Shallow Flooding Analysis

Sheet Runoff Flooding in Zone A Areas

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Sheetflow Flooding Methodology
based on

Guidelines and Specifications
for
Flood Hazard Mapping Partners

Appendix E: Guidance for Shallow Flooding Analyses and Mapping

http://www.fema.gov/pdf/fhm/frm_gsae.pdf

FEMA

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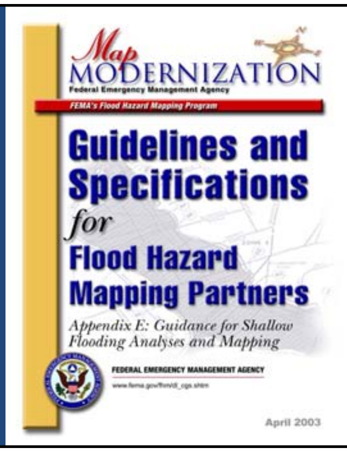

3

Guidelines and Specifications for Flood Hazard Mapping Partners

"The general guidelines cited herein are applicable to all areas of shallow flooding. They are indicative of the general approach taken to the study of shallow flooding problems in order to fulfill the requirements of the NFIP."

Appendix E – Section E.5

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Shallow Flooding Types

- ❖ Sheet Runoff
- ❖ Ponding

5

Sheet runoff is the broad, relatively unconfined down slope movement of water across sloping terrain. Like an AO Zone, these areas have flood depths less than 3 feet.

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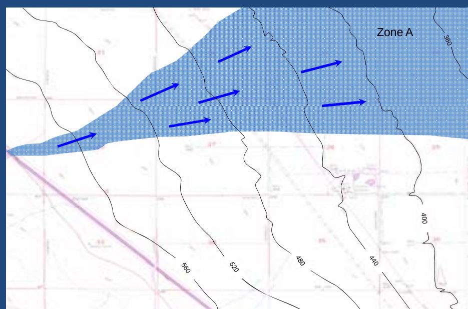
Sheet Runoff Sources

Channel Loses Definition



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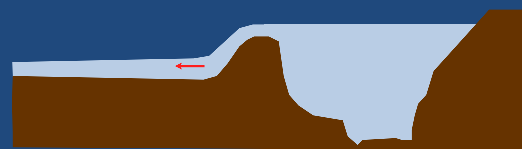
Sheet Runoff Sources

Perched Channel Overflow



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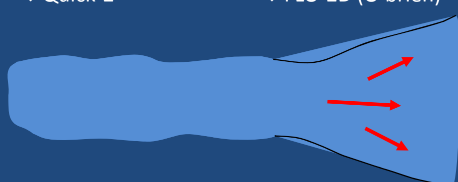
Hydraulic Models

One Dimensional :
- HEC-RAS
- HEC-2
- Quick-2

Two Dimensional:
- MIKE FLOOD (DHI)
- RMA (Corps)
- FLO-2D (O'brien)



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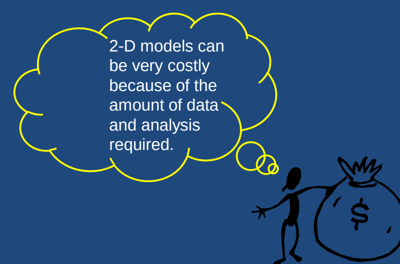

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Guidelines and Specifications for Flood Hazard Mapping Partners

"Two-dimensional models will be used where one-dimensional models, currently accepted techniques, and engineering judgment will not provide satisfactory information for floodplain management and NFIP purposes."
[Appendix C – Section C.3.4.2]

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Guidelines and Specifications for Flood Hazard Mapping Partners

"Sheet runoff typically takes place across broad areas of low relief. This makes it likely that sheet runoff depths will be less than 1.0 foot."
Appendix E – Section E.5.3

