Project Background

- Client
  - Phil Ronnerud, P.E.,
    Greenlee County Engineer

- Technical Advisor
  - Tom Loomis, P.E., RLS,
    CFM, Flood Control District
    of Maricopa County

- Request
  - Analyze possible mitigation
    measures for Duncan
    flooding

- Purpose
  - Provide analysis for
    structure-based, vegetation
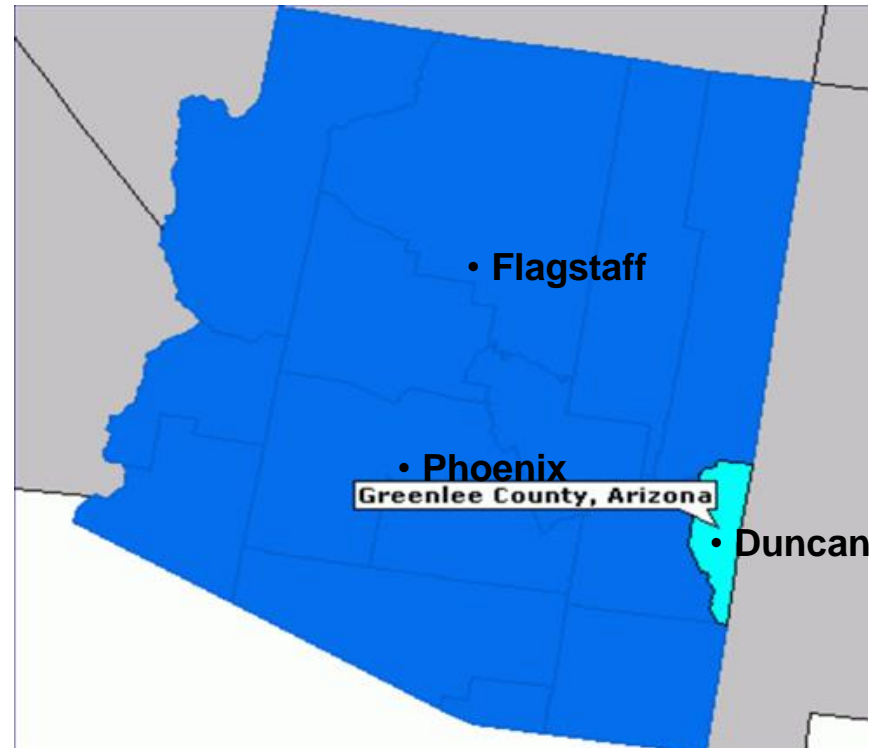   management, &
    encroachment removal
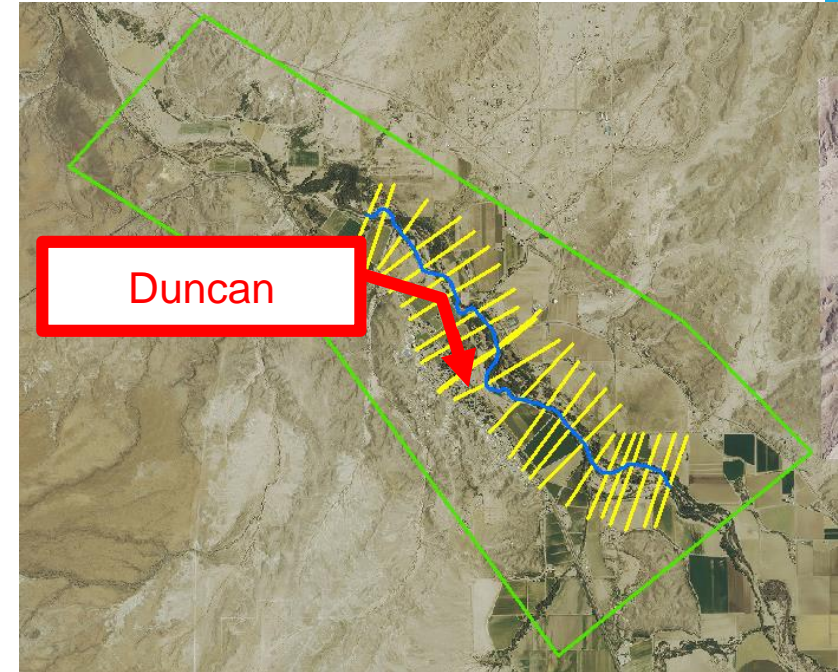

Figure 1: Project Site Location [1]

Figure 2: Project Boundary

[1] ePodunk Inc, "Profile for Greenlee County, Arizona," 2007. [Online]. Available: http://www.epodunk.com/cgi-bin/genInfo.php?locIndex=11205

Schedule (Projected)

Task Name	Start	Finish
1.0 Data Collection	Thu 9/1/16	Fri 9/2/16
1.1 County Data	Thu 9/1/16	Thu 9/1/16
1.2 NAU Crown Engineering Data	Thu 9/1/16	Thu 9/1/16
1.3 FEMA Data	Fri 9/2/16	Fri 9/2/16
2.0 Hydraulics: 2D Modeling	Mon 9/5/16	Fri 11/18/16
2.1 Model Parameters	Mon 9/5/16	Tue 9/20/16
2.1.1 Grid System	Mon 9/5/16	Tue 9/13/16
2.1.2 Manning's Number	Wed 9/14/16	Thu 9/15/16
2.1.3 Courant & DEPTOL Values	Fri 9/16/16	Mon 9/19/16
2.2 Two Dimensional Modeling	Wed 9/21/16	Wed 11/16/16
2.2.1 FLO-2D Pro & RAS-2D	Wed 9/21/16	Wed 11/16/16
2.2.1.1 Existing Conditions	Wed 9/21/16	Wed 11/16/16

