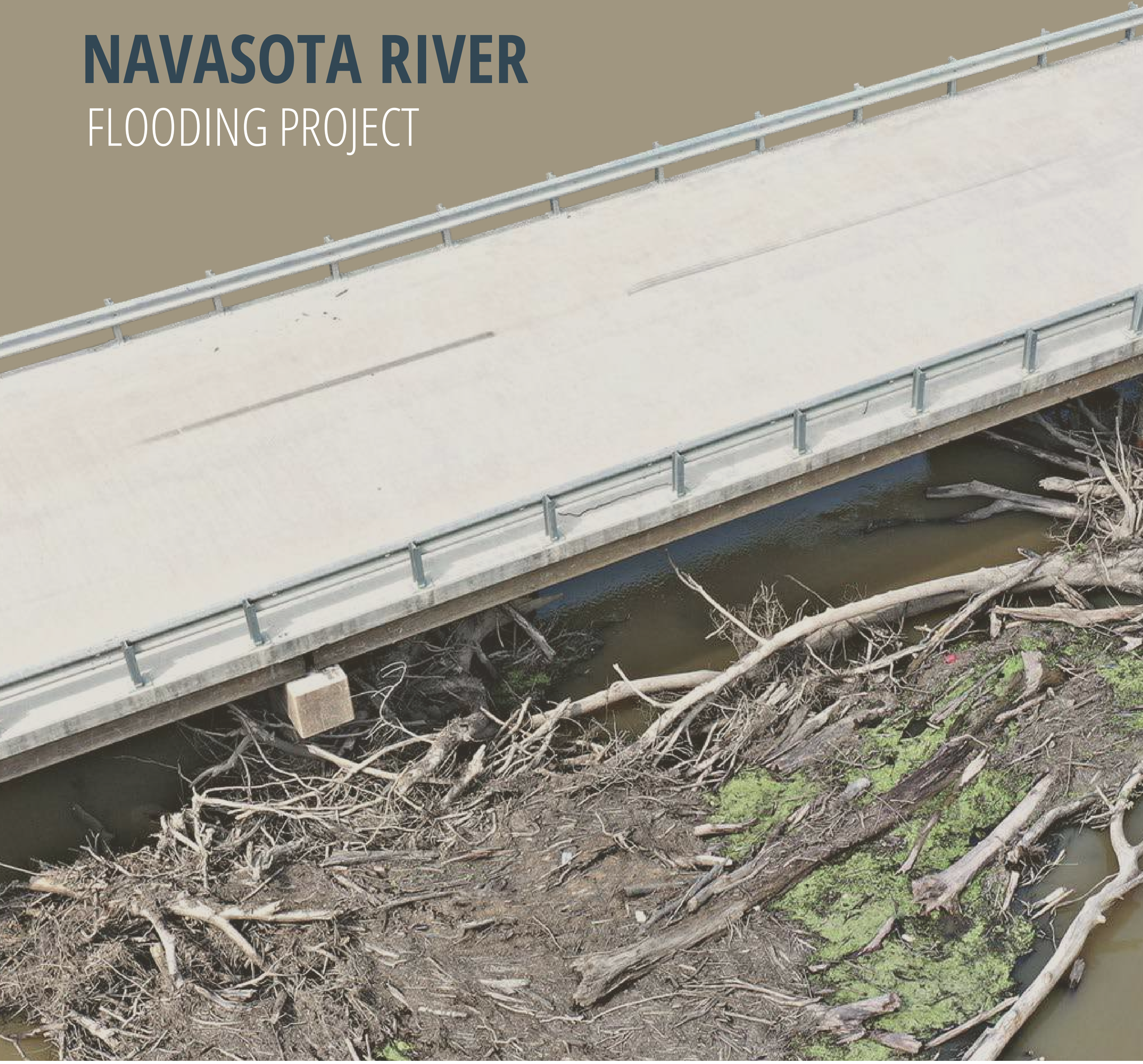
NAVASOTA RIVER
FLOODING PROJECT



SUPPLEMENTARY MATERIALS

FLOOD IMPACT ANALYSIS

DECEMBER 2022

FLOOD IMPACT ANALYSIS

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METHODOLOGICAL OVERVIEW

The flood hazard/impact analysis of Lake Limestone in the Navasota River basin is primarily conducted by using a two-dimensional (2D) hydraulic model, HEC-RAS 2D, to evaluate the flood impacts of the dam to downstream communities under existing, hypothetical, historical, and projected future conditions. **Figure 1** shows an overview of the study / modeling workflow.

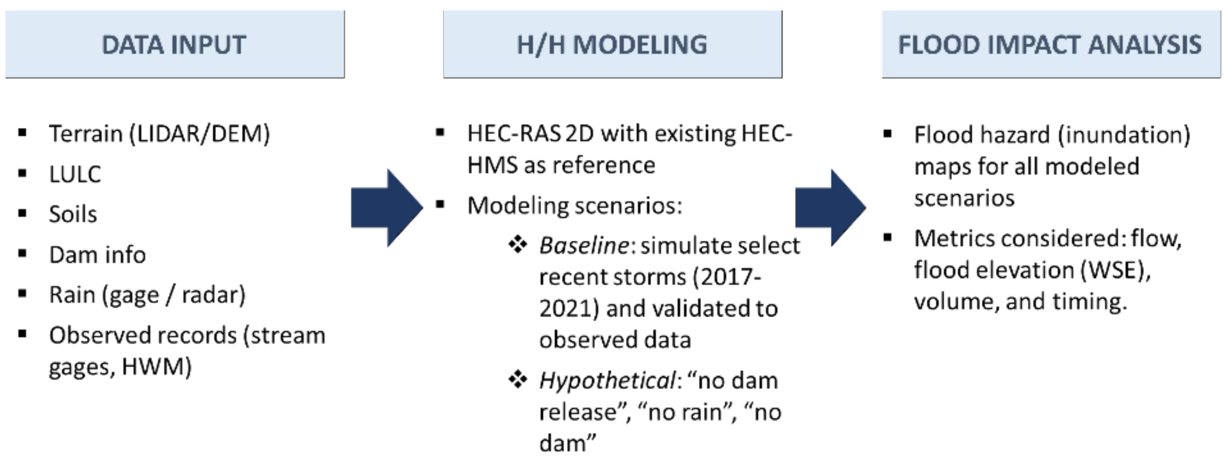


Figure 1: Study / Modeling Workflow

Hydrologic / Hydraulic Modeling

The hydraulic model used in this study is the Hydrologic Engineering Center – River Analysis System (HEC-RAS) developed by the US Army Corps of Engineers (USACE). HEC-RAS[i] is a publicly available software that has been prevalently used in a wide variety of studies, including floodway/floodplain studies, flood risk / hazard analysis, sediment transport, and water quality modeling. HEC-RAS is also one of the Federal Emergency Management Agency’s (FEMA) approved software that meets the requirements of the National Flood Insurance Program (NFIP) to generate Flood Insurance Rate Maps (FIRMs).

A recent release version of HEC-RAS, 6.2, is used in this study. Since version 5.0, HEC-RAS features a 2D module that simulates 2D unsteady surface flow by solving the 2D Saint Venant equations. These equations are based on the conservation of mass and momentum and are derived from the shallow water equations. In practice, HEC-RAS 2D allows the user to represent the study area in a 2D domain or mesh, which comprises combination of structured (square) and unstructured (up to 8-sided) cells. The main advantage of using a 2D hydraulic model lies in its ability to simulate inundation from a variety of sources (e.g., riverine/fluvial and local/pluvial) and directions, whereas a typical 1D model is only capable of capturing riverine flooding, with flood conveyance moving in one direction (either upstream or downstream). Furthermore, HEC-RAS version 6 and newer add the ability to incorporate spatially distributed precipitation (e.g., radar rainfall), infiltration, and more extensive hydraulic structure options (e.g., bridges) in the 2D domain. The model's new capabilities largely negate the need for a separate hydrologic model.

