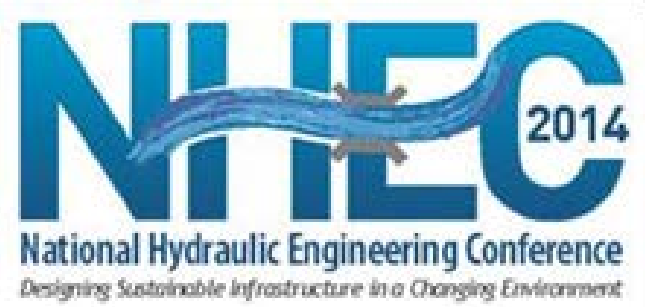
Advantages of 2-D Versus 1-D Hydraulic Modeling



August 20, 2014

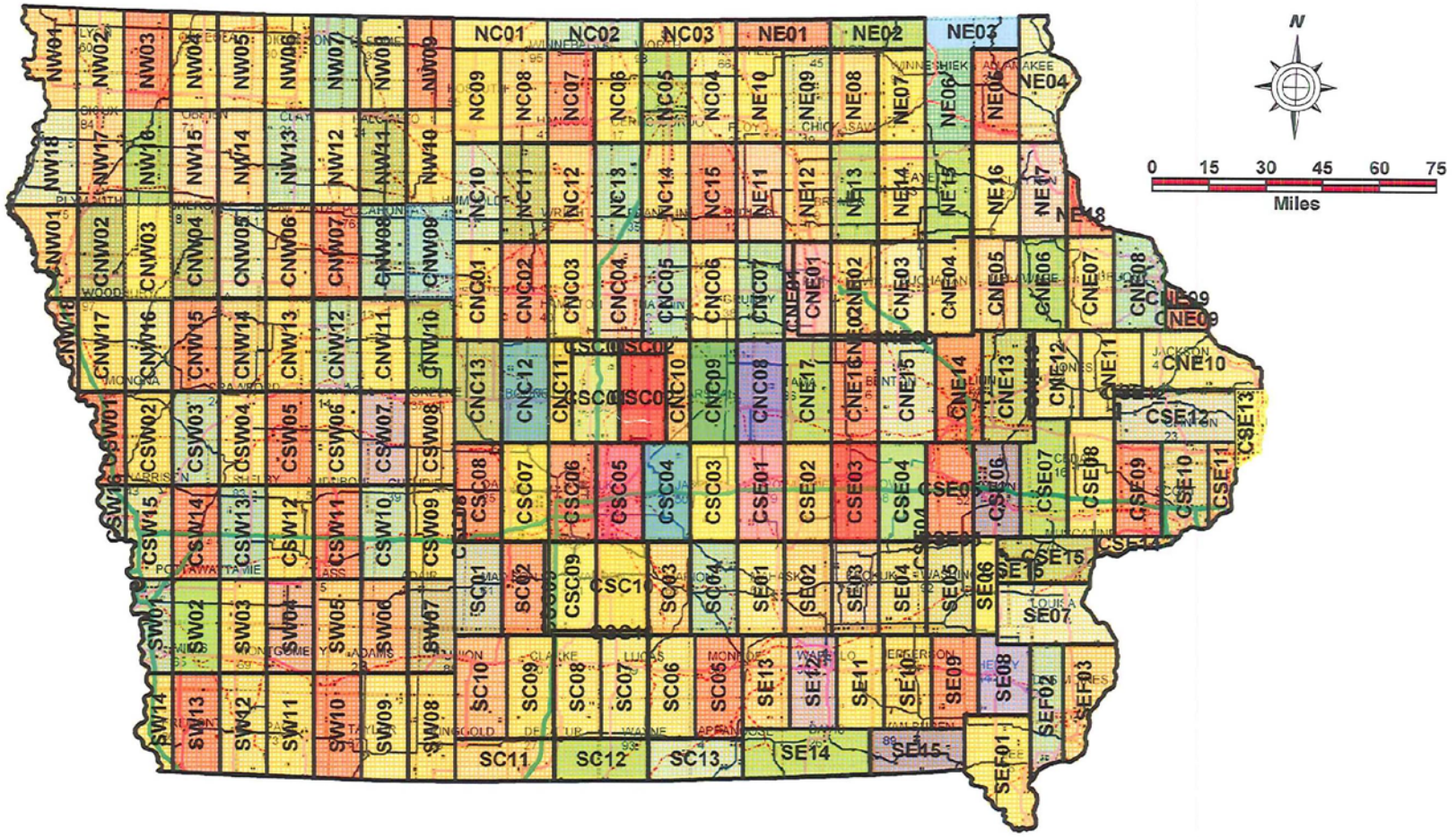
IOWA DOT

Iowa DOT Projects Using 2D Modeling

- Statewide Lidar – Completed in 2010
- U.S. 69 over Iowa River near Belmond
- IA 330 over Iowa River near Albion
- I-35 over South Skunk River south of Ames
- U.S. 65 over Des Moines River near Pleasant Hill
- City of Dumont Flood Mitigation
- I-80 over N. Raccoon River – Bendway Weirs

IOWA DOT

LiDAR Data Received
October 14, 2010

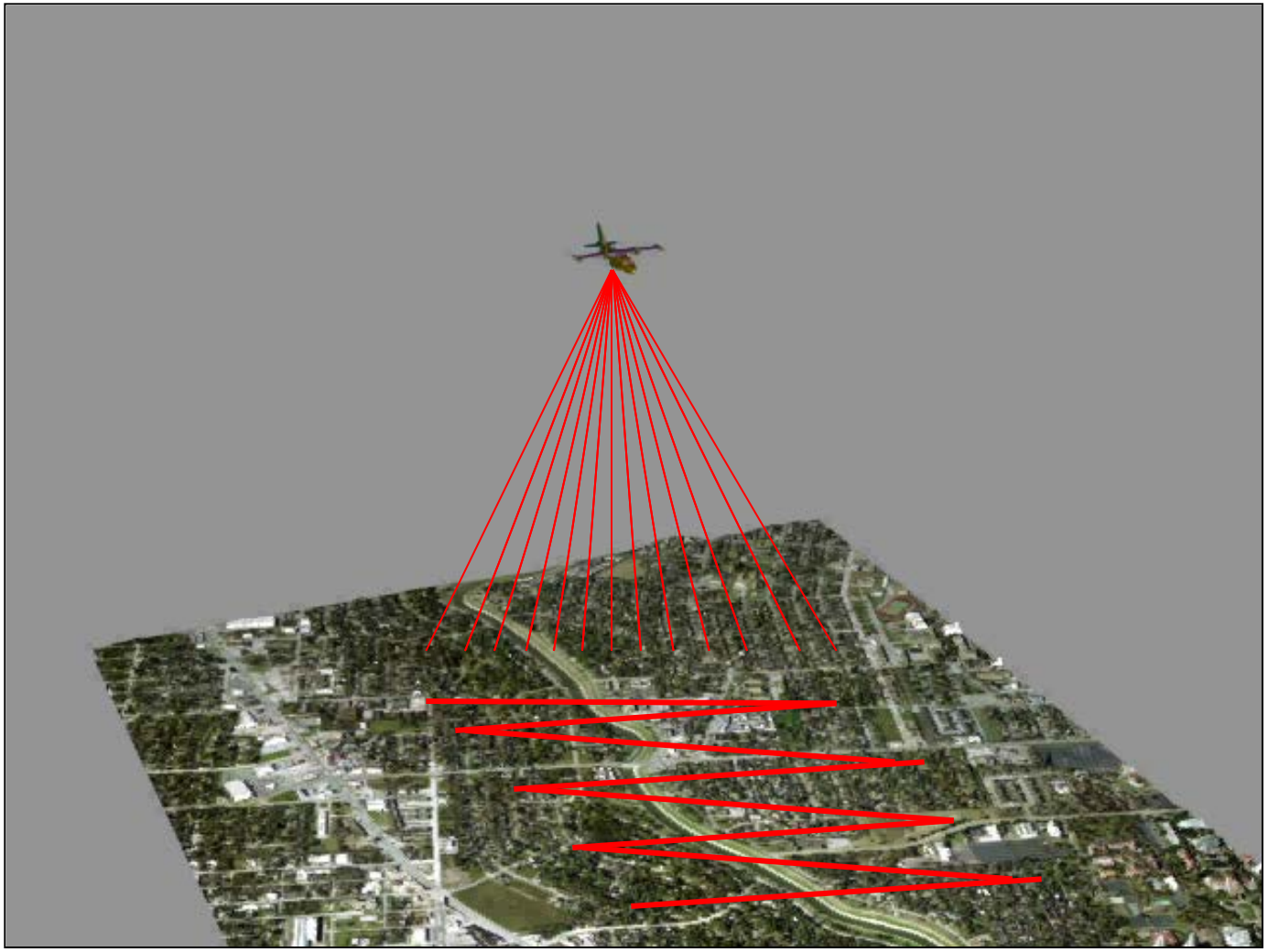


Data set is now complete.
New Tiles (LAS and XYZi formats):
CNC01, CNC02, CNC04, CNC05, CNC06, CNE10, CNE14, CNE02, CNE09, CNW02, CNW06, CNW07, CNW08, CSE11, CSE07, CSW14, NE18, NW10, NW11, NW12, NW07, SEF01 and SEF03

Legend

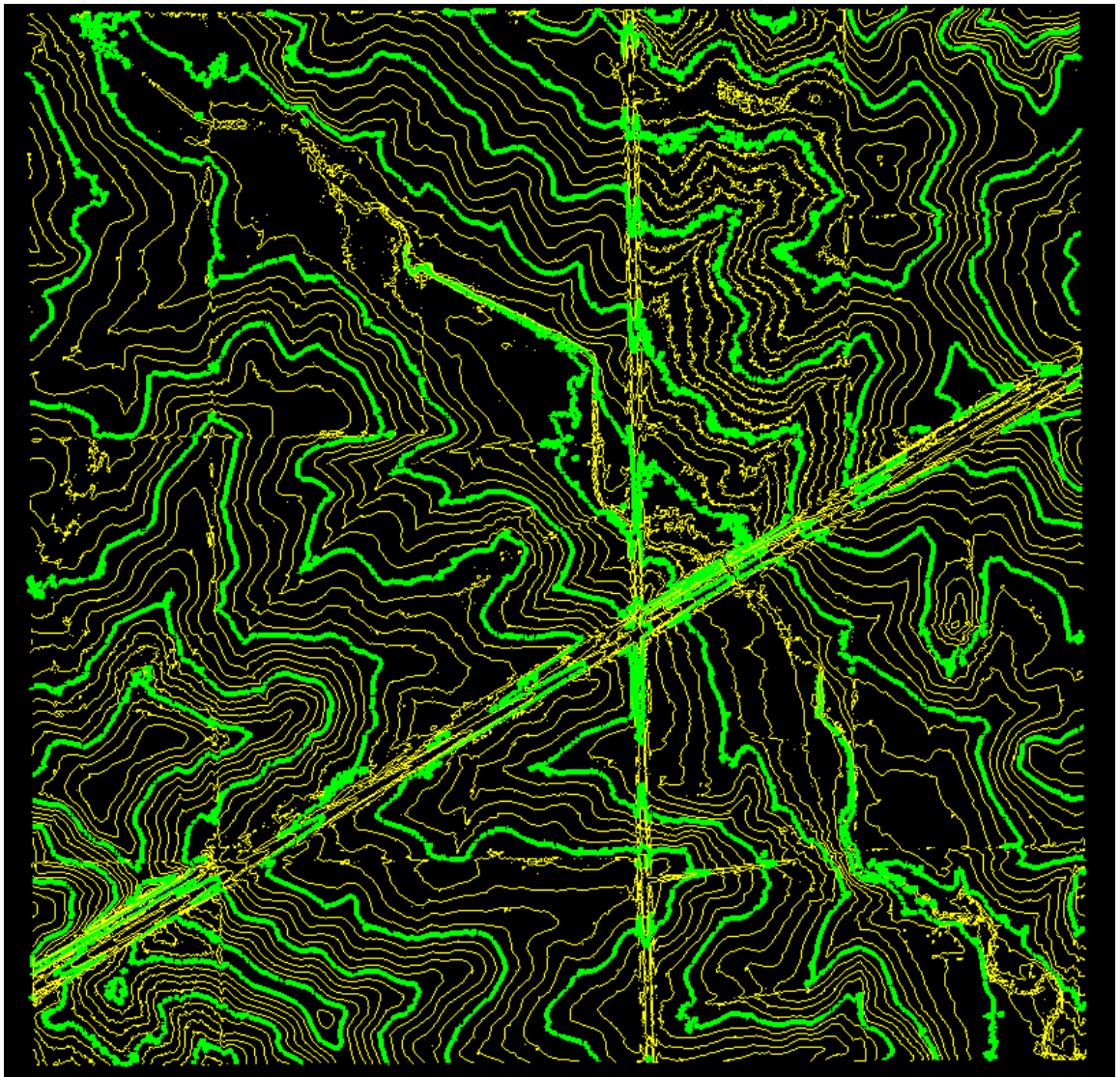
Iowa_Tiles

What is LiDAR?



Courtesy of Dodson & Associates

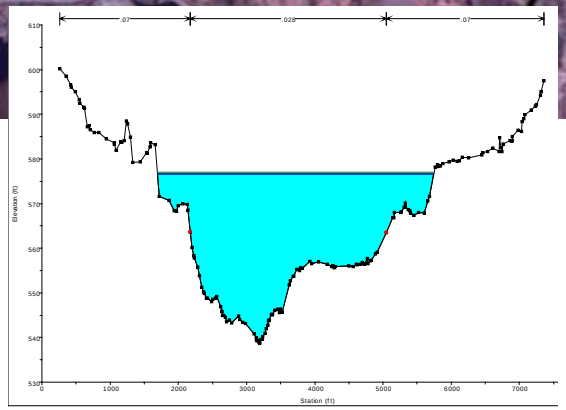
Contours/DEM



LiDAR Tools

- UNI GeoTREE
  - http://www.geotree.uni.edu/lidarProject.aspx
- Quick Terrain Modeler
  - http://appliedimagery.com/index.html
- ESRI ArcGIS
  - Spatial Analyst Extension
  - 3d Analyst Extension

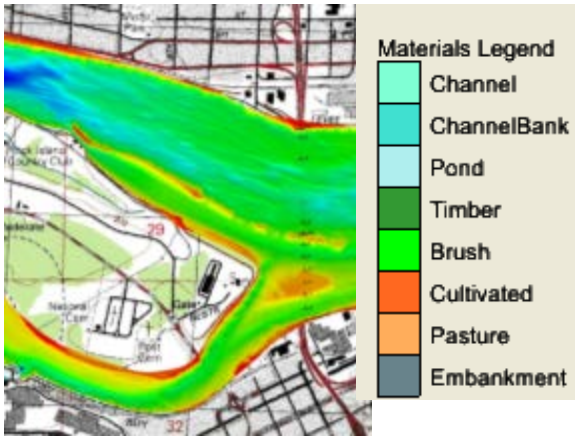
1D Hydraulic Model (HEC-RAS)



Sections from USACE – Des Moines River Model

- 1D – HEC-RAS – widely accepted – predicts average velocity in cross section and water surface elevation
- Very challenging to model in 1D, Ineffective Flow Areas, Losses from channel bends, Overtopping levee systems

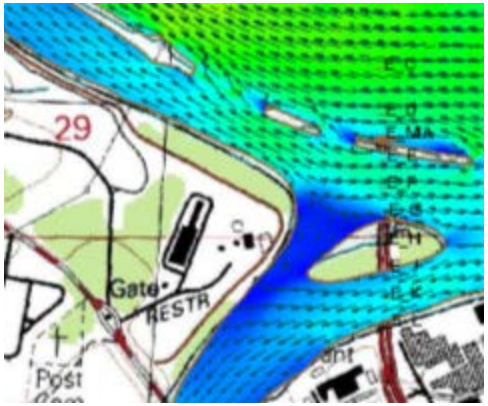
2D Hydraulic Models



Bathymetry

Roughness

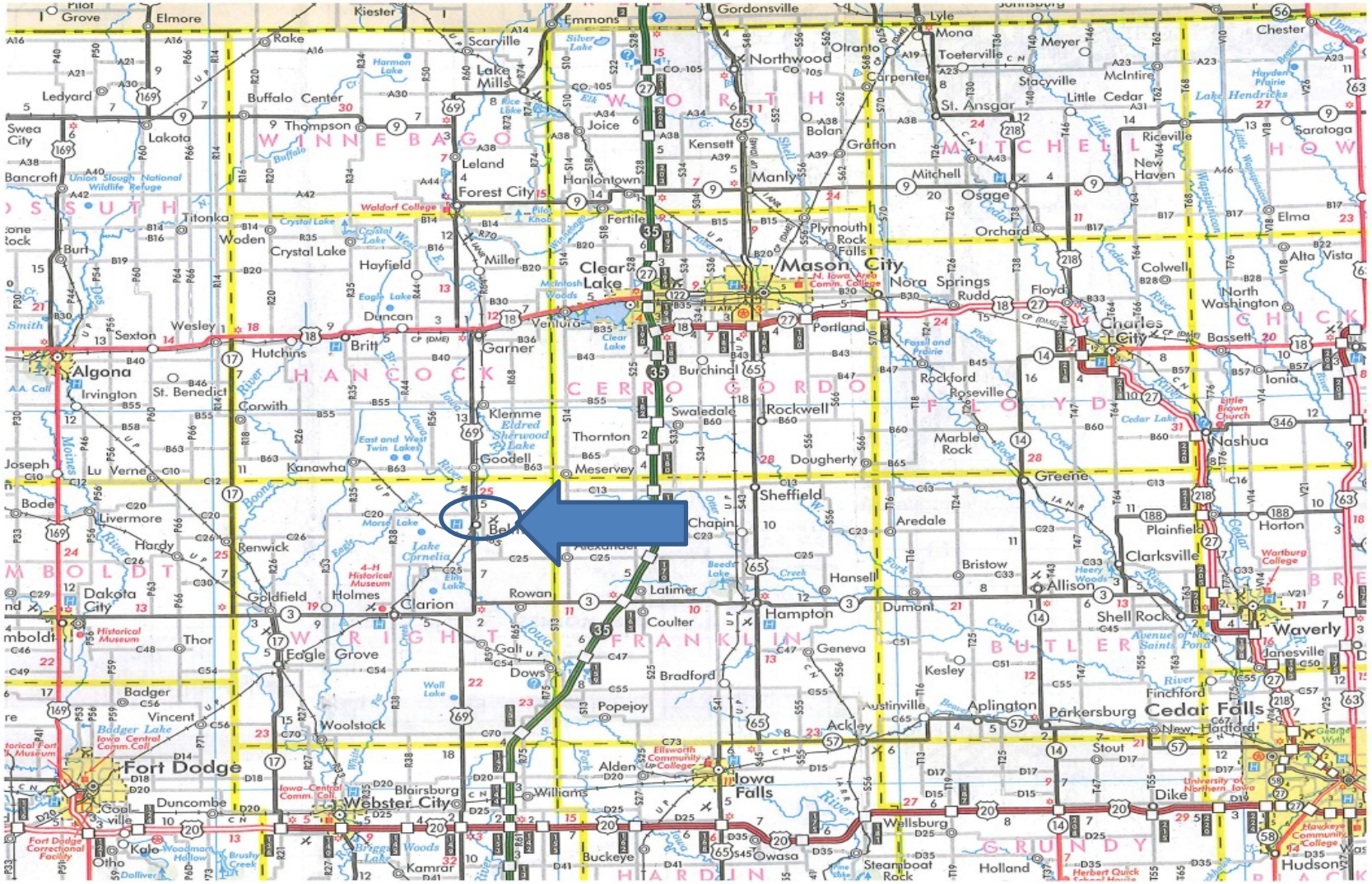
Mesh



Computed velocity field

- 2D Models– predicts depth-averaged two-dimensional velocity and water surface elevation
- Combines channel bathymetry + LiDAR (floodplains) + Surface Roughness into a velocity field

