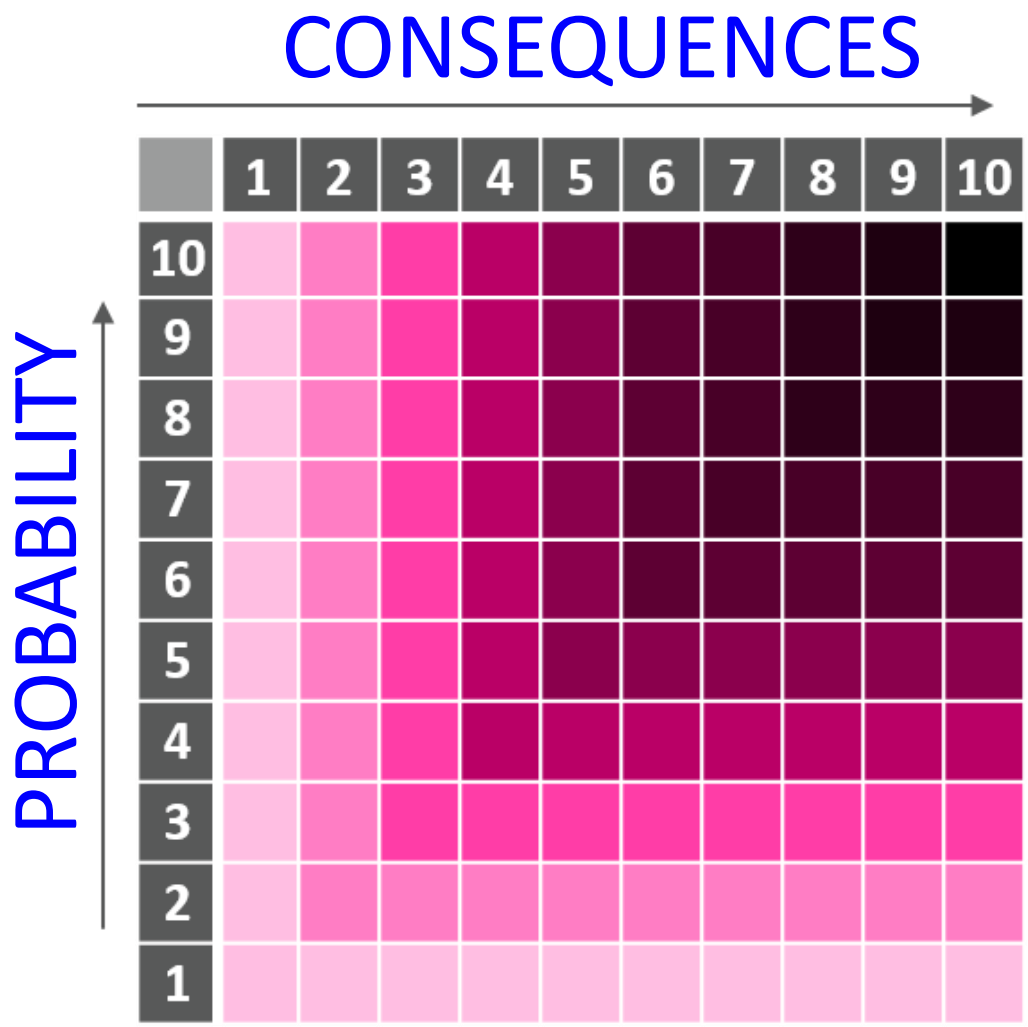
(2) The dynamic, or momentum, equation

$$\frac{\partial Q}{\partial t} + \frac{\partial\left(Q^2 / A\right)}{\partial x} + gA\left(\frac{\partial y}{\partial x} - S_0\right) + gAS_f = 0$$

Software Available

- Innovyze products
  - InfoWorks® (by Wallingford)
  - XP-SWMM® (by XP Software)
- MIKE FLOOD® by DHI
- HEC-RAS 2D
- FLO-2D
- Several other products

(4) Understanding Risk



Darker shading = greater impetus to take action

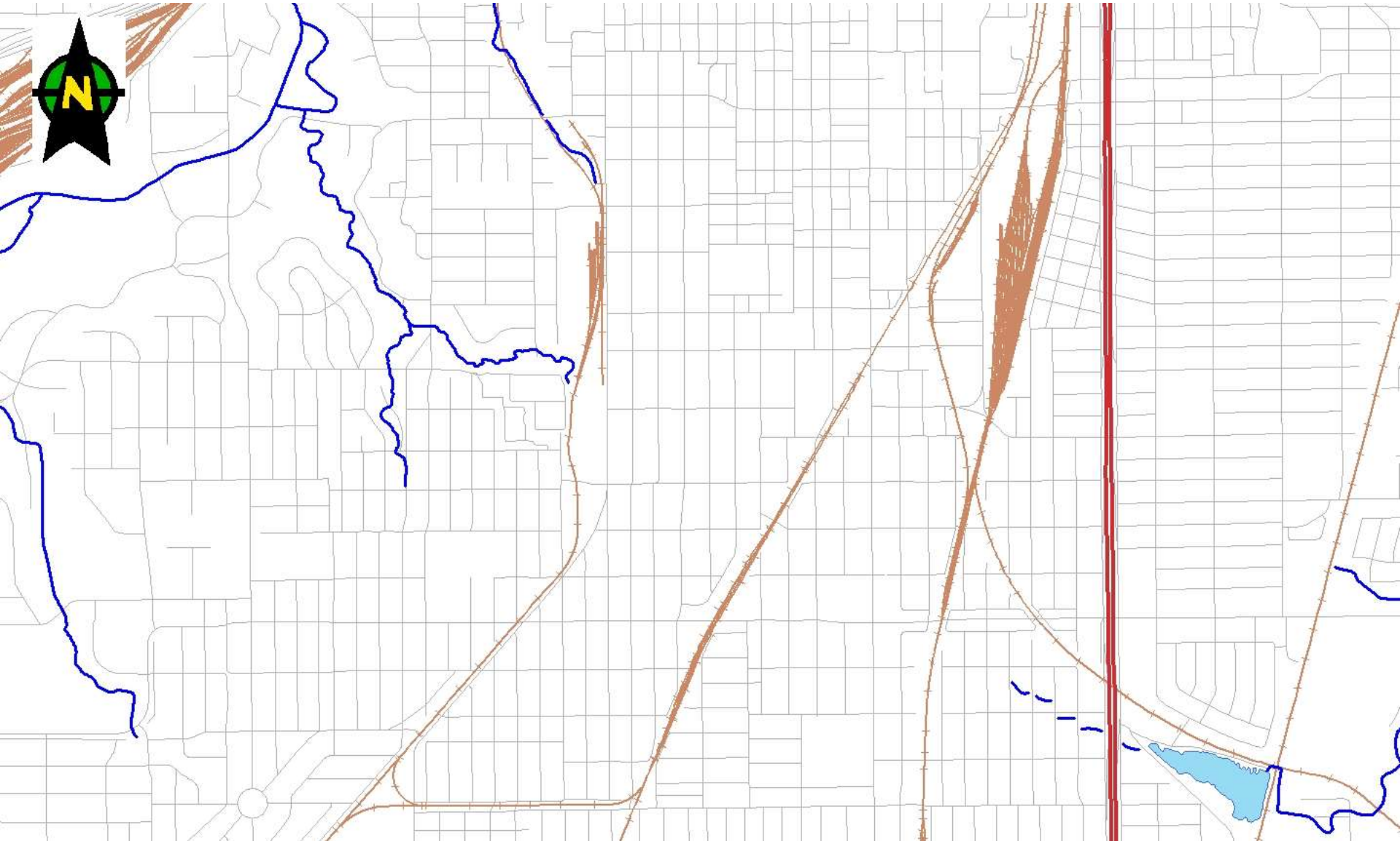
(4) Understanding Risk

- 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

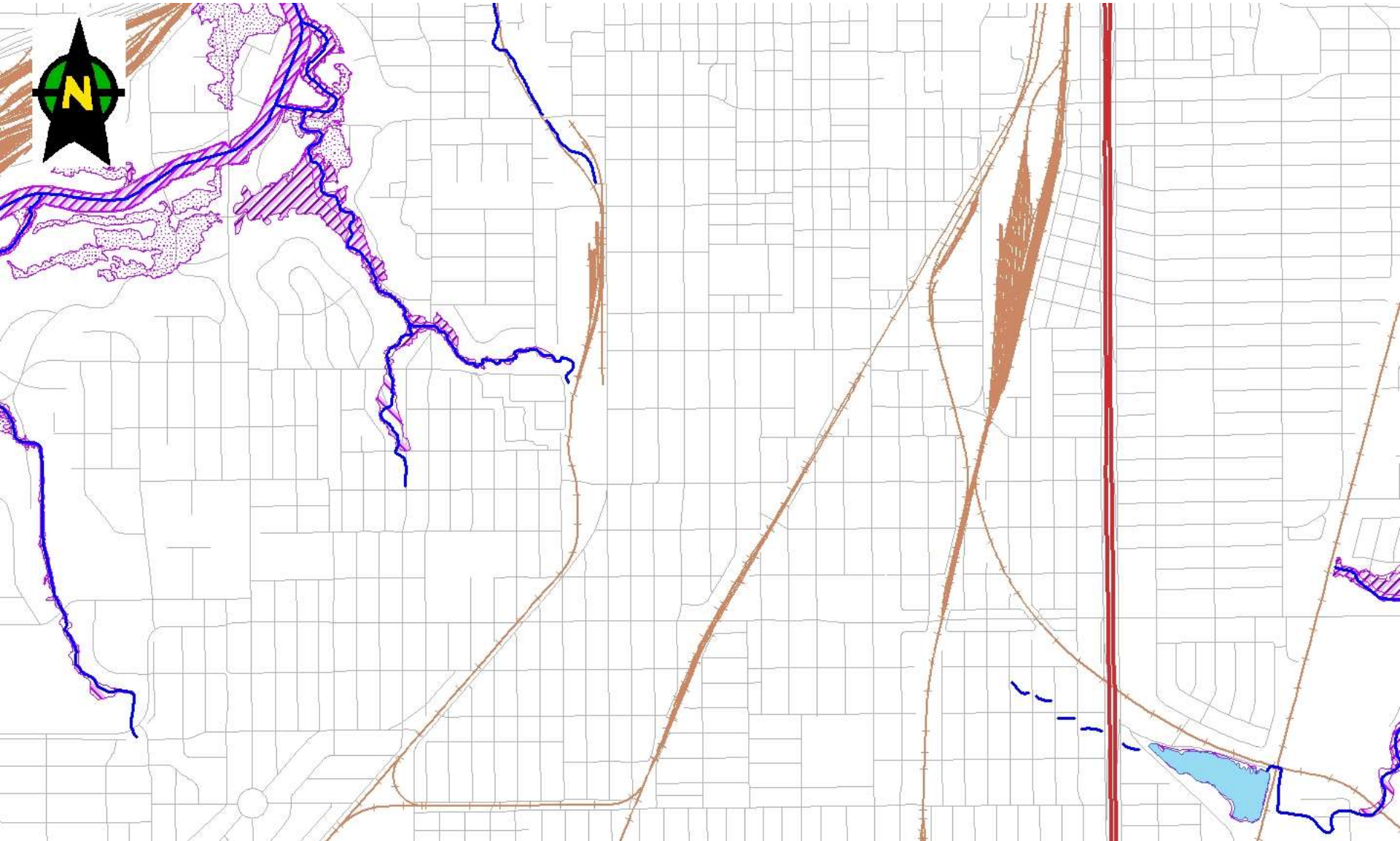
Issues in Urban (Zone X) Flooding

SO WHAT'S THE PROBLEM?

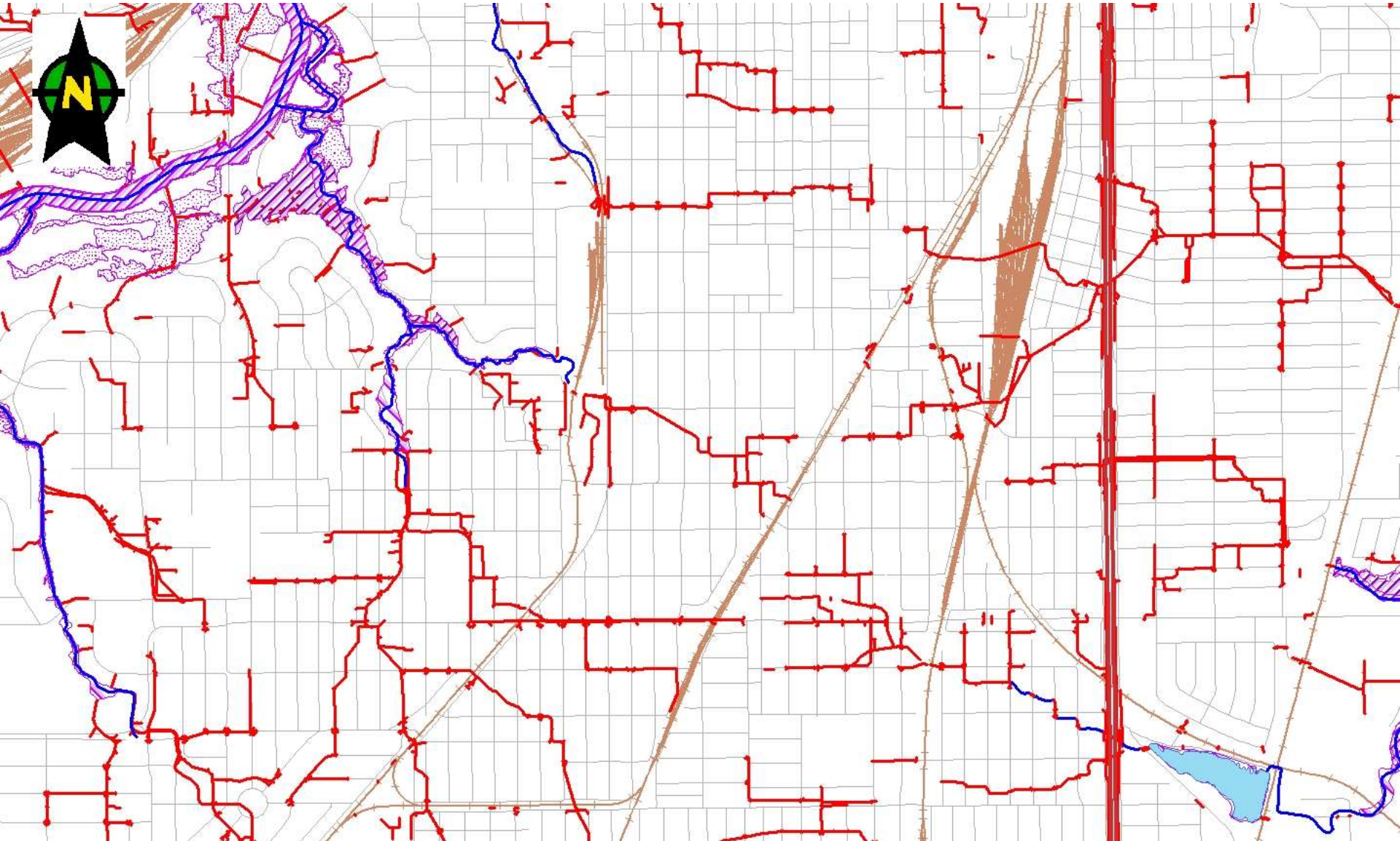
Typical urban drainage patterns



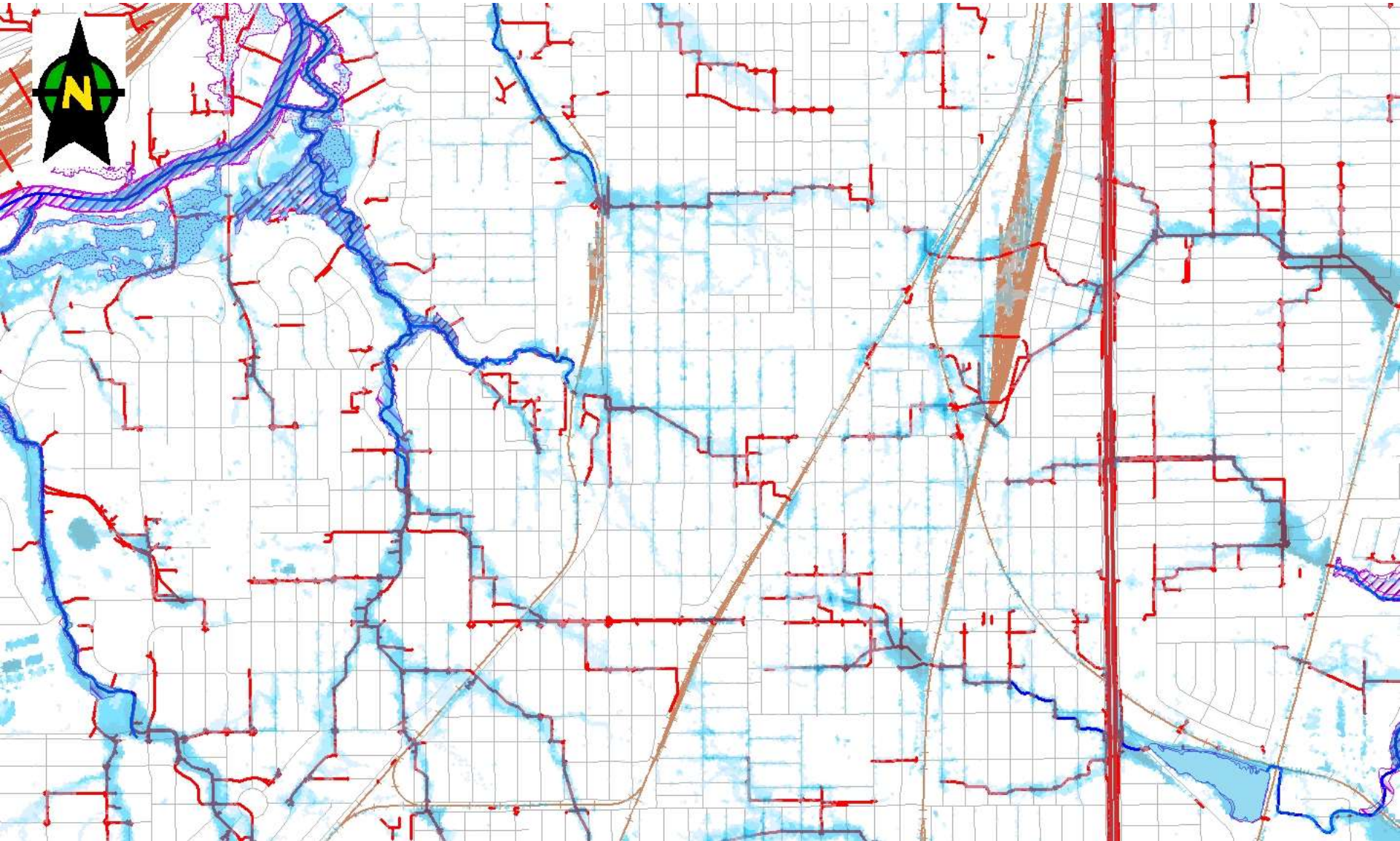
Typical urban drainage patterns



Typical urban drainage patterns



Typical urban drainage patterns



Main Causes of Urban Flooding

- Pre-1960 lower design standards meant storm drains often severely undersized compared to current standards
- Street grid often ignored drainage patterns, leading to mid-block sumps
- Houses and buildings constructed over storm drains in some cases