Baseline Model Setup

Data from various sources are used to develop a baseline HEC-RAS 2D model that represents the existing/current conditions for the Navasota River basin:

- Terrain: 2018 Light Detection and Ranging (LIDAR) from U.S. Geological Survey (USGS)[ii] with 1-meter resolution
- Landuse/land cover and impervious cover: 2016 National Land Cover Database (NLCD) from the Multi-Resolution Land Characteristics (MRLC)[iii] Consortium with 30-meter resolution
- Soils: Gridded Soil Survey Geographic Database (gSSURGO) from Natural Reources Conservation Service[iv]
- Dam release info: Brazos River Authority (BRA)[v]
- Radar precipitation: Multi-Radar/Multi-Sensor (MRMS) from National Oceanic and Atmospheric Administration (NOAA) with 1-hour time intervals and 1-kilometer resolution, obtained from Iowa State Mesonet system (https://mesonet.agron.iastate.edu/)
- Stream gage: Stream flow and stage for model validation (USGS gages[vi] 08110500 and 08110800)

(Note: More details on these datasets are available in **Appendix A**)

The modeling domain (see **Figure 2**) begins downstream of Lake Limestone, covering a drainage area of approximately 1,700 miles^2. The 2D mesh consists of approximately 500,000 cells with an average grid cell resolution of 300 feet. Water is introduced into the modeling domain using hourly MRMS (radar) rainfall and dam release information provided by the BRA in the form of an interpolated flow hydrograph as an upstream boundary condition. To ensure water can drain out of the domain, normal depth is set as the downstream boundary condition near the watershed outlet.

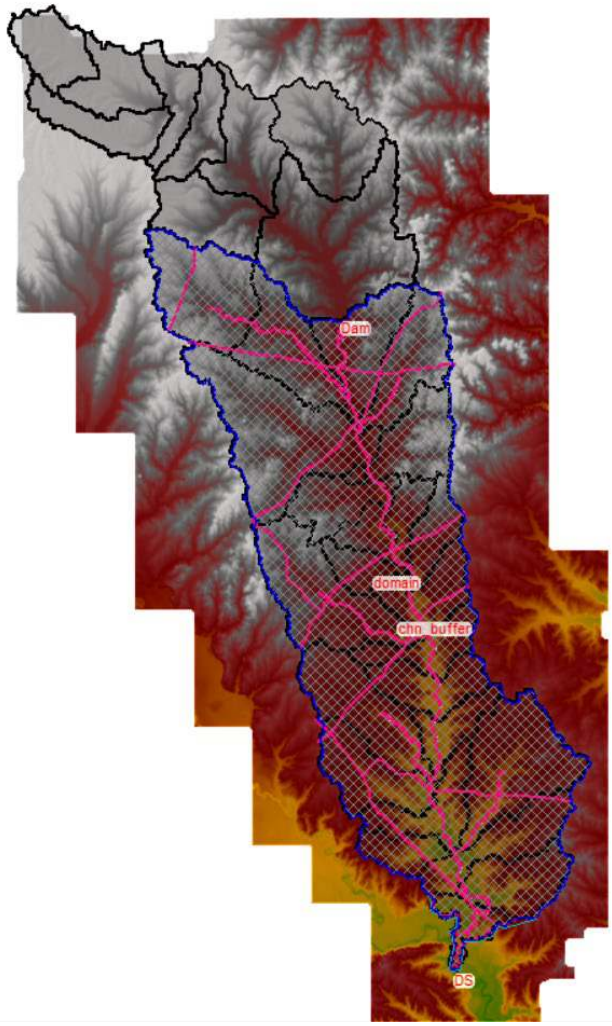


Figure 2: Flood hazard model for the study area (Note: hashed area is the HEC-RAS 2D modeling domain, underlying terrain data is 2018 LIDAR from USGS)

Within the mesh, Manning's n values are assigned to corresponding NLCD land cover classes to account for overland roughness. The n values used in this model are referenced and adapted from Kalyanapu's 2009 article[vii], which have been found to be suitable for watersheds in the nearby Greater Houston region. The n value for the channel is set to 0.04, which represents the roughness of a natural or undeveloped channel. Impervious cover within the model domain is defined by using a corresponding NLCD 2016 impervious cover dataset. Other considerations include spatially distributed infiltration, which applies the Green and Ampt method to the modeling domain. Parameters (e.g., saturated hydraulic conductivity, wetting front, and porosity) based on existing literature[viii] are assigned to corresponding soil types from the gSSURGO dataset. Finally, the mesh configuration is refined by using buffers and/or breaklines along the main channel, major tributaries, and major highways.

Model Scenarios

To evaluate the flood impacts of Lake Limestone on downstream communities, several scenarios (baseline and hypothetical) based on the current or existing watershed conditions are simulated. These scenarios are developed based on existing terrain (LIDAR 2018) and LULC (NLCD 2016) datasets. Two recent rainfall events that occurred in April 11-16, 2017, and June 1-6, 2021, are simulated for the study area. These storms are selected primarily because they coincided with notable dam releases from Lake Limestone according to the information provided by the BRA. The spatial distribution of rainfall for both storms are quite similar in areas upstream of the dam (approximately 4 inches of total rainfall). Downstream of the dam however, the rainfall distribution for the two storms is noticeably different, with most areas accumulating less than 2 inches of rainfall during the April 2017 storm, but some areas getting more than 3 inches during the June 2021 storm. The simulated storms serve as baseline scenarios to better understand current watershed hydrodynamics and to quantify the flood impacts of the releases from Lake Limestone in its immediate vicinity. Once simulated, the baseline model results are compared and validated to observed flow and stage records from available USGS gages. It is important to note that while the initial setup of the baseline scenarios included the implementation of spatially distributed infiltration using the gSSURGO soil dataset and the Green and Ampt method, it was ultimately excluded during the model validation/calibration process and subsequent model scenario runs. A major reason for its exclusion lies in the presence, variability, and uncertainty of antecedent moisture conditions for the two storms across the study area. Prior to both simulated events, the study area recorded several smaller storms, which meant that the soils would have been saturated to varying degrees, if not fully saturated. Thus, excluding infiltration from the modeling process was deemed reasonable. More details on baseline model validation are provided in **Appendix B**.

After validating the baseline scenarios, three hypothetical scenarios using the same two storms in 2017 and 2021 are simulated and evaluated. These consist of the “no release,” “no rain,” and “no dam” scenarios. The “no release” scenarios assume that no water is released from Lake Limestone during the storm event, hence rainfall and consequently local basin inflow are the only flood drivers downstream of the dam. By contrast, the “no rain” scenarios assume that there is no precipitation on the study area, hence the only flood driver is the dam release during the rainfall event. Finally, the “no dam” scenarios assume that Lake Limestone did not exist. The flood drivers consist of both rainfall and local basin inflows. This setup is similar to the baseline scenario, with the exception that there is no flood control structure present to detain the inflow upstream of the dam. To simulate this particular scenario, an existing hydrologic (HEC-HMS) model developed by Halff Associates for the BRA[ix] is used as reference. The HEC-HMS model is trimmed and modified to only include the Navasota River basin up to Lake Limestone instead of the entire Lower Brazos River project area. Subbasin-averaged radar rainfall for the 2017 and 2021 storms are generated and input into the model. By combining computed basin inflows as well as recoded flow data from two gages (USGS gage 08110325[x] and 08110430[xi]), the resulting inflow hydrographs for Lake Limestone are used as upstream boundary conditions into the HEC-RAS 2D model. More information on the setup of this scenario is available in **Appendix C**.

Key Findings

Flood Impact Analysis of Lake Limestone

While both the April 2017 and June 2021 storms were simulated, the following discussion will only focus on the results of the April 2017 storm since both storms yielded similar conclusions and/or insights regarding the impact of Lake Limestone on the Navasota River basin. The full results for both storms and scenario comparisons are available in **Appendix D**.

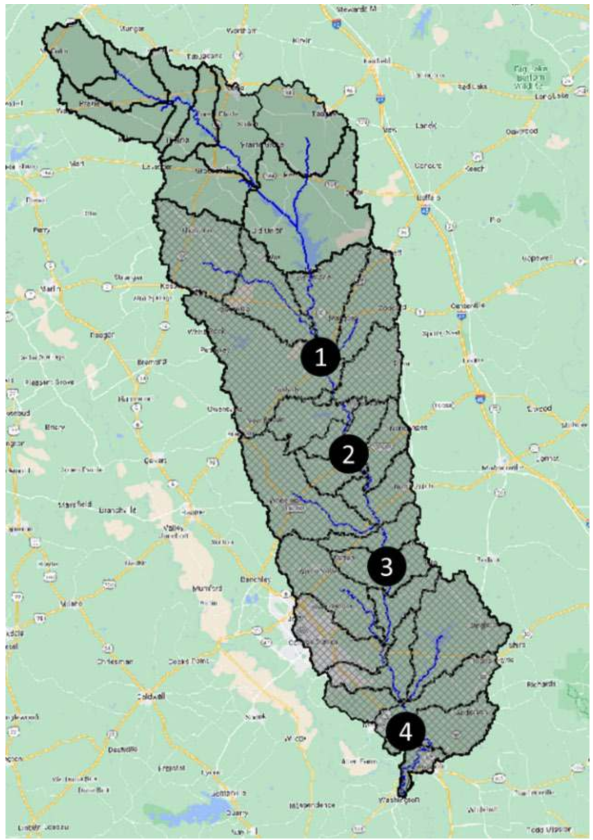


Figure 3: Selected watchpoints along Navasota River for model comparison

Four watchpoints (see **Figure 3**) along the Navasota River are selected for comparison across the modeled scenarios, with Watchpoint 1 located at the most upstream end closest to the dam. Watchpoints 1 and 2 coincide with the locations of USGS gages 08110500 and 08110800, which are also used for model validation, while Watchpoints 3 and 4 are selected to evaluate the impacts of Lake Limestone at locations that are farther downstream from the dam.