Task Name	Start	Finish
2.2.1.3 Proposed Levee	Mon 10/10/16	Wed 11/16/16
2.2.1.4 Gila River Restoration	Mon 10/10/16	Wed 11/16/16
3.0 Model Analysis	Thu 11/17/16	Fri 11/18/16
4.0 FLO 2D Pro & HEC-RAS 2D Model Comparison	Mon 11/21/16	Wed 11/30/16
4.1 Cost Analysis	Mon 11/21/16	Tue 11/22/16
4.2 Recommended Solutions	Wed 11/23/16	Mon 11/28/16
4.3 Impacts	Tue 11/29/16	Fri 12/2/16
5.0 Project Management	Thu 9/1/16	Fri 12/16/16
5.1 Coordination	Thu 9/1/16	Fri 12/16/16
5.2 50% Design Report	Mon 9/26/16	Thu 10/13/16
5.3 Final Presentation	Wed 11/30/16	Wed 12/7/16
5.4 Impacts Report	Fri 12/9/16	Fri 12/9/16
5.5 Final Report	Fri 12/16/16	Fri 12/16/16
5.6 Website	Fri 12/16/16	Fri 12/16/16

Schedule (Actual)

Task Name	Start	Finish
1.0 Data Collection	Thu 9/1/16	Fri 9/2/16
1.1 County Data	Thu 9/1/16	Thu 9/1/16
1.2 NAU Crown Engineering Data	Thu 9/1/16	Thu 9/1/16
1.3 FEMA Data	Fri 9/2/16	Fri 9/2/16
2.0 Hydraulics: 2D Modeling	Mon 9/5/16	Fri 11/18/16
2.1 Model Parameters	Mon 9/5/16	Tue 9/20/16
2.1.1 Grid System	Mon 9/5/16	Tue 9/13/16
2.1.2 Manning's Number	Wed 9/14/16	Thu 9/15/16
2.1.3 Courant & DEPTOL Values	Fri 9/16/16	Mon 9/19/16
2.2 Two Dimensional Modeling	Wed 9/21/16	Wed 11/16/16
2.2.1 FLO-2D Pro	Wed 9/21/16	Wed 11/16/16
2.2.1.1 Existing Conditions	Wed 9/21/16	Wed 11/16/16

Task Name	Start	Finish
2.2.1.3 Proposed Levee	Mon 10/10/16	Wed 11/16/16
2.2.1.4 Gila River Restoration	Mon 10/10/16	Wed 11/16/16
3.0 Model Analysis	Thu 11/17/16	Fri 11/18/16
4.0 FLO 2D Pro Model Comparison	Mon 11/21/16	Wed 11/30/16
4.1 Cost Analysis	Mon 11/21/16	Tue 11/22/16
4.2 Recommended Solutions	Wed 11/23/16	Mon 11/28/16
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5.5 Final Report	Fri 12/16/16	Fri 12/16/16
5.6 Website	Fri 12/16/16	Fri 12/16/16

Models Simulated

- 1978 Flood
  - Q=57,800 cfs
  - Used to model the exiting conditions (calibration)

- Gila River Restoration
  - Q=47,400 cfs (100-yr)
  - WWTF removed

- Levee
  - Q=47,400 cfs (100-yr)
  - Determine minimum height

- Levee with Gila River Restoration
  - Q=47,400 cfs (100-yr)
  - WWTF removed

Figure 3: Bridge Crossing the Gila River in Duncan, AZ [5]

[5] R. Shantz, "Photograph of Flood on Gila River 2/13/05 near Duncan, Arizona", Rshantz.com, 2005. [Online]. Available: http://www.rshantz.com/Scenes/Arizona/Southeast/20050213GilaFlood/20050213Flood13.htm. [Accessed: 15- Apr- 2016].

Hydrographs

- 1978 Flow: 57,800 cfs

- 100-year Flow: 47,400 cfs

- 25-year Flow: 28,000 cfs
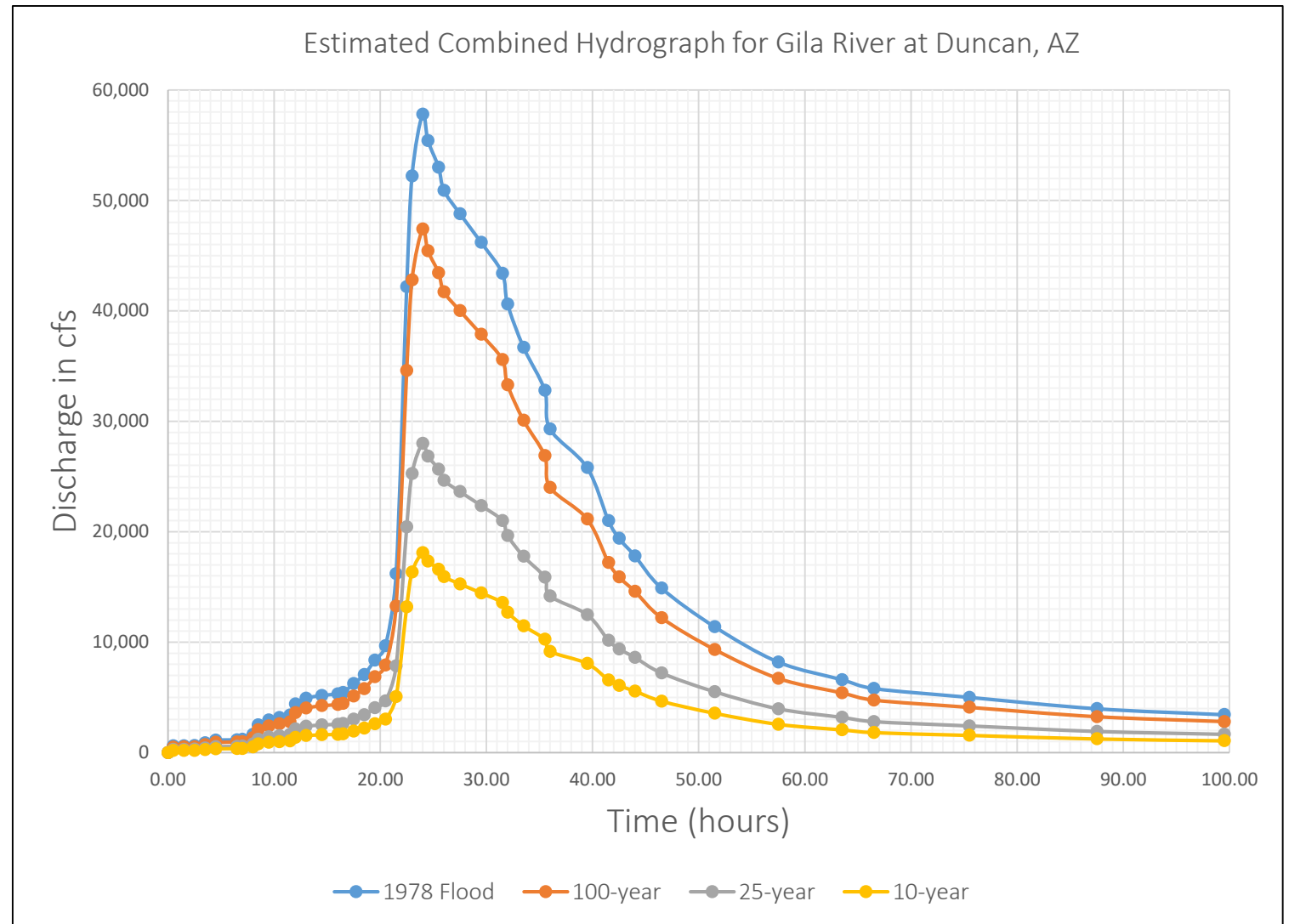
- 10-year Flow: 18,100 cfs