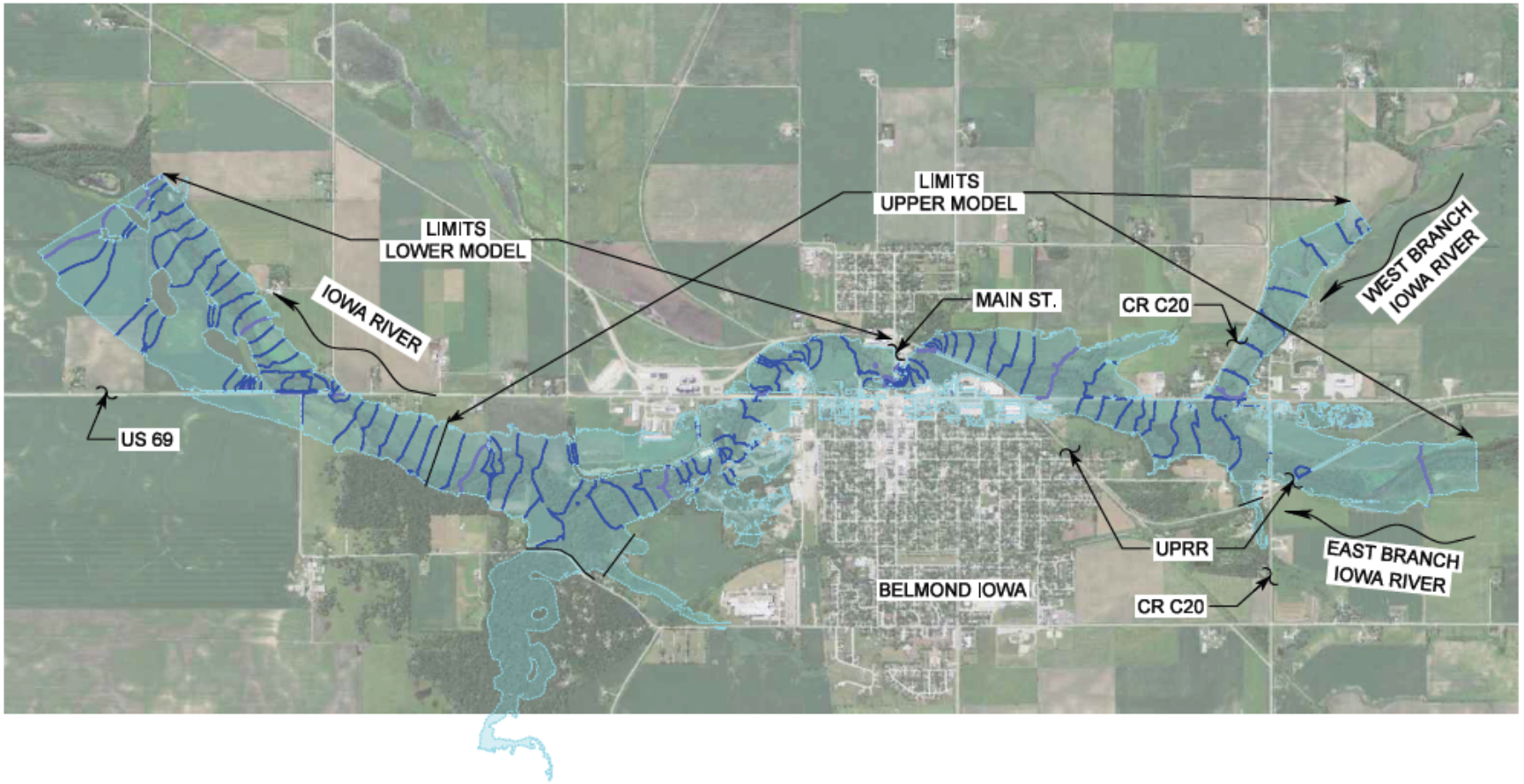
U.S. 69 over Iowa River – Belmond, IA



EXISTING CONDITION – 2008
EVENT WATER SURFACE
CONTOURS 0.1 FT INTERVAL

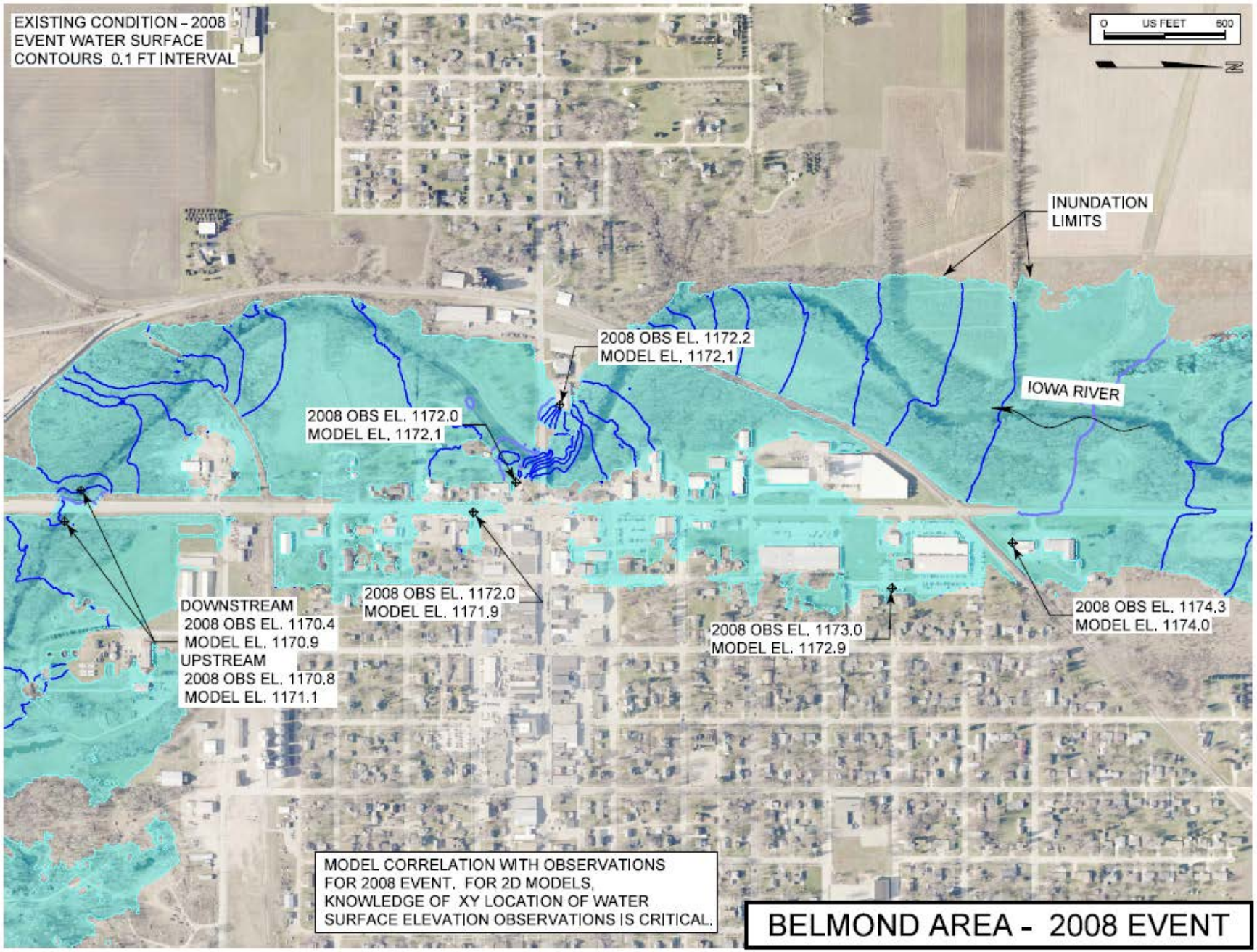
0 US FEET 2500

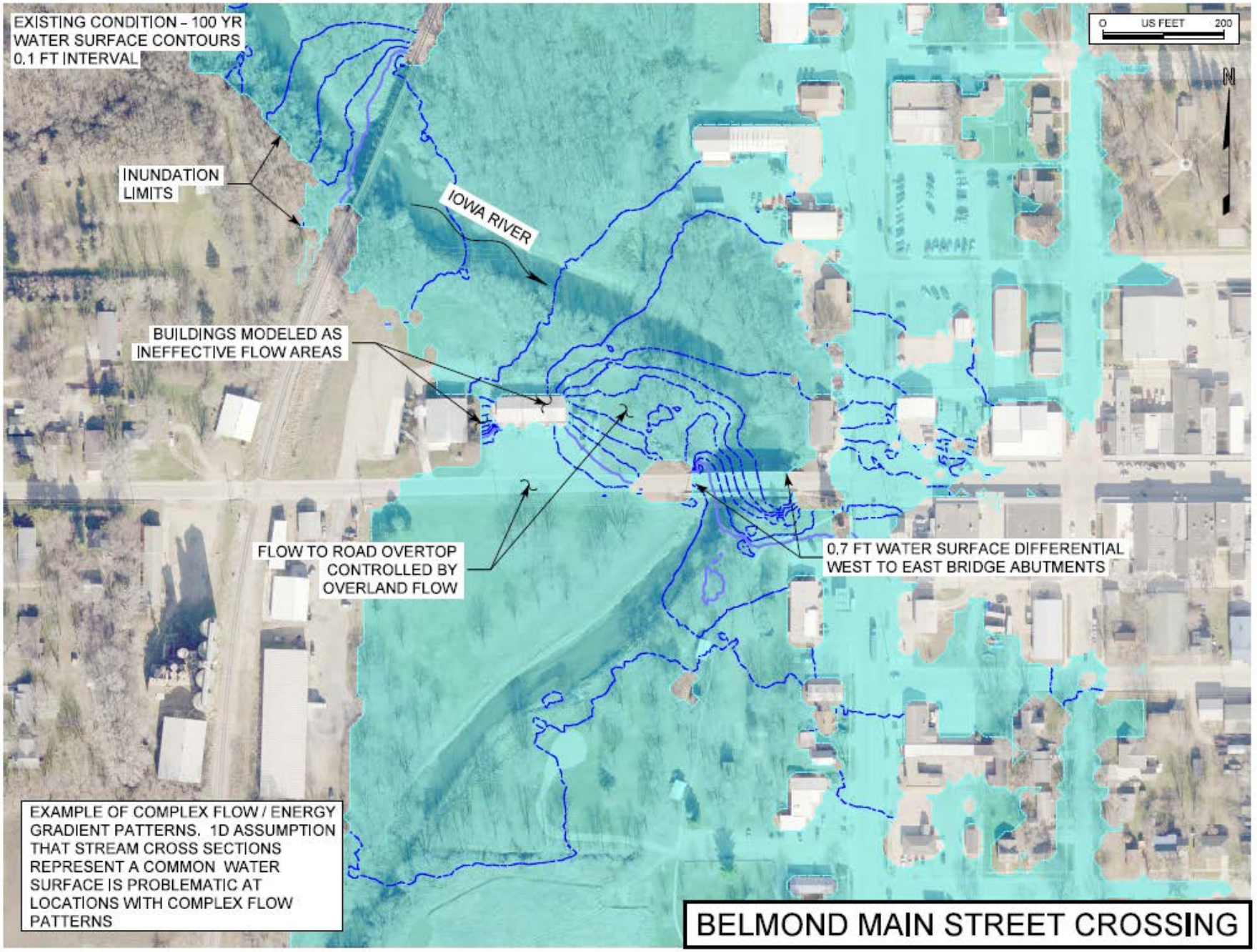
N

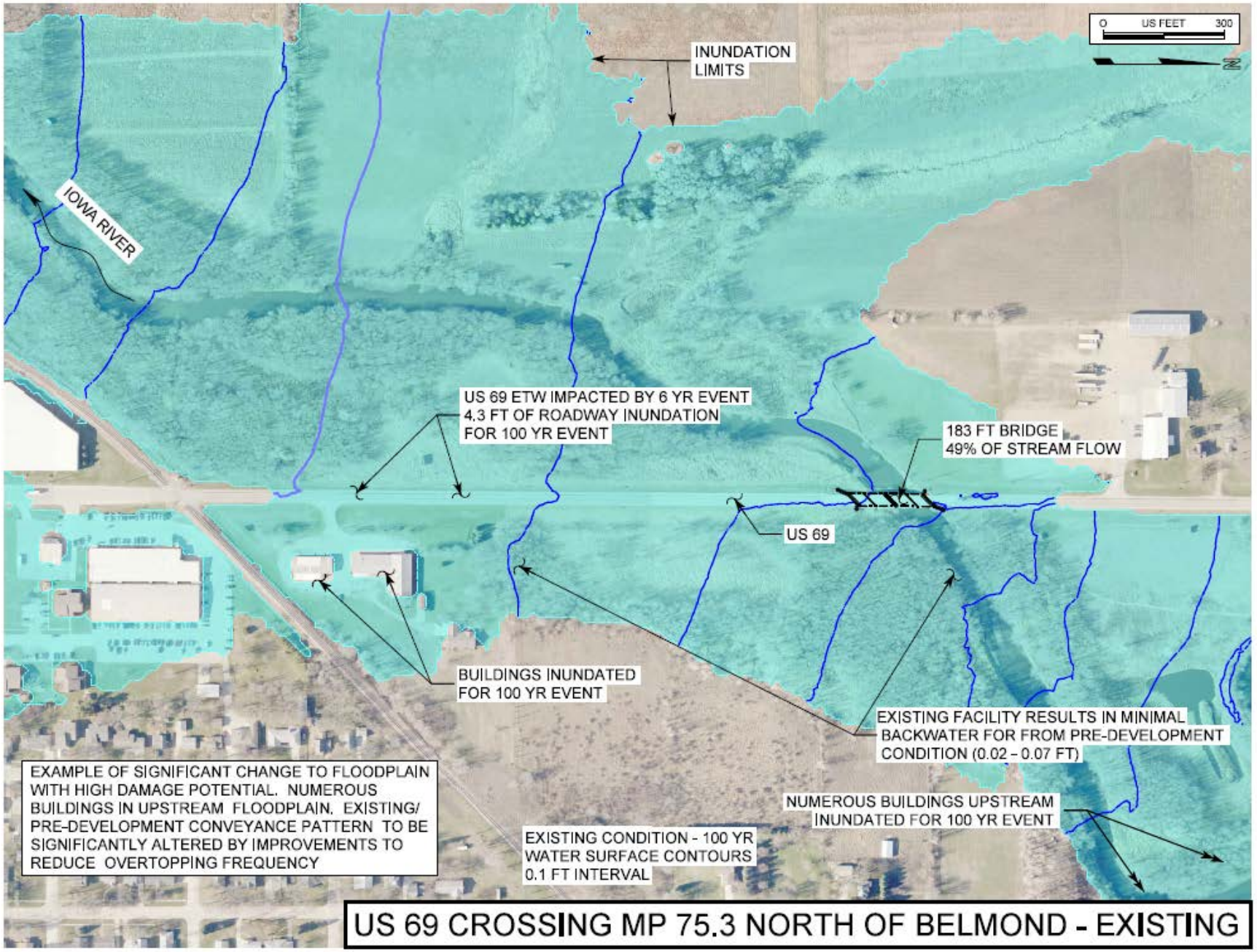


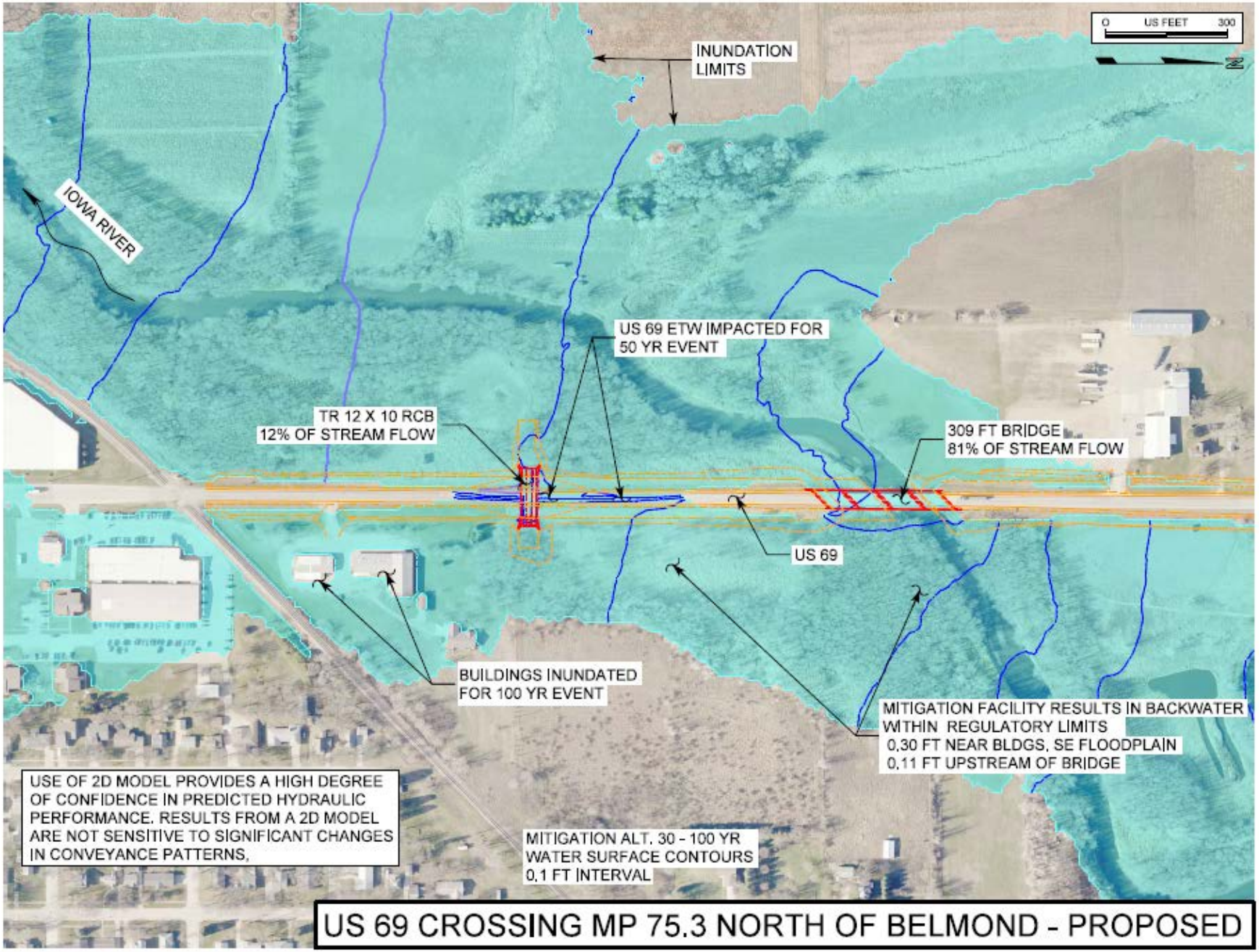
UPPER MODEL LOWER BOUNDARY USES WATER SURFACE CALULATED BY LOWER MODEL. BOUNDARY DIGITIZED ALONG LINE TO REFLECT NEARLY UNIFORM WATER SURFACE THROUGH THE RANGE OF FLOWRATES TO BE MODELED.