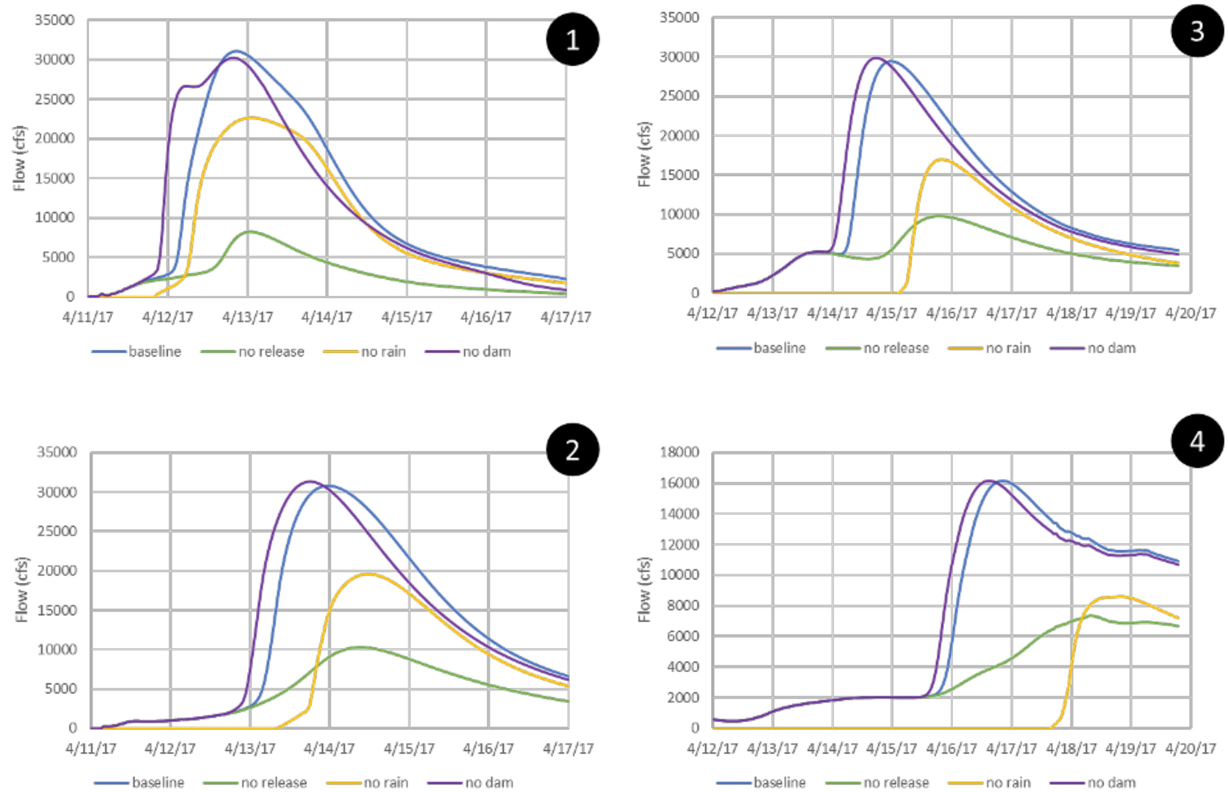


Figure 4: Flow comparison of modeled scenarios at 4 watchpoints for April 2017 storm

Figure 4 shows flow comparison of the modeled scenarios at the four selected watchpoints for the April 2017 storm. It is important to note that the simulation for all scenarios assume no baseflow in the channel (i.e., channel starts out completely dry). While this assumption does not impact the validity of the comparison across scenarios, it does mean that certain watchpoints and/or scenarios would record zero flows at the beginning of the simulation. This is especially evident in areas that are farthest from the dam (e.g., Watchpoints 3 and 4) under the “no rain” scenario.

Looking at the baseline scenario results along Watchpoints 1 through 4, it appears that peak flow timing lags by a day or more as one moves from one watchpoint to the next downstream watchpoint. Therefore, residents of the Navasota River basin would experience periods of high flows or inundation at different times depending on their location, with those located the farthest from the dam likely experiencing periods of high flow the latest (i.e., several days after a dam release occurrence). Furthermore, to assess the role of the dam during this storm, one method is to take the volume ratio of water (i.e., area under the flow hydrographs) for the “no rain” scenario against the baseline scenario. Since the “no rain” scenario represents the impact of only the dam release without precipitation, comparing its volume against the baseline scenario would signify its relative contribution during the rainfall event. At Watchpoint 1, the volume ratio of the “no rain” to baseline scenario is approximately 74%. This ratio drops to approximately 58%, 48%, and 26% at Watchpoints 2, 3, and 4, respectively. These results imply that the influence of the dam is greatest at locations closest to Lake Limestone, and that its impact diminishes as one moves farther downstream. The opposite is true for the role of precipitation during this rainfall event. At upstream watchpoints (i.e., 1 and 2), rainfall-induced local basin inflows are relatively small due to having smaller contributing drainage areas. Contributing drainage areas grow larger as one moves downstream, hence the influence of rainfall could become more significant due to the accumulation of more basin inflows into the channel. In practice however, the relative contribution of precipitation to the overall flow volume is highly dependent on rainfall intensity, magnitude, and its spatial distribution.

A different method to assess the role of the dam is to compare the baseline scenario against a hypothetical “no dam” condition. The “no dam” scenario assumed that Lake Limestone did not exist and that inflows to Lake Limestone (which are equivalent to its outflows) are caused by local basin inflows from upstream contributing drainage areas driven by precipitation. Comparing the flow response of the “no dam” scenario against the baseline scenario in **Figure 4**, it was observed that with the exception of Watchpoint 1, both scenarios exhibit similar flow responses, with comparable peak flows and volume but earlier peak timing for the “no dam” scenario. These findings are echoed in the modeled flood levels as shown in **Figure 5**. The “no dam” scenario shows similar peak flood levels (WSEmax) compared to the baseline scenario, and that it reaches peak and recedes earlier compared to the baseline scenario. Next, since Watchpoints 1 and 2 are USGS gage locations, the duration of high flood stage (i.e., water surface elevations above the official National Weather Service (NWS) flood levels, 290.46 feet for Watchpoint 1 and 260 feet for Watchpoint 2) are computed. There was a significant difference between the duration of high flood stage for both scenarios at Watchpoint 1 (137 hours for the baseline scenario and 119 hours for the “no dam” scenario). At Watchpoint 2, however, the duration of high flood stage is similar, 63 hours for the baseline scenario and 64 hours for the “no dam” scenario. Overall, areas that experienced flooding in the baseline scenario would have flooded earlier had there been no dam, but they would have experienced a similar extent and duration of flooding. Based on how the estimated inflow volume into Lake Limestone is comparable to the release volume provided by the BRA, and the pool elevation records of Lake Limestone, it is apparent that the role of the dam during this rainfall event is to merely release the same amount of water it receives, albeit at a later time.