Typical Older Neighborhood

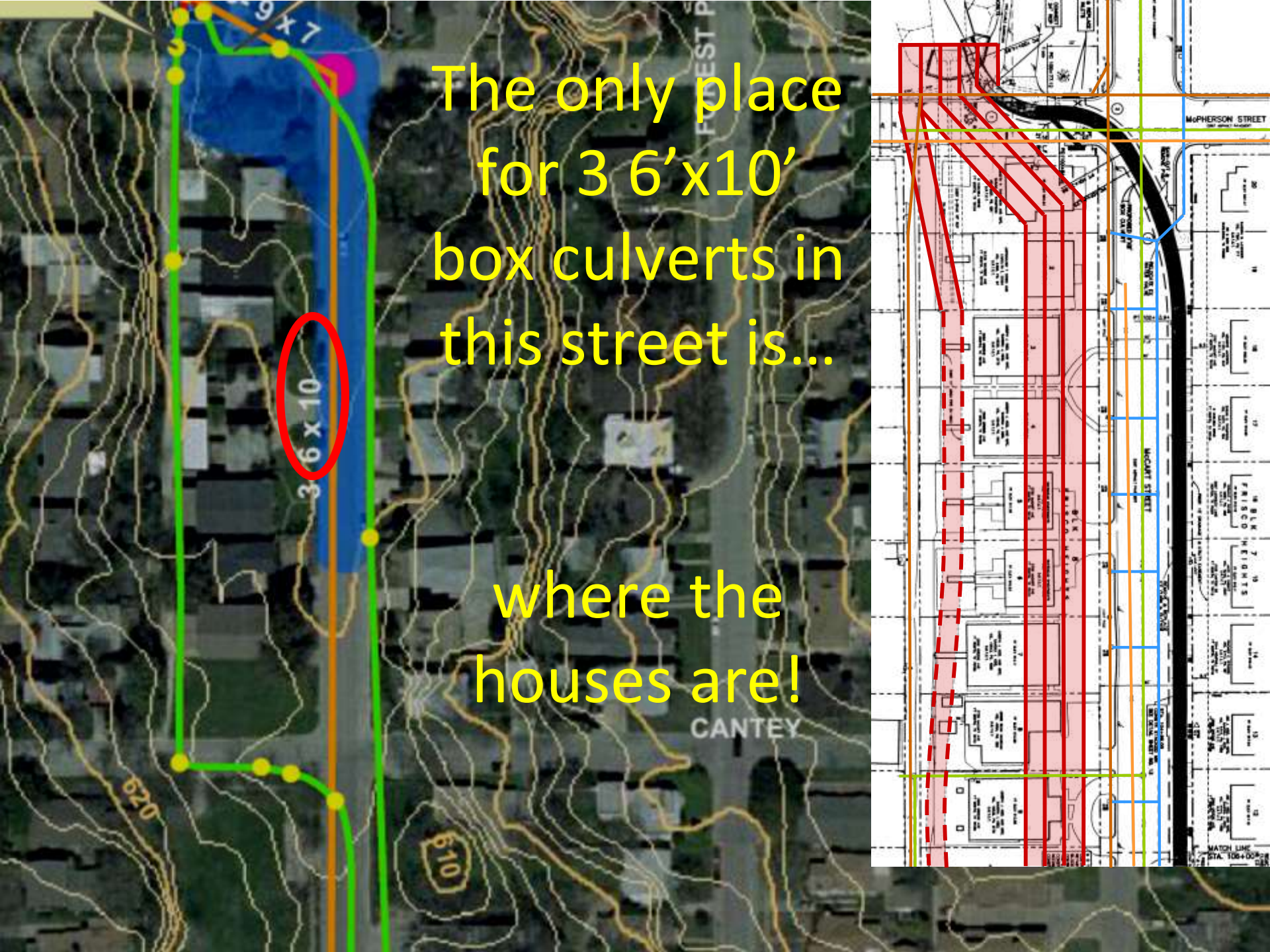
June 28, 2004 – Arlington Heights in Fort Worth

Issues in Urban (Zone X) Flooding

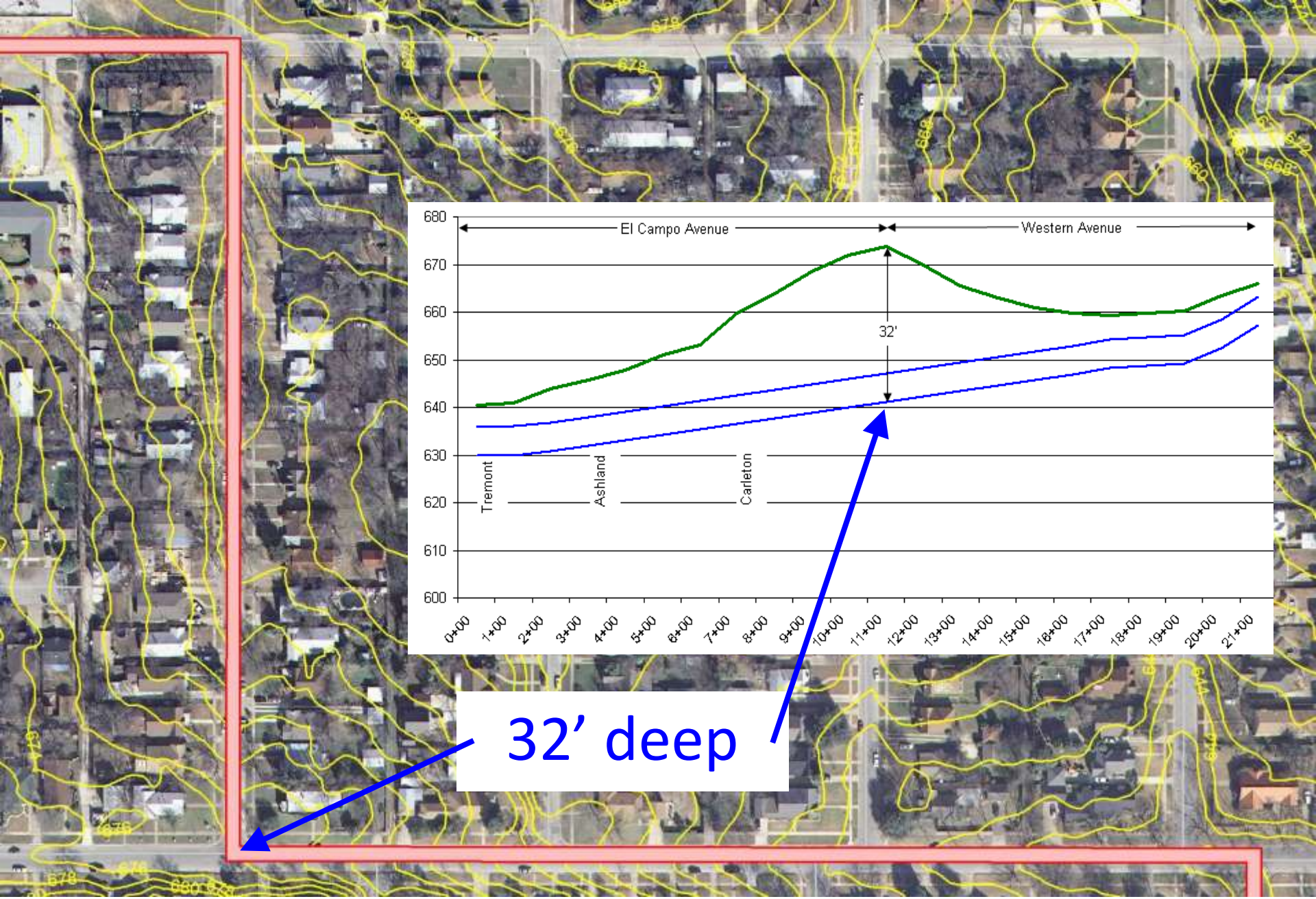
HOW CAN WE SOLVE THIS?

NEW PIPE ON EXISTING ALIGNMENT


Three houses and
several garages
must be removed
for two 6’x6’ boxes


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

CAN WE FOLLOW THE STREET GRID TO REDUCE HOME BUY-OUTS?


El Campo Avenue
Western Avenue
32'
Tremont
Ashland
Carleton
680
670
660
650
640
630
620
610
600
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
11+00
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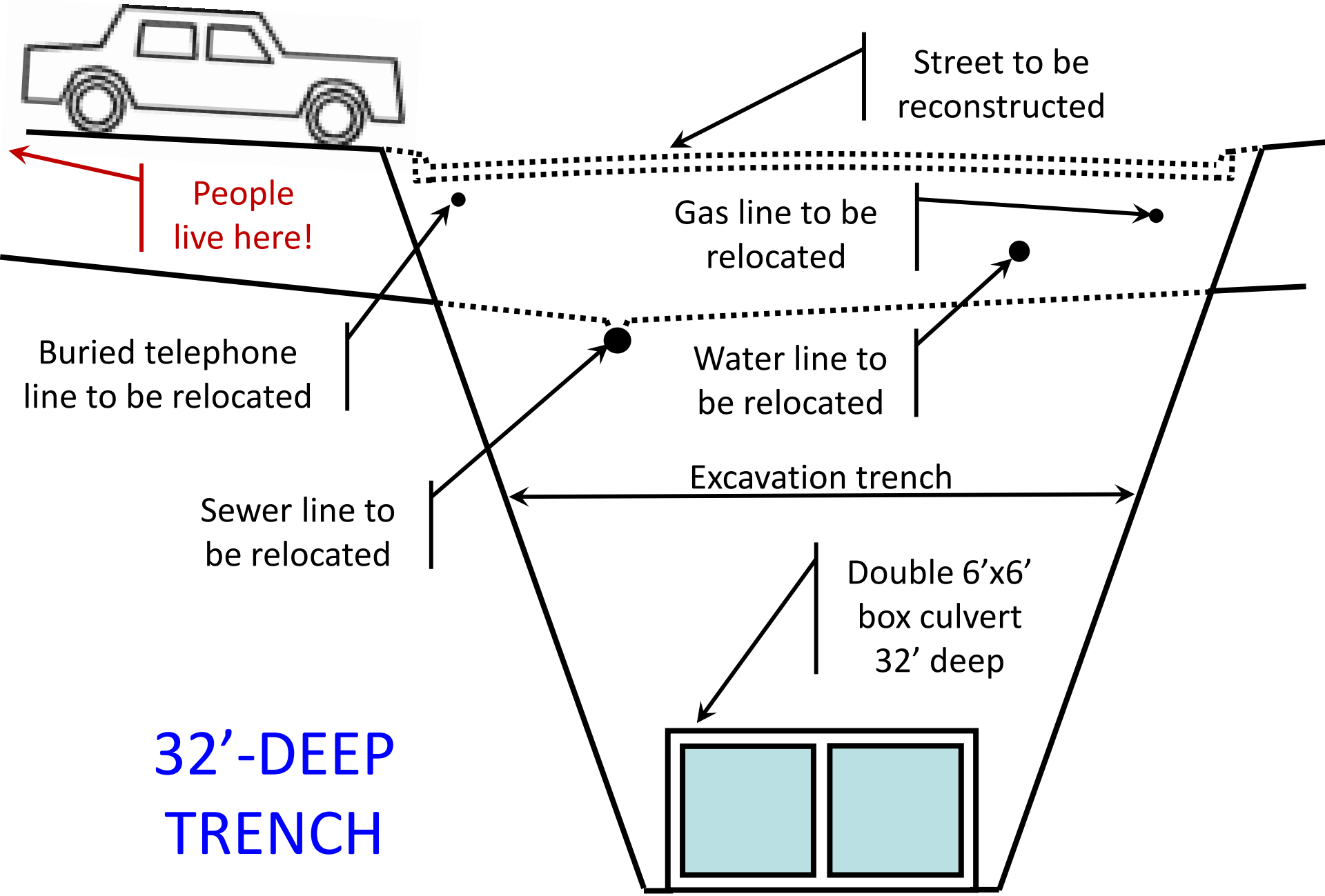
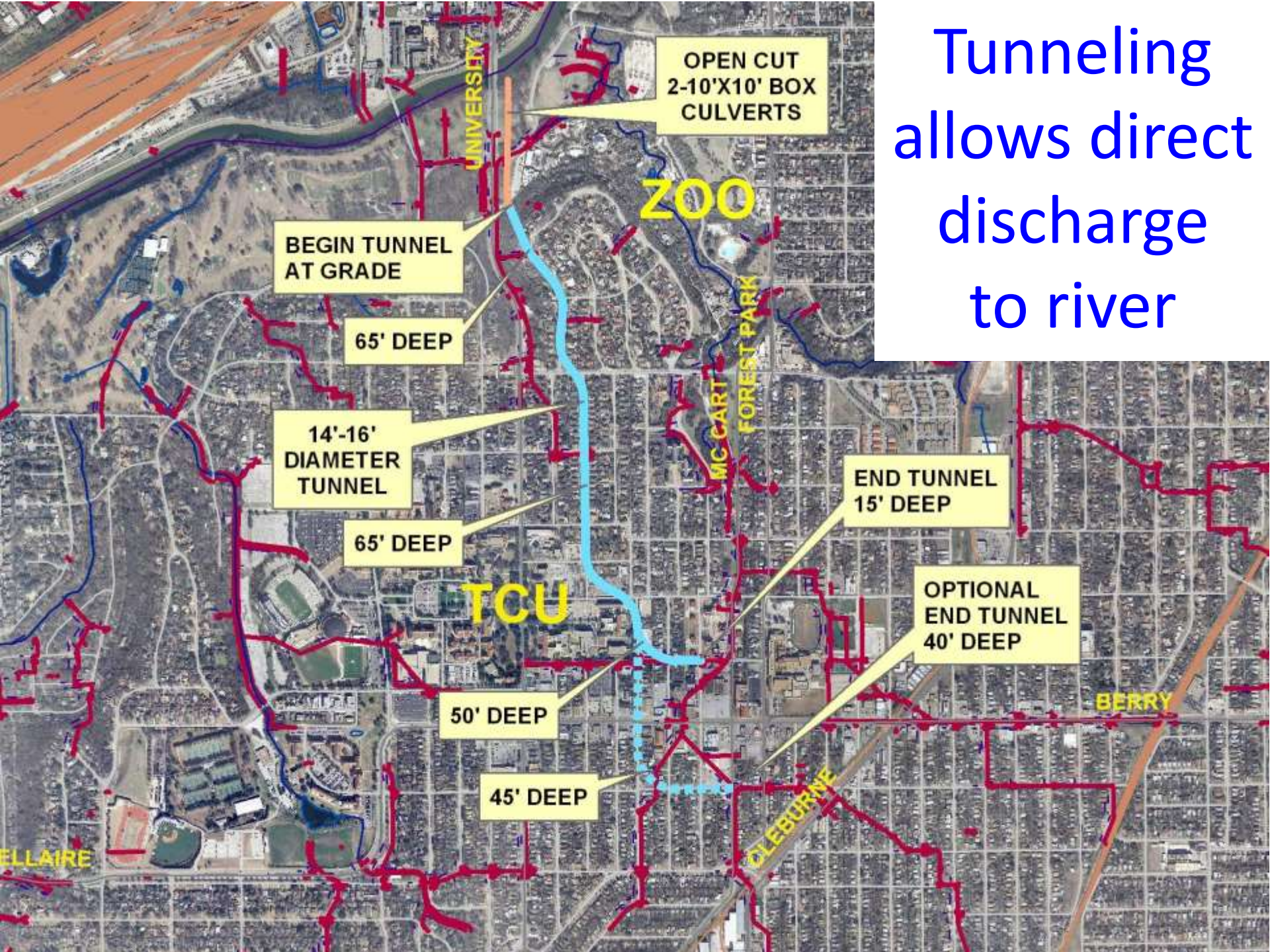
17+00
18+00
19+00
20+00
21+00
32’ deep


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
32’-DEEP TRENCH

WHAT ABOUT TUNNELING?