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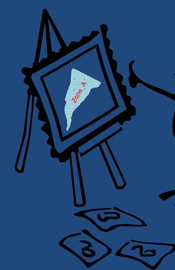
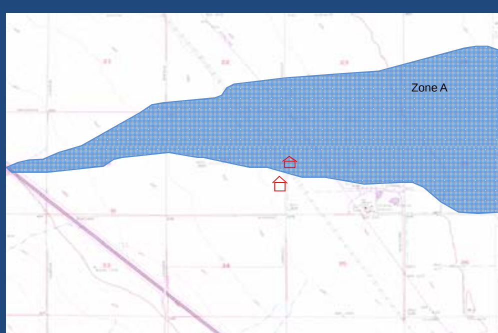
Shallow Flooding Restrictions

❖Analysis is based on Zone A Boundary



The shallow flooding methodology assumes that the Zone A boundary is reasonable and can be used as the basis of developing depths.

Zone A Flood Boundaries



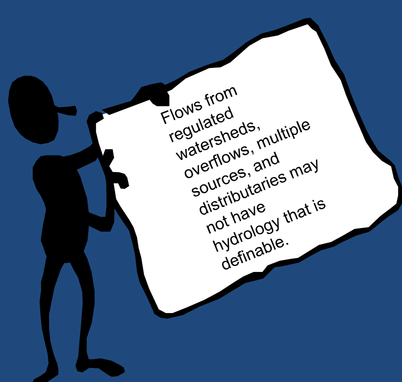
Shallow Flooding Restrictions

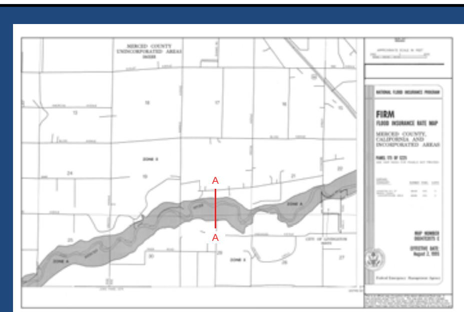
❖Analysis is based on Zone A Boundary

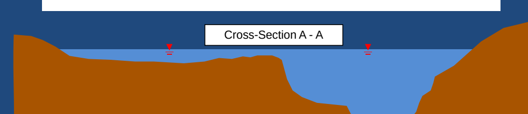
❖Average floodplains less than 3 foot depth

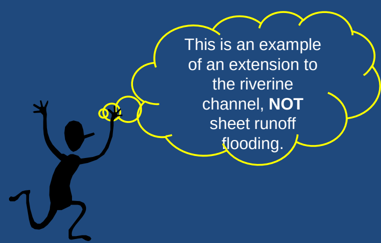
❖Known or easily identified hydrology

❖Shallow areas not extensions of riverine systems







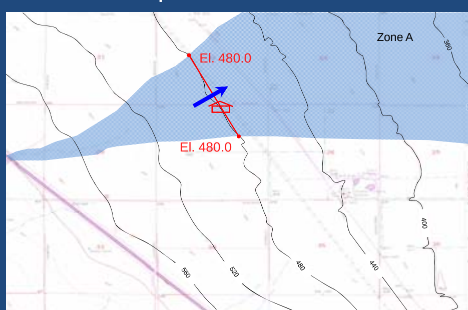


Shallow Flooding Restrictions

- Analysis is based on Zone A Boundary
- Average floodplains less than 3 foot depth
- Known or easily identified hydrology
- Shallow areas not extensions of riverine systems
- Unconfined flooding patterns generally perpendicular to contours

Sheet Runoff Pattern

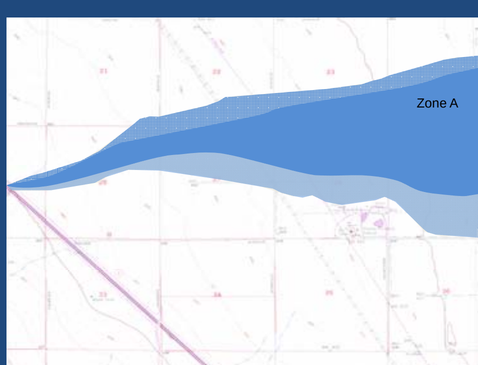
Flow Perpendicular to Contours



Shallow Flooding Restrictions

- Analysis is based on Zone A Boundary
- Average floodplains less than 3 foot depth
- Known or easily identified hydrology
- Shallow areas not extensions of riverine systems
- Unconfined flooding patterns generally perpendicular to contours
- Minimal impact from obstructions