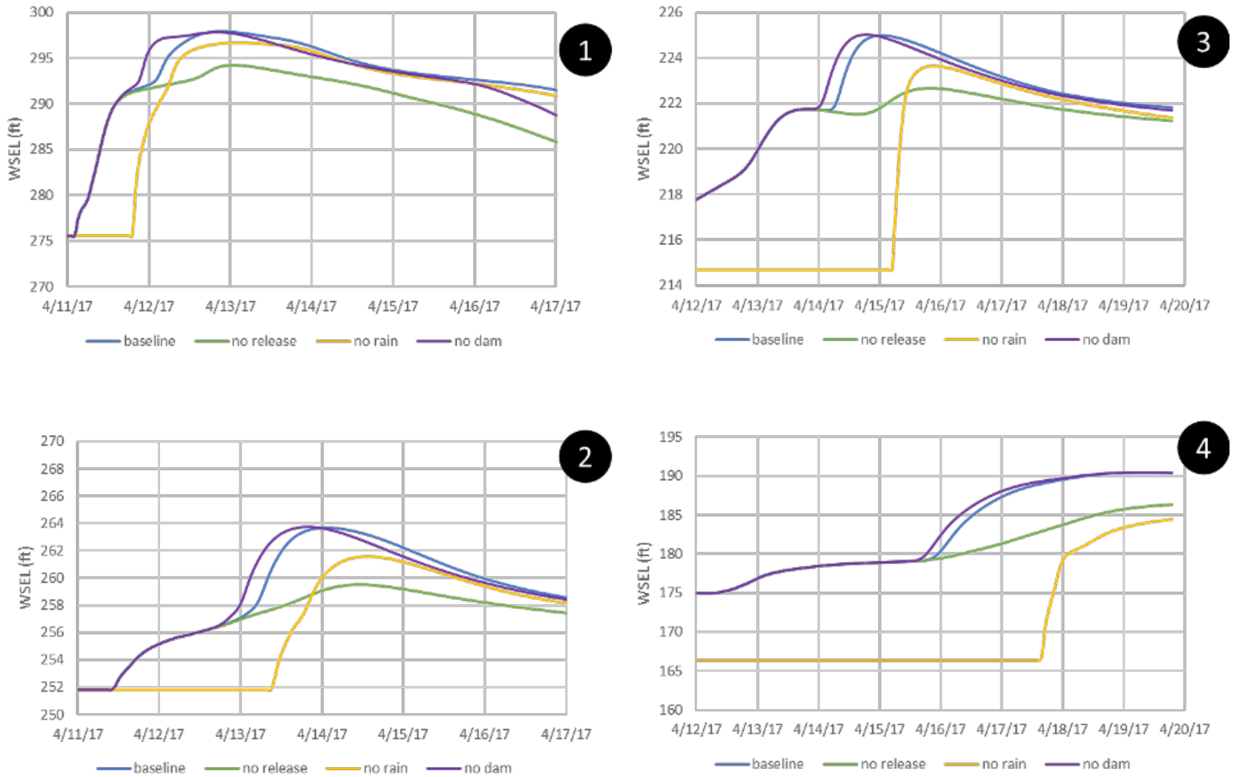


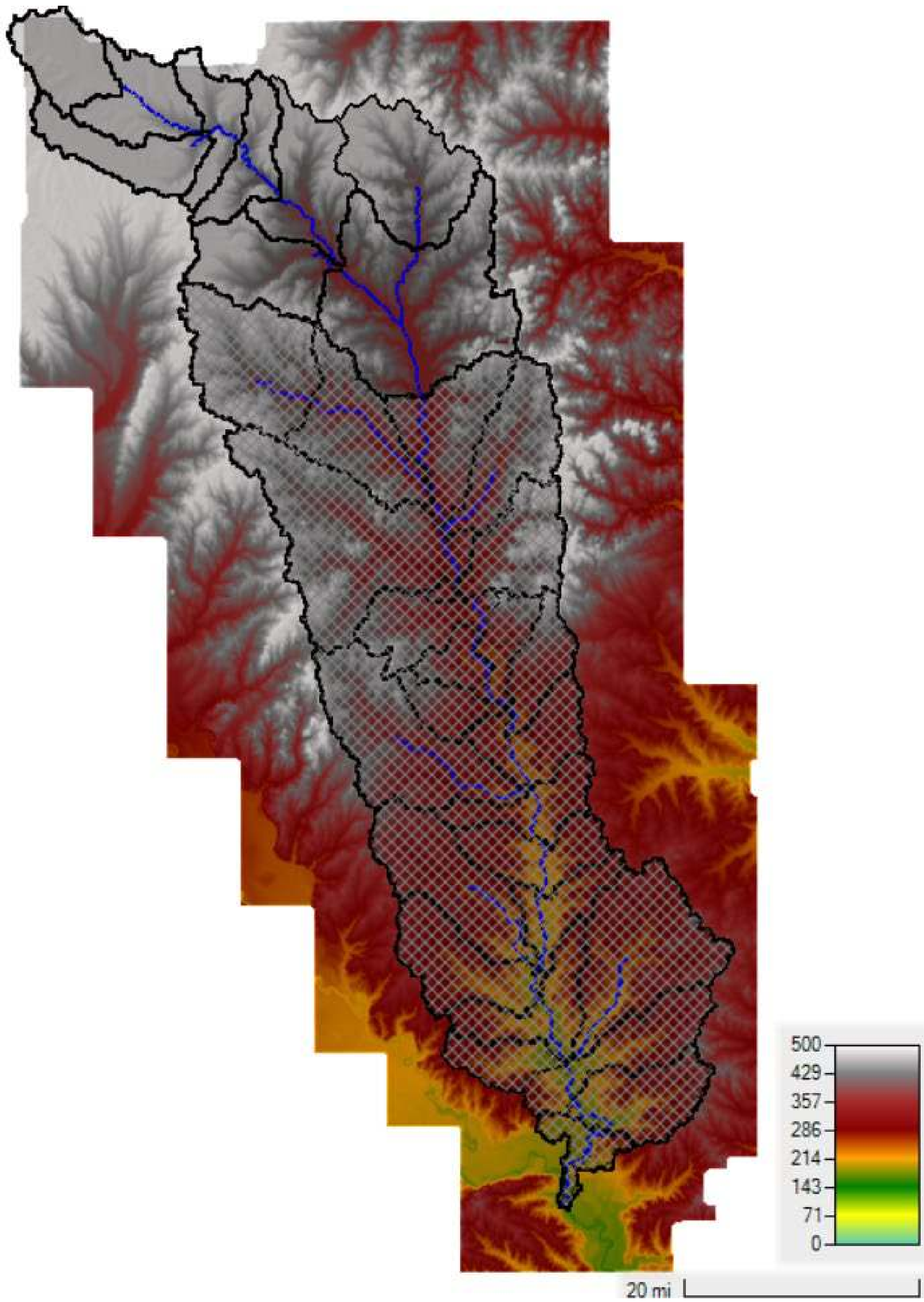
Figure 5: Water surface elevation comparison of modeled scenarios at 4 watchpoints for April 2017 storm

Appendices

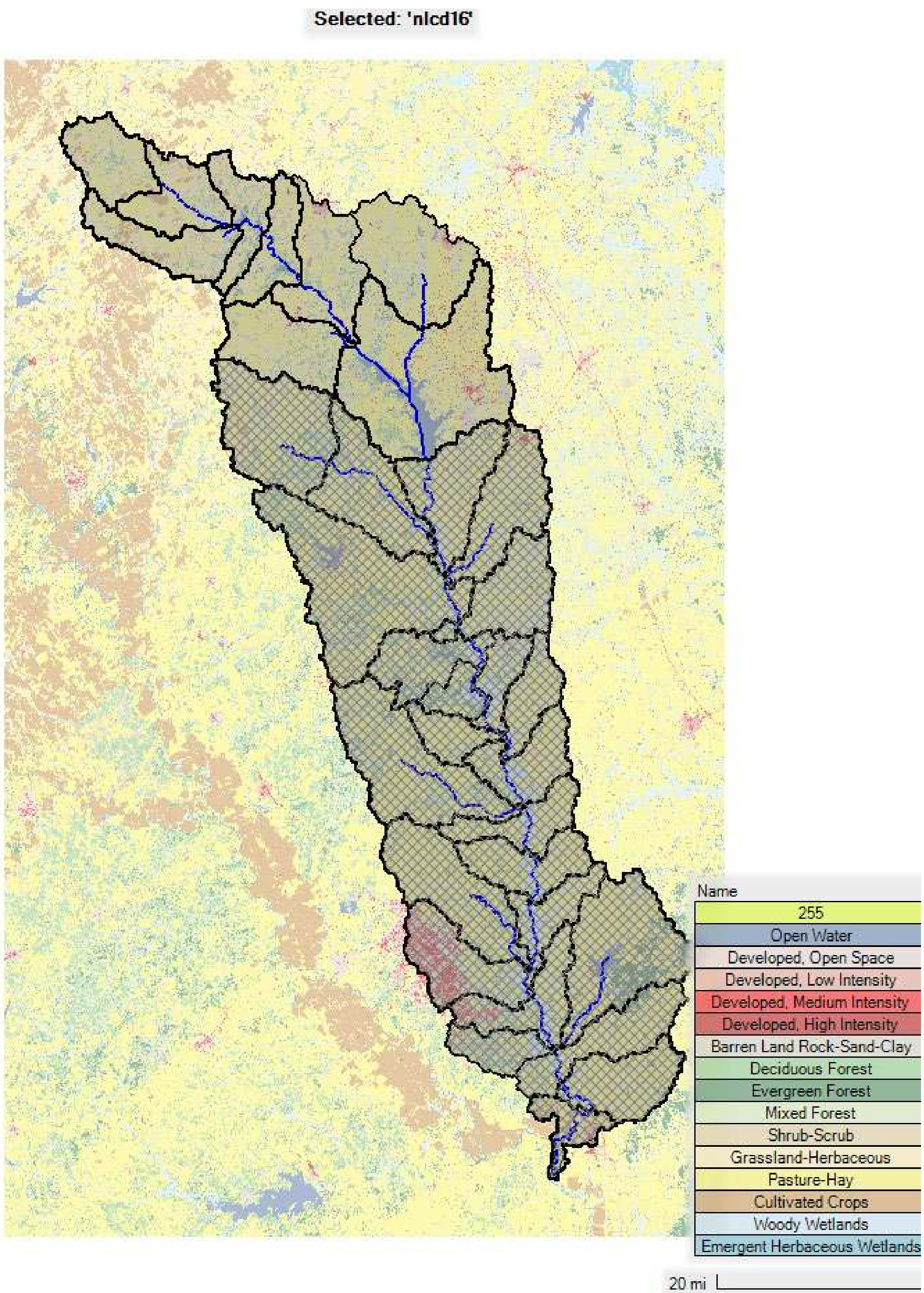
Appendix A: Data Sources
Appendix B: Baseline Model Comparison and Validation
Appendix C: “No Dam” Scenario Model Development
Appendix D: Scenario Comparison