IOWA RIVER NEAR BELMOND IOWA - WRIGHT COUNTY

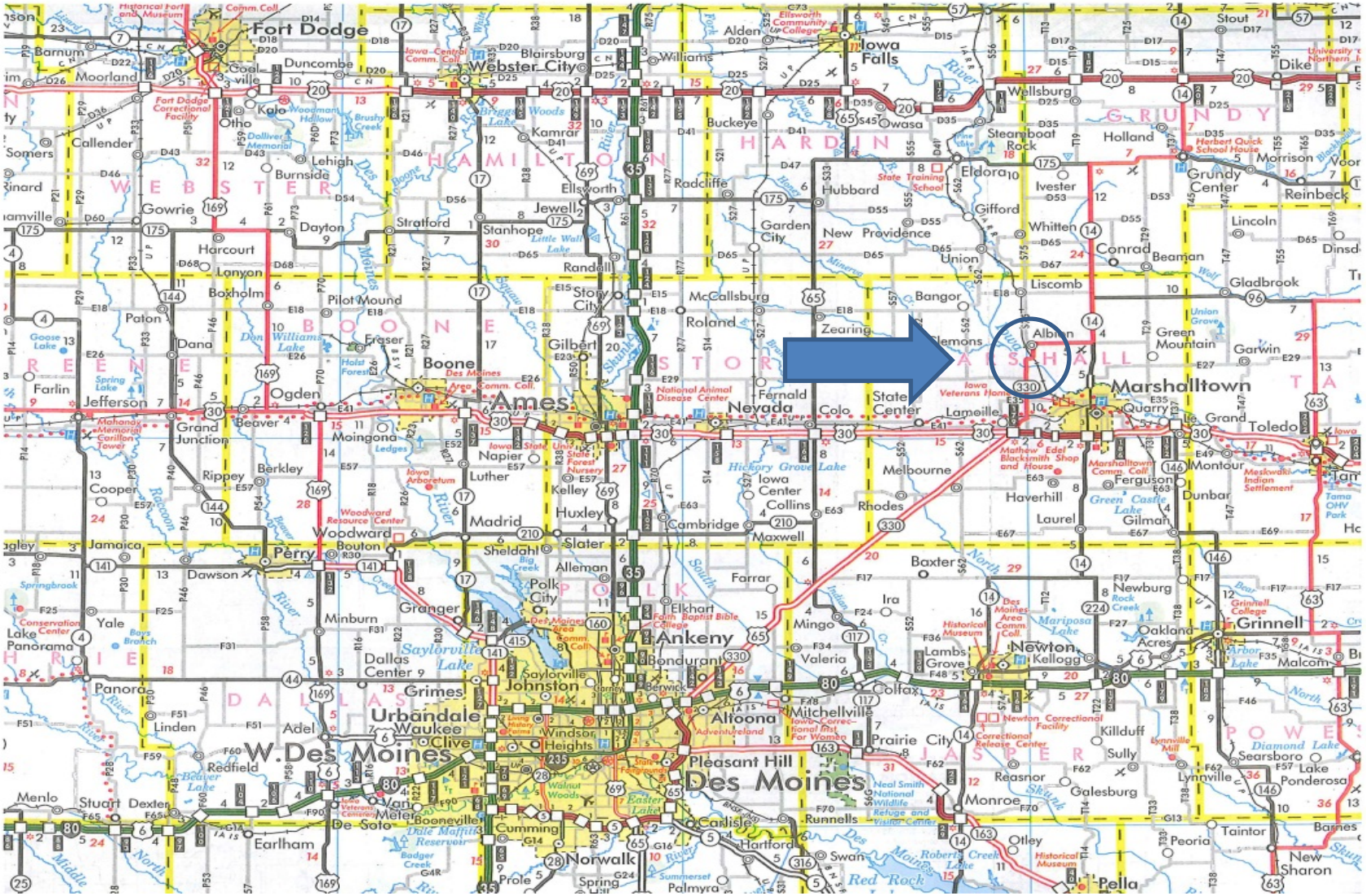

EXISTING CONDITION – 2008
EVENT WATER SURFACE
CONTOURS 0.1 FT INTERVAL
0 US FEET 600
N
INUNDATION
LIMITS
2008 OBS EL. 1172.2
MODEL EL. 1172.1
IOWA RIVER
2008 OBS EL. 1172.0
MODEL EL. 1172.1
DOWNSTREAM
2008 OBS EL. 1170.4
MODEL EL. 1170.9
UPSTREAM
2008 OBS EL. 1170.8
MODEL EL. 1171.1
2008 OBS EL. 1172.0
MODEL EL. 1171.9
2008 OBS EL. 1173.0
MODEL EL. 1172.9
2008 OBS EL. 1174.3
MODEL EL. 1174.0
MODEL CORRELATION WITH OBSERVATIONS
FOR 2008 EVENT. FOR 2D MODELS,
KNOWLEDGE OF XY LOCATION OF WATER
SURFACE ELEVATION OBSERVATIONS IS CRITICAL.
BELMOND AREA - 2008 EVENT


EXISTING CONDITION – 100 YR
WATER SURFACE CONTOURS
0.1 FT INTERVAL
0 US FEET 200
N
INUNDATION
LIMITS
IOWA RIVER
BUILDINGS MODELED AS
INEFFECTIVE FLOW AREAS
FLOW TO ROAD OVERTOP
CONTROLLED BY
OVERLAND FLOW
0.7 FT WATER SURFACE DIFFERENTIAL
WEST TO EAST BRIDGE ABUTMENTS
EXAMPLE OF COMPLEX FLOW / ENERGY
GRADIENT PATTERNS. 1D ASSUMPTION
THAT STREAM CROSS SECTIONS
REPRESENT A COMMON WATER
SURFACE IS PROBLEMATIC AT
LOCATIONS WITH COMPLEX FLOW
PATTERNS
BELMOND MAIN STREET CROSSING

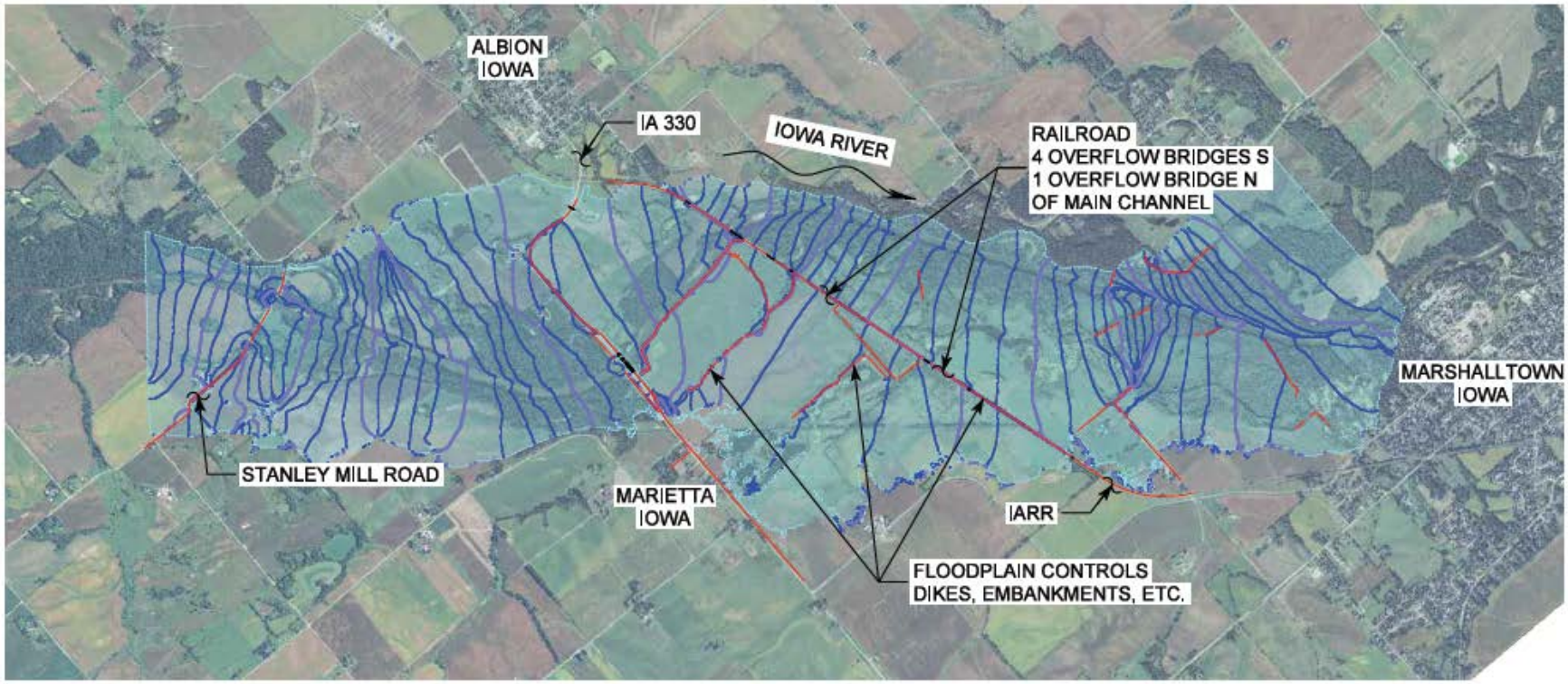

0 US FEET 300
N
INUNDATION LIMITS
IOWA RIVER
US 69 ETW IMPACTED BY 6 YR EVENT
4.3 FT OF ROADWAY INUNDATION
FOR 100 YR EVENT
183 FT BRIDGE
49% OF STREAM FLOW
US 69
BUILDINGS INUNDATED
FOR 100 YR EVENT
EXISTING FACILITY RESULTS IN MINIMAL
BACKWATER FOR FROM PRE-DEVELOPMENT
CONDITION (0.02 – 0.07 FT)
EXAMPLE OF SIGNIFICANT CHANGE TO FLOODPLAIN WITH HIGH DAMAGE POTENTIAL. NUMEROUS BUILDINGS IN UPSTREAM FLOODPLAIN. EXISTING/ PRE-DEVELOPMENT CONVEYANCE PATTERN TO BE SIGNIFICANTLY ALTERED BY IMPROVEMENTS TO REDUCE OVERTOPPING FREQUENCY
NUMEROUS BUILDINGS UPSTREAM
INUNDATED FOR 100 YR EVENT
EXISTING CONDITION - 100 YR
WATER SURFACE CONTOURS
0.1 FT INTERVAL
US 69 CROSSING MP 75.3 NORTH OF BELMOND - EXISTING


0 US FEET 300
N
INUNDATION LIMITS
IOWA RIVER
US 69 ETW IMPACTED FOR 50 YR EVENT
TR 12 X 10 RCB 12% OF STREAM FLOW
309 FT BRIDGE 81% OF STREAM FLOW
US 69
BUILDINGS INUNDATED FOR 100 YR EVENT
MITIGATION FACILITY RESULTS IN BACKWATER WITHIN REGULATORY LIMITS
0.30 FT NEAR BLDGS, SE FLOODPLAIN
0.11 FT UPSTREAM OF BRIDGE
USE OF 2D MODEL PROVIDES A HIGH DEGREE OF CONFIDENCE IN PREDICTED HYDRAULIC PERFORMANCE. RESULTS FROM A 2D MODEL ARE NOT SENSITIVE TO SIGNIFICANT CHANGES IN CONVEYANCE PATTERNS.
MITIGATION ALT. 30 - 100 YR WATER SURFACE CONTOURS 0.1 FT INTERVAL
US 69 CROSSING MP 75.3 NORTH OF BELMOND - PROPOSED