Variable Flooding Patterns



Flows have a highly unpredictable flow direction due to low relief or shifting of channels and debris loads. The flows will likely concentrate in certain areas and the entire area defined by the Zone A will likely not always be flooded.

Guidelines and Specifications for Flood Hazard Mapping Partners

"Shallow flooding is often characterized by highly unpredictable flow direction because of low relief or shifting channels and debris loads. Where such conditions exist, the Mapping Partner shall delineate the entire area susceptible to this unpredictable flow as an area of equal risk."

Appendix E – Section E.5

The equal risk (or averaging of the risk) means that some of the areas in a Zone A will have a higher risk of flooding and some areas will have a lower risk of flooding than the analysis will show.

Shallow Flooding Methodology

- ❖Map and Field Verification
- ❖Cross-section Development
- ❖Normal Depth Analysis

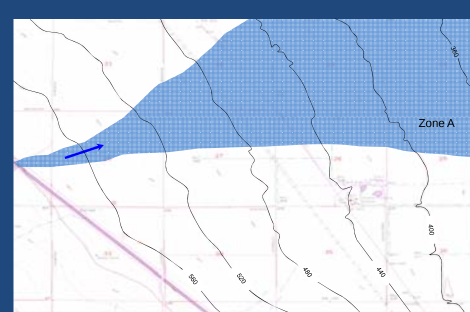
Map and Field Verification

Verify Zone A Mapping

- ❖Plot Zone A Boundary on Contour Map
- ❖Flood patterns should be downslope and roughly perpendicular to contours

When verifying the Zone A boundary, a quadrangle map should be sufficient if nothing else is suitable.

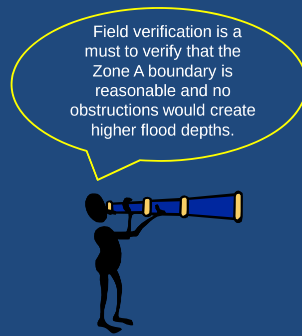
Sheet Runoff Flow Pattern



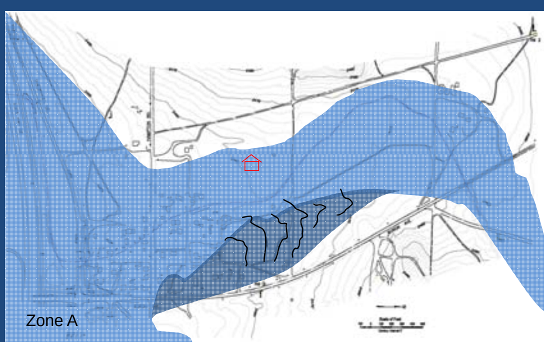
Map and Field Verification

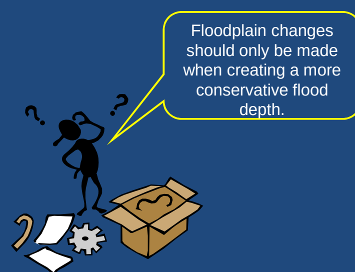
Field Check Floodplain Boundary

- ❖Floodplain appears reasonable
- ❖Raised roads or levees
- ❖ Large structures
- ❖ Large-scale topographic variations