Tunneling preserves neighborhood
...FOR $30 MILLION!
Central Arlington Heights Watershed Planning Study
FIGURE
WESTERN
CARLETON
ASHLAND
TREMONT
BRYCE
TJ3A-1
30 in.
30 in.
30 in.
48 in.
24 in.
30 in.
60 in.
54 in.
60 in.
1 box 6 ft x 8 ft
EL CAMPO
PERSHING
TREMONT
1 box 6 ft x 8 ft
South Hi Mount Elementary School
PERSHING
CALMONT
NATM TUNNEL BEGINS
36 in.
Start 3 boxes 6 ft x 8 ft
CALMONT
30
LOCKE
CHAMBERS
LANDERS
LOCKE
RELOCATE OUTFALL
RAILROAD YARD
ALAMO
LISBON
CONCRETE
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

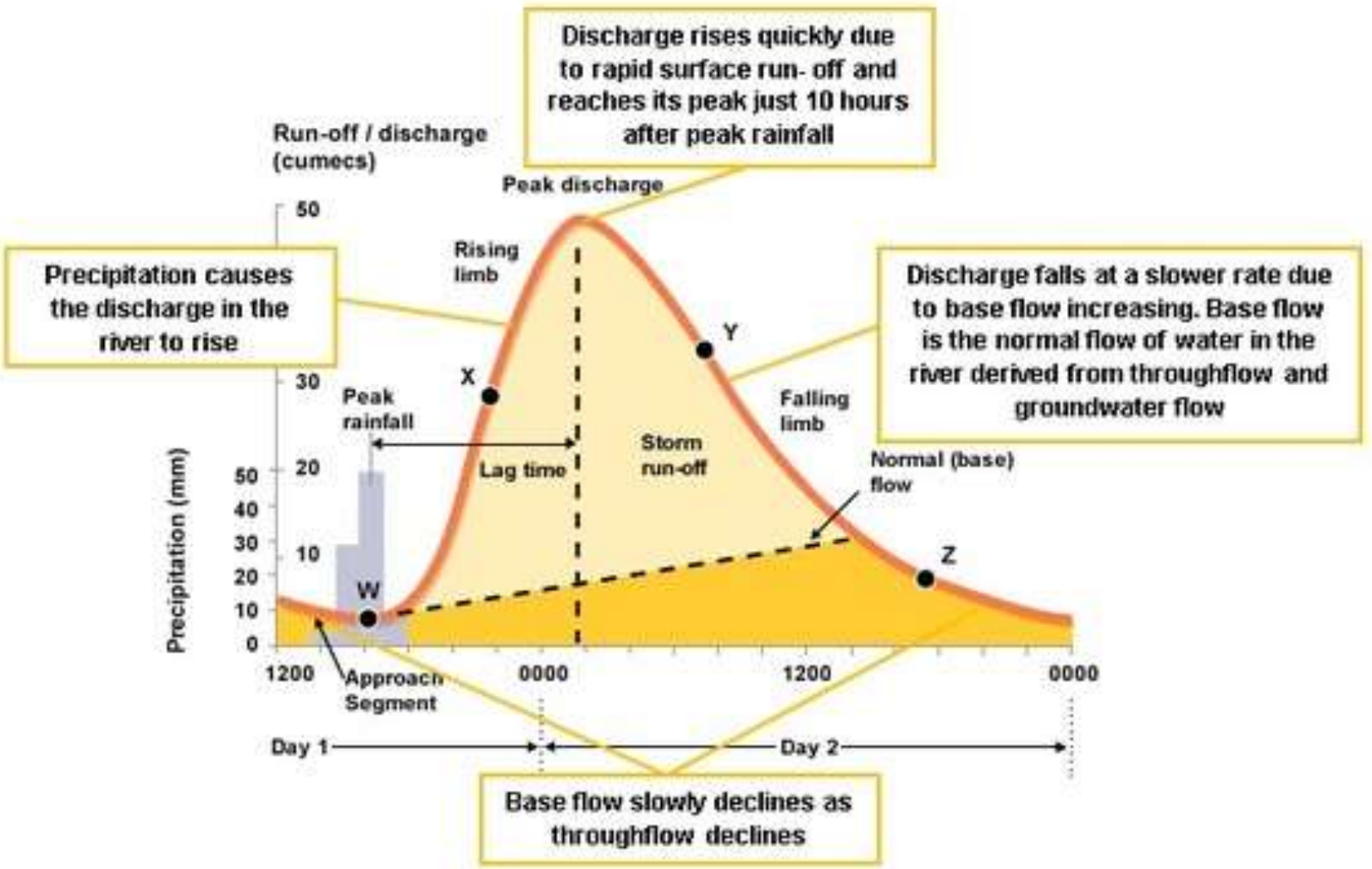


Tunneling allows direct discharge to river

Issues in Urban (Zone X) Flooding

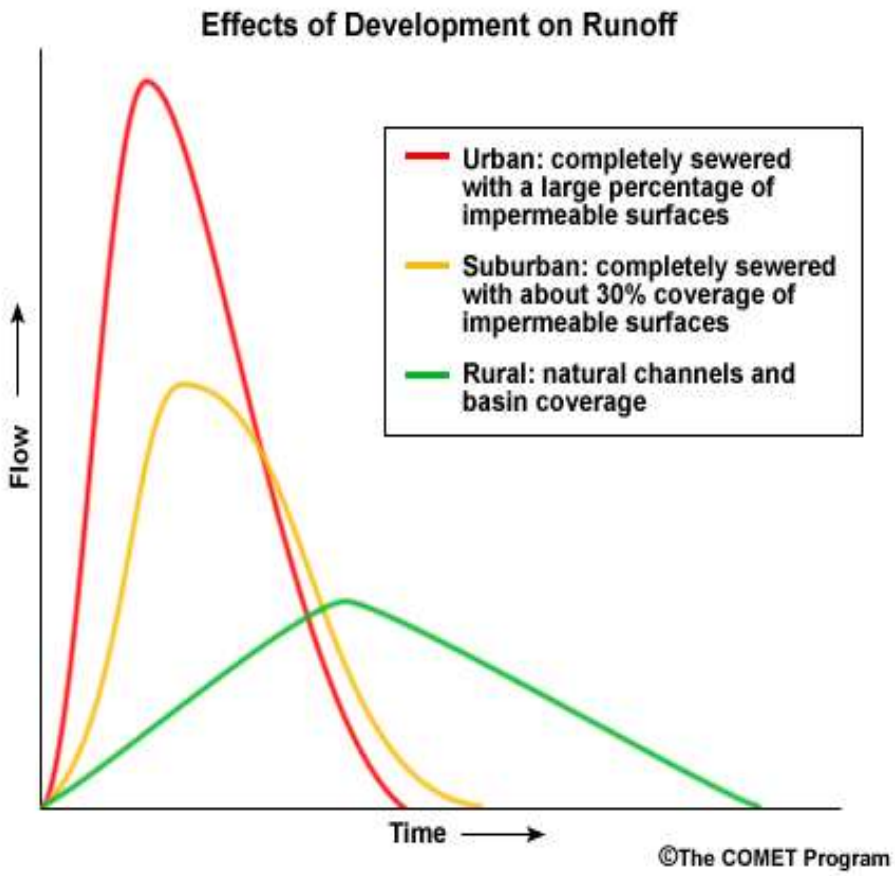
HYDROLOGIC CONSIDERATIONS WITH CONVEYANCE

(1) Unit Hydrograph 101



Effects of Urbanization

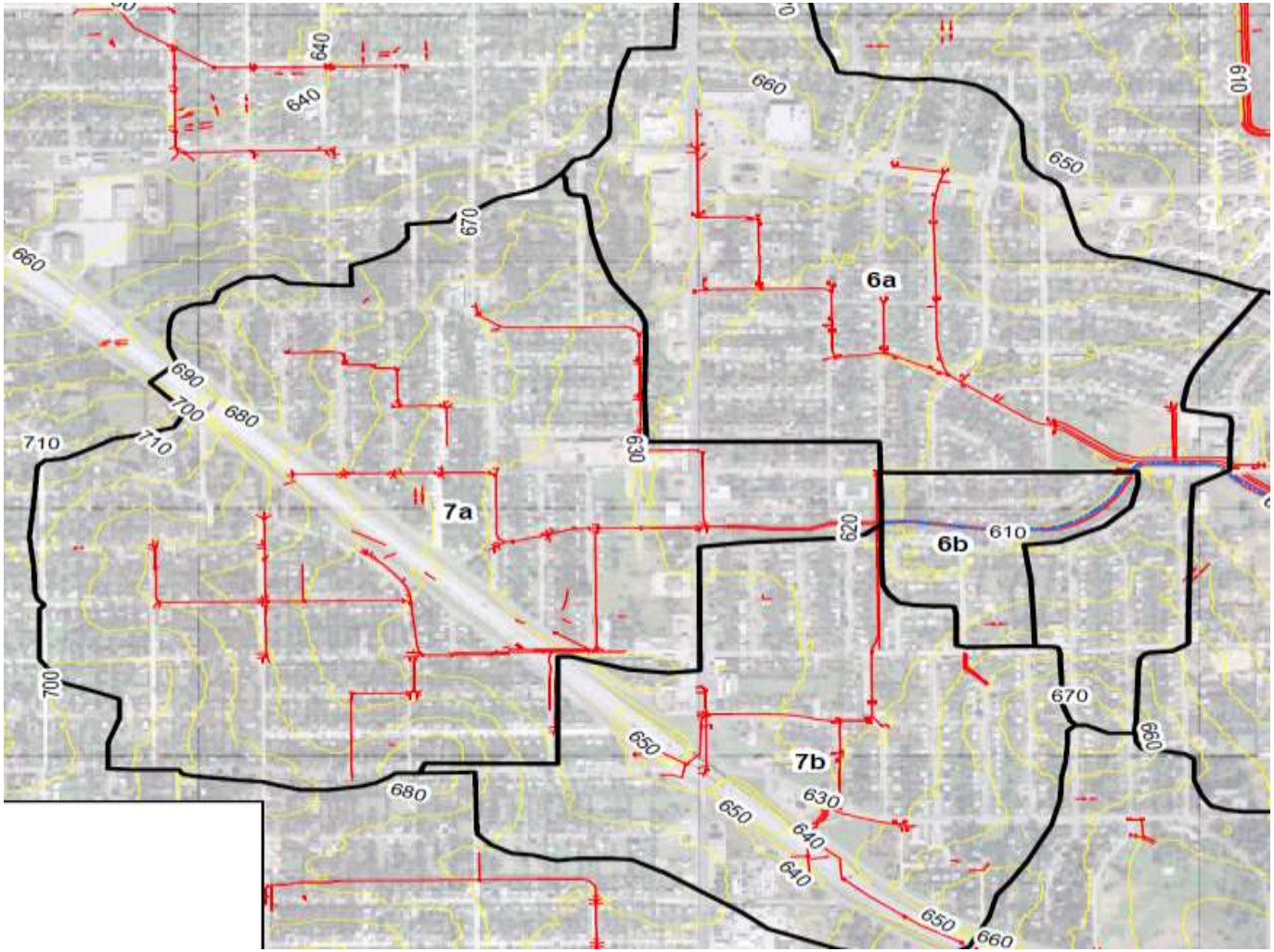
- Total Volume greater due to less infiltration
- Time to peak shorter due to faster flow on paving and in pipes
- Peak flow rate may be doubled or tripled



Eastland Creek – Eastern Fort Worth

Fort Worth Storm Water Management

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



HDR

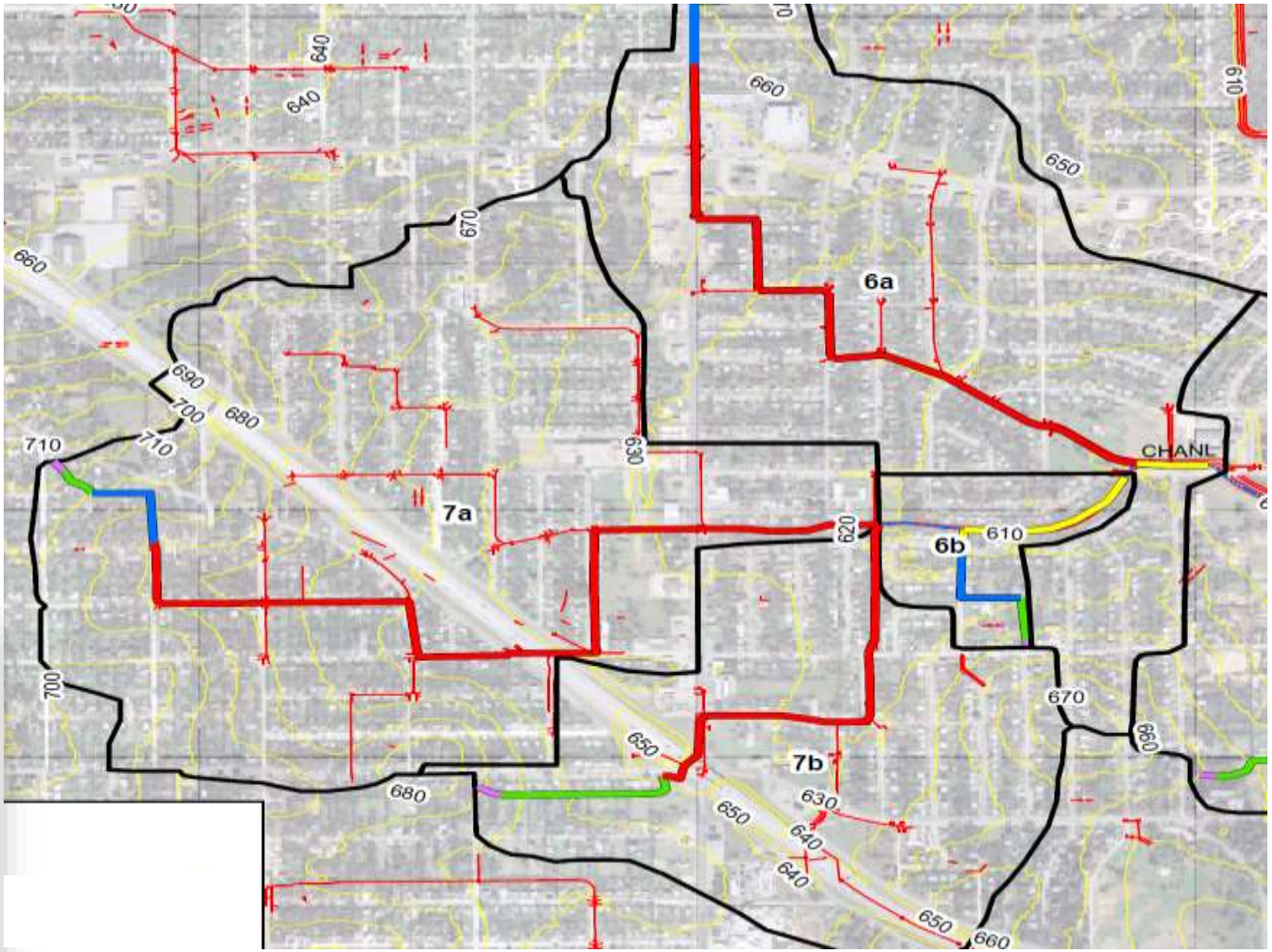
Storm Drain Flow Paths

Fort Worth Storm Water Management

- 18,000 Ft
- Average

  4 ft/s

  Velocity



Legend

- Eastland Watershed Delineation

Tc Flow Type

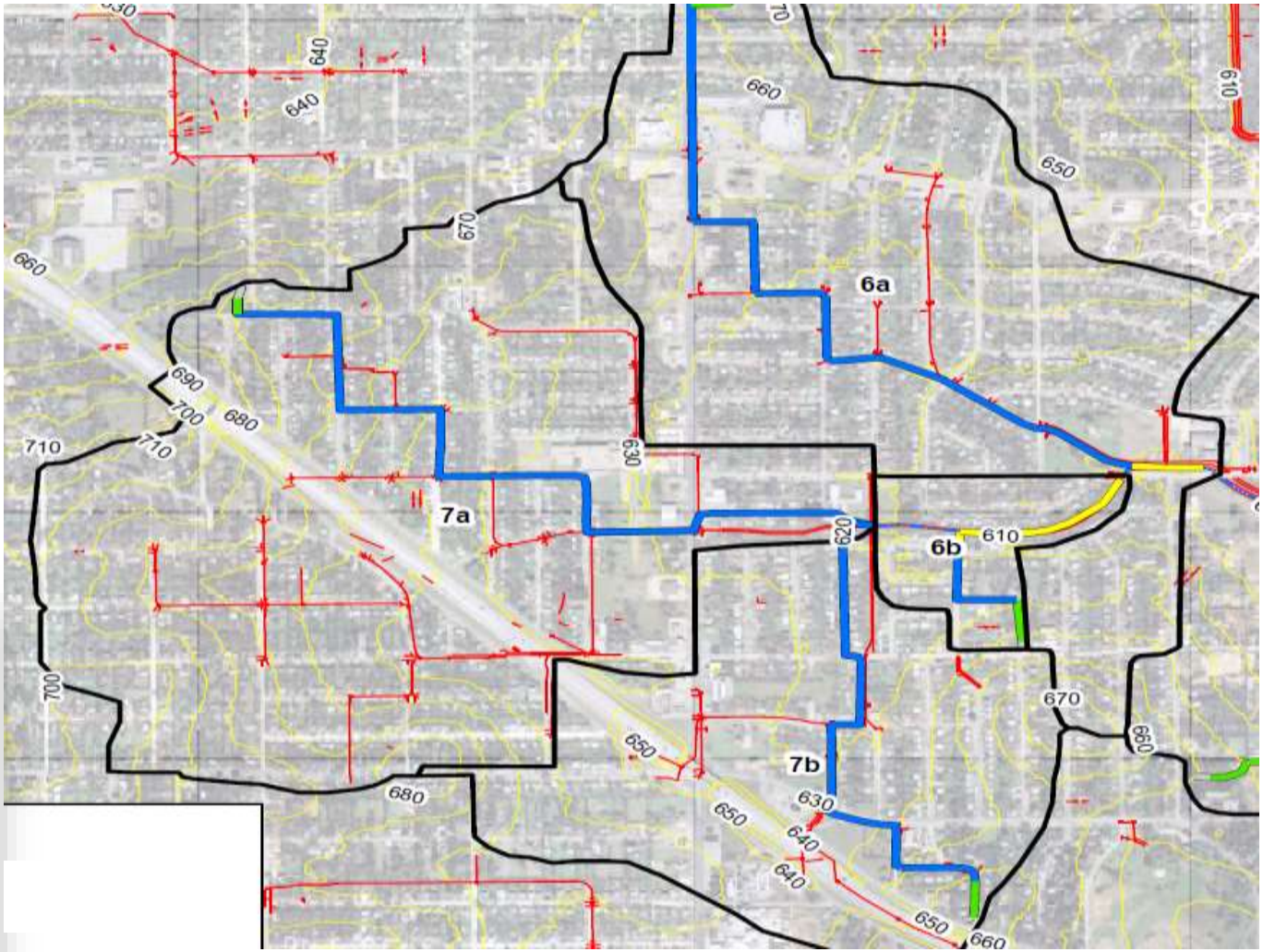
- channel
- gutter
- pipe
- shallow
- sheet
- Eastland Creek
- Storm Sewer
- 2001 NCTCOG 10' Contours