IA 330 over Iowa River Near Albion



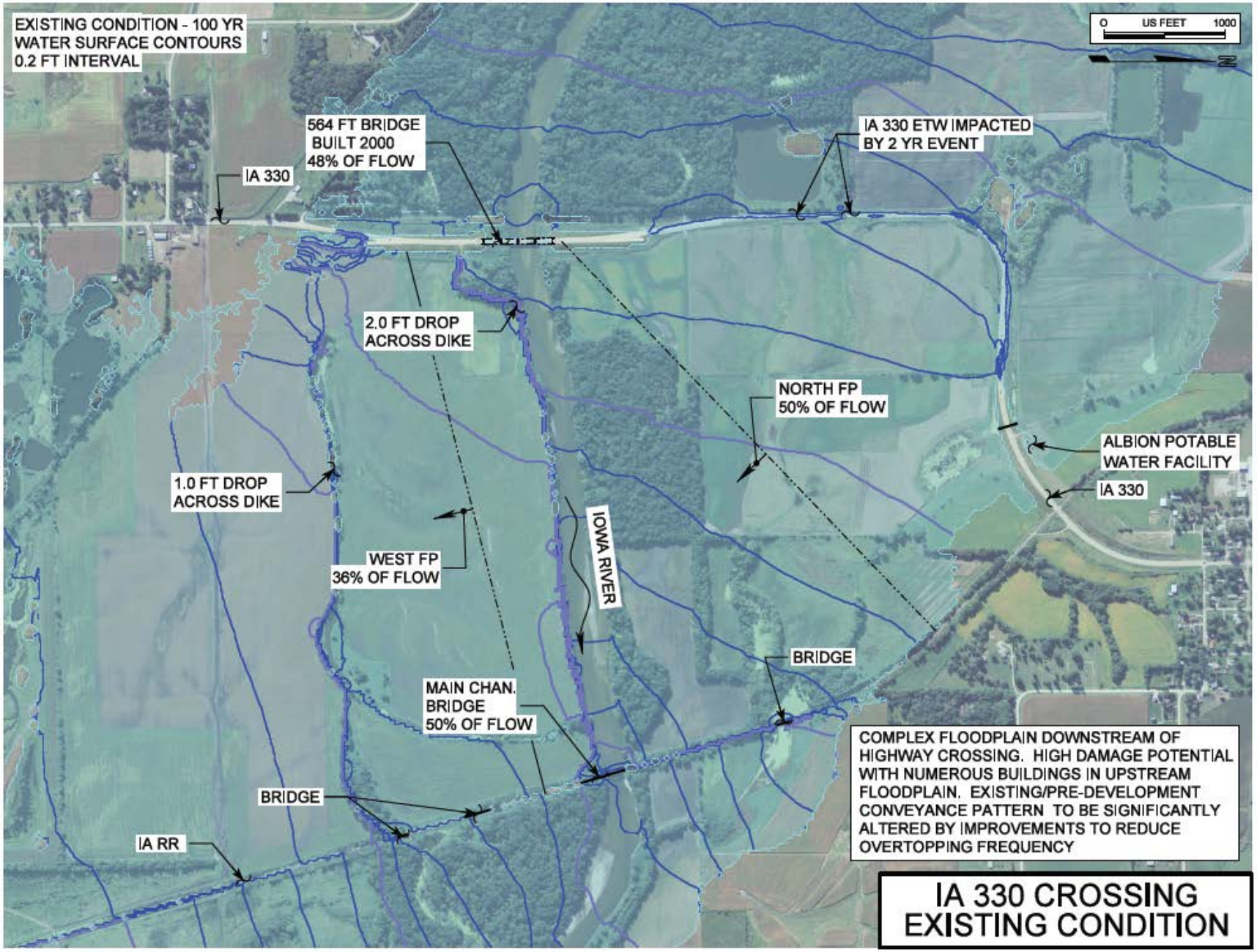
EXISTING CONDITION – 100 YR
EVENT WATER SURFACE
CONTOURS 0.2 FT INTERVAL

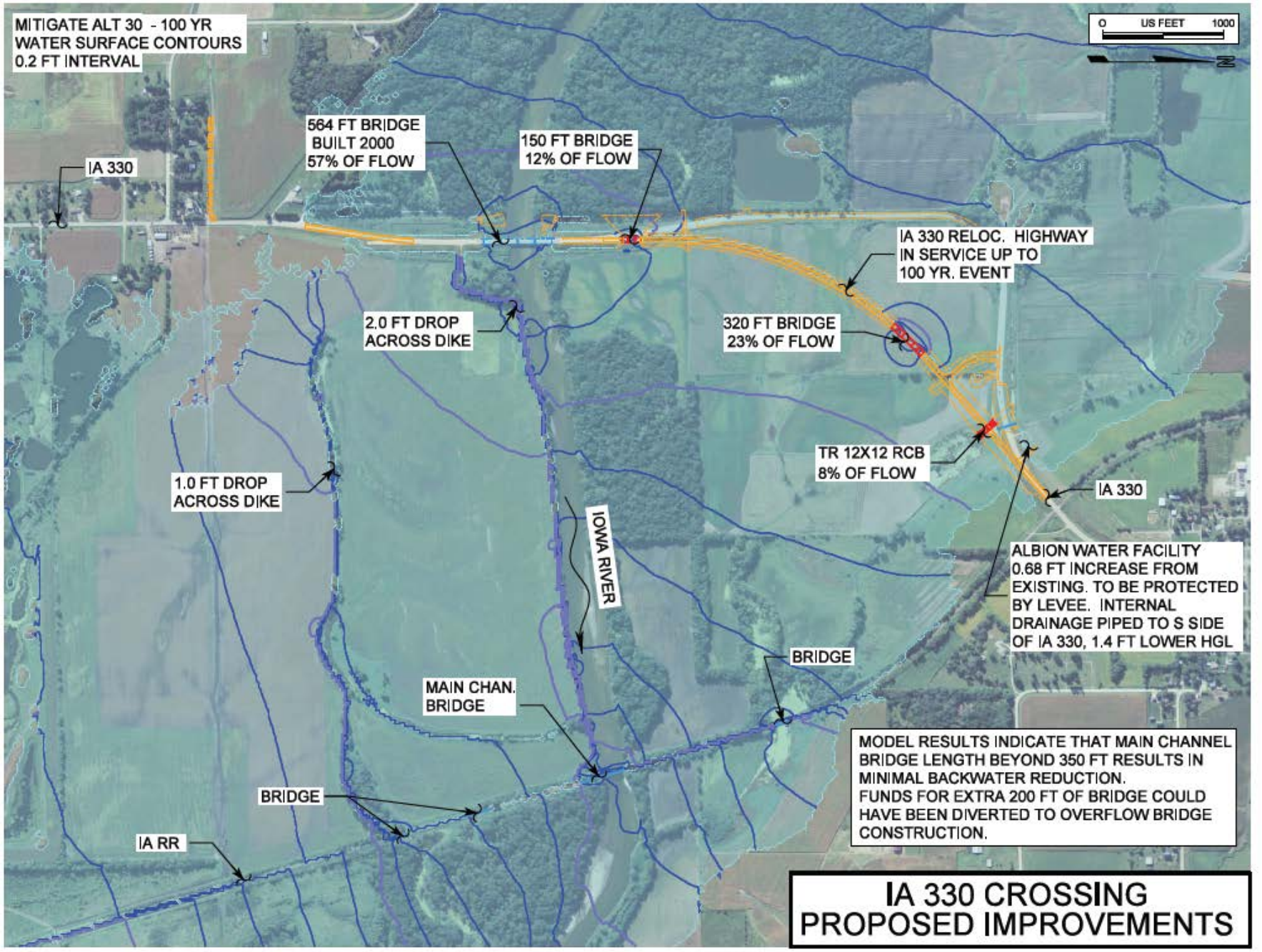


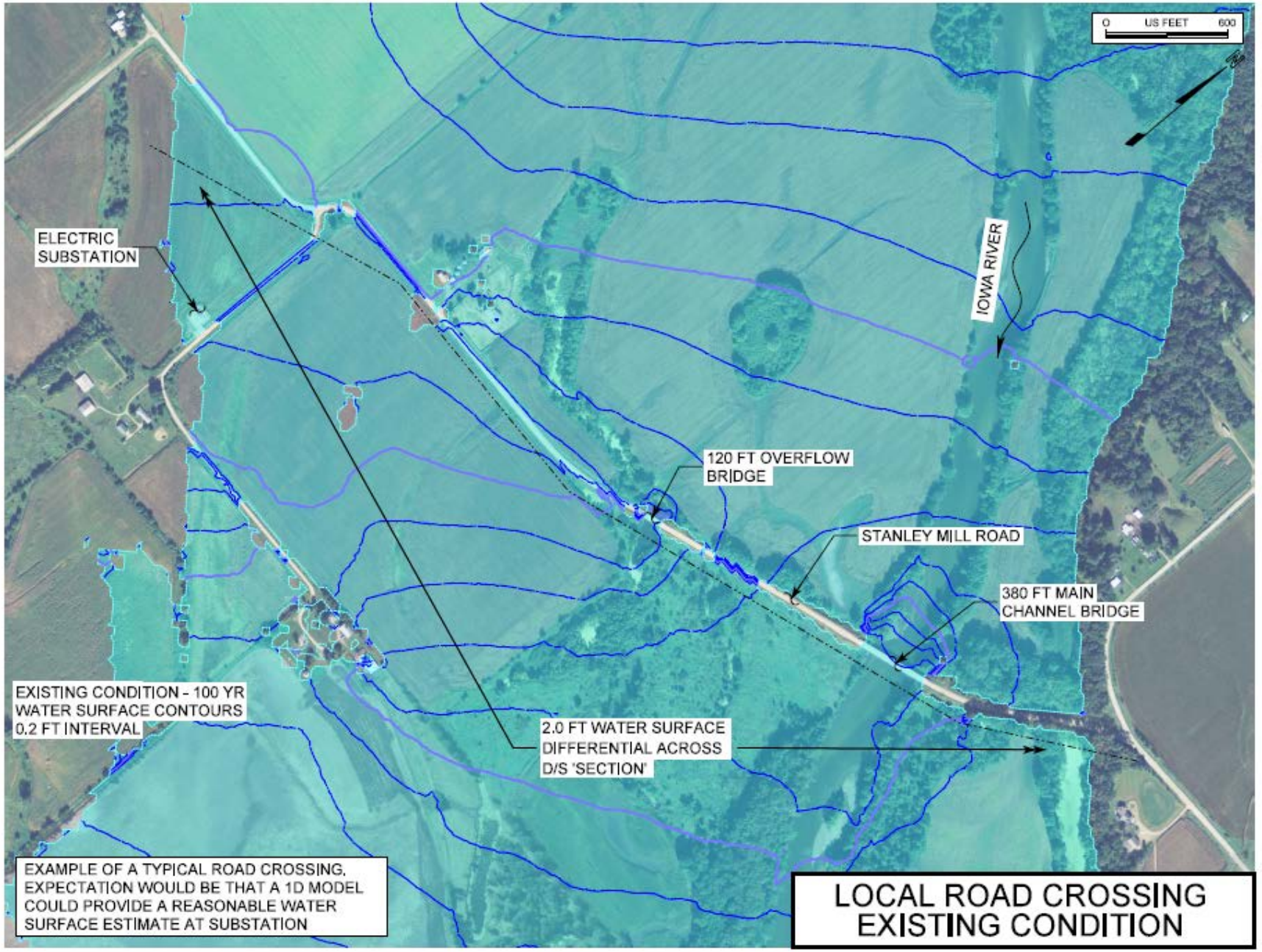
0 US FEET 4000

NUMEROUS DIKES AND EMBANKMENTS THAT ACT AS HYDRAULIC CONTROLS.
RAILROAD WITH MULTIPLE OVERFLOW BRIDGES.
2D MODEL SIMPLIFIES ANALYSIS OF A COMPLEX FLOODPLAIN

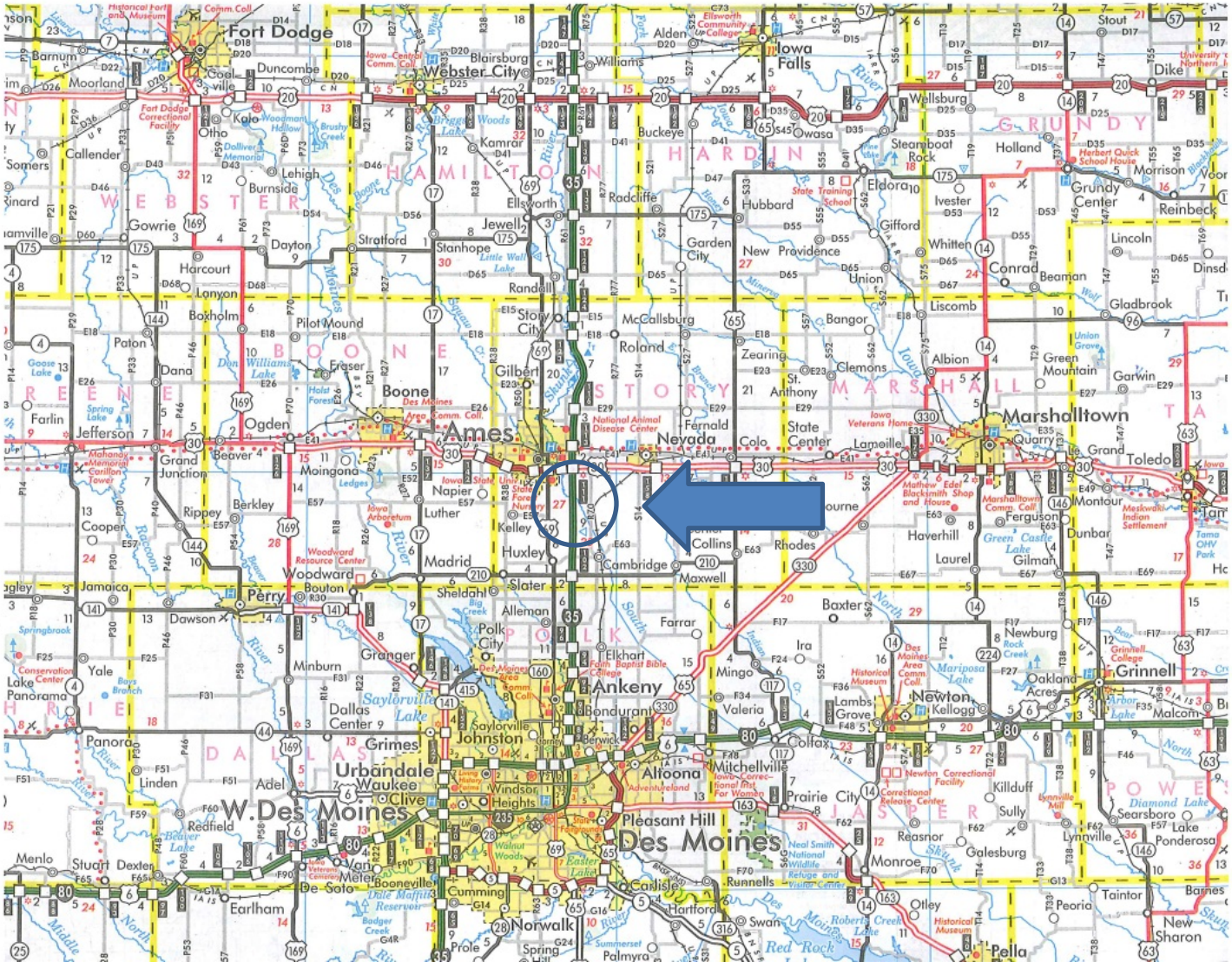
IOWA RIVER NEAR ALBION IOWA - MARSHALL COUNTY

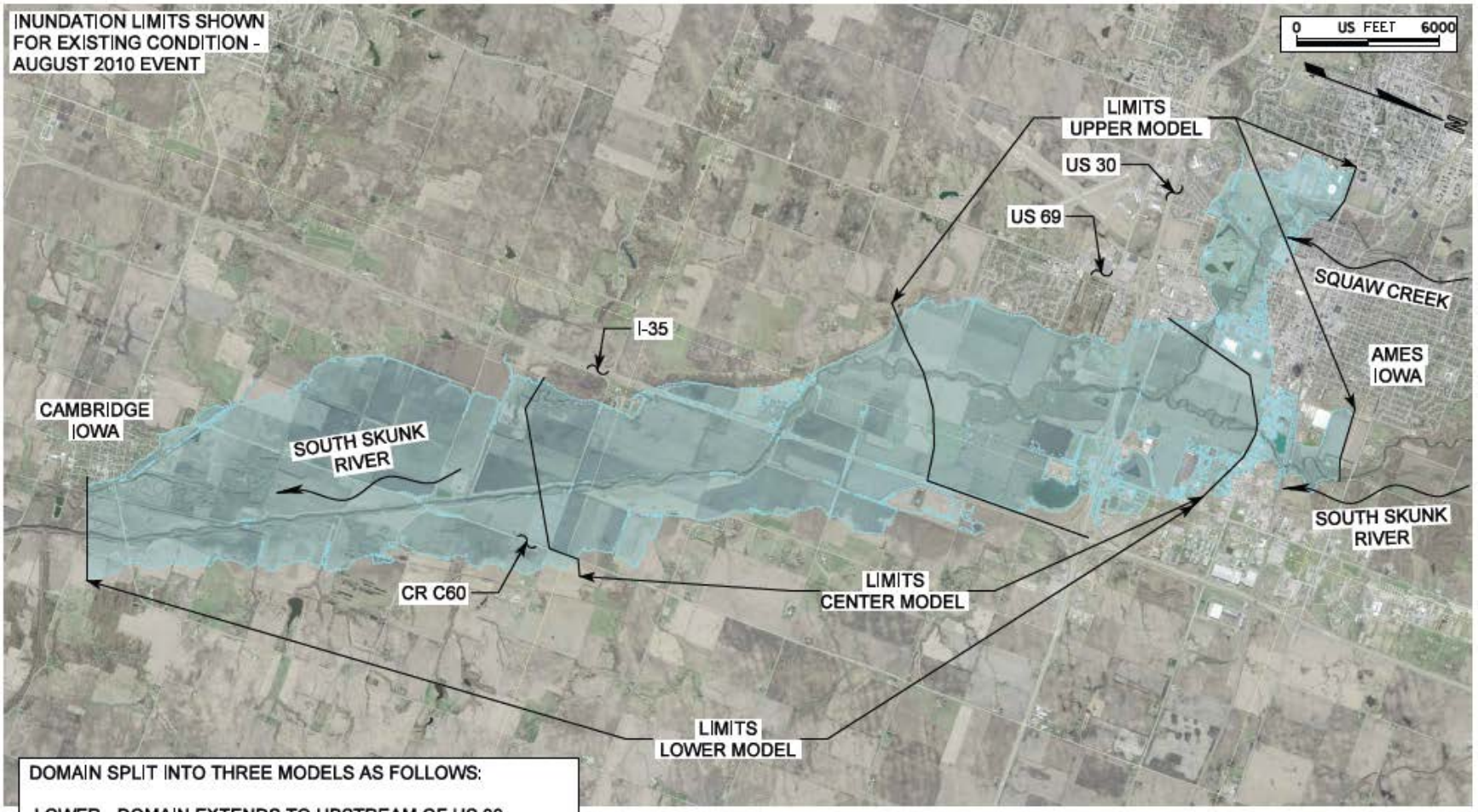

EXISTING CONDITION - 100 YR
WATER SURFACE CONTOURS
0.2 FT INTERVAL
0 US FEET 1000
N
564 FT BRIDGE
BUILT 2000
48% OF FLOW
IA 330
IA 330 ETW IMPACTED
BY 2 YR EVENT
2.0 FT DROP
ACROSS DIKE
NORTH FP
50% OF FLOW
ALBION POTABLE
WATER FACILITY
IA 330
1.0 FT DROP
ACROSS DIKE
WEST FP
36% OF FLOW
IOWA RIVER
BRIDGE
MAIN CHAN.
BRIDGE
50% OF FLOW
BRIDGE
IA RR
COMPLEX FLOODPLAIN DOWNSTREAM OF HIGHWAY CROSSING. HIGH DAMAGE POTENTIAL WITH NUMEROUS BUILDINGS IN UPSTREAM FLOODPLAIN. EXISTING/PRE-DEVELOPMENT CONVEYANCE PATTERN TO BE SIGNIFICANTLY ALTERED BY IMPROVEMENTS TO REDUCE OVERTOPPING FREQUENCY
IA 330 CROSSING
EXISTING CONDITION


MITIGATE ALT 30 - 100 YR
WATER SURFACE CONTOURS
0.2 FT INTERVAL
0 US FEET 1000
N
564 FT BRIDGE
BUILT 2000
57% OF FLOW
150 FT BRIDGE
12% OF FLOW
IA 330
IA 330 RELOC. HIGHWAY
IN SERVICE UP TO
100 YR. EVENT
2.0 FT DROP
ACROSS DIKE
320 FT BRIDGE
23% OF FLOW
TR 12X12 RCB
8% OF FLOW
IA 330
1.0 FT DROP
ACROSS DIKE
IOWA RIVER
ALBION WATER FACILITY
0.68 FT INCREASE FROM
EXISTING. TO BE PROTECTED
BY LEVEE. INTERNAL
DRAINAGE PIPED TO S SIDE
OF IA 330, 1.4 FT LOWER HGL
BRIDGE
MAIN CHAN.
BRIDGE
MODEL RESULTS INDICATE THAT MAIN CHANNEL
BRIDGE LENGTH BEYOND 350 FT RESULTS IN
MINIMAL BACKWATER REDUCTION.
FUNDS FOR EXTRA 200 FT OF BRIDGE COULD
HAVE BEEN DIVERTED TO OVERFLOW BRIDGE
CONSTRUCTION.
BRIDGE
IA RR
IA 330 CROSSING
PROPOSED IMPROVEMENTS


0 US FEET 600
ELECTRIC SUBSTATION
IOWA RIVER
120 FT OVERFLOW BRIDGE
STANLEY MILL ROAD
380 FT MAIN CHANNEL BRIDGE
EXISTING CONDITION - 100 YR WATER SURFACE CONTOURS 0.2 FT INTERVAL
2.0 FT WATER SURFACE DIFFERENTIAL ACROSS D/S 'SECTION'
EXAMPLE OF A TYPICAL ROAD CROSSING. EXPECTATION WOULD BE THAT A 1D MODEL COULD PROVIDE A REASONABLE WATER SURFACE ESTIMATE AT SUBSTATION
LOCAL ROAD CROSSING
EXISTING CONDITION