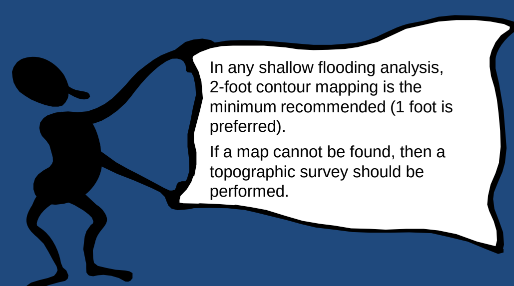
Zone A Boundary Modification



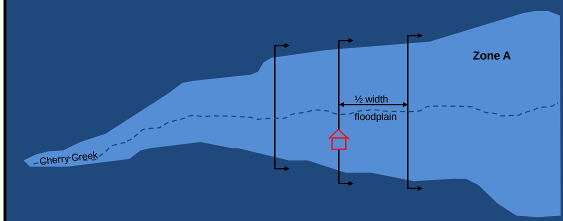


Cross-Section Development

- ❖Topographic Mapping
- ❖3 Cross-sections Preferred
- ❖Cross-Section Location and Spacing



Cross-Section Development



The three cross-sections should include: one through the structure, one upstream, and one downstream. Cross-section spacing should be about half of the floodplain width.

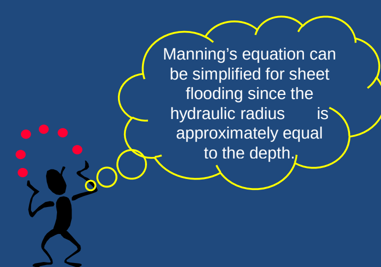
Normal Depth Analysis

Manning's Equation

$$Q = \frac{1.486}{n} * A * R^{2/3} * S^{1/2}$$

$$R = \frac{\text{Area}}{\text{Wetted Perimeter}} = \frac{W * D}{W + 2D} = D$$

$$Q = \frac{1.486}{n} * W * D * D^{2/3} * S^{1/2}$$



Normal Depth Analysis

Simplified Manning's Equation

$$D = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

D = Depth of flow
Q = Quantity of flow
n = Roughness value
W = Width of flow
S = Slope of floodplain topography

Manning's n-value*

Type of Channel and Description	Minimum	Normal	Maximum
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage < 100 ft			
a. Streams on plain			
1. Clean, straight, full stage, no rifts, or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
D-2. Floodplains			
c. Brush			
1. Scatter brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160

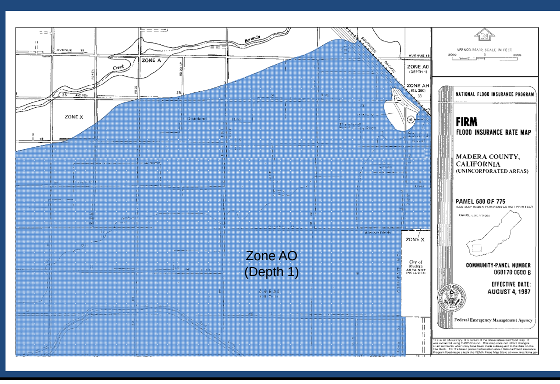
* Partial table taken from FEMA 265 Handbook, Appendix 5, pA5-1 to A5-5

In general, roughness in overbank areas is much higher than in channels due to the fact that the shallower flows will be obstructed much more from average height vegetation. Conservative values should be used.

Shallow Flooding Hydraulic Guidelines

- Limited to average flooding depths

Standard Depth in AO Areas



Like AO Zones, once you get the average depth for each section, the depths should be averaged into one standard depth for the entire area—though changes in depth can be identified at obvious topographic changes.

Shallow Flooding Hydraulic Guidelines

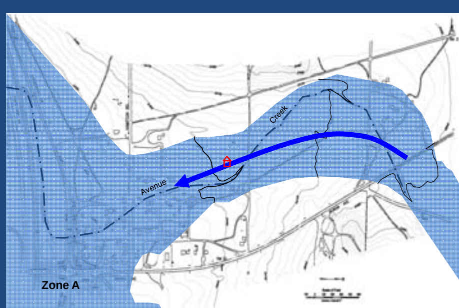
- Limited to average flooding depths
- Reasonable velocities
- Ground contour slopes
- Cross-section spacing

- Average flooding depths limited to 3 feet.
- Reasonable shallow flooding velocities should be between 1 and 5 fps.
- Shallow flooding ground contours should have a slope less than 2% (to prevent confined floods and create conditions not reasonable for sheet flooding methods).
- Cross-sections should be spaced closer together when floodplain widths vary significantly.