HDR

Overland Flow Paths

Fort Worth Storm Water Management

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



Legend

- Eastland Watershed Delineation

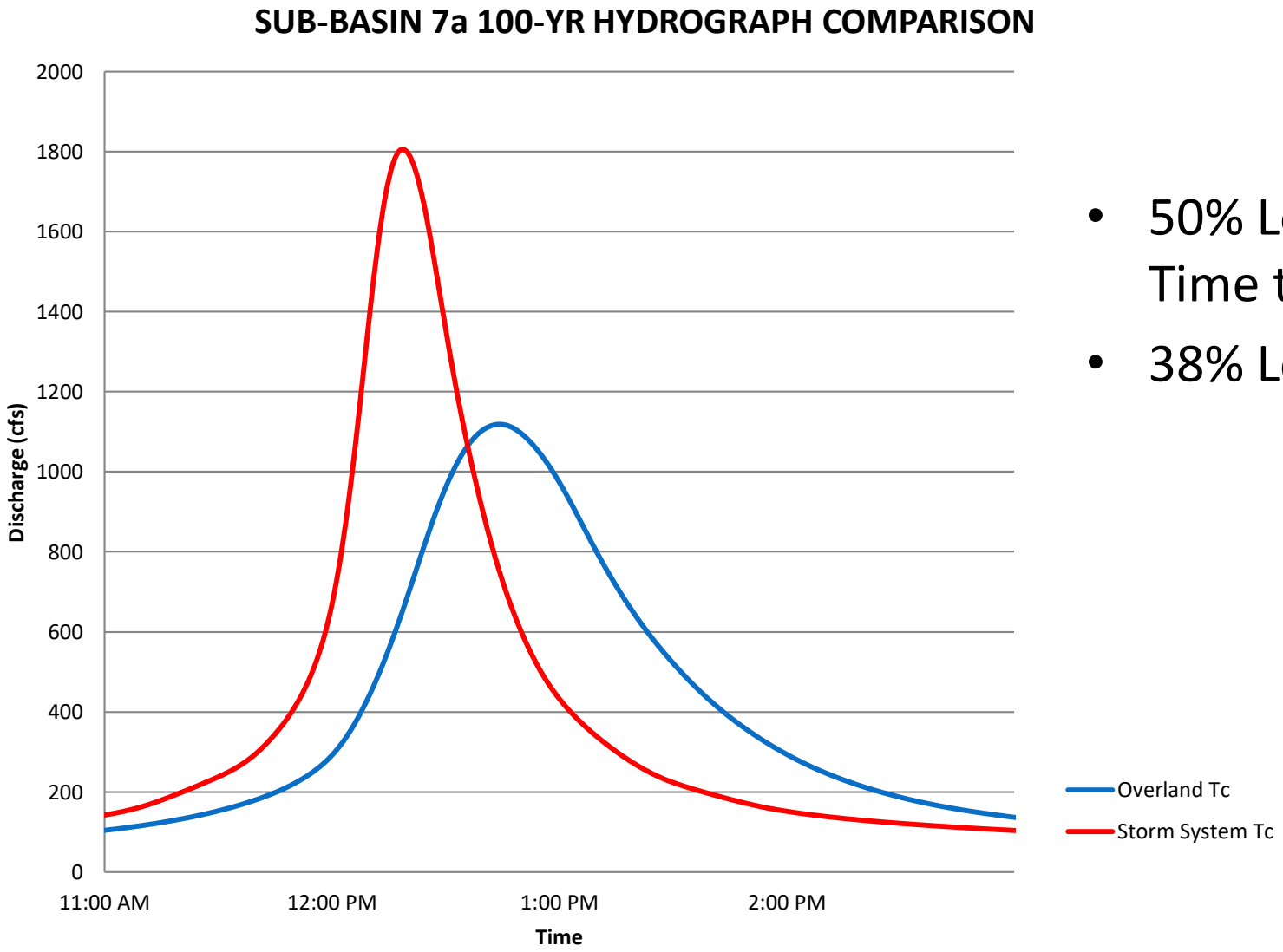
Tc Flow Type

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

HDR

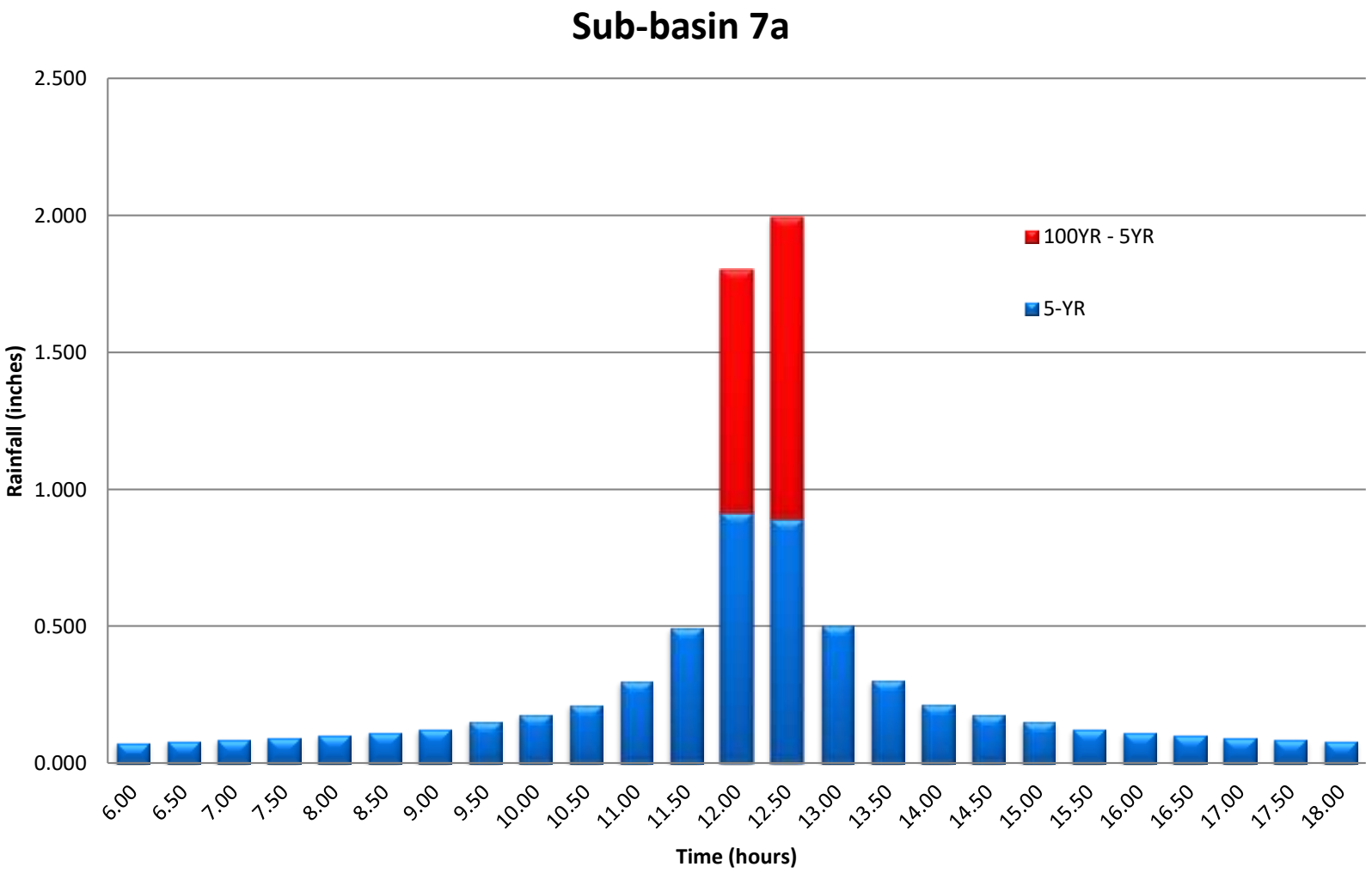
Sub-basin	Area	Tc (min)		Peak Discharge (cfs)		% Difference
	(acres)	Overland	Storm drain	Overland	Storm drain	
6a	272	57	25	1,023	1,561	34%
7a	342	68	28	1,118	1,804	38%