I-35 over South Skunk River





DOMAIN SPLIT INTO THREE MODELS AS FOLLOWS:

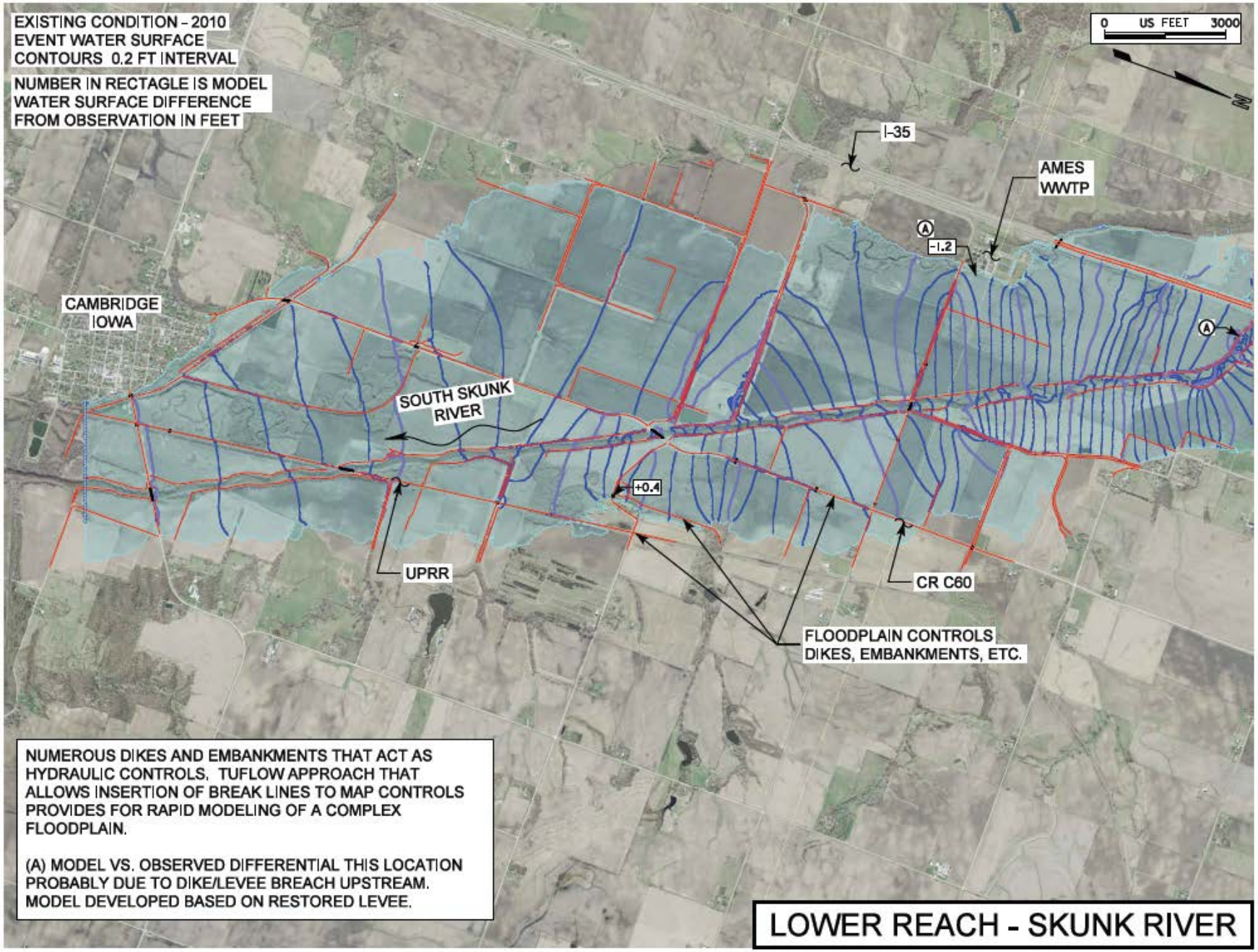
LOWER - DOMAIN EXTENDS TO UPSTREAM OF US 30. DEVELOPED TO PROVIDE REALISTIC HEAD BOUNDARIES FOR 'PRODUCTION' MODELS.

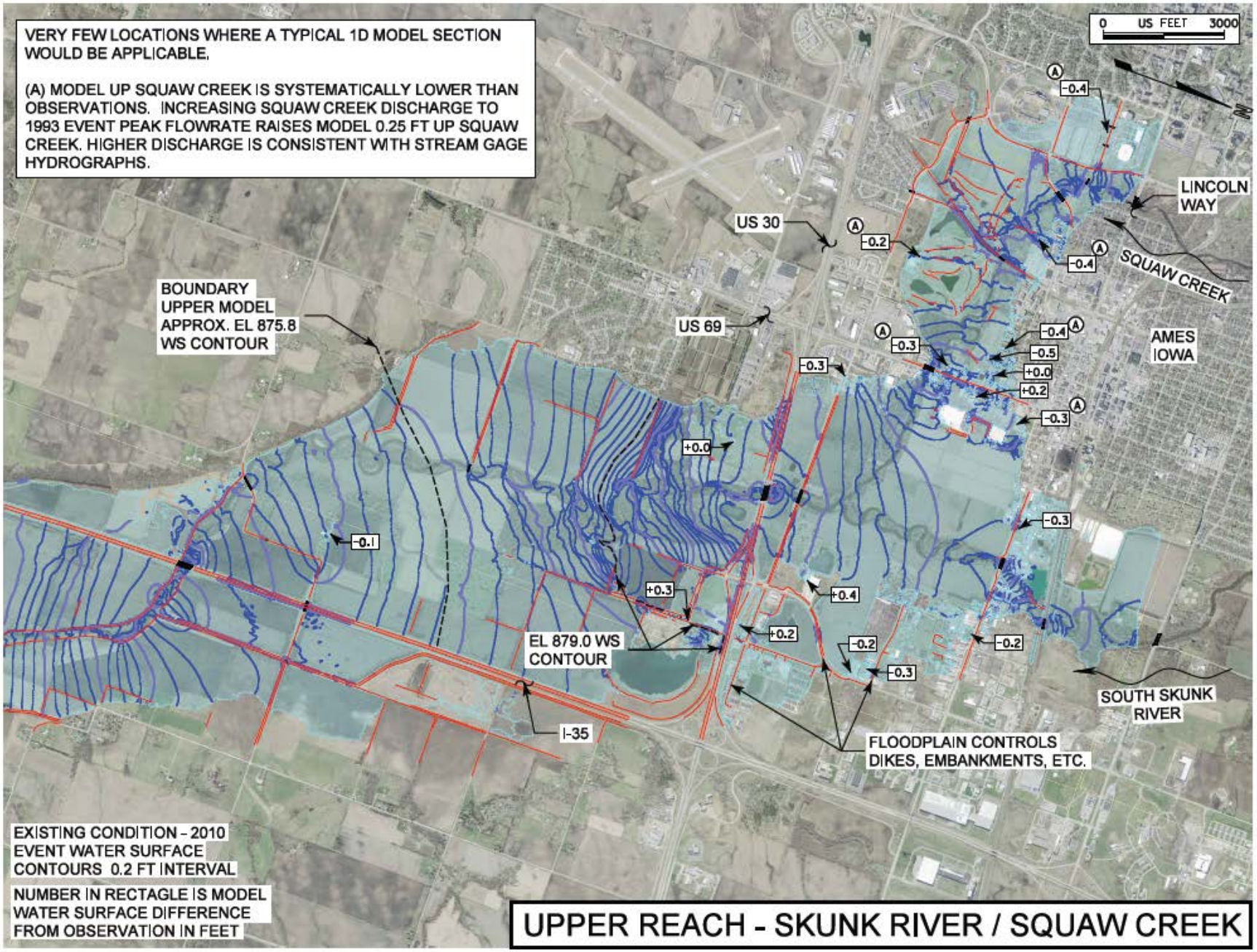
CENTER - TRUNCATED LOWER MODEL TO PROVIDE A MORE RESPONSIVE (SMALLER) MODEL FOR DESIGN ANALYSIS AT I-35 CROSSING.

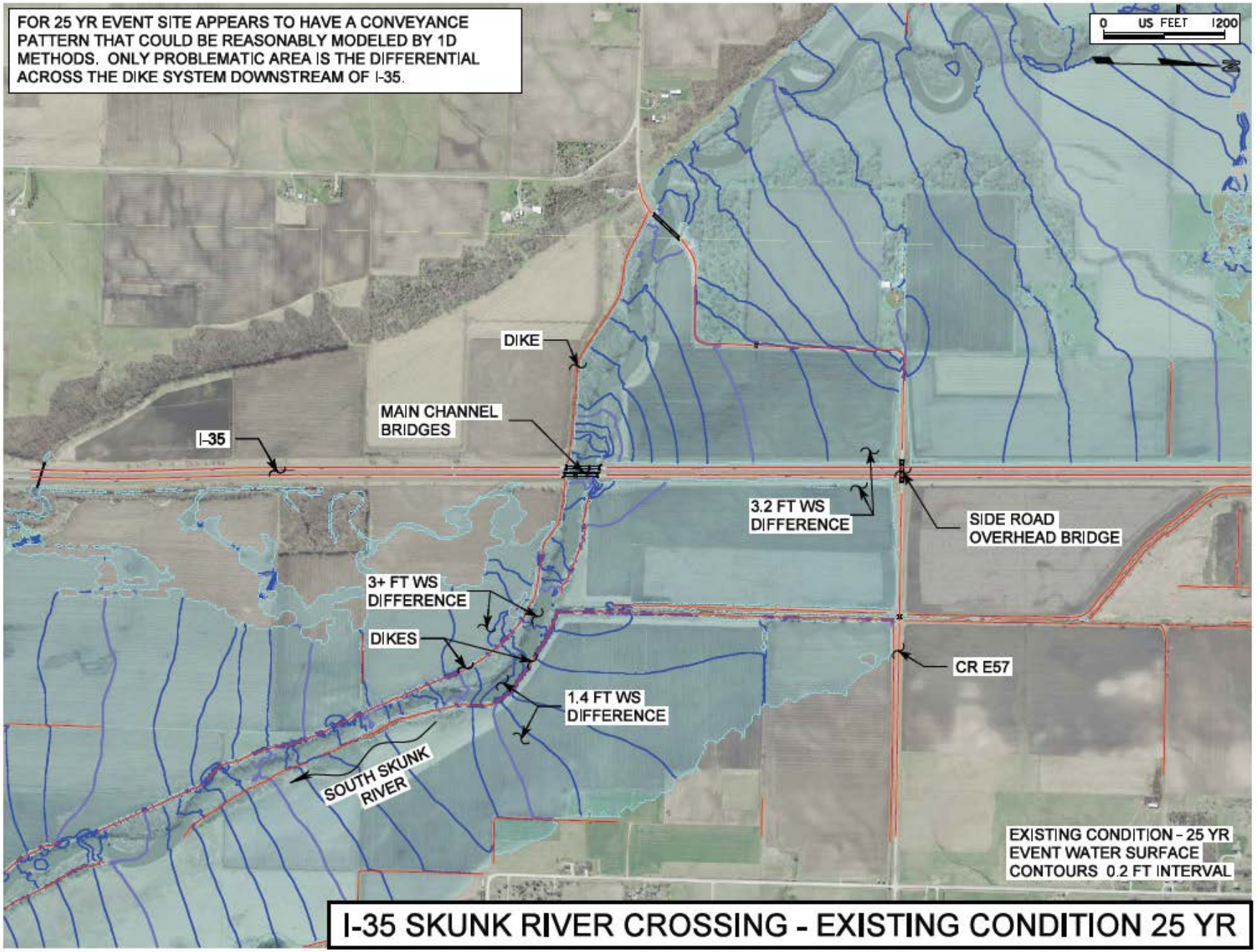
UPPER – MODEL WITH 30% SMALLER CELL SIZE TO BETTER CAPTURE URBAN EFFECTS IN AMES AREA.

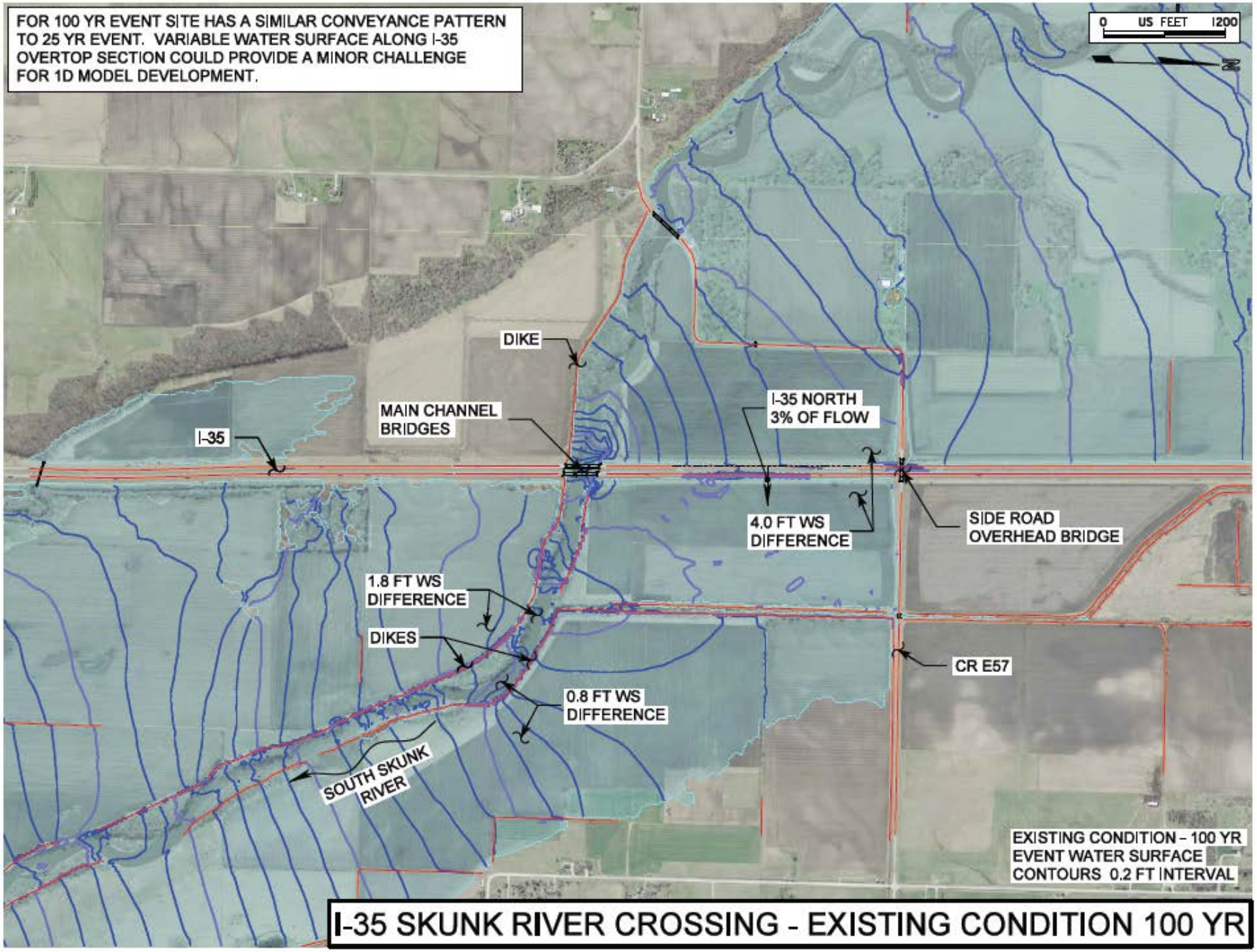
TUFLOW MODEL DOMAIN

SKUNK RIVER / SQUAW CREEK NEAR AMES, IOWA - STORY COUNTY

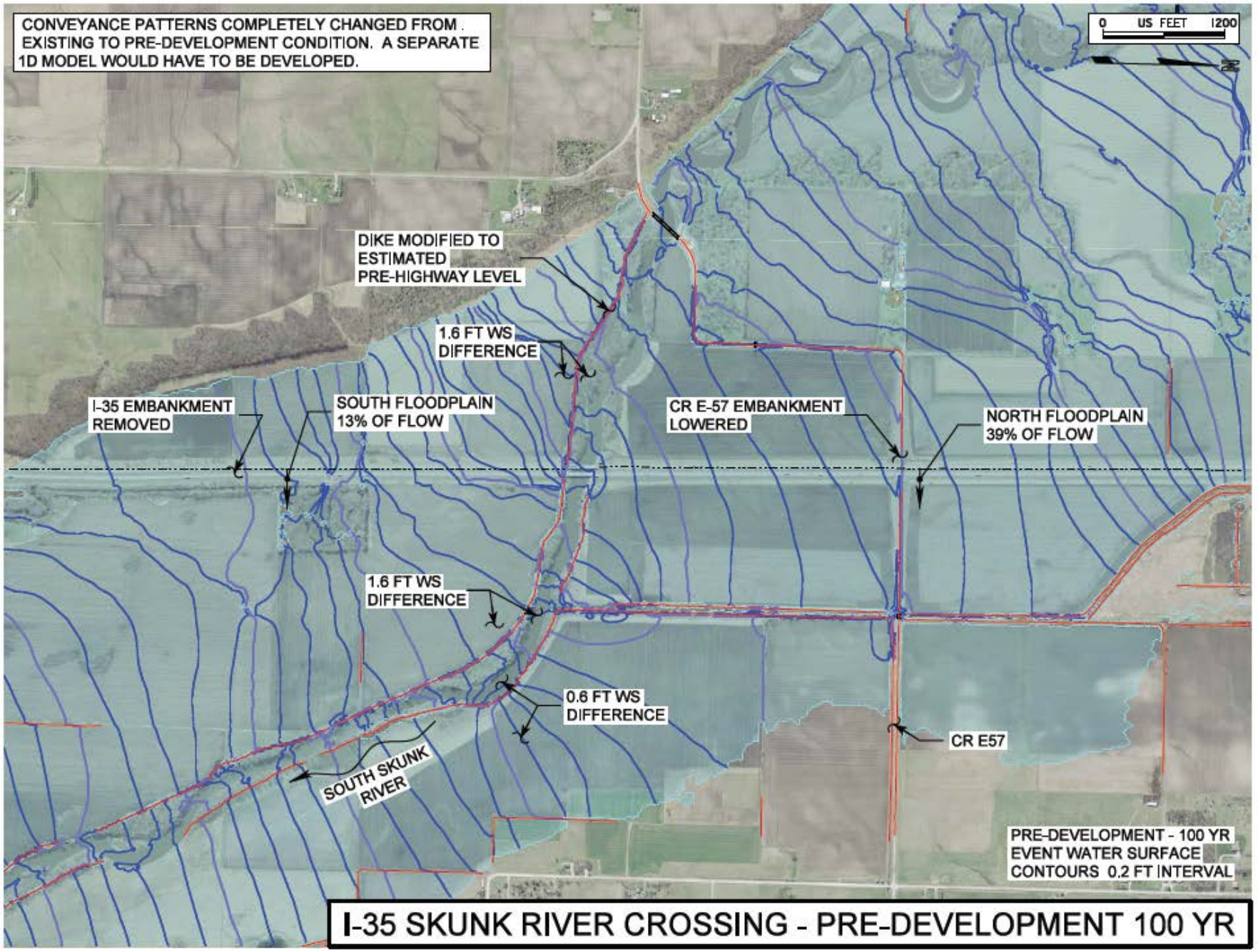

EXISTING CONDITION – 2010
EVENT WATER SURFACE
CONTOURS 0.2 FT INTERVAL
NUMBER IN RECTAGLE IS MODEL
WATER SURFACE DIFFERENCE
FROM OBSERVATION IN FEET
0 US FEET 3000
N
I-35
AMES
WWTP
A
-1.2
CAMBRIDGE
IOWA
SOUTH SKUNK
RIVER
+0.4
UPRR
CR C60
FLOODPLAIN CONTROLS
DIKES, EMBANKMENTS, ETC.
NUMEROUS DIKES AND EMBANKMENTS THAT ACT AS HYDRAULIC CONTROLS. TUFLOW APPROACH THAT ALLOWS INSERTION OF BREAK LINES TO MAP CONTROLS PROVIDES FOR RAPID MODELING OF A COMPLEX FLOODPLAIN.
(A) MODEL VS. OBSERVED DIFFERENTIAL THIS LOCATION PROBABLY DUE TO DIKE/LEVEE BREACH UPSTREAM. MODEL DEVELOPED BASED ON RESTORED LEVEE.
LOWER REACH - SKUNK RIVER