Appendix A: Data Sources

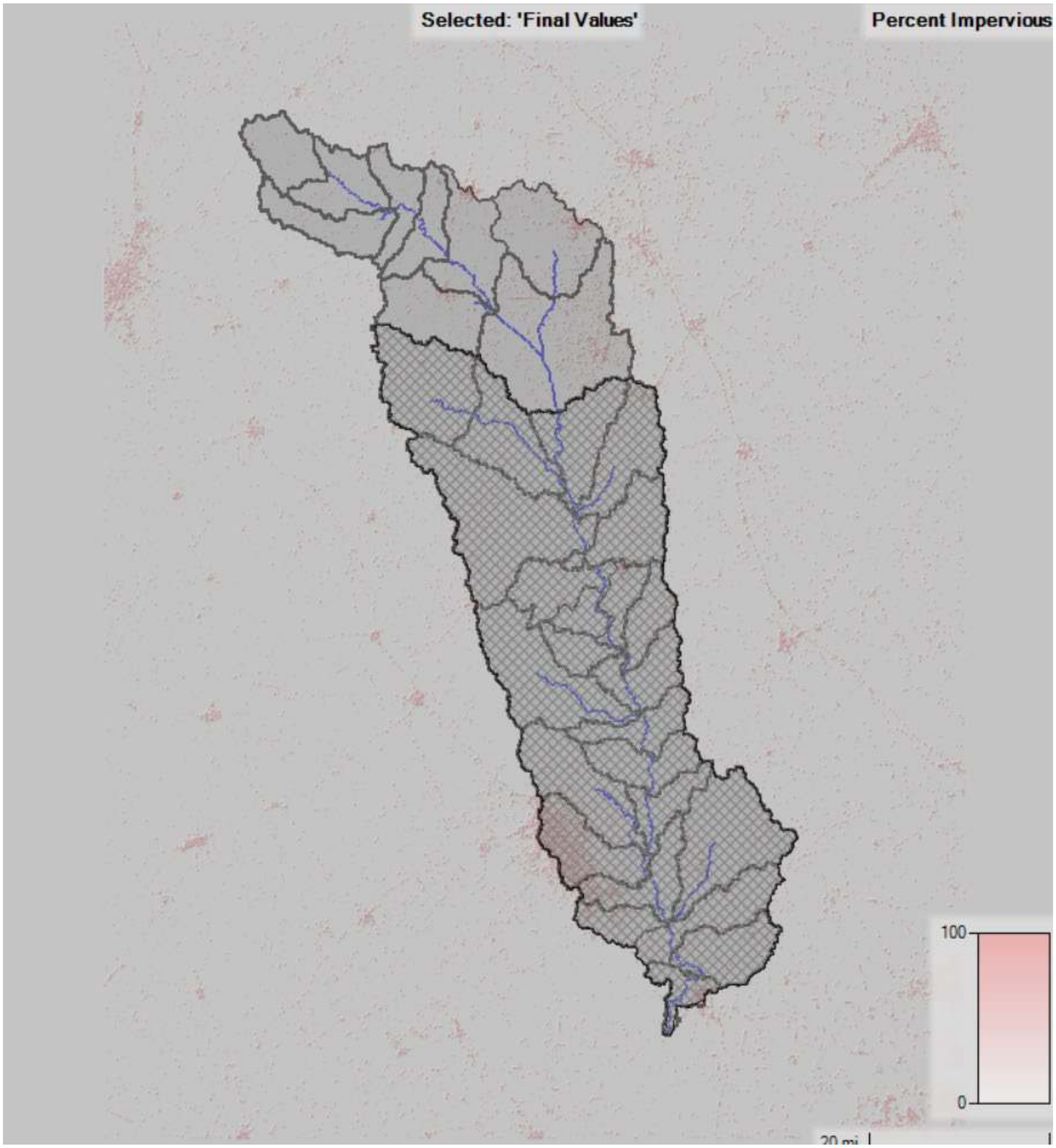
Terrain dataset (2018 LIDAR) from USGS with 1 m resolution



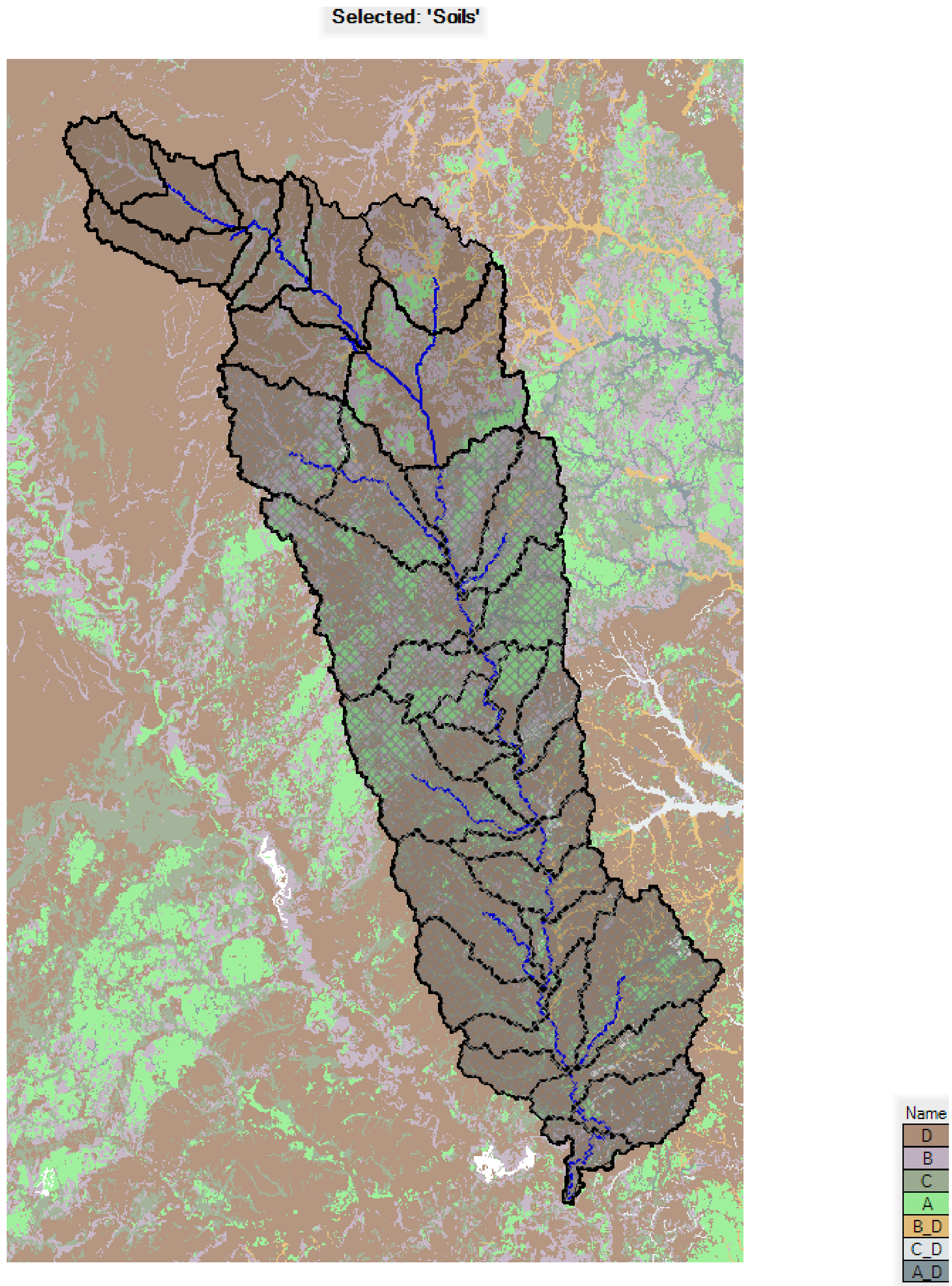
LULC Map (NLCD 2016) with Manning's n values from Kalyanapu et al. 2009