Hydrograph Comparison

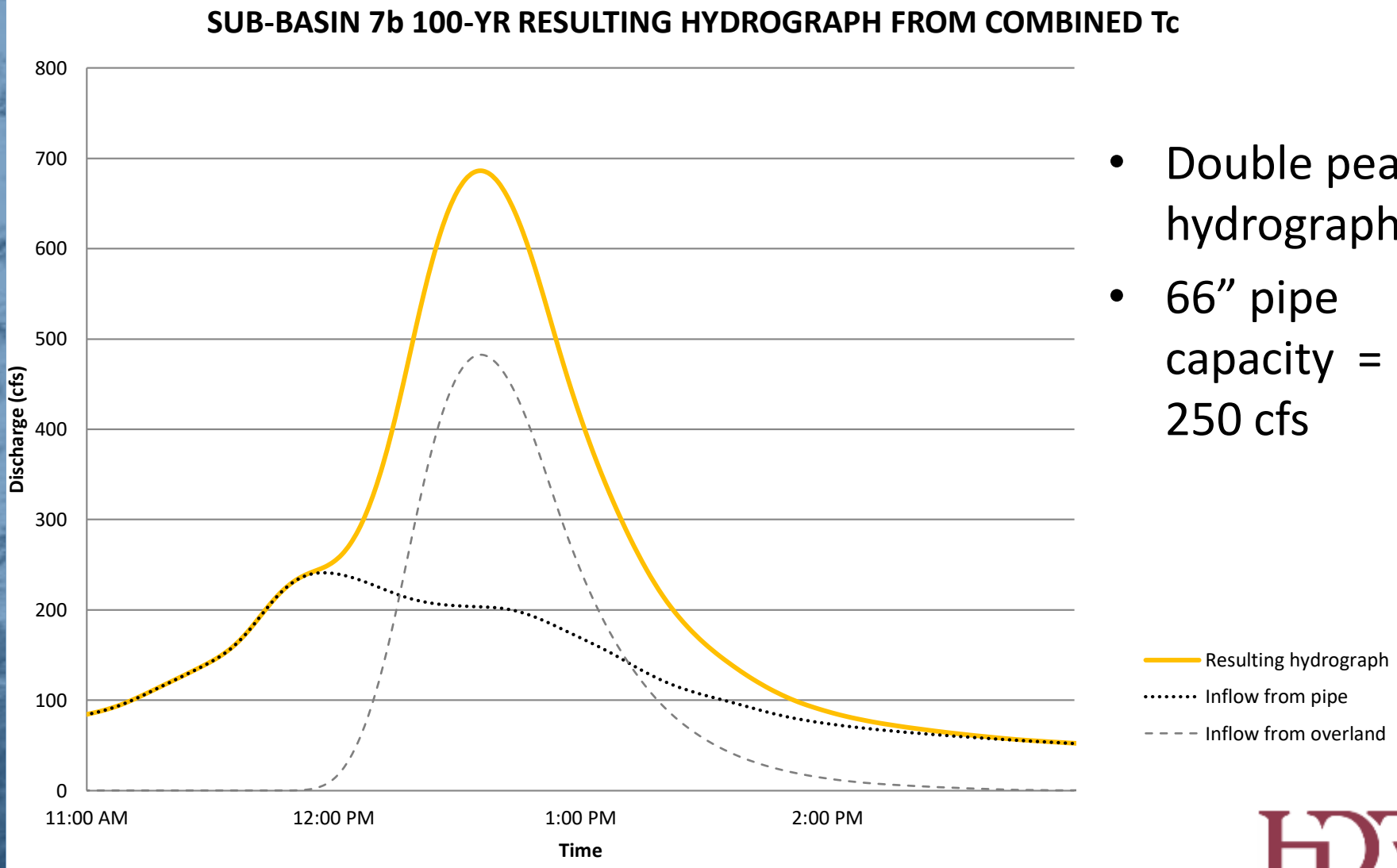


- 50% Longer Time to Peak
- 38% Lower Q

Hyetographs

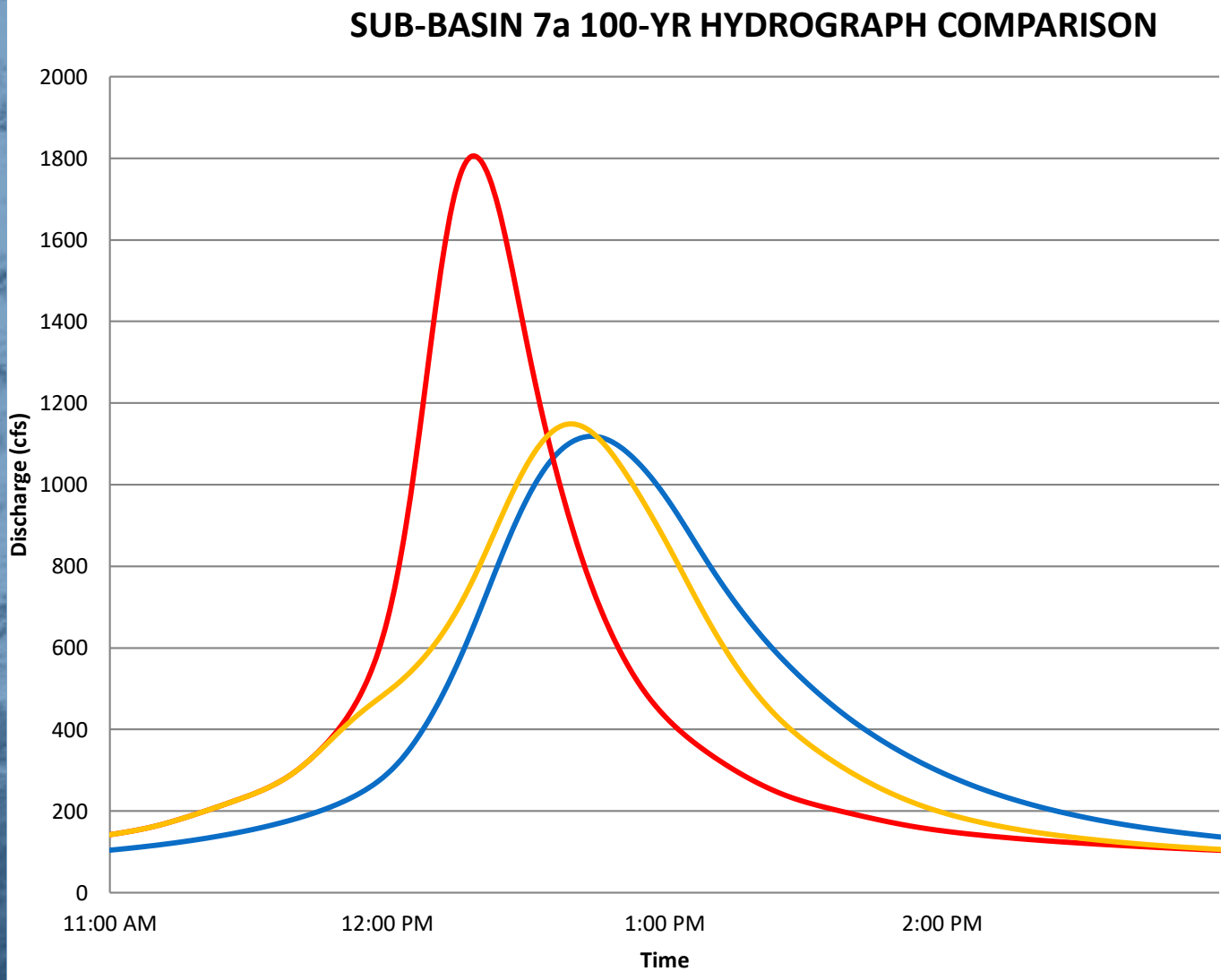


Combined Hydrograph



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

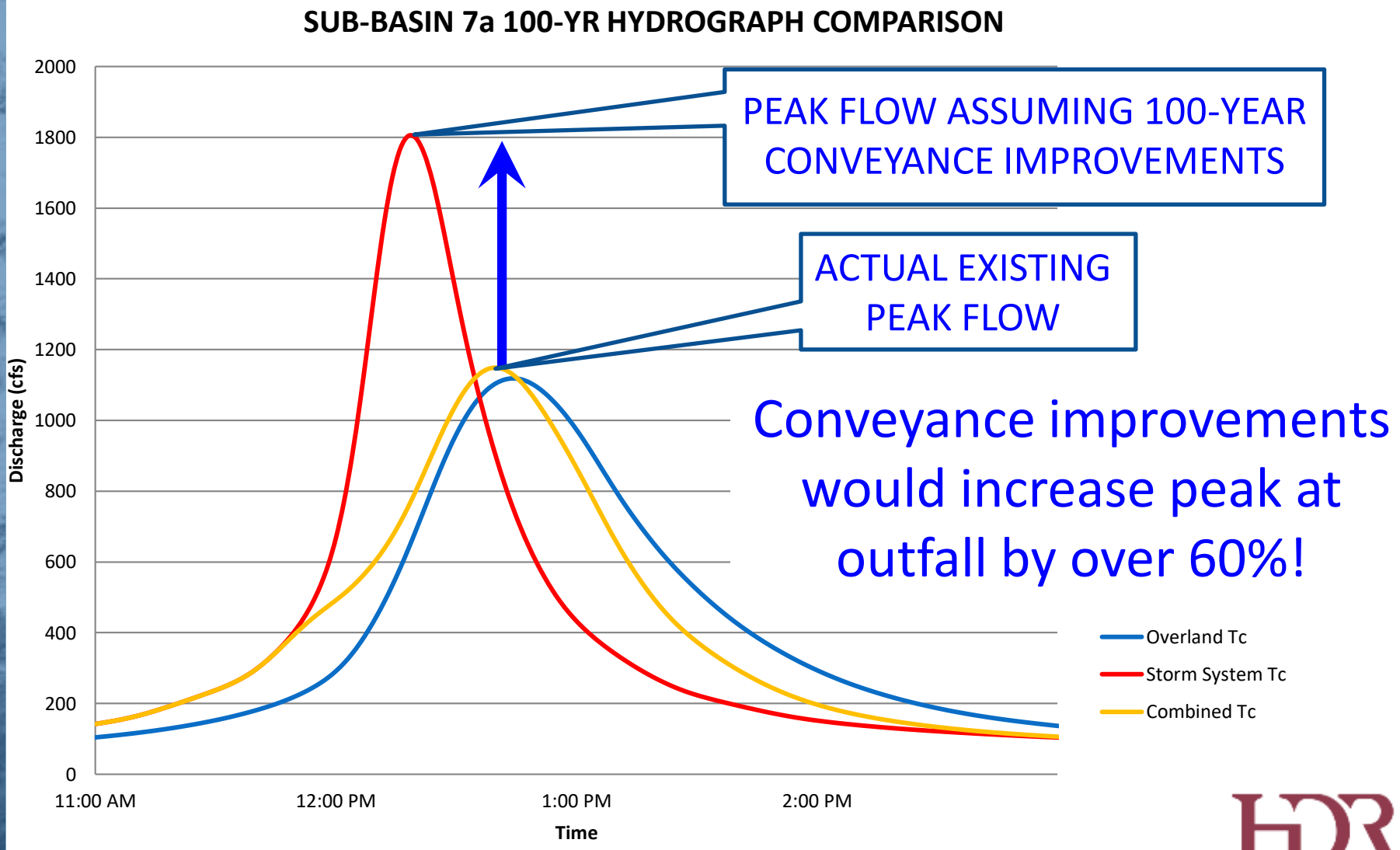
Hydrograph Comparison



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

Hydrograph Comparison

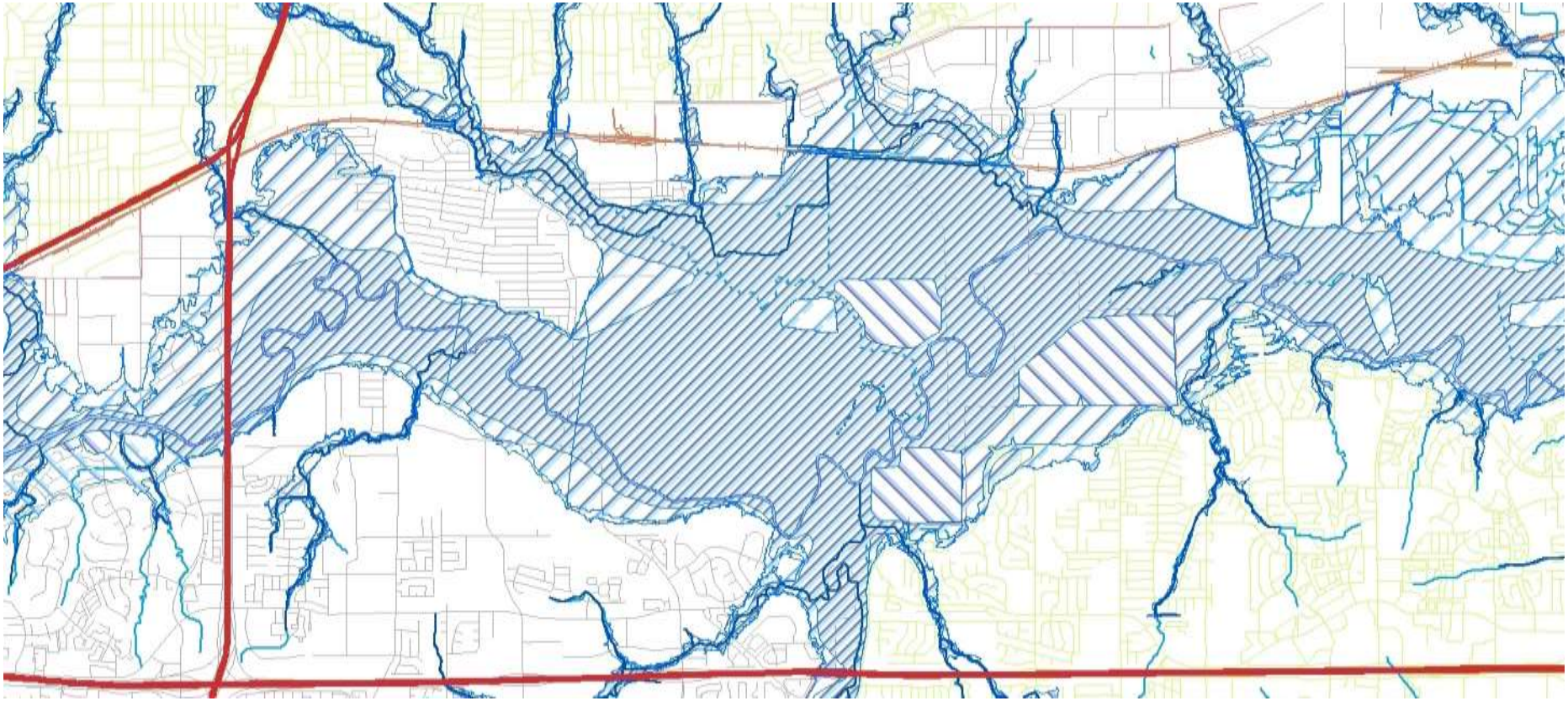
Fort Worth Storm Water Management



HDR

(2) Valley Storage

The measure of a stream's ability to store water as it moves downstream.



Valley Storage in Neighborhoods ("Living Room Detention")

(3) Downstream Effects

- State Water Laws
- No Adverse Impacts policies

Floodplain Hydraulics

HYPOTHETICAL COMPARISON

Fort Worth Storm Water Management

- Difference in 100-Year inundation of north overbank

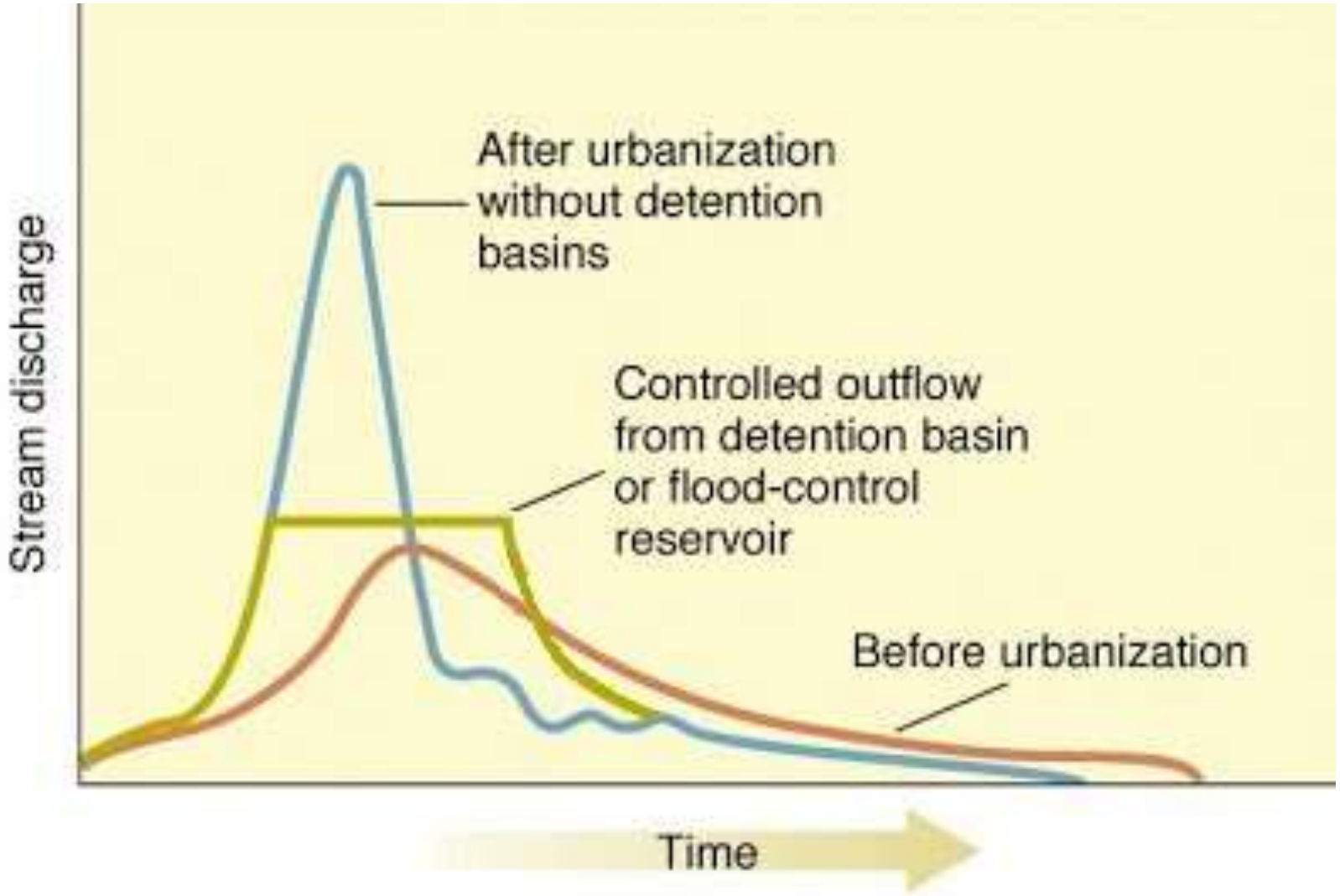
Conclusions

- “Living room detention” (bad) = valley storage (good)
- Upland flooding caused by undersized storm drains reduces flooding downstream.
- Increased conveyance (larger pipes) likely to move flooding downstream.

Issues in Urban (Zone X) Flooding

WHAT ABOUT DETENTION?

Mimicking Pre-Developed Hydrology



Why Detention?

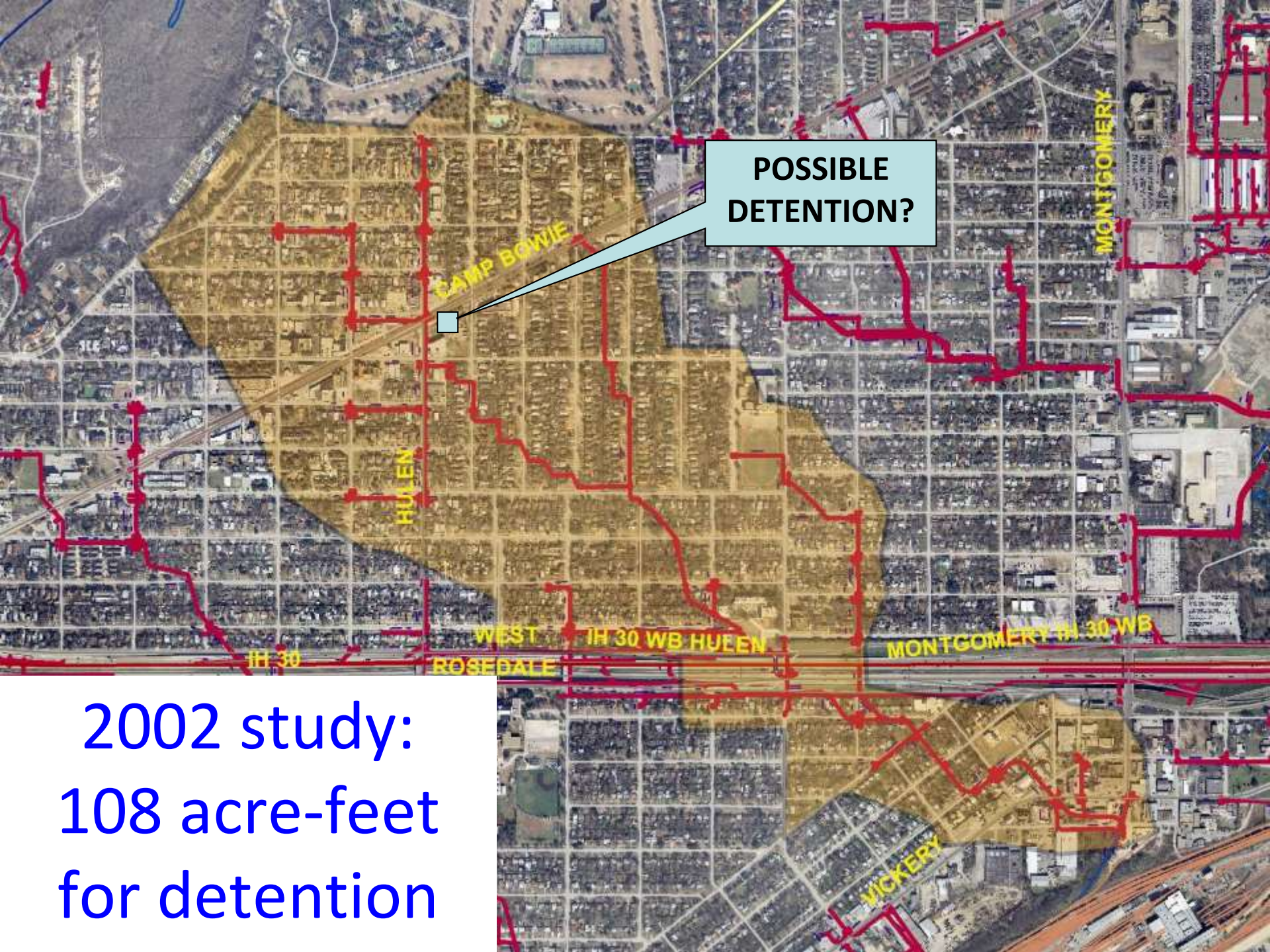
- Flood hazards often due to undersized drainage systems
- Pipe and channel improvements can be very expensive

Why Detention?

- Conveyance improvements can push flooding downstream
- Legal implications for causing downstream impacts

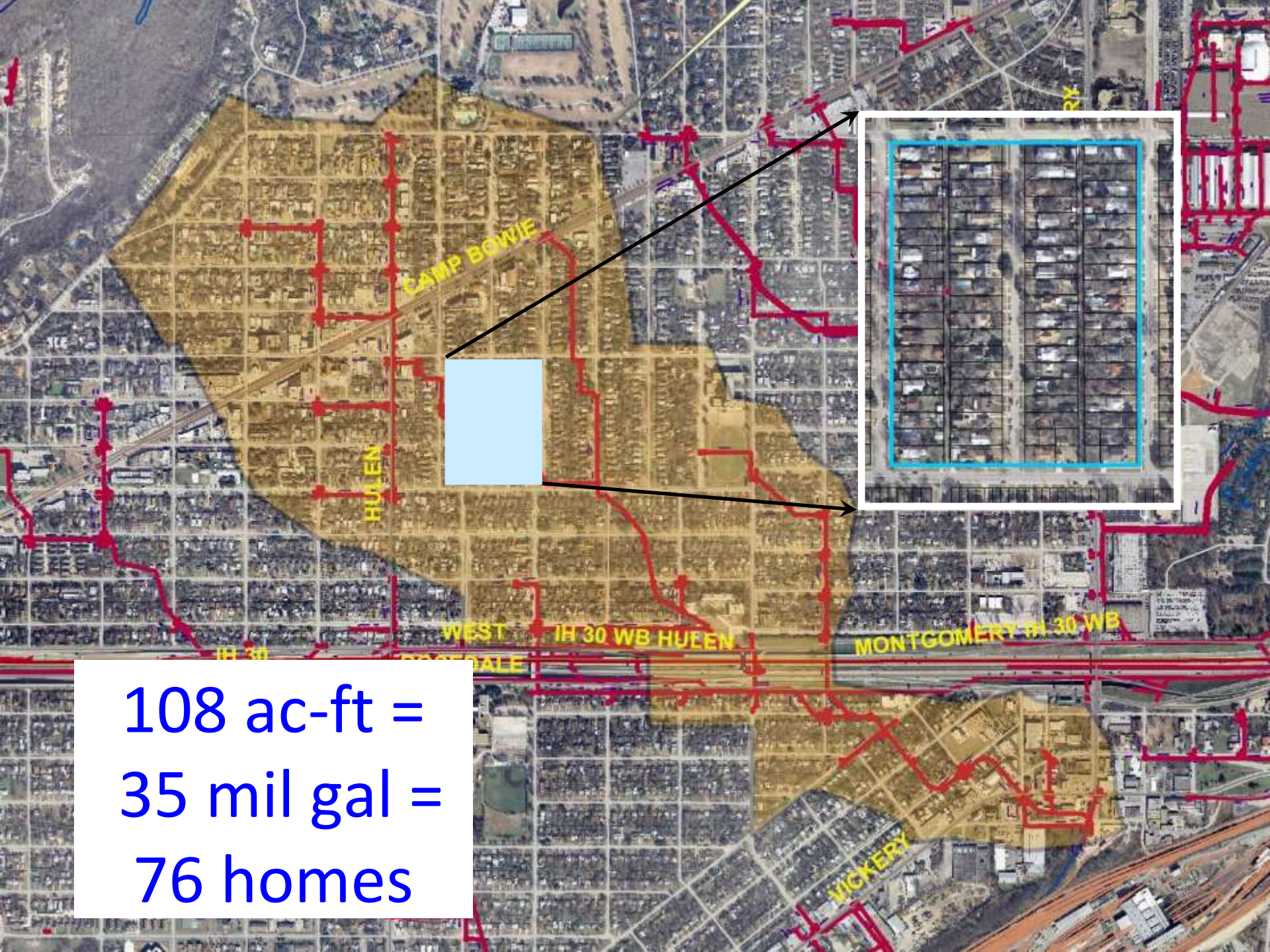
Why Detention?