VERY FEW LOCATIONS WHERE A TYPICAL 1D MODEL SECTION WOULD BE APPLICABLE.
(A) MODEL UP SQUAW CREEK IS SYSTEMATICALLY LOWER THAN OBSERVATIONS. INCREASING SQUAW CREEK DISCHARGE TO 1993 EVENT PEAK FLOWRATE RAISES MODEL 0.25 FT UP SQUAW CREEK. HIGHER DISCHARGE IS CONSISTENT WITH STREAM GAGE HYDROGRAPHS.
0 US FEET 3000
LINCOLN WAY
US 30
SQUAW CREEK
BOUNDARY UPPER MODEL APPROX. EL 875.8 WS CONTOUR
US 69
AMES IOWA
EL 879.0 WS CONTOUR
I-35
SOUTH SKUNK RIVER
FLOODPLAIN CONTROLS DIKES, EMBANKMENTS, ETC.
EXISTING CONDITION - 2010 EVENT WATER SURFACE CONTOURS 0.2 FT INTERVAL
NUMBER IN RECTAGLE IS MODEL WATER SURFACE DIFFERENCE FROM OBSERVATION IN FEET
UPPER REACH - SKUNK RIVER / SQUAW CREEK

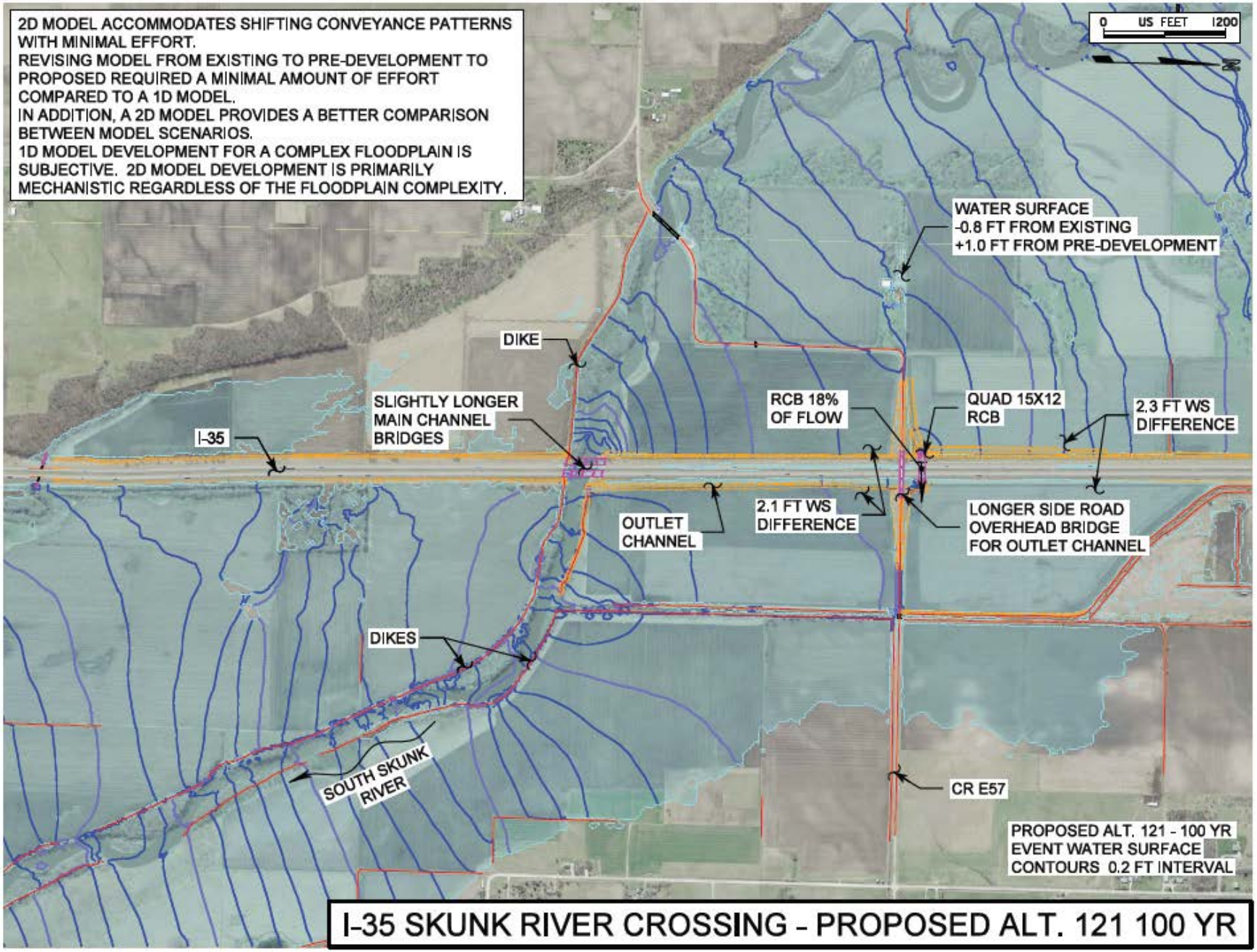

FOR 25 YR EVENT SITE APPEARS TO HAVE A CONVEYANCE PATTERN THAT COULD BE REASONABLY MODELED BY 1D METHODS. ONLY PROBLEMATIC AREA IS THE DIFFERENTIAL ACROSS THE DIKE SYSTEM DOWNSTREAM OF I-35.
0 US FEET 1200
DIKE
MAIN CHANNEL BRIDGES
I-35
3.2 FT WS DIFFERENCE
SIDE ROAD OVERHEAD BRIDGE
3+ FT WS DIFFERENCE
DIKES
CR E57
1.4 FT WS DIFFERENCE
SOUTH SKUNK RIVER
EXISTING CONDITION - 25 YR EVENT WATER SURFACE CONTOURS 0.2 FT INTERVAL
I-35 SKUNK RIVER CROSSING - EXISTING CONDITION 25 YR



I-35 SKUNK RIVER CROSSING - EXISTING CONDITION 100 YR



I-35 SKUNK RIVER CROSSING - PRE-DEVELOPMENT 100 YR

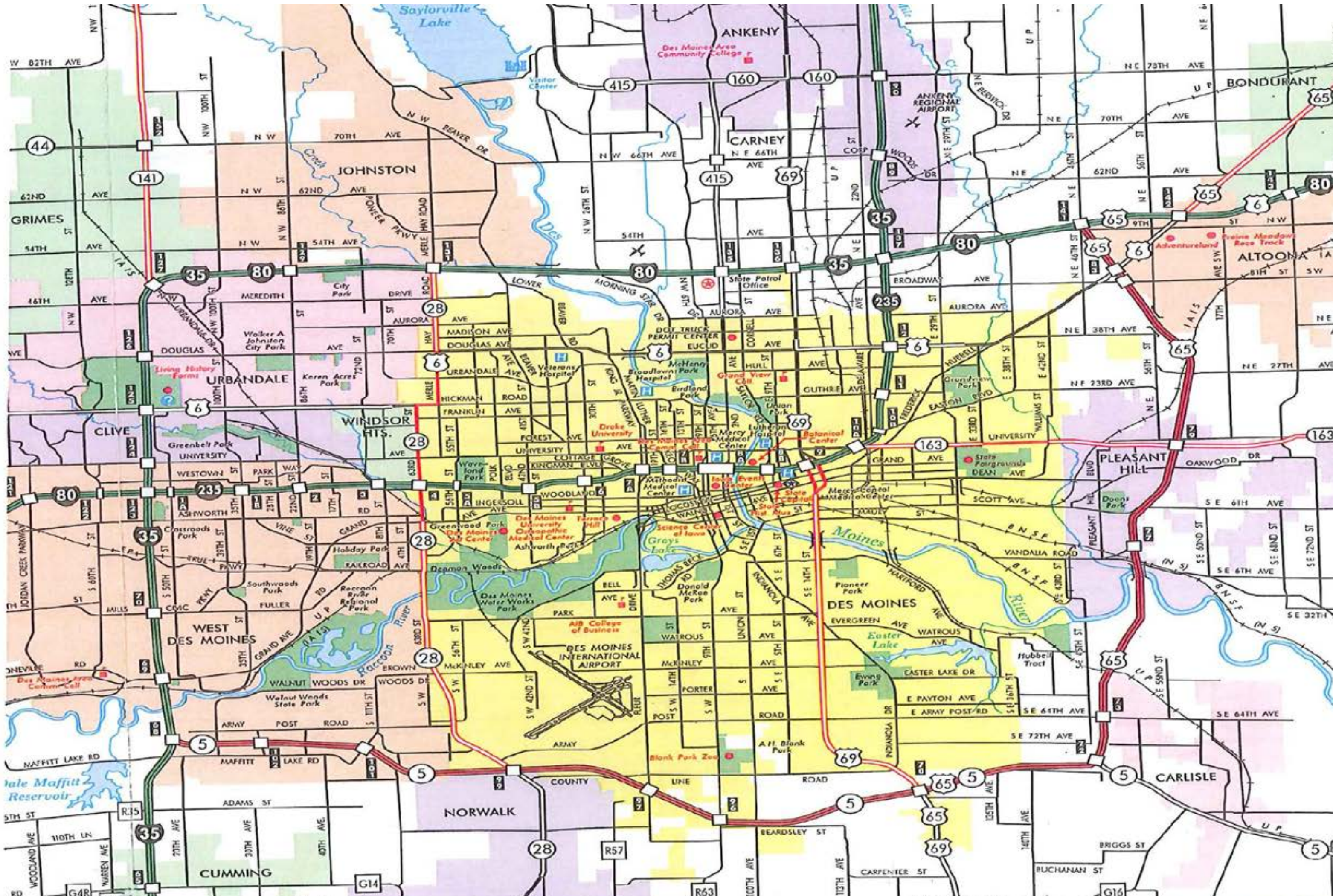


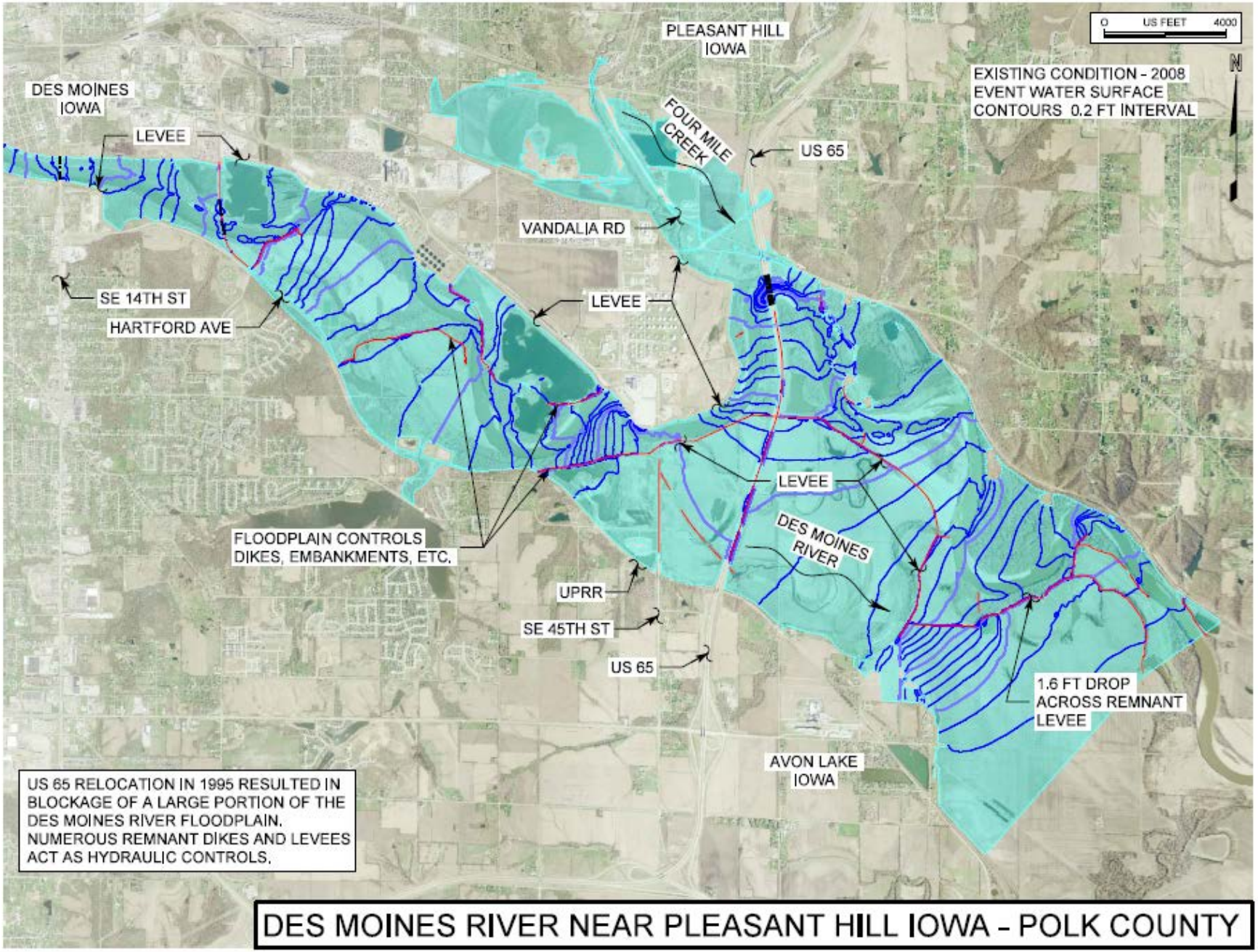
I-35 SKUNK RIVER CROSSING - PROPOSED ALT. 121 100 YR

I-35 Skunk River Crossing - 2010 Event

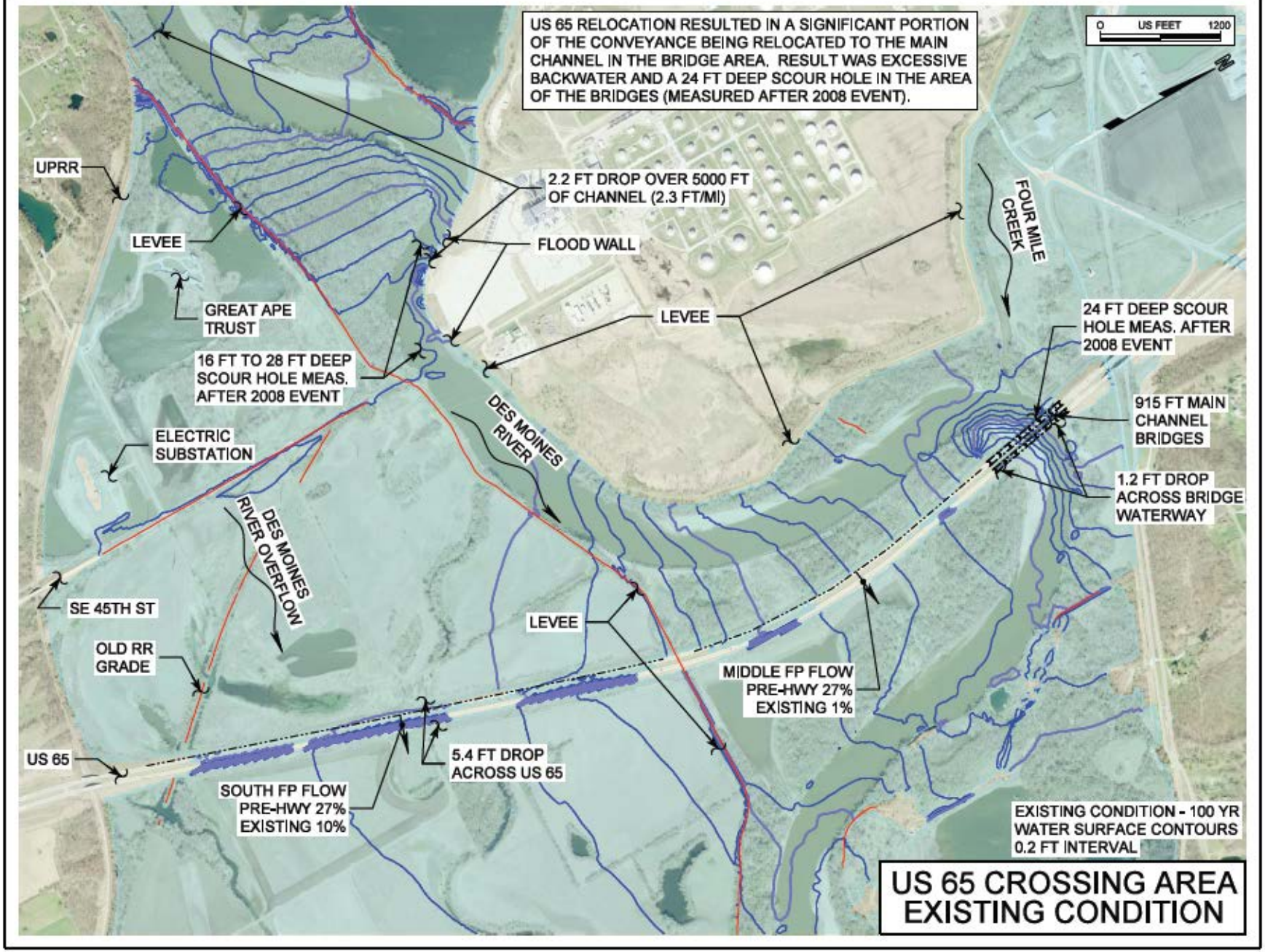
Squaw Creek University Blvd. - 2010 Event