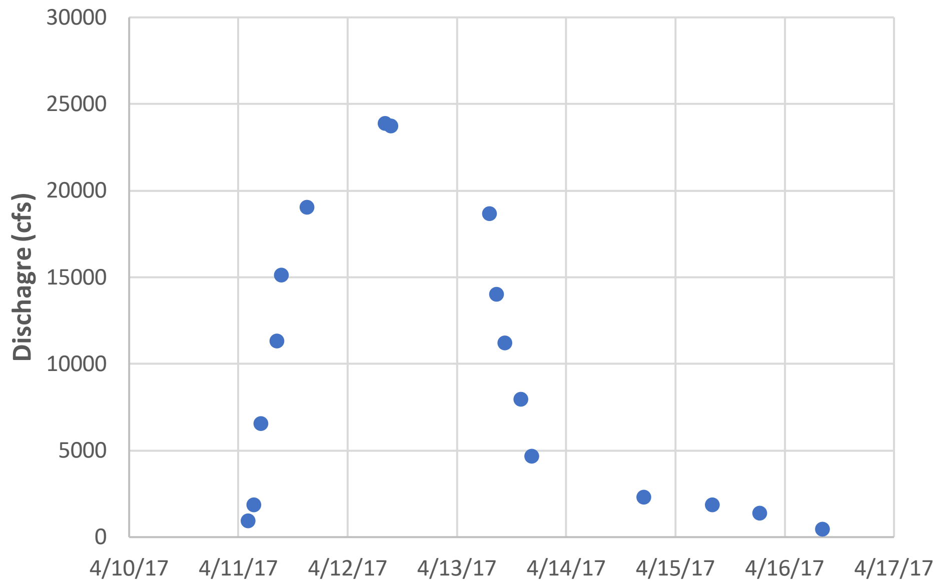
Impervious Cover Map (NLCD 2016)

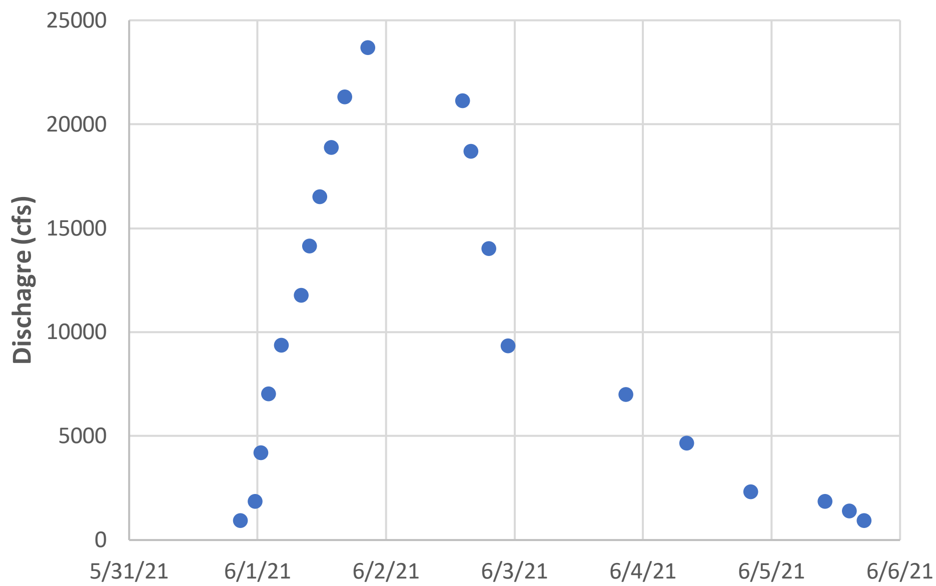


Soils data from gSSURGO

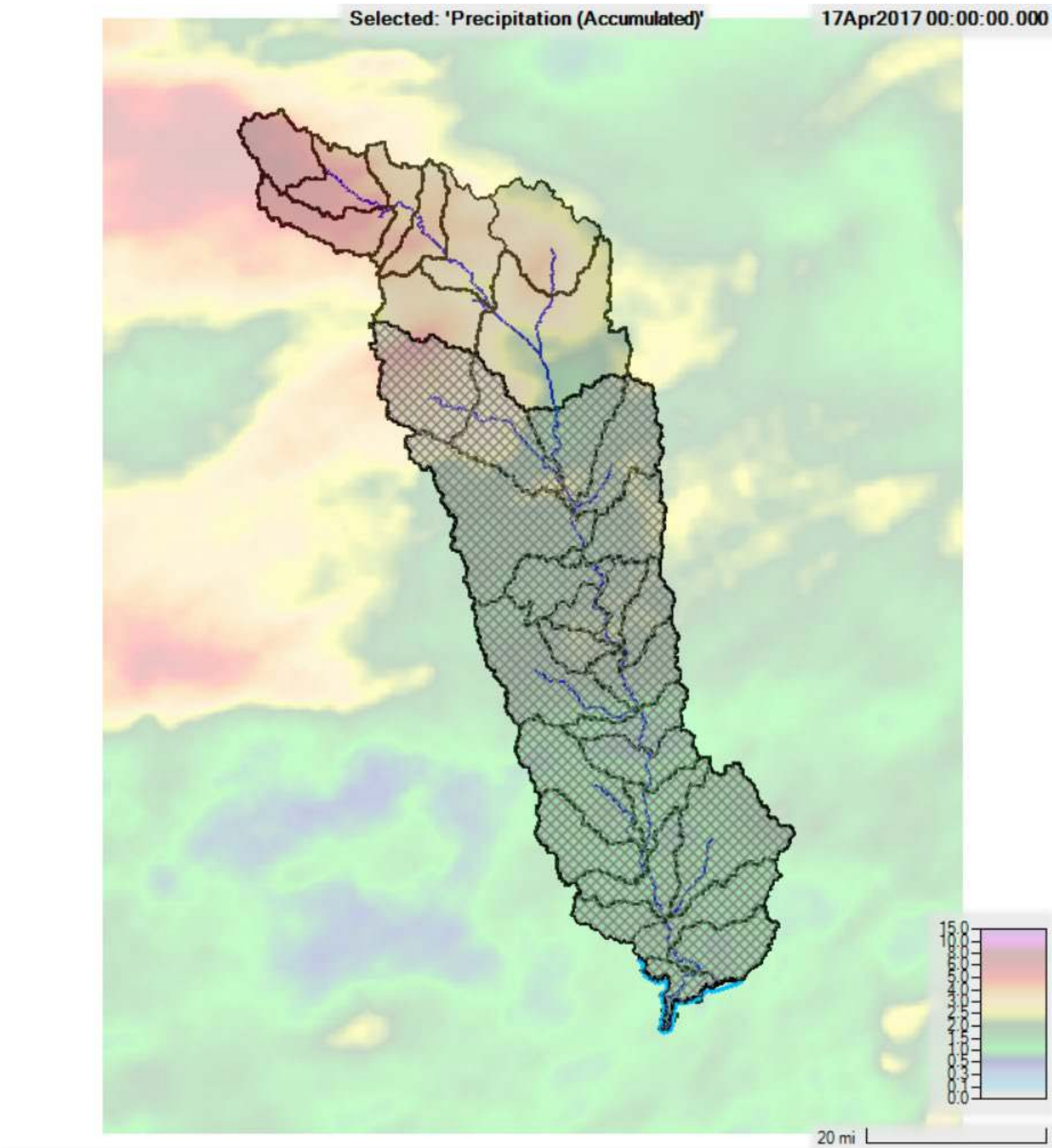


BRA Lake Limestone dam release info for the April 2017 storm (top) and the June 2021 storm (bottom)