- Detention decreases flooding impacts continuously
- Detention is much cheaper to build (except for land costs)

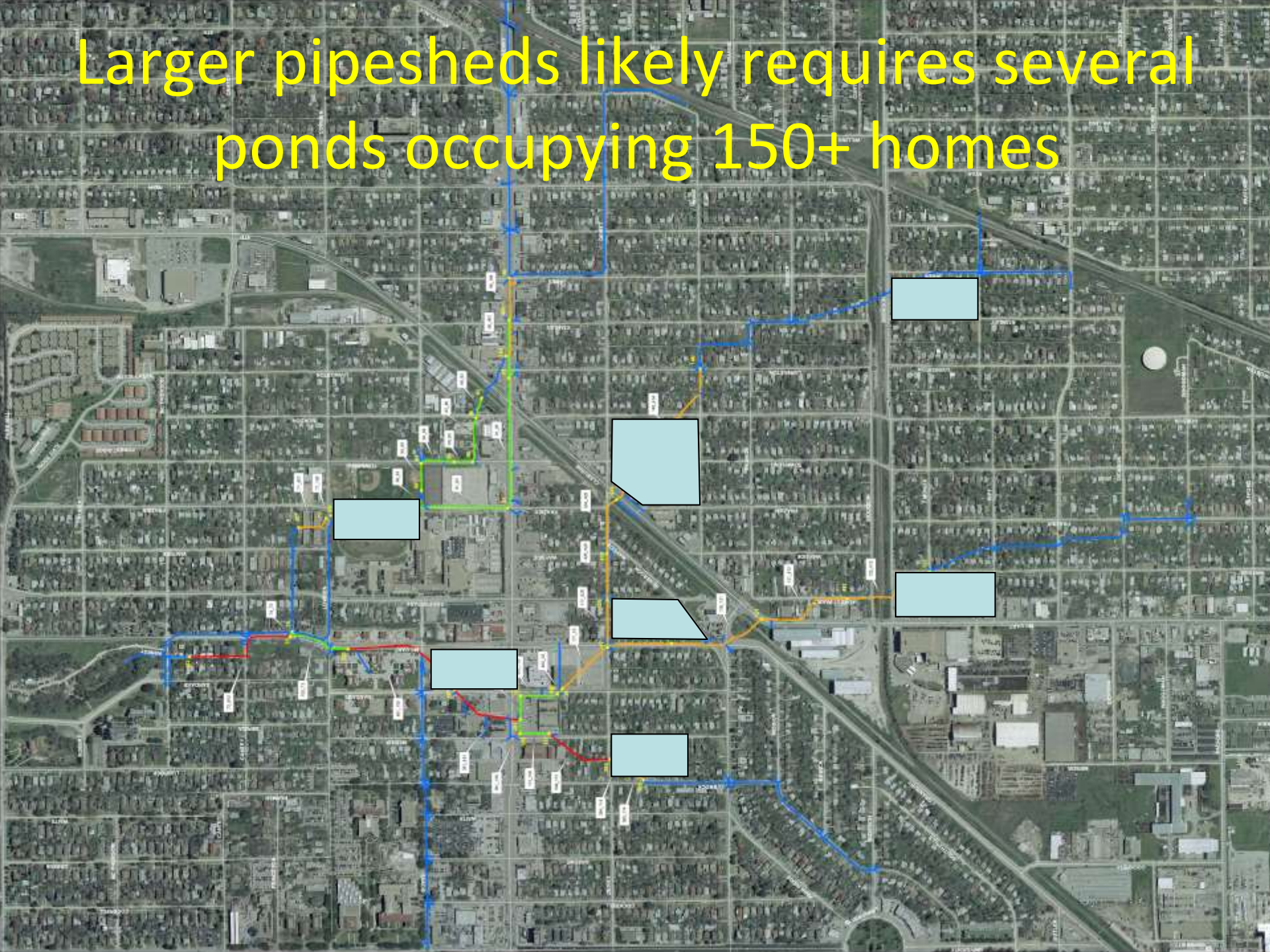


2002 study:
108 acre-feet
for detention

108 acre-feet = filling the bowl on TCU's Amon Carter Stadium … *TWICE*

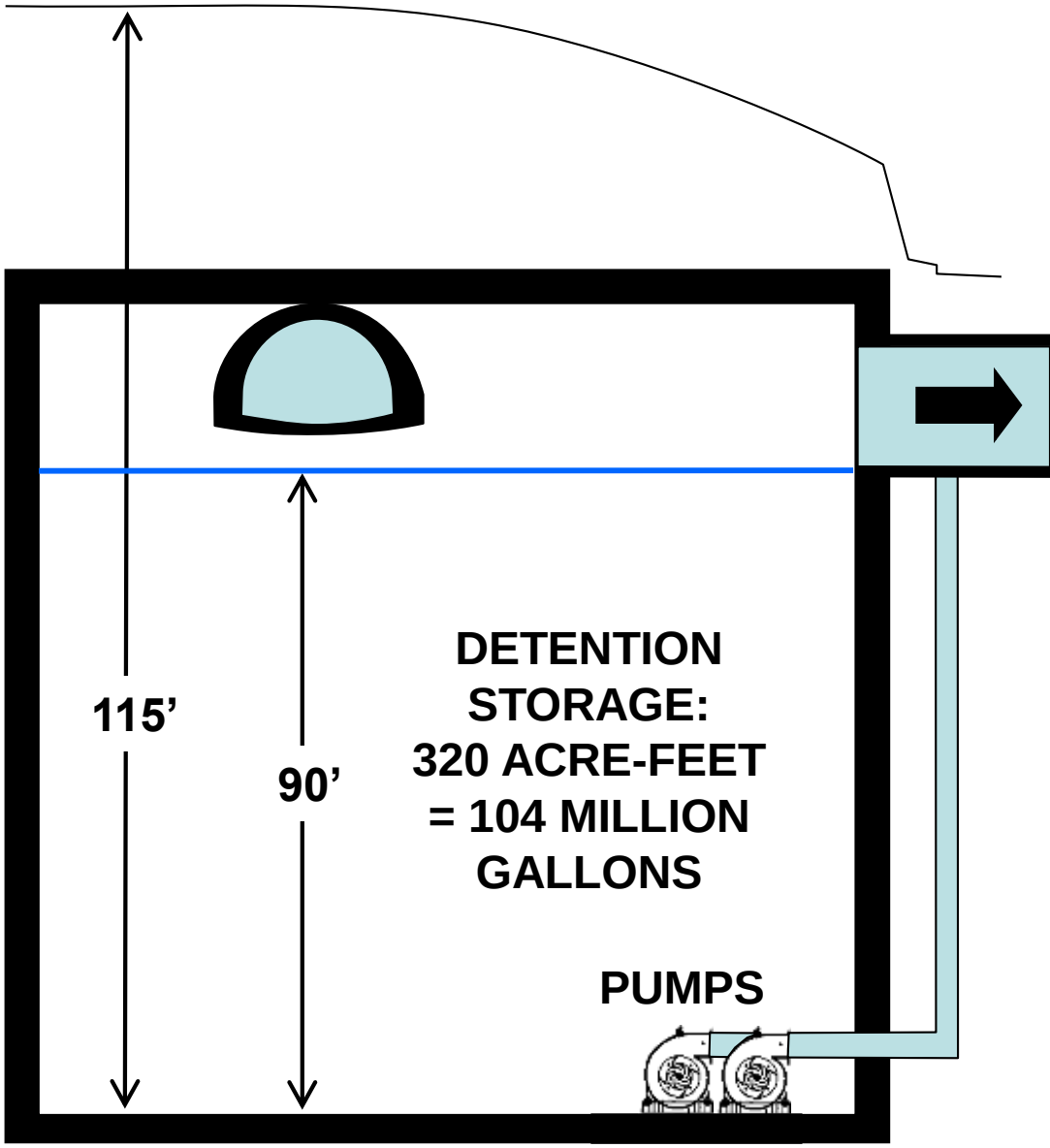


108 ac-ft =
35 mil gal =
76 homes


Larger pipesheds likely requires several ponds occupying 150+ homes

Deep Detention with Pumps

Exorbitantly Expensive!!!



Historic Detention

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

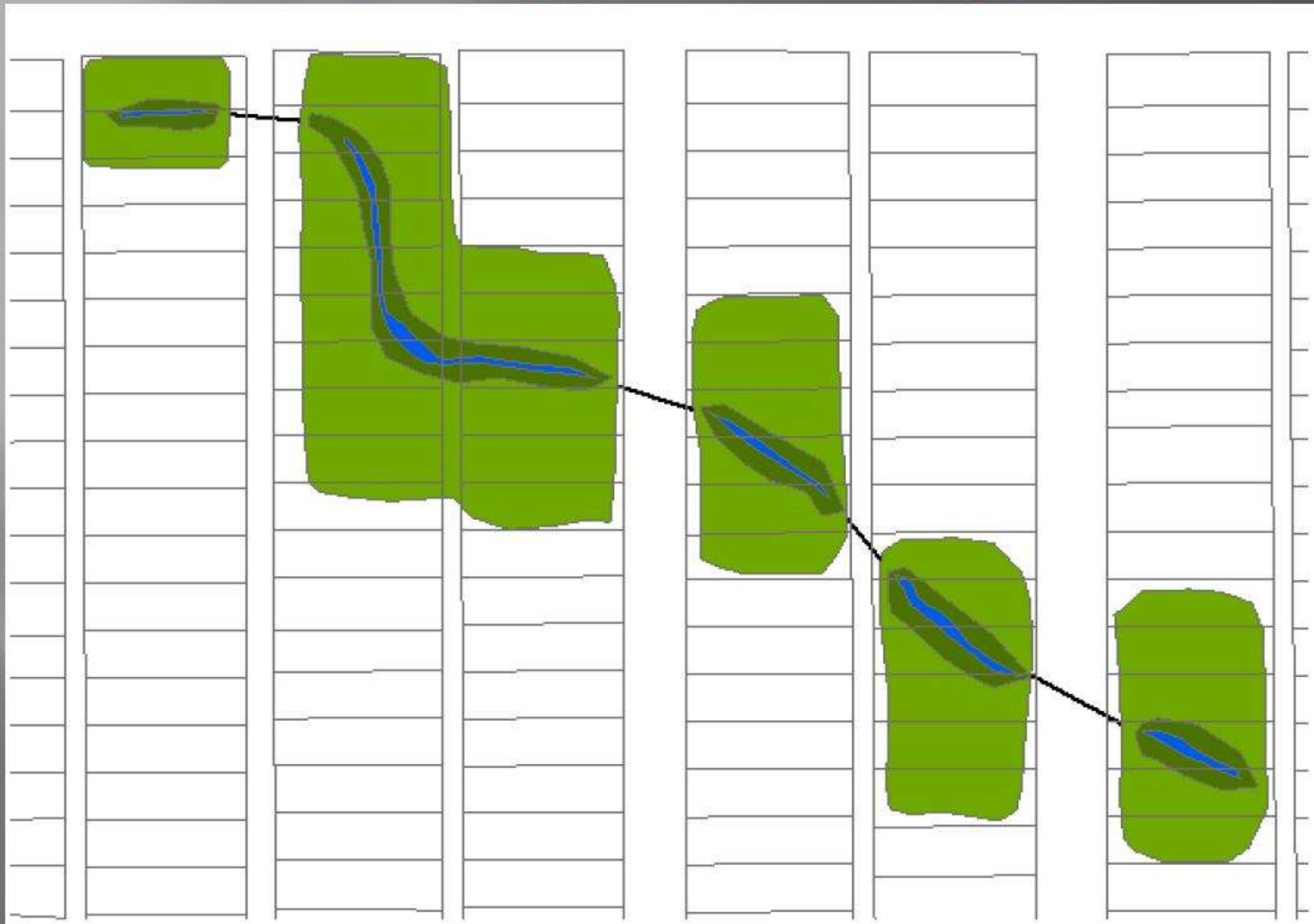
Challenges to Detention

- Location! Location! Location!
- High cost of land
- Underground detention is very expensive
- Difficult to justify if flooding is sporadic

Neighborhood Integrity

- Buy-outs leaving empty lots destroy neighborhood integrity
- Become an eyesore
- Discourage investment
- Encourage crime

Greenway Detention (Large)



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

Multi-Use Detention

Recent CFW-FWISD partner project:

Eastern Hills Detention Basin

Multi-Use Detention

Recent CFW-FWISD partner project:

Luella Merrett Detention Basin

Multi-Use Detention

Neighborhood project in construction:

Bryce-Hulen Detention Basin

Transit Oriented Development Detention Concept

Daylighting Streams

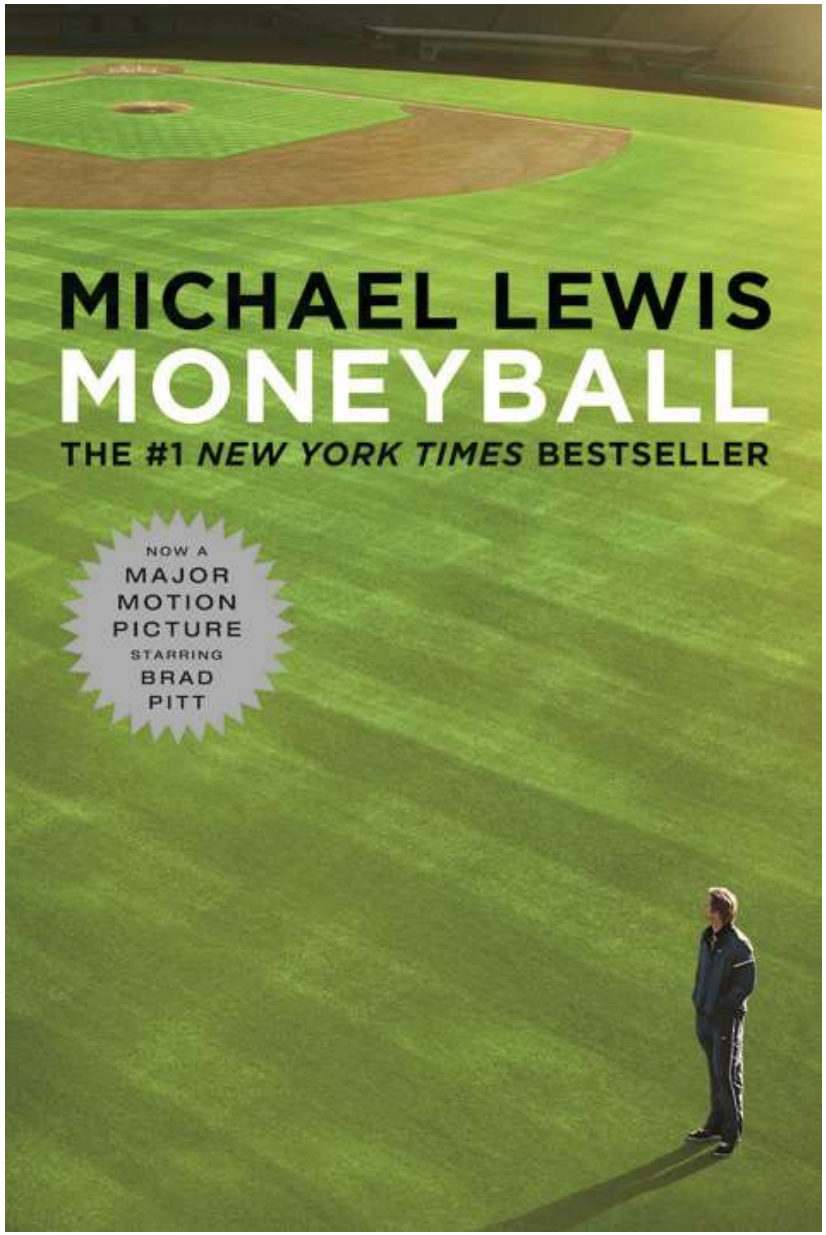
Storm Drain with Overflow Swale

Conclusions

- **Any sustainable urban flooding reduction program must manage flooding in place!**
- Detention and storage must account for timing as well as hydrograph peaks.
- Detention is only acceptable as a widespread strategy if it also a useful space for the public.

Issues in Urban (Zone X) Flooding

LET'S APPLY A DIFFERENT PARADIGM



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

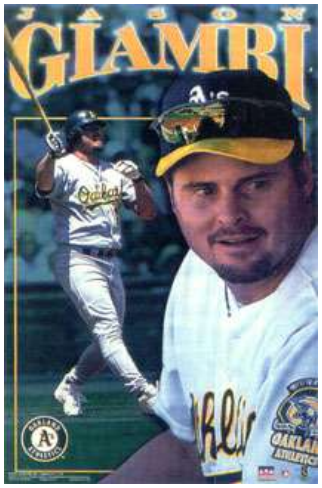
Challenging the conventional wisdom

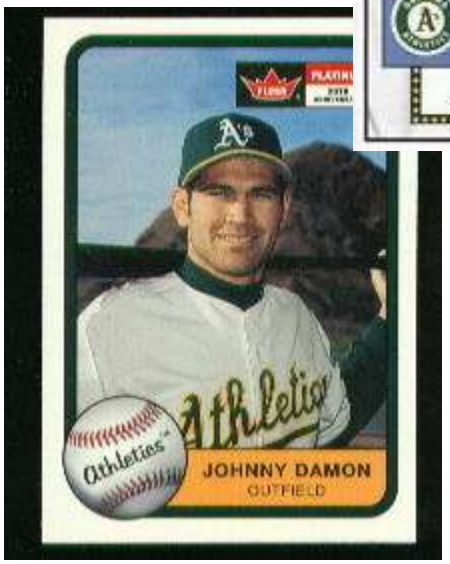
- Baseball teams have traditionally relied upon scouts who assess players based upon observations, biases, and prejudices
- Process never challenged or validated
- A “good ol’ boy” system
- A lot of bad investments

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?