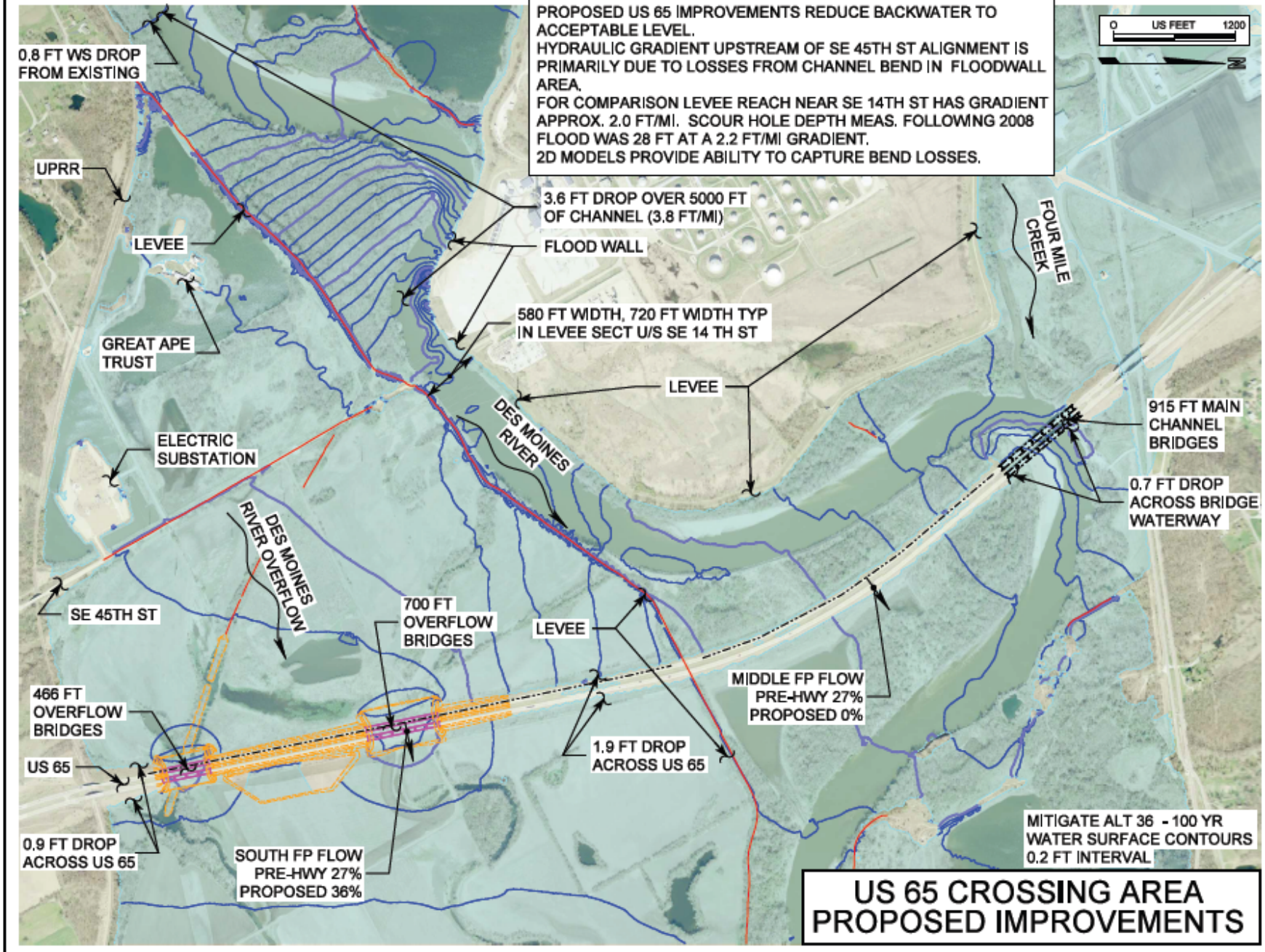
U.S. 65 over Des Moines River




0 US FEET 4000
N
PLEASANT HILL
IOWA
DES MOINES
IOWA
EXISTING CONDITION - 2008
EVENT WATER SURFACE
CONTOURS 0.2 FT INTERVAL
LEVEE
FOUR MILE
CREEK
US 65
VANDALIA RD
SE 14TH ST
HARTFORD AVE
LEVEE
LEVEE
DES MOINES
RIVER
FLOODPLAIN CONTROLS
DIKES, EMBANKMENTS, ETC.
UPRR
SE 45TH ST
US 65
1.6 FT DROP
ACROSS REMNANT
LEVEE
AVON LAKE
IOWA
US 65 RELOCATION IN 1995 RESULTED IN
BLOCKAGE OF A LARGE PORTION OF THE
DES MOINES RIVER FLOODPLAIN.
NUMEROUS REMNANT DIKES AND LEVEES
ACT AS HYDRAULIC CONTROLS.
DES MOINES RIVER NEAR PLEASANT HILL IOWA - POLK COUNTY

US 65 Des Moines River Crossing - 2008 Event

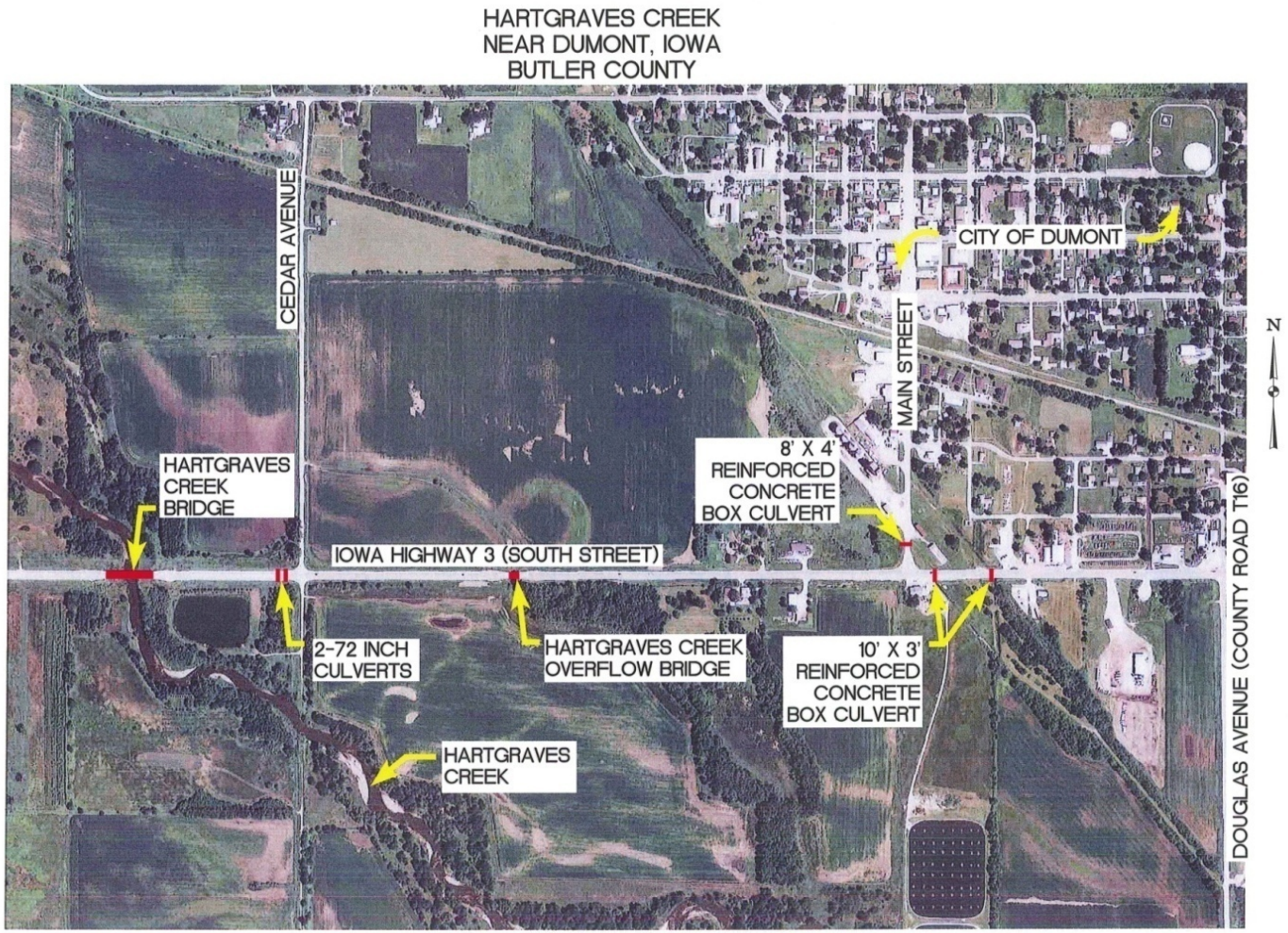

US 65 RELOCATION RESULTED IN A SIGNIFICANT PORTION OF THE CONVEYANCE BEING RELOCATED TO THE MAIN CHANNEL IN THE BRIDGE AREA. RESULT WAS EXCESSIVE BACKWATER AND A 24 FT DEEP SCOUR HOLE IN THE AREA OF THE BRIDGES (MEASURED AFTER 2008 EVENT).
0 US FEET 1200
UPRR
LEVEE
GREAT APE TRUST
16 FT TO 28 FT DEEP SCOUR HOLE MEAS. AFTER 2008 EVENT
2.2 FT DROP OVER 5000 FT OF CHANNEL (2.3 FT/MI)
FLOOD WALL
LEVEE
FOUR MILE CREEK
24 FT DEEP SCOUR HOLE MEAS. AFTER 2008 EVENT
915 FT MAIN CHANNEL BRIDGES
1.2 FT DROP ACROSS BRIDGE WATERWAY
DES MOINES RIVER
ELECTRIC SUBSTATION
DES MOINES RIVER OVERFLOW
SE 45TH ST
OLD RR GRADE
LEVEE
MIDDLE FP FLOW PRE-HWY 27% EXISTING 1%
US 65
5.4 FT DROP ACROSS US 65
SOUTH FP FLOW PRE-HWY 27% EXISTING 10%
EXISTING CONDITION - 100 YR WATER SURFACE CONTOURS 0.2 FT INTERVAL
US 65 CROSSING AREA EXISTING CONDITION


PROPOSED US 65 IMPROVEMENTS REDUCE BACKWATER TO ACCEPTABLE LEVEL.
HYDRAULIC GRADIENT UPSTREAM OF SE 45TH ST ALIGNMENT IS PRIMARILY DUE TO LOSSES FROM CHANNEL BEND IN FLOODWALL AREA.
FOR COMPARISON LEVEE REACH NEAR SE 14TH ST HAS GRADIENT APPROX. 2.0 FT/MI. SCOUR HOLE DEPTH MEAS. FOLLOWING 2008 FLOOD WAS 28 FT AT A 2.2 FT/MI GRADIENT.
2D MODELS PROVIDE ABILITY TO CAPTURE BEND LOSSES.
0 US FEET 1200
N
0.8 FT WS DROP FROM EXISTING
UPRR
LEVEE
3.6 FT DROP OVER 5000 FT OF CHANNEL (3.8 FT/MI)
FLOOD WALL
580 FT WIDTH, 720 FT WIDTH TYP IN LEVEE SECT U/S SE 14 TH ST
FOUR MILE CREEK
GREAT APE TRUST
LEVEE
DES MOINES RIVER
915 FT MAIN CHANNEL BRIDGES
ELECTRIC SUBSTATION
0.7 FT DROP ACROSS BRIDGE WATERWAY
DES MOINES RIVER OVERFLOW
SE 45TH ST
700 FT OVERFLOW BRIDGES
LEVEE
MIDDLE FP FLOW PRE-HWY 27% PROPOSED 0%
466 FT OVERFLOW BRIDGES
US 65
1.9 FT DROP ACROSS US 65
0.9 FT DROP ACROSS US 65
SOUTH FP FLOW PRE-HWY 27% PROPOSED 36%
MITIGATE ALT 36 - 100 YR WATER SURFACE CONTOURS 0.2 FT INTERVAL
US 65 CROSSING AREA PROPOSED IMPROVEMENTS