Figure 4: Hydrograph for varied flows

Model Preparation

- ArcGIS
  - Cross-sections close to bridge
  - Added Vertices

- Site Visit
  - Simpson Hotel
    - High Water Mark = 9.3 ft
    - Low Water Mark = 2.4 ft
  - County Building
    - High Water Mark = 6.5 ft
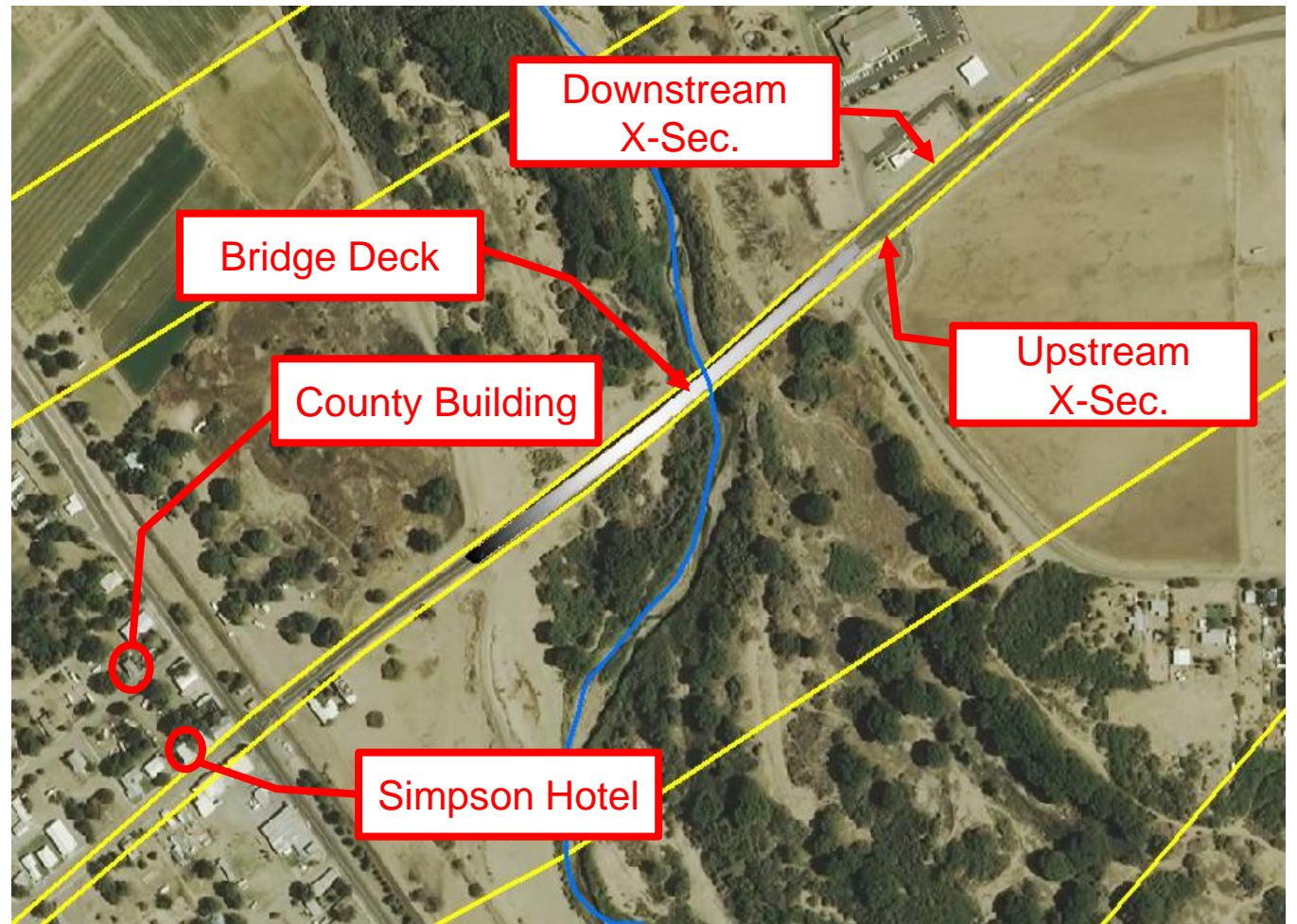   - Low Water Mark = 1.8 ft

Figure 5: Bridge Deck Cross Sections

Model Parameters

- ArcGIS
  - Surface feature characterization
  - Defines spatially-varied roughness
  - Defines flow obstructions