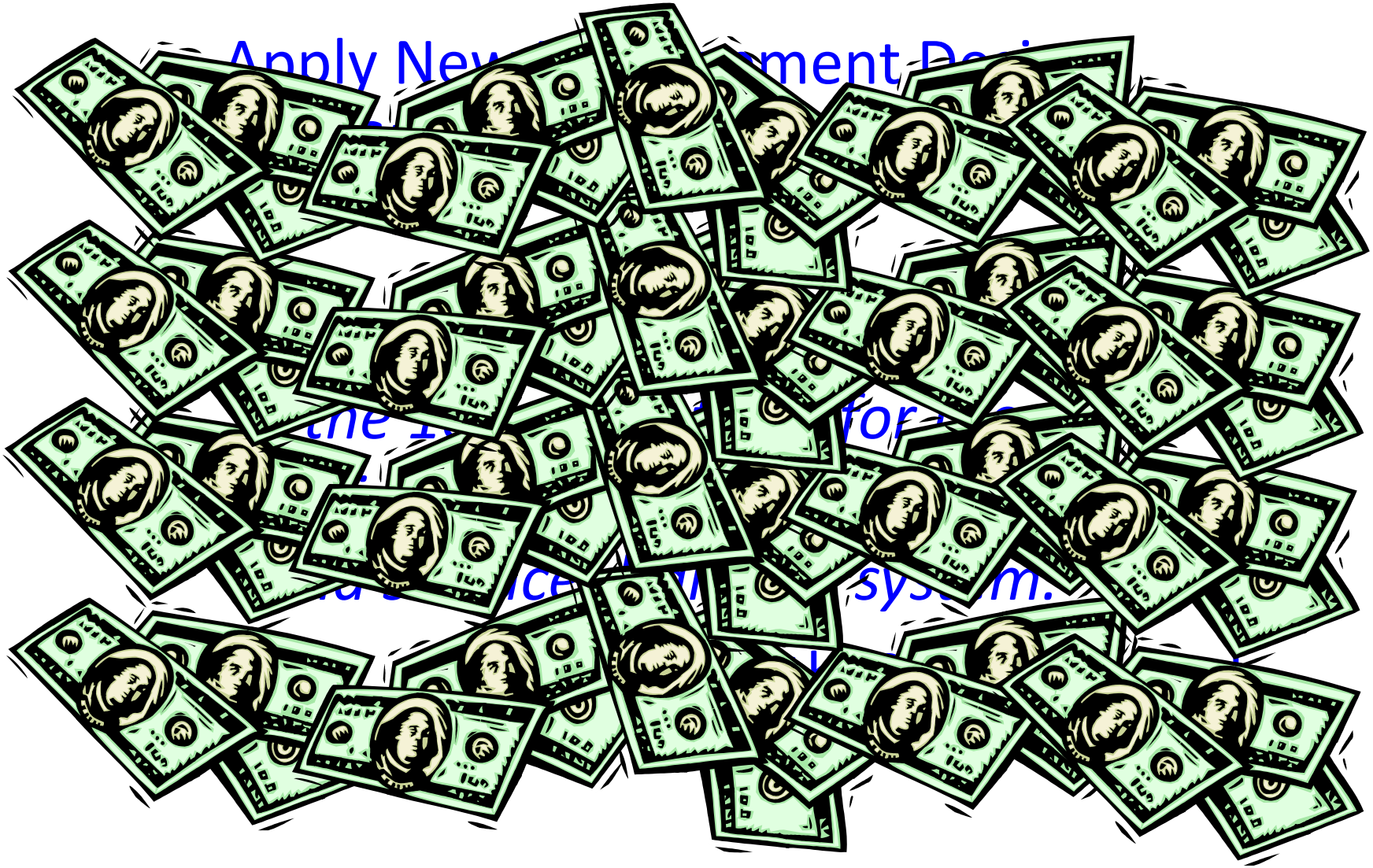
- You are the Oakland A's, not the Yankees!
  - Never enough funding
  - Your fans (citizens) have high expectations
  - Must compete with higher profile funding expenditures (traffic, police, schools)
- Can we take a "sabremetric" approach to flood mitigation?
- Should we? YES!

Arlington Heights Neighborhood Fort Worth

- 90-year old storm drain system
- Under-capacity
- Mid-block sumps
- No flow escape path
- Frequent flooding

Central Arlington Heights, Fort Worth

Conventional Wisdom

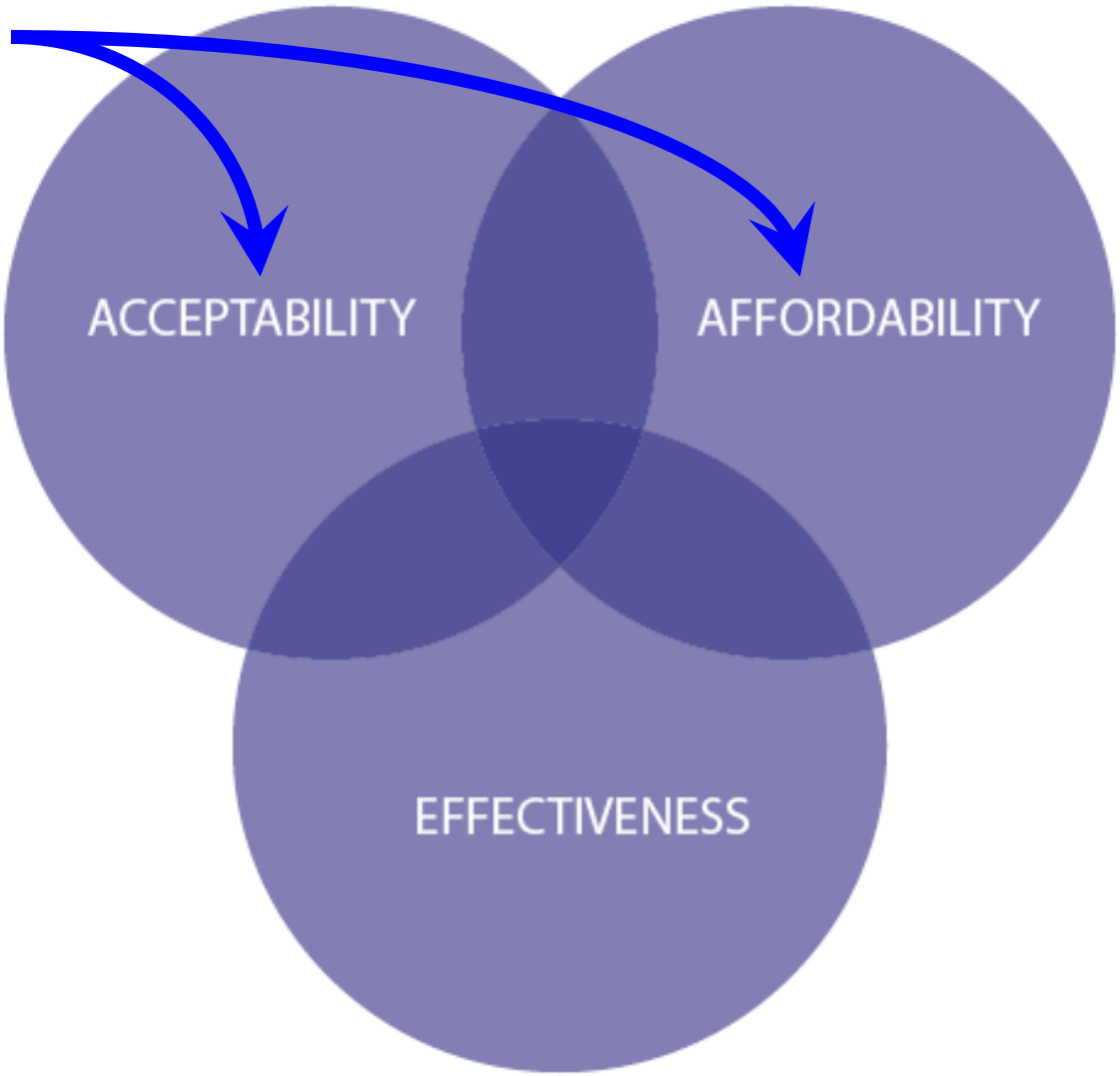


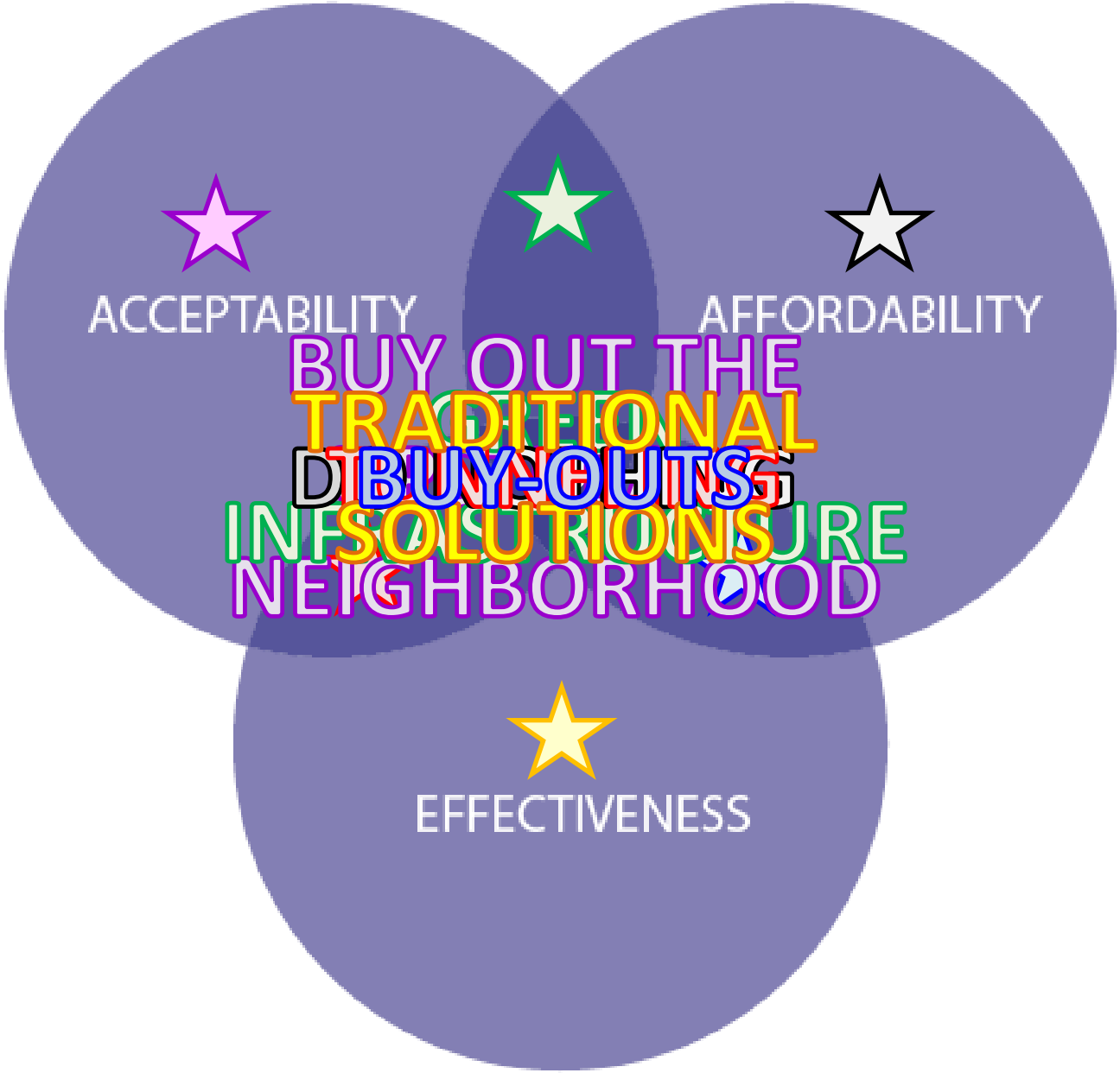
Conventional Wisdom

- Must provide 100-year capacity
- Based on a 24-hour rainfall event
- Minimize disruption to neighborhood
- Preserve neighborhood: no buyouts

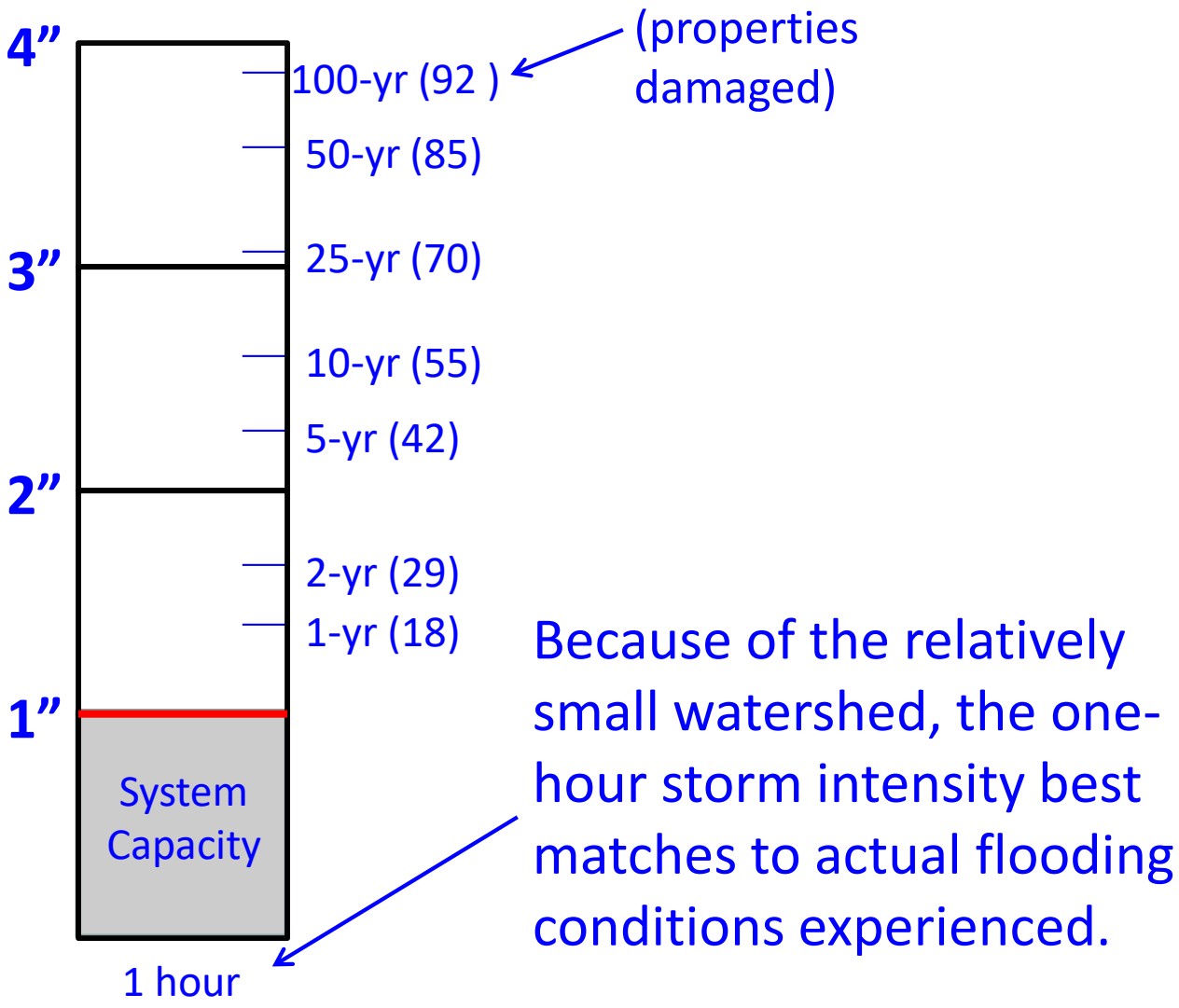
Our Sabremetrics

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

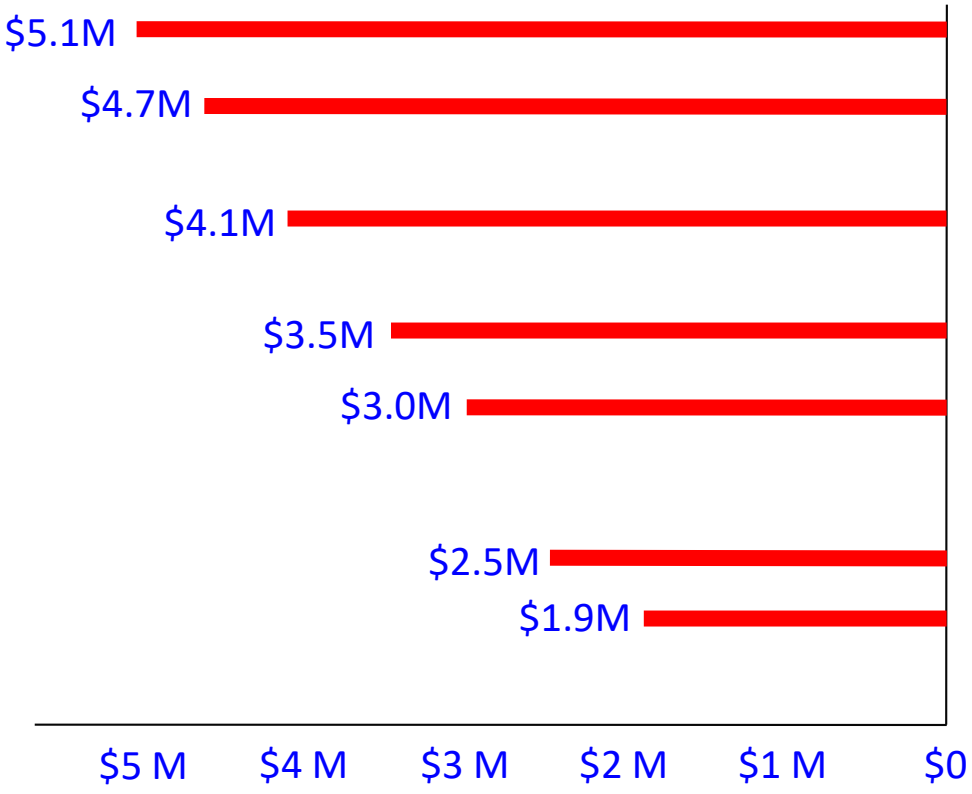



ACCEPTABILITY
AFFORDABILITY
EFFECTIVENESS
BUY OUT THE
TRADITIONAL
BUY-OUTS
SOLUTIONS
NEIGHBORHOOD

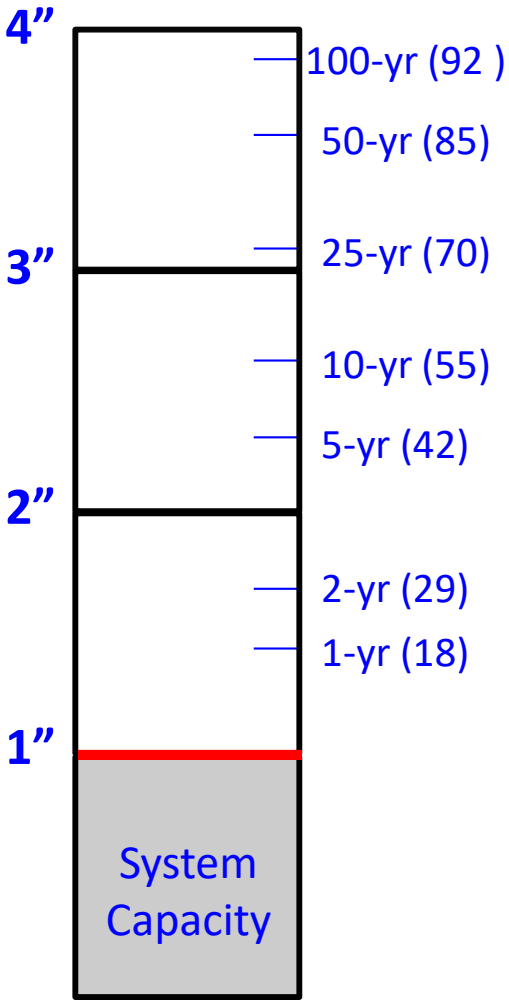
Let's think about a rain gauge



What if it rains more than 1”?