Sheetflow Runoff Examples

Avenue Creek

Avenue Creek



Avenue Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

Q$_{100}$ = 1720 cfs

n-value =

Width =

Slope =

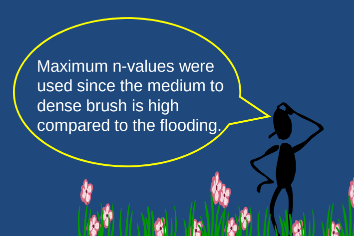
Avenue Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

n-value = 0.16

Width =

Slope =

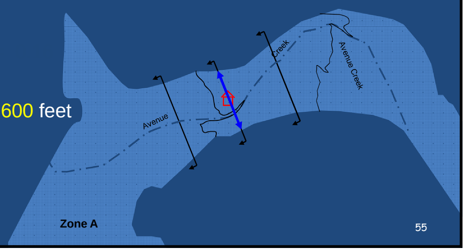


Avenue Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

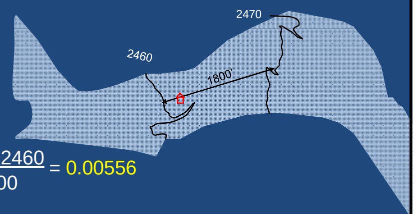
Width = 600 feet

Slope =



Avenue Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$



Slope = $\frac{2470-2460}{1800}$ = 0.00556

The slope should be the slope of the floodplain perpendicular to the flow, not along the path of the small channel.

Avenue Creek Normal Depth Analysis

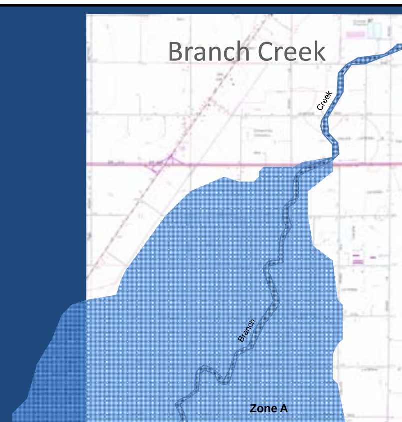
$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

$$D_{structure} = \left[\frac{1{,}720 * 0.16}{1.486 * 600 * 0.00556^{1/2}}\right]^{3/5} = 2.35 \text{ feet}$$

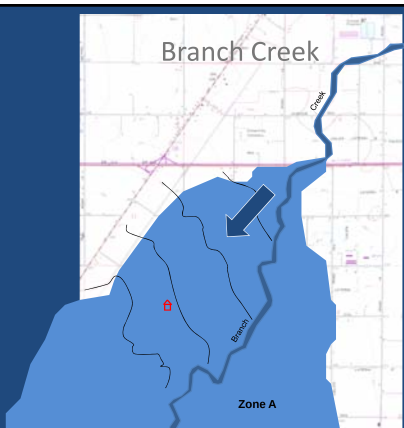
Velocity = Q / A = 1,720/(600*2.35) = 1.2 fps

Average Floodplain Depth = 2 feet
(3 cross-sections)

Branch Creek



This example involves two complexities: a channel that has significant capacity and levees that are overtopped or fail.



The worse case scenario for water overtopping the levee or levee failure is that the overflow will go west towards the proposed structure.