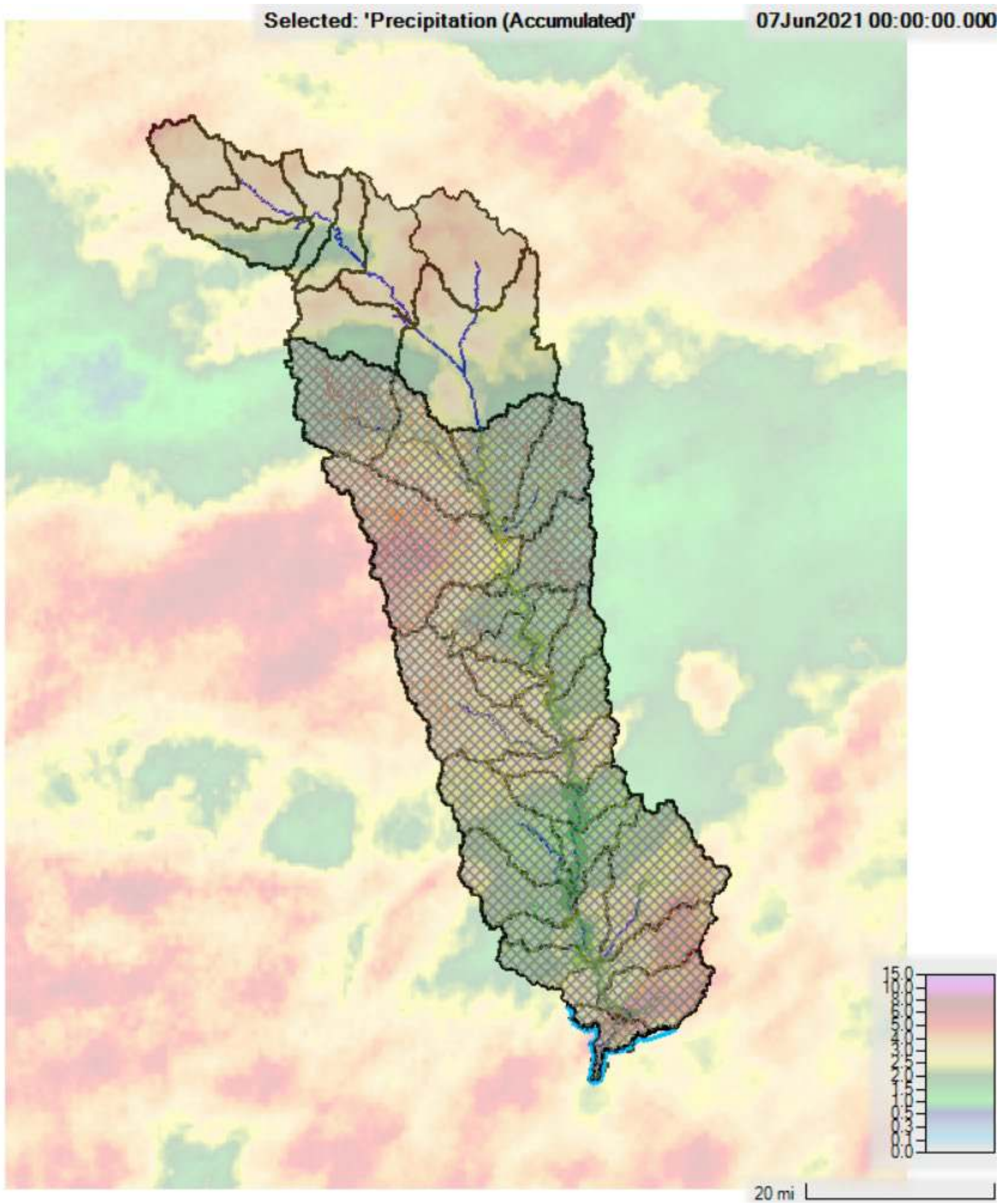




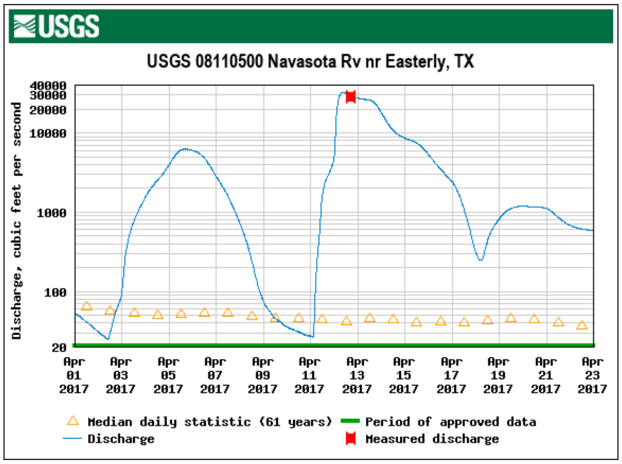
Radar rainfall data from MRMS with 1 km resolution for the April 2017 storm

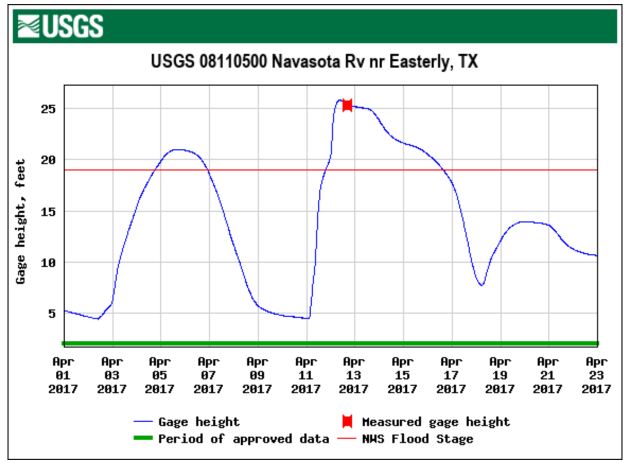


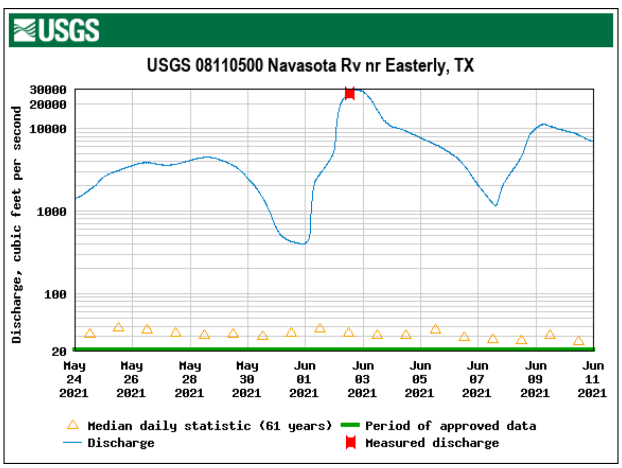
Radar rainfall data from MRMS with 1 km resolution for the June 2021 storm

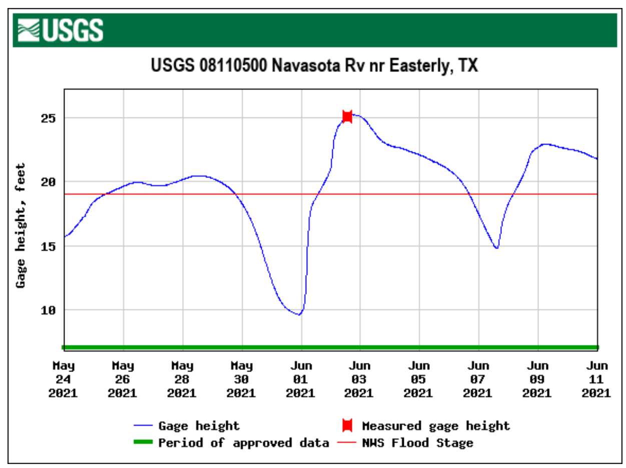


Recorded flow and stage data from USGS Gage 08110500

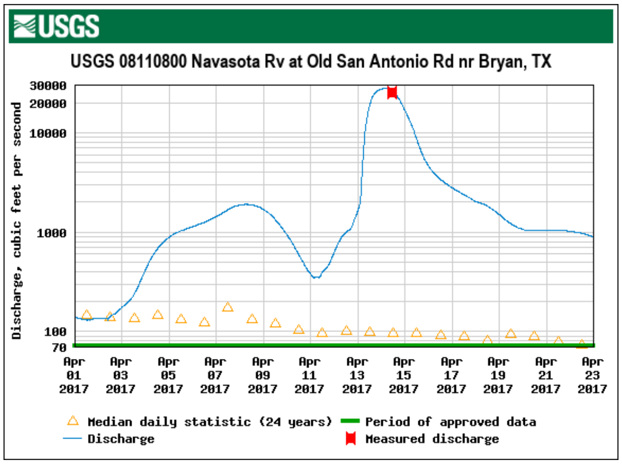


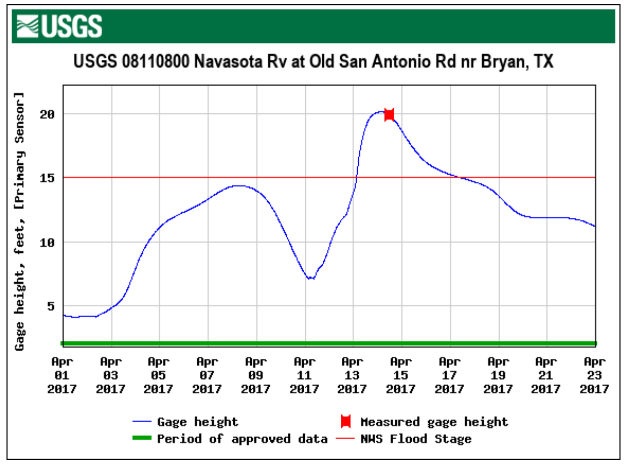


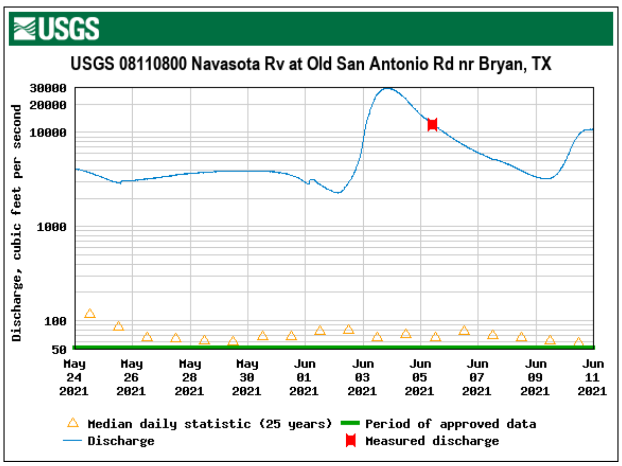


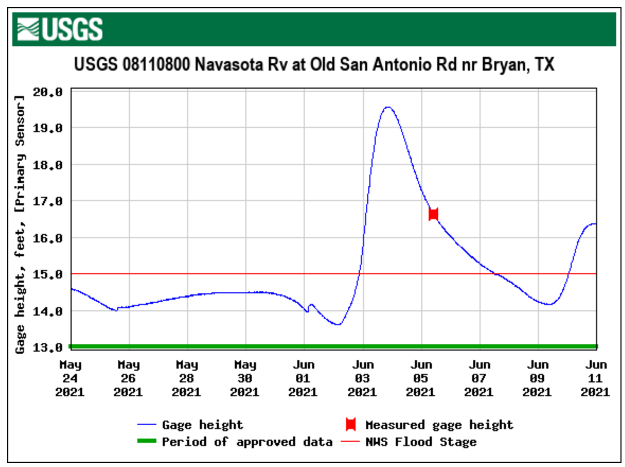


Recorded flow and stage data from USGS Gage 08110800



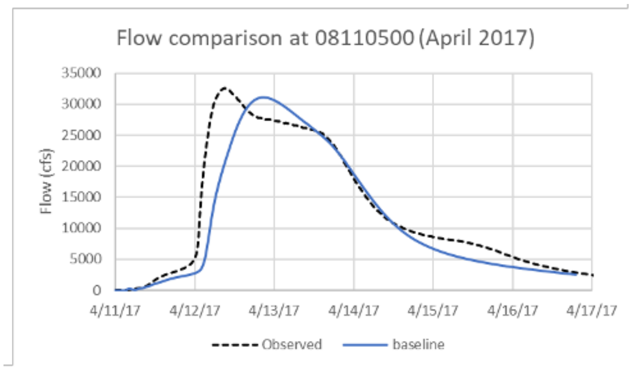


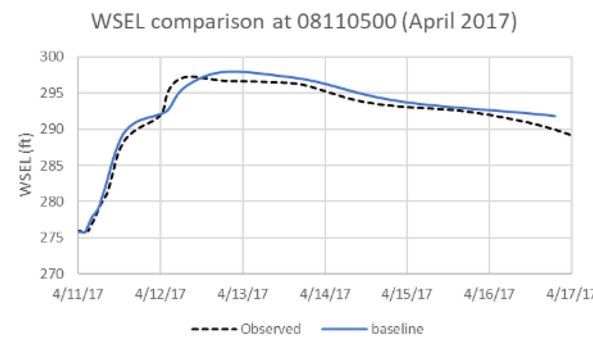


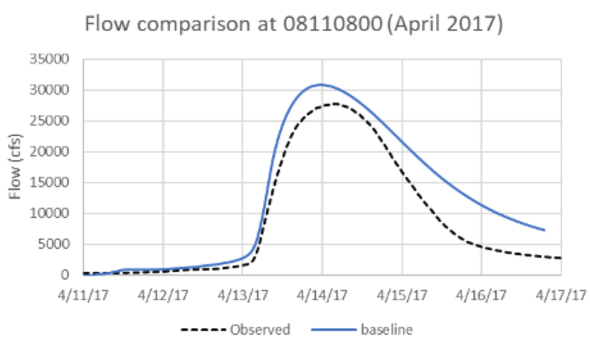


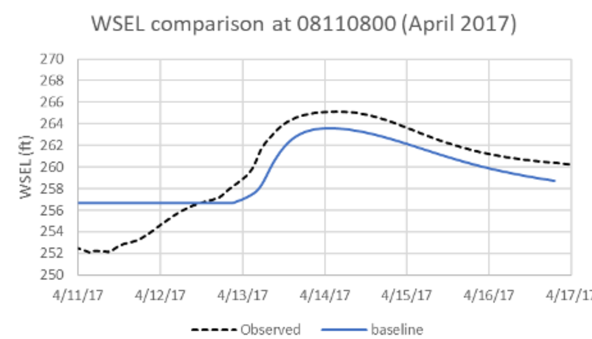
Appendix B: Baseline Model Comparison and Validation

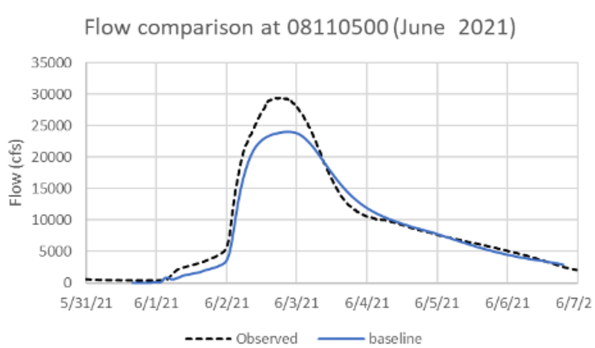
Modeled flow and stage for the April 2017 and June 2021 storms are compared at two USGS gage locations: 08110500 and 08110800.

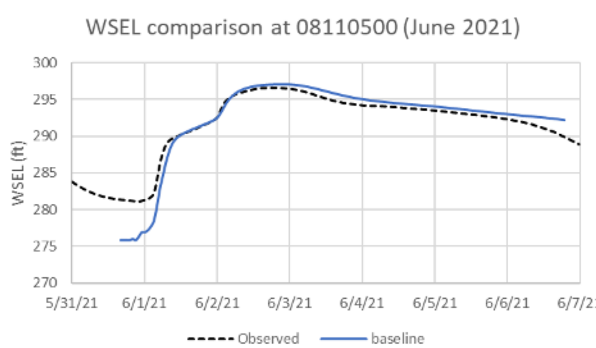


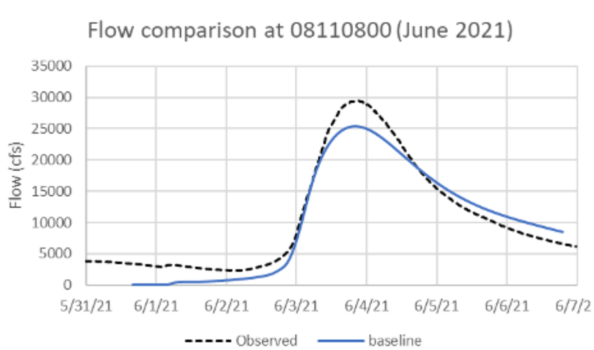


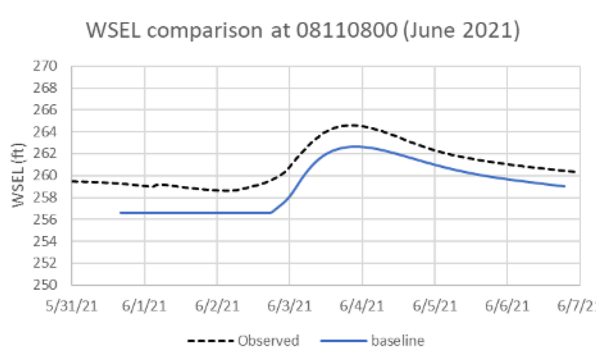