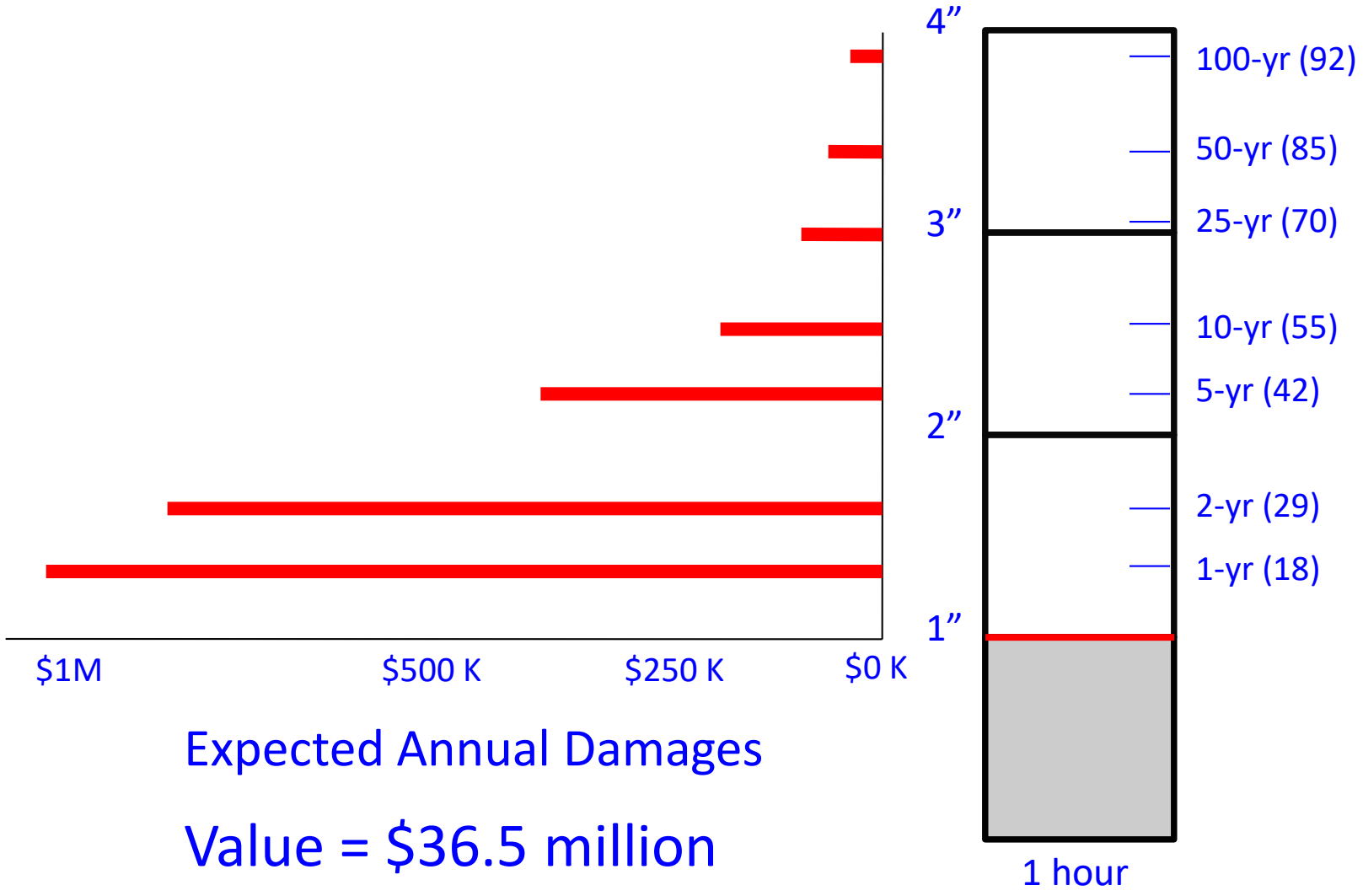


Single Event Damages



1 hour

Damage X Annual Probability

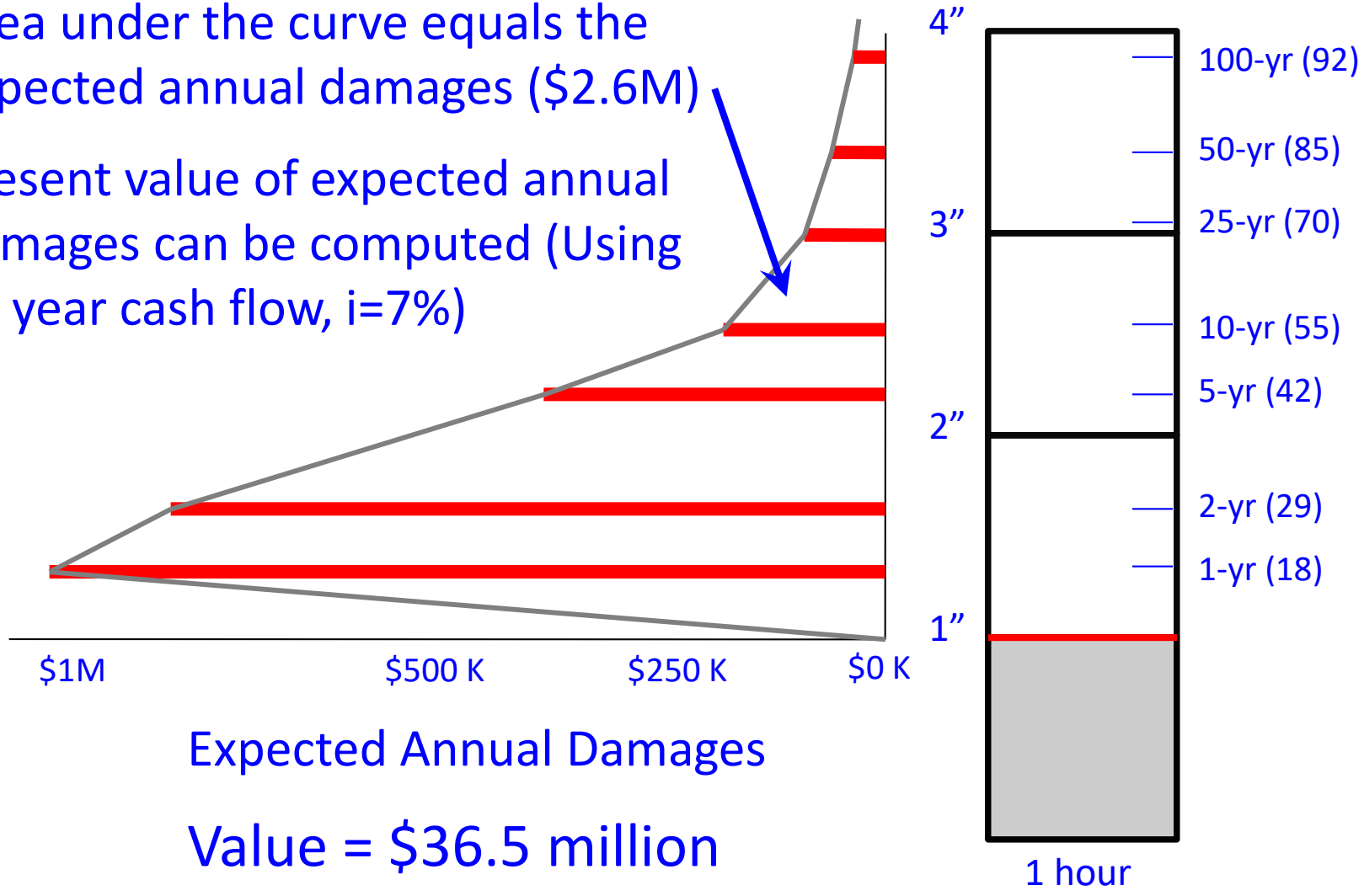


Expected Annual Damages

Value = $36.5 million

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%)

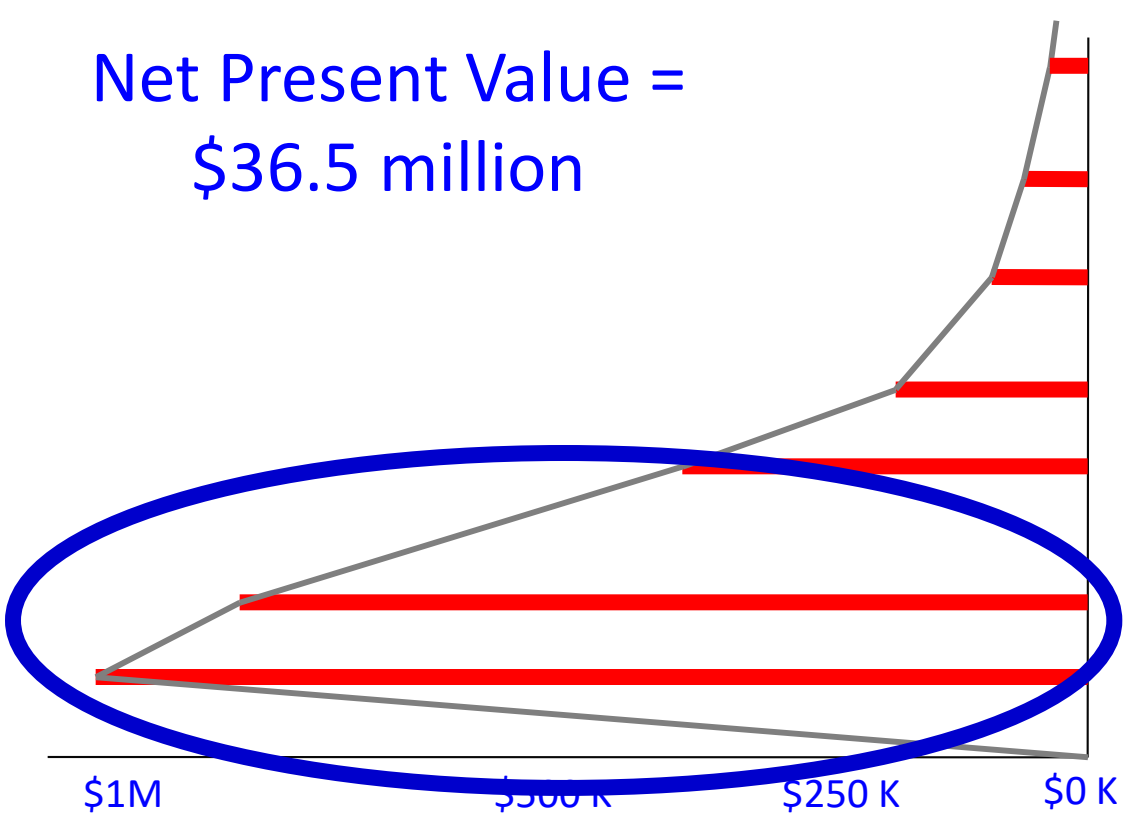


Expected Annual Damages

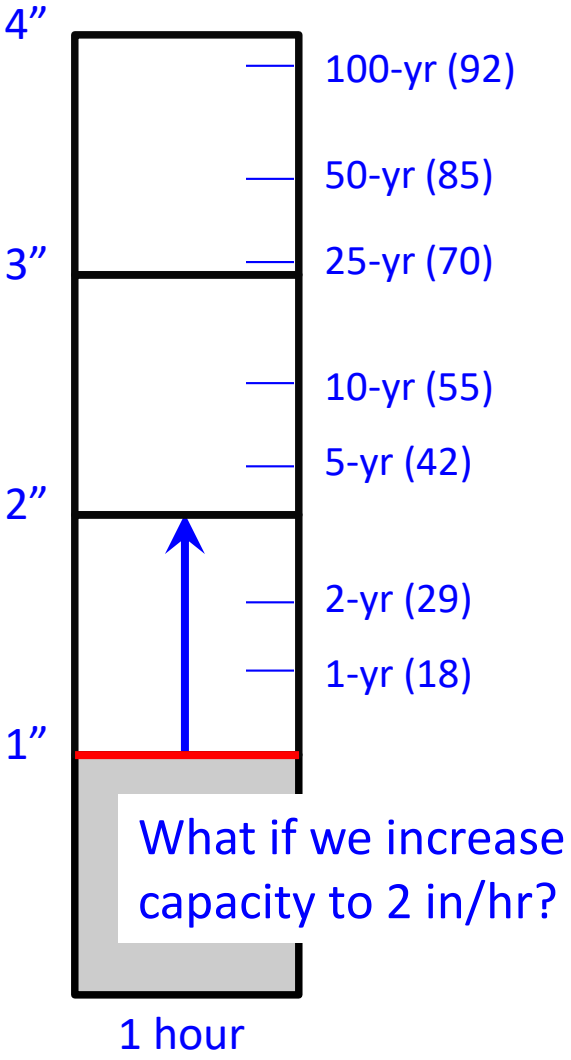
Value = $36.5 million

Moneyball Approach

Net Present Value =
$36.5 million

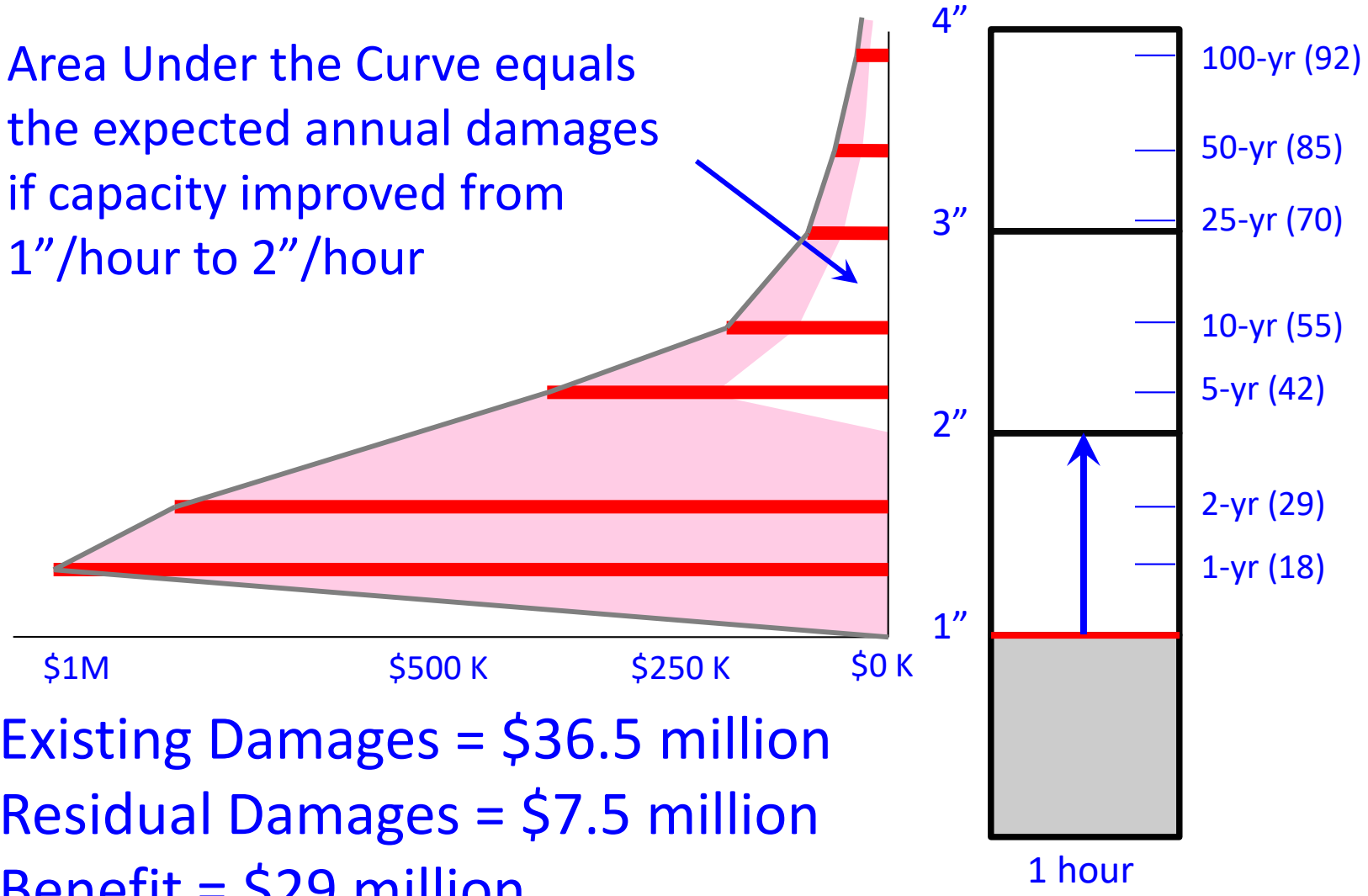


Expected Annual Damages



Feasible Projects with Huge Benefits!

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



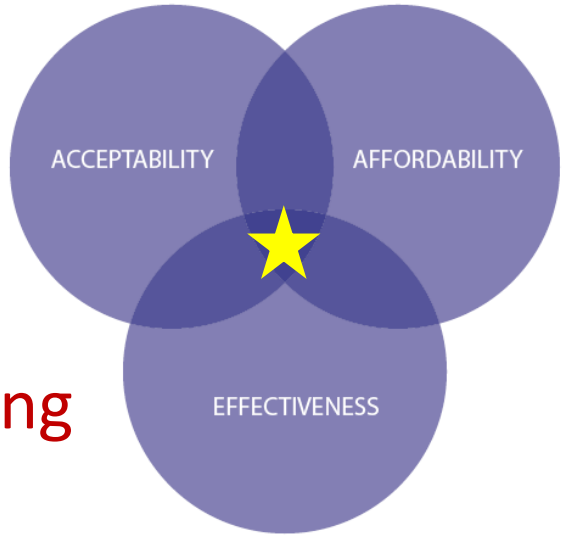
Existing Damages = $36.5 million

Residual Damages = $7.5 million

Benefit = $29 million

Using the Moneyball approach…

- Challenge conventional wisdom
  - Rethink Level of Service
  - Rethink your hydrology
- The numbers do not lie
  - Technology can assist in developing information over a larger area
  - Develop smart metrics
- You can compete with the Yankees!
  - Optimize performance
  - Find value



Issues in Urban (Zone X) Flooding

QUESTIONS?