Branch Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

Q$_{overland}$ =

n-value =

Width =

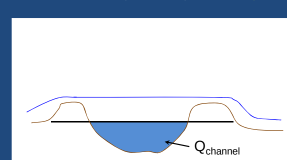
Slope =

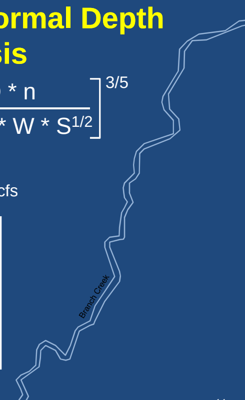
Branch Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

Q$_{overland}$ = Q_{100} - $Q_{channel}$

= 15,000 – 5,000 = 10,000 cfs





Since the channel has a significant capacity, the flow capacity of the channel (with levees at ground level) will be removed from the Q_{100}.

Branch Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

n-value = 0.05

Width =

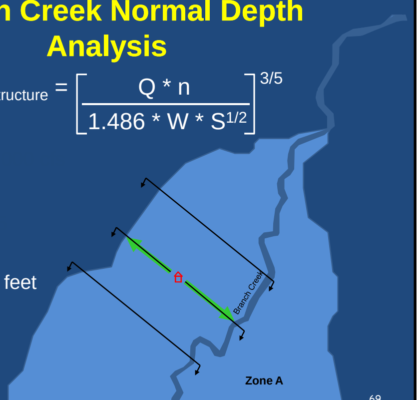
Slope =

Branch Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

Width = 7500 feet

Slope =

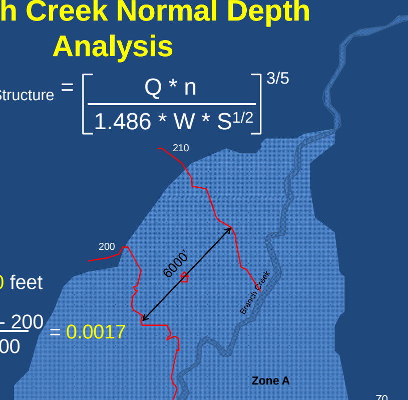


Branch Creek Normal Depth Analysis

$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

Width = 7500 feet

Slope = $\frac{210 - 200}{6000}$ = 0.0017



Branch Creek Normal Depth Analysis

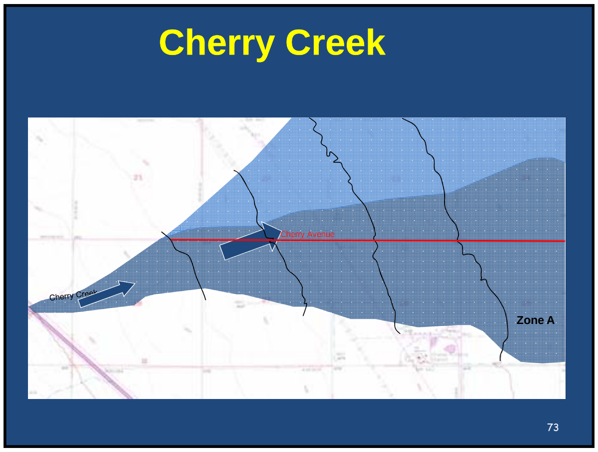
$$D_{Structure} = \left[\frac{Q * n}{1.486 * W * S^{1/2}}\right]^{3/5}$$

$$D_{structure} = \left[\frac{10{,}000 * 0.05}{1.486 * 7{,}500 * 0.0014^{1/2}}\right]^{3/5} = 1.05 \text{ feet}$$

Velocity = Q / A = 10,000/(7,500*1.05) = 1.27 fps

Average Floodplain Depth = 1 foot
(3 cross-sections)