Looking West at 466’ Overflow Bridge

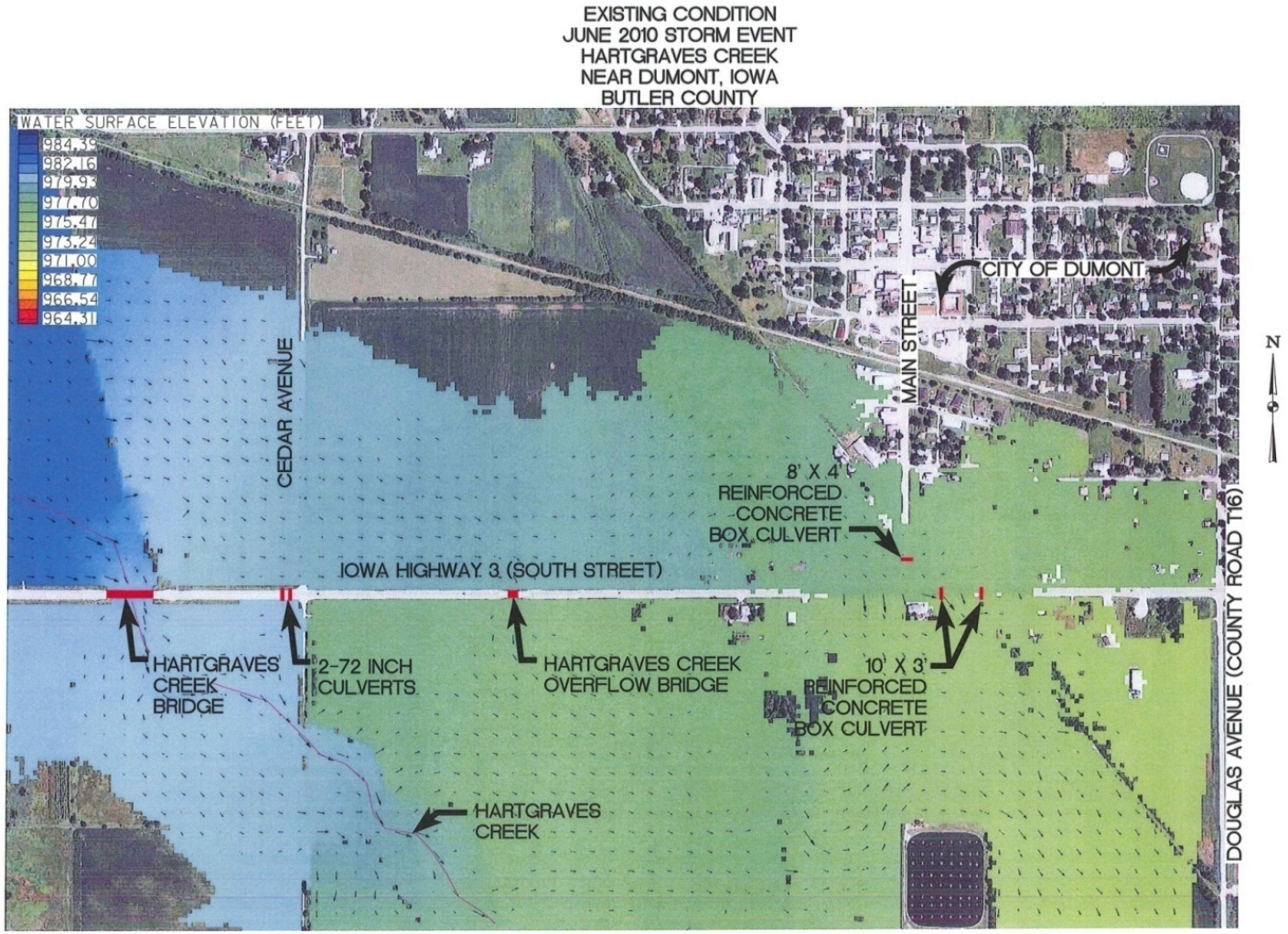
466’ Overflow Bridge

City of Dumont – Flood Mitigation



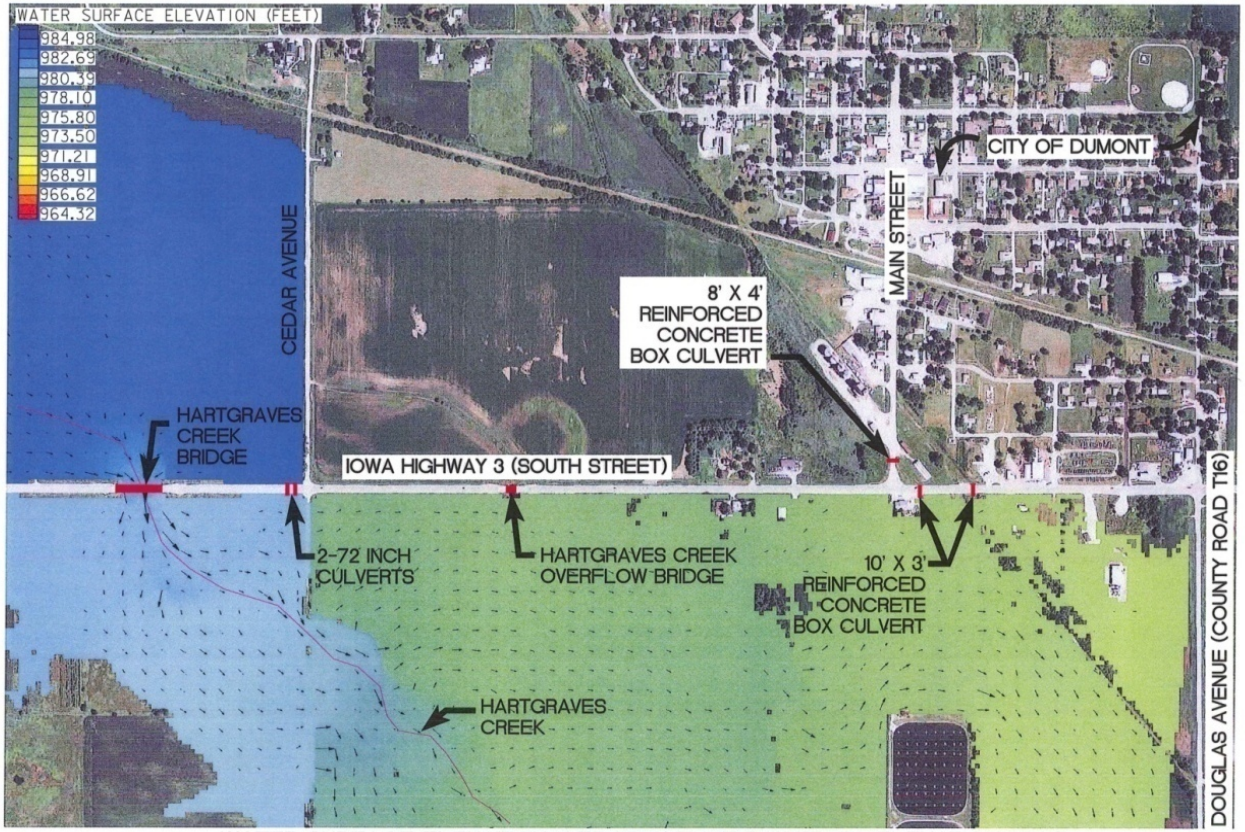
VICINITY MAP
FIGURE 1

City of Dumont – Flood Inundation



WATER SURFACE ELEVATION-EXISTING CONDITION
FIGURE 2

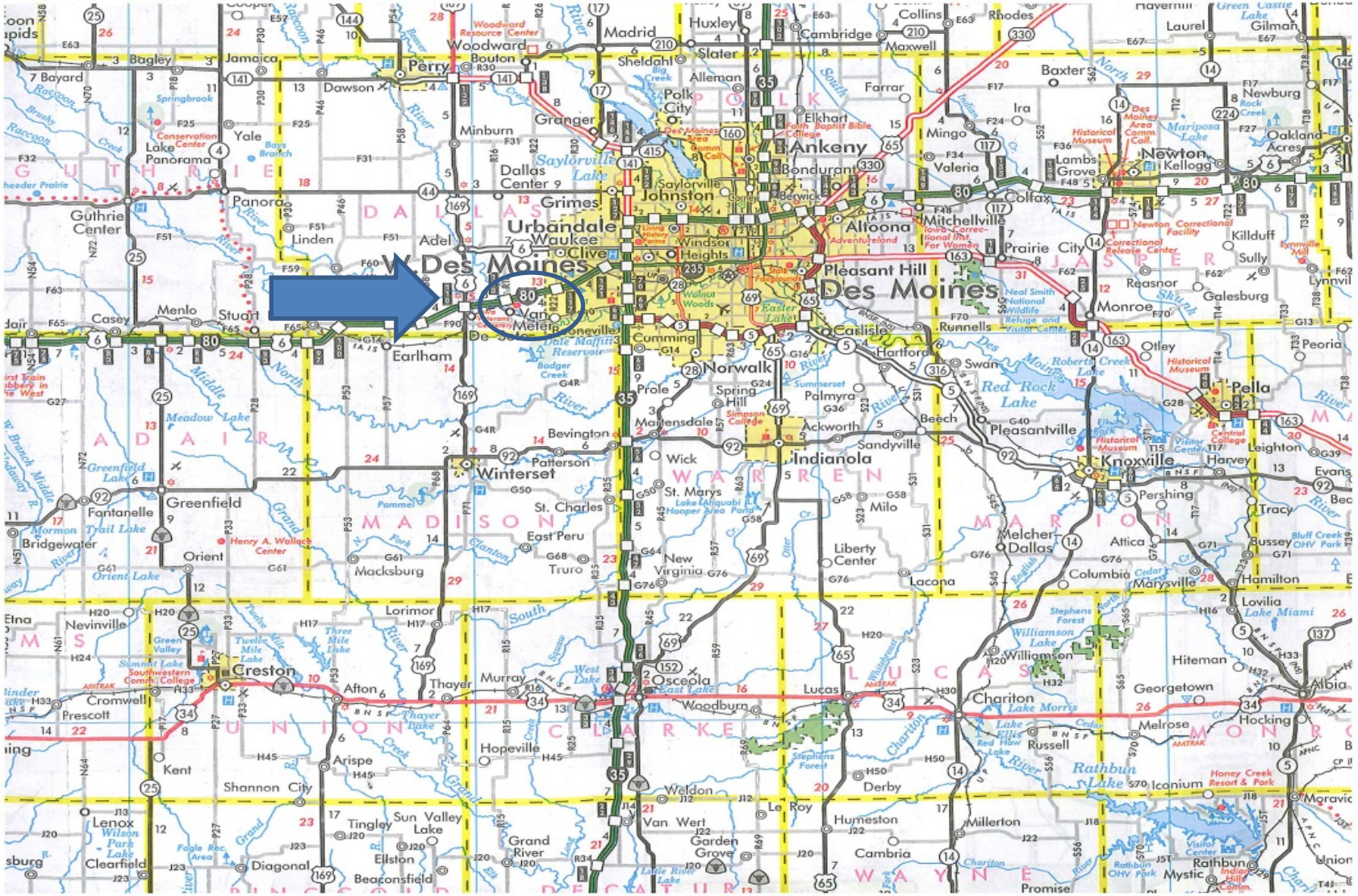
Raise Cedar Ave. w/Closures



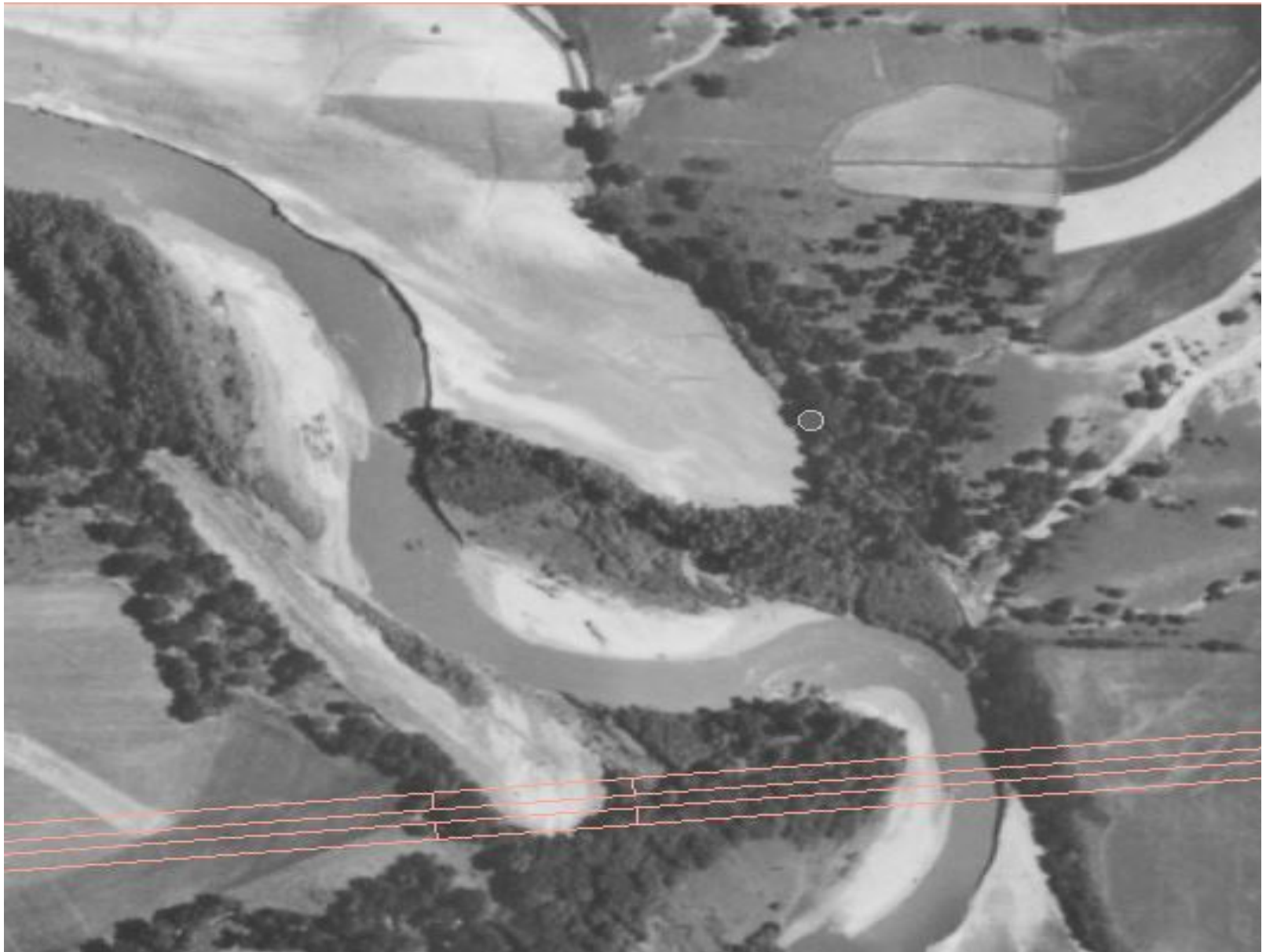
WATER SURFACE ELEVATION-CEDAR AVENUE RAISED TO ELEVATION 984.0
WITH OVERFLOW BRIDGE AND BOTH 10' X 3' CULVERTS TEMPORARILY PLUGGED

FIGURE 6

I-80 over North Raccoon River



1950’s



Early 1960’s

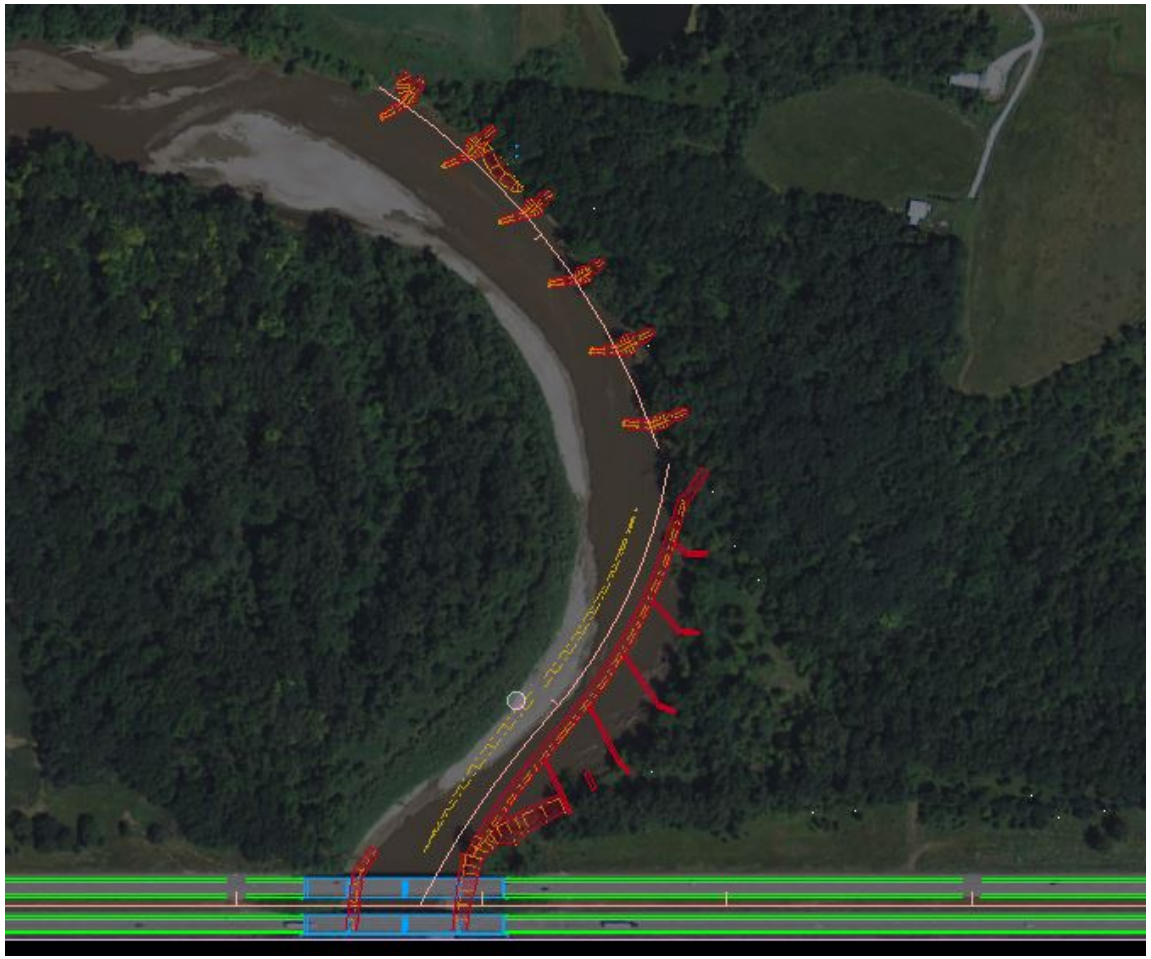
1970’s

Current Aerial

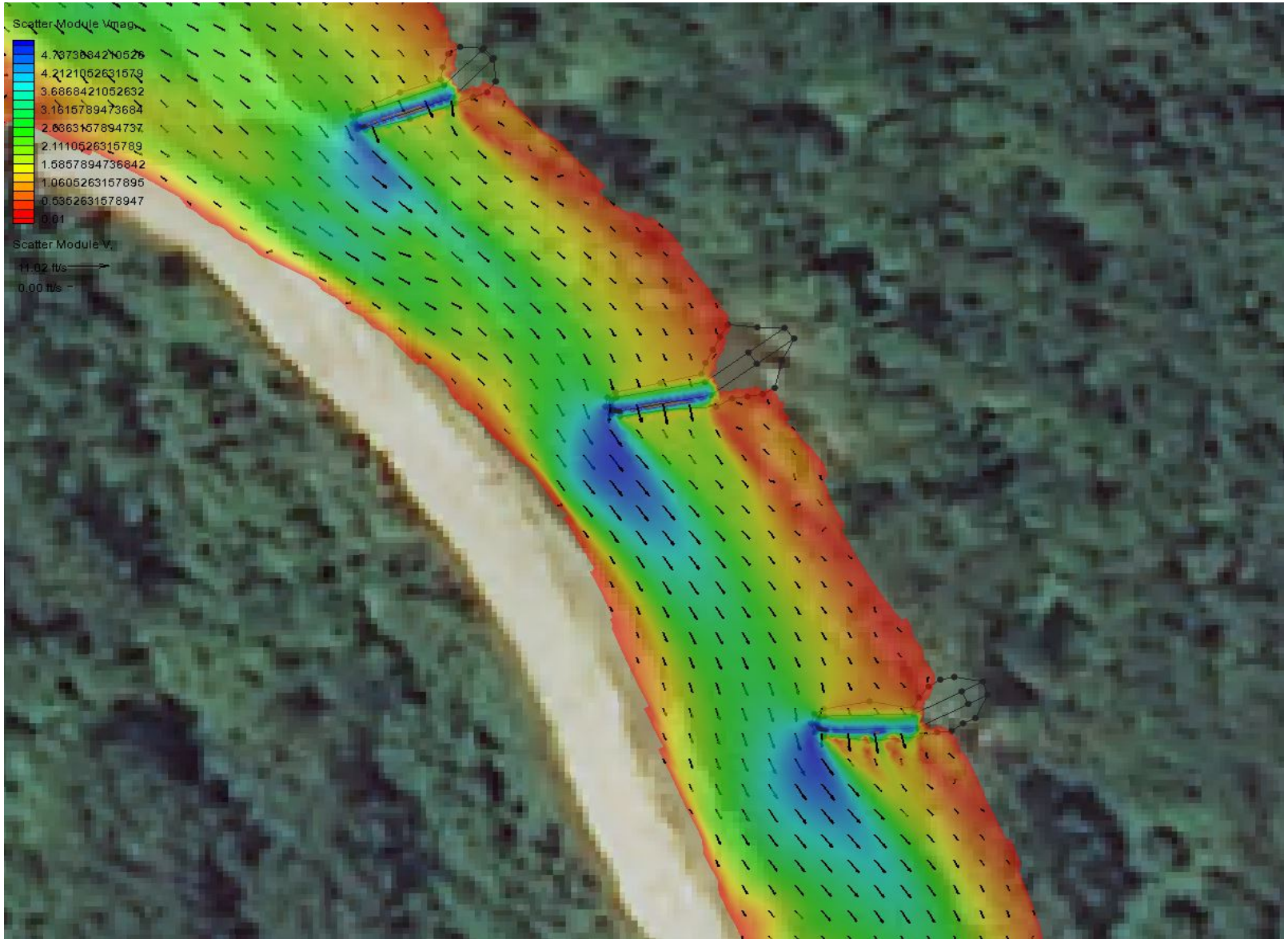
Looking D.S. at I-80 Bridge

Looking U.S. from East Bank

Bendway Weir & Stone Toe Design



Verification of Bendway Weir Design



When Should 2-D Hydraulic Modeling Be Used?

- Overflow Bridges
- Flood Plains with Flank/Lateral Levees
- Roadways Significantly Skewed to the Flood Plain/River
- Locations that are Hydraulically Complex

Questions?

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