	Priority	
1	Paved Surface	
2	Buildings	
3	Low Vegetation	
4	Wash Bottom	
5	Cottonwood	
6	Heavy Vegetation	
7	Agriculture	
8	Bare Ground	

Figure 6: Surface feature Characterization

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Model Parameters

- Friction Loss (Manning's n)
  - Obtained n-value from manuals and technical advisor input
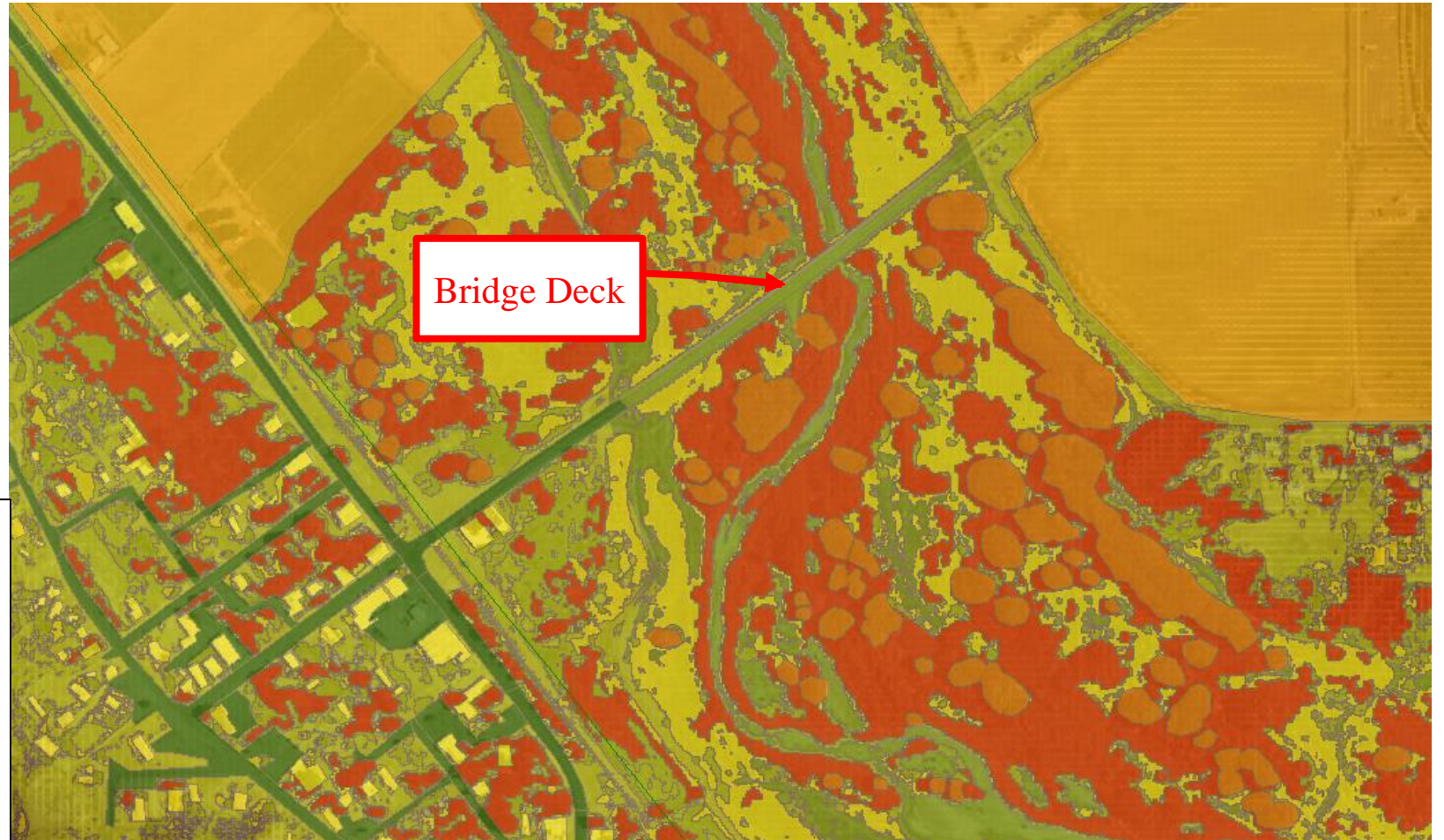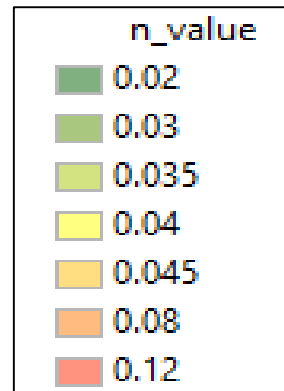 - The n-values points varies along each surface feature characterization

Bridge Deck

n_value	
	0.02
	0.03
	0.035
	0.04
	0.045
	0.08
	0.12

Figure 7: ArcGIS n-values layer

Bridge and Piers

- HEC-RAS
  - Overbanks
  - Bridge deck elevation
  - Model Piers
  - Change in Bridge Capacity

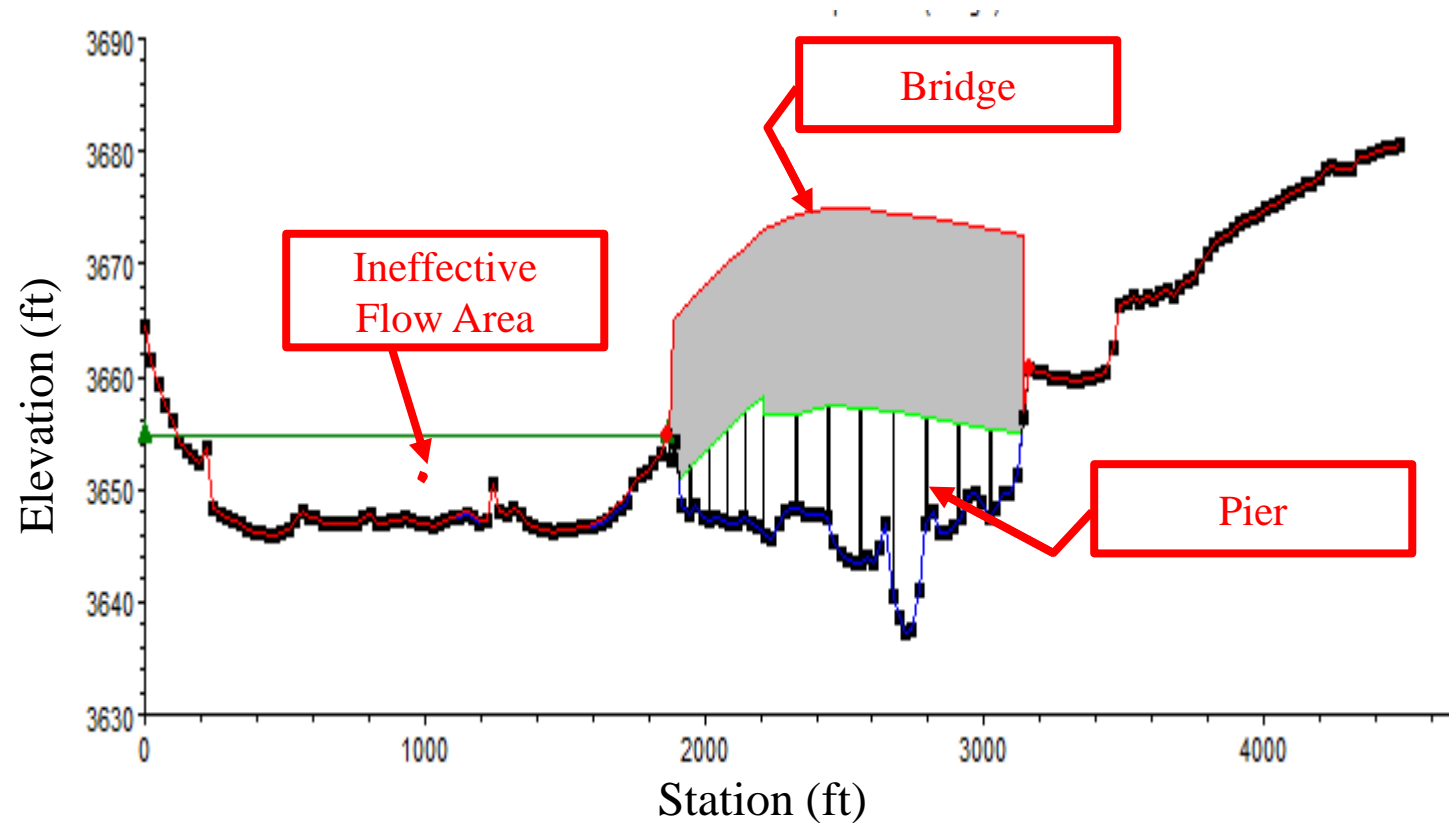*Figure 8: Downstream view of bridge*

Figure 9: Upstream cross section view with bridge and piers

HEC-RAS to Flo-2D Pro

- HEC-RAS
  - Define depth vs. discharge
  - Model hydraulic structures
- Flo 2D Pro Model
  - 271,399 grids
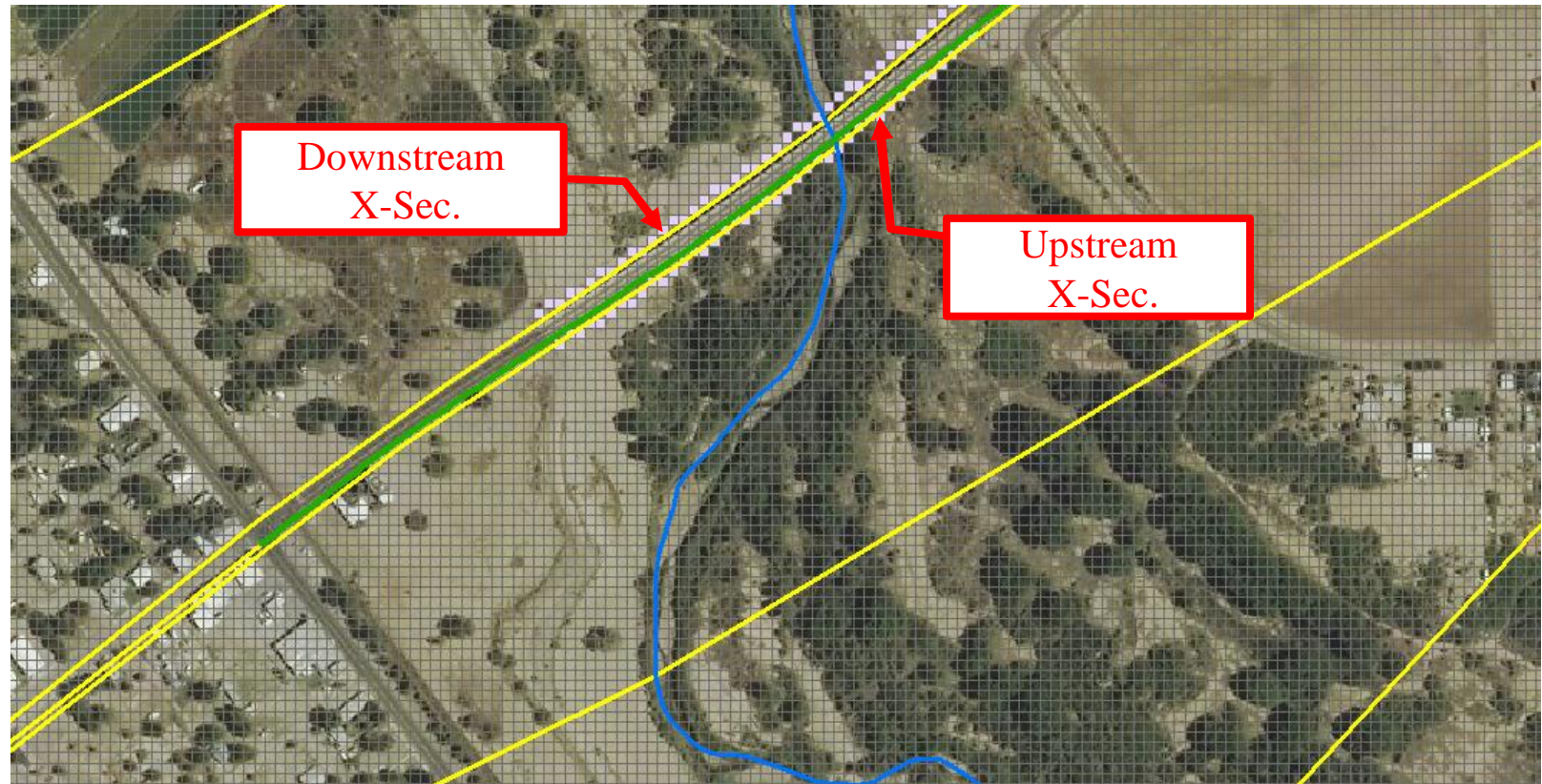 - Allows manual flow input

Figure 10: 25' x 25' Grids- ArcMap

Existing Conditions

Table 1: Survey data from site visit

Location	Max Survey Depth (ft)	Model Depth (ft)
Simpson Hotel	9.3	7.5
County Building	6.5	7.5

- 1978 Flow: 57,800 cfs
- 23 hours to reach town
- 25 hours to reach max depth in town

Max Depth Range (ft)	
0 - 1	
0.5 - 1	
1 - 2.5	
2.5 - 5	
5 – 7.5	
7.5 - 10	
10 - 24	

Figure 11: Maximum depth results of existing conditions model

Gila River Restoration

- Revised n-values
  - Based on approximation of tree removal and tree trimming
  - Removed WWTF

Old n-values

n_value	
0.02	
0.03	
0.035	
0.04	
0.045	
0.08	
0.12	

New n-values

n_value	
0.02	
0.03	
0.035	
0.04	
0.045	
0.06	
0.08	

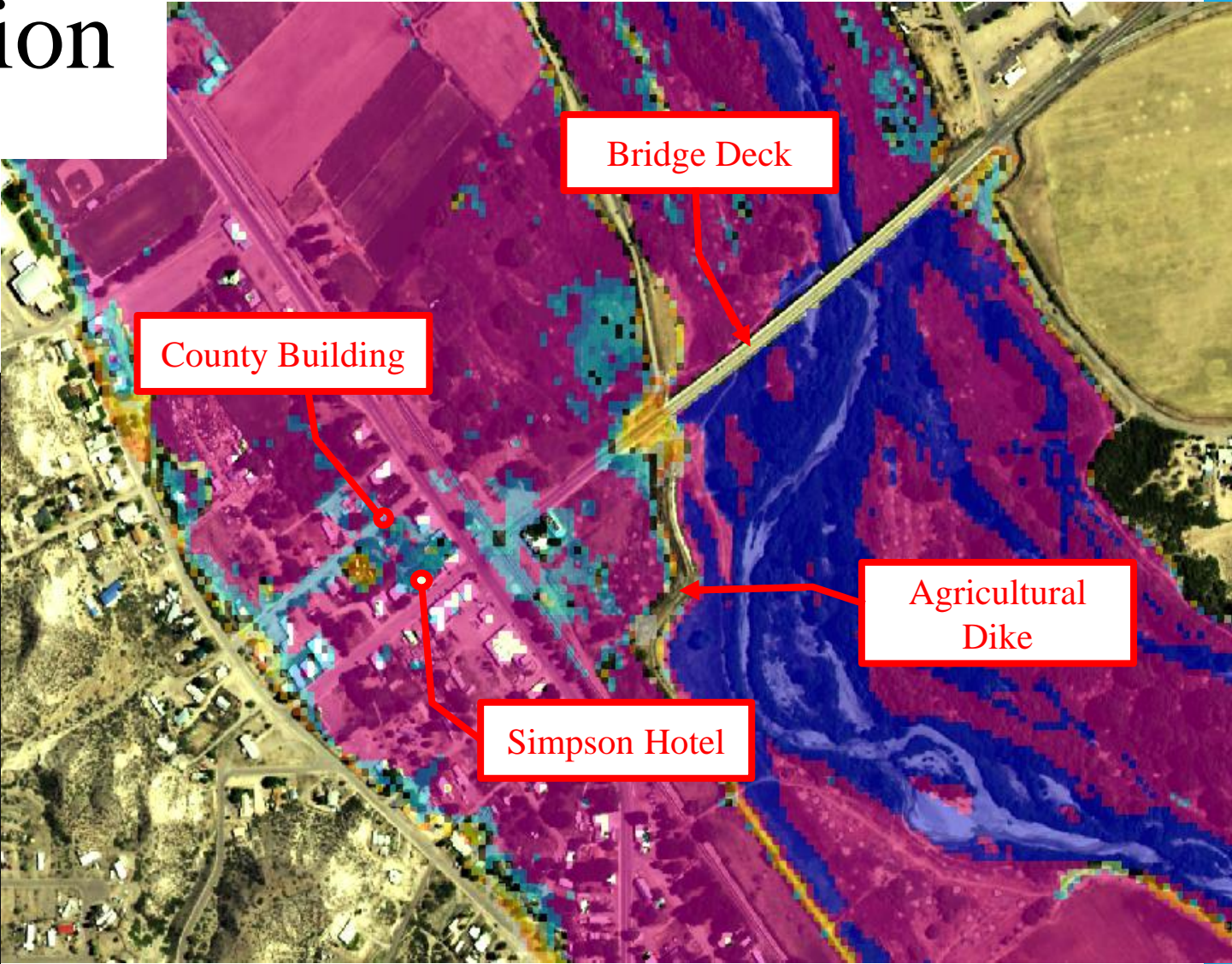| Max Depth Range (ft)	
0.0005 - 0.16	
0.16 - 0.5	
0.5 - 1	
1 - 1.5	
1.5 - 2	
2 - 2.5	
2.5 - 3	
3 - 3.5	
3.5 - 4	
4 - 10	
10 - 50	

Figure 12 : Gila river restoration maximum depth results

Proposed Levee

- 100-year Flow: 47,400 cfs
- Levee height: 23 ft
- 3 feet of freeboard [2]

Max Depth Range (ft)	
0.0005 - 0.16	
0.16 - 0.5	
0.5 - 1	
1 - 1.5	
1.5 - 2	
2 - 2.5	
2.5 - 3	
3 - 3.5	
3.5 - 4	
4 - 20	
20 - 50	

Bridge Deck

Duncan

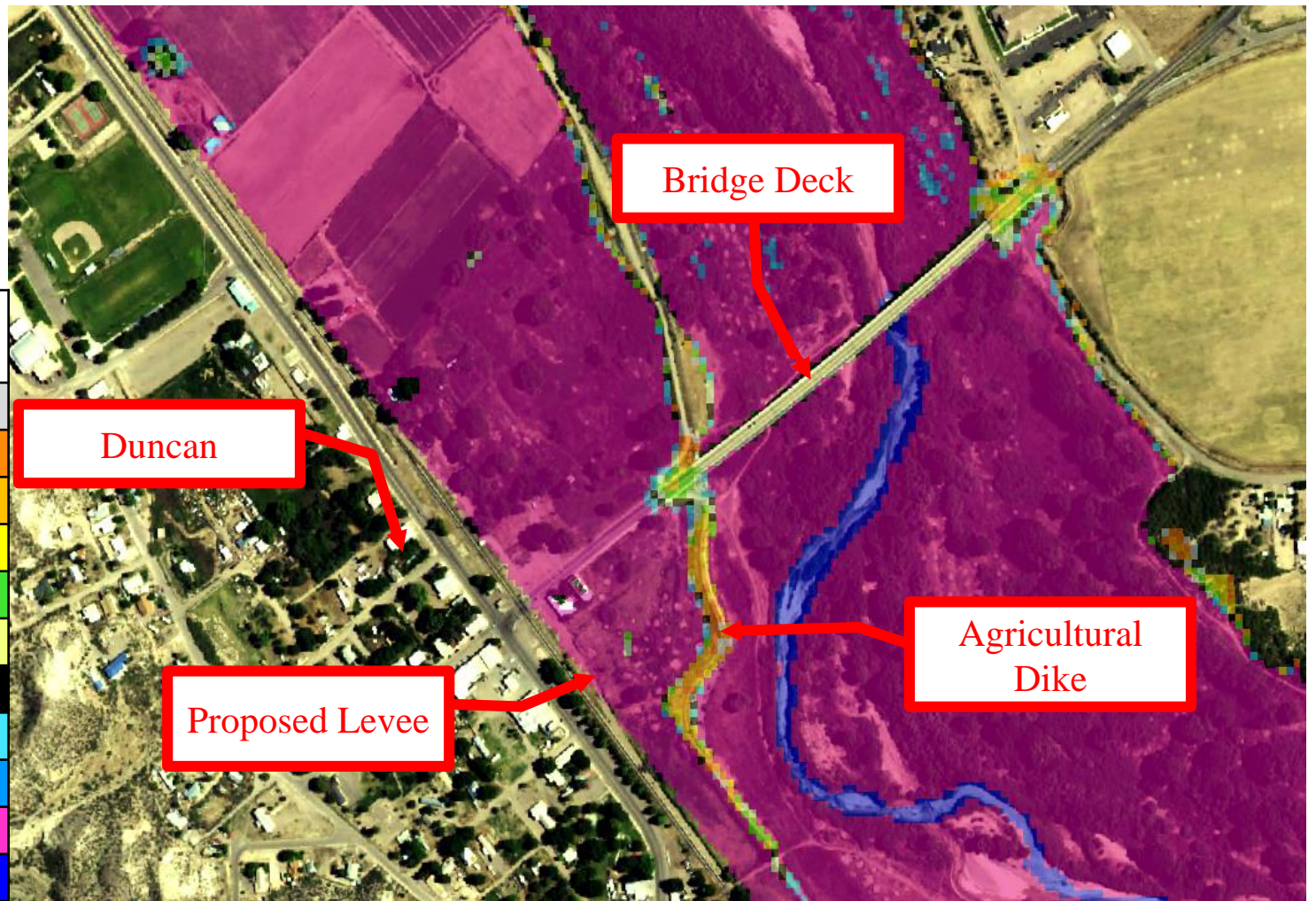Agricultural Dike

Proposed Levee

Figure 13: Maximum depth results of proposed levee model

[2] Code of Federal Regulations 44, Office of the Federal Register National Archives and Records Administration, 2002

Combined Model

- Proposed levee with Gila river restoration and WWTF removed

- 100-year Flow: 47,400 cfs

- Levee height: 20 ft

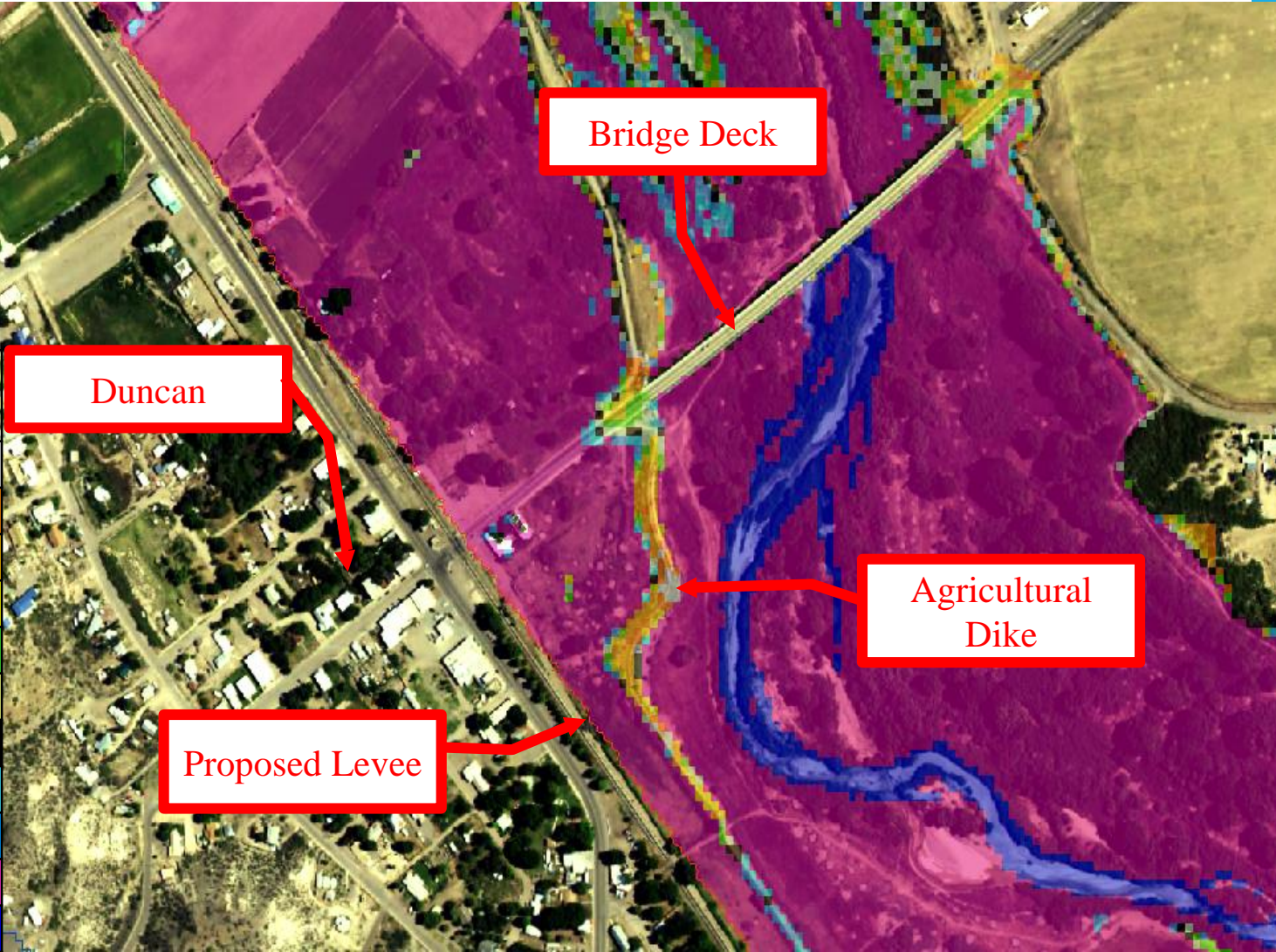| Max Depth Range (ft)	
0.0005 - 0.16	
0.16 - 0.5	
0.5 - 1	
1 - 1.5	
1.5 - 2	
2 - 2.5	
2.5 - 3	
3 - 3.5	
3.5 - 4	
4 - 17	
17 - 50	

Figure 14 : Proposed levee with Gila river restoration and WWTF removal

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Proposed Levee Impacts

Table 2: Impacts for the proposed levee

	Social Impacts	Environmental Impacts	Economic Impacts
Positives	• Safety for residents in downtown Duncan	• Still providing habit for most animals	• Construction of levee brings jobs into Duncan
Negatives	• Property acquisition • Relocations of homes • Birdwatching impacts	• Wildlife Concerns	• Maintenance costs of levee

Gila River Restoration Impacts

Table 3: Impacts for the Gila river restoration

	Social Impacts	**Environmental Impacts**	**Economic Impacts**
Positives	• Duncan's everyday life will stay the same	• Invasive species will be removed	• No need to maintain the growth of invasive species
Negatives	• Possible floodplain flooding still	• Invasive species of trees will eventually return	• Possible birdwatching visitors might be reduced

Cost Analysis

Table 4: Cost analysis for provided solutions

	Length (mi)	Cost ($/mi)					Levee Cost $6,487,500	Combined Cost $6,545,250
Levee	1.73	3.75M						
River Restoration	Tree Removal	Tree Trimming	Total Trees Removed	Total Trees Trimmed	Total Cost for Tree Removal	Total Cost for Tree Trimming	Restoration Cost $57,750	
	$300 per tree [3]	$150 per tree [3]	150	85	$45,000	$12,750		
Property Acquisition	Cost Per Acre	Acres in Duncan					Land Cost $600,000	
	$2,000	300						

[3]   "How Much Does Tree Removal Cost?," TreeRemoval.com, 2015. [Online]. Available: http://www.treeremoval.com/costs/#averagecost. [Accessed 28 November 2016].

Staffing Cost

- Removed RAS-2D
  - Does not model the Hydraulic Structure the same as Flo-2D
  - Flo-2D also took longer than expected
- Removed Existing w/o Dike
  - Overtops at low flows
  - Similar results to existing conditions

Table 5: Staffing Cost

Classification	Billing Rate ($/hr)	Proposed Hours	Actual Hours	Proposed Cost	Actual Total Cost
SENG	117.51	169	156	$19,859	$18,332
ENG	70.11	300	278	$21,033	$19,491
INT	29.64	283	272	$8,388	$8,062
		752	**706**	**$49,280**	**$45,884**

Acknowledgements

- Client
  - Phil Ronnerud, P.E., Greenlee County Engineer

- Technical Advisor
  - Tom Loomis, P.E., RLS, CFM, FCDMC

- Grading Instructor
  - Mark Lamer, P.E.

Figure 15 : Site Visit in Duncan, AZ