Cherry Creek


Cherry Creek
Cherry Creek
Cherry Avenue
Zone A
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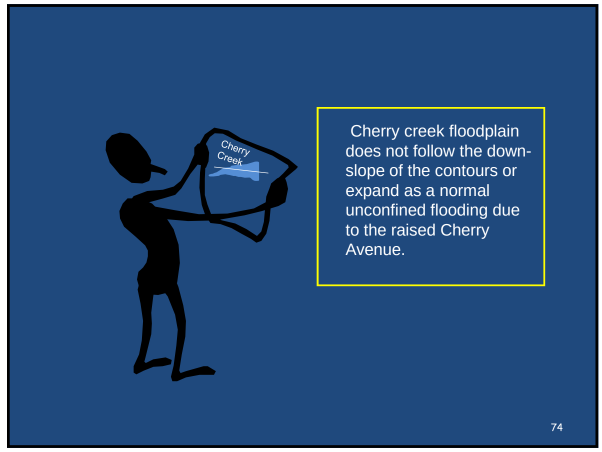
Cherry Creek
Cherry creek floodplain does not follow the down-slope of the contours or expand as a normal unconfined flooding due to the raised Cherry Avenue.
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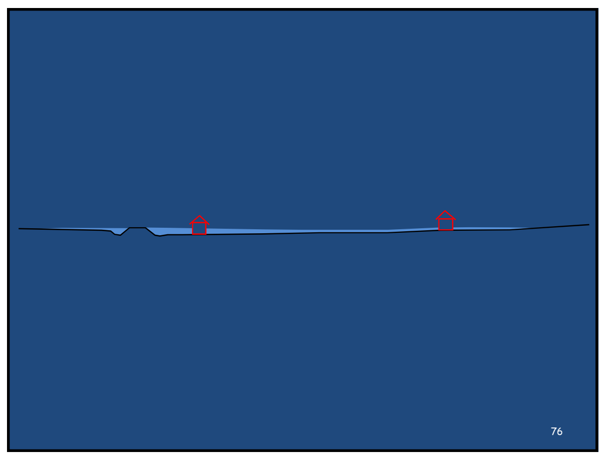
Typical Floodplain Characteristics
5' road height
75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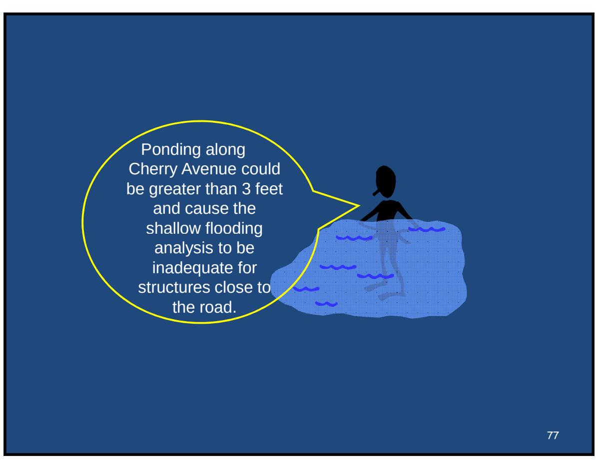
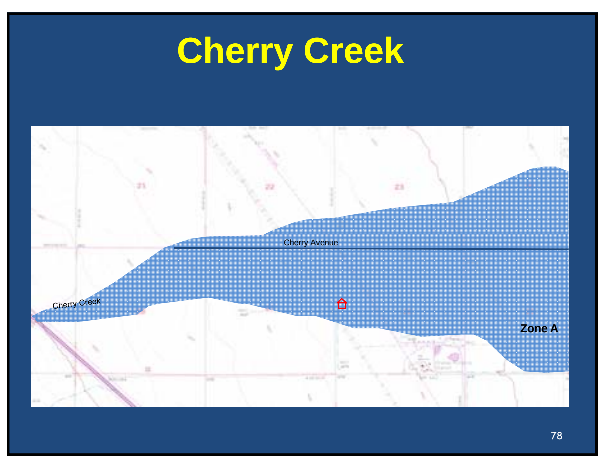

Ponding along Cherry Avenue could be greater than 3 feet and cause the shallow flooding analysis to be inadequate for structures close to the road.
77


Cherry Creek
Cherry Avenue
Cherry Creek
Zone A
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If the structure was away from the influence of the road, a shallow flooding analysis may be approximated if modified to handle all of the flow south of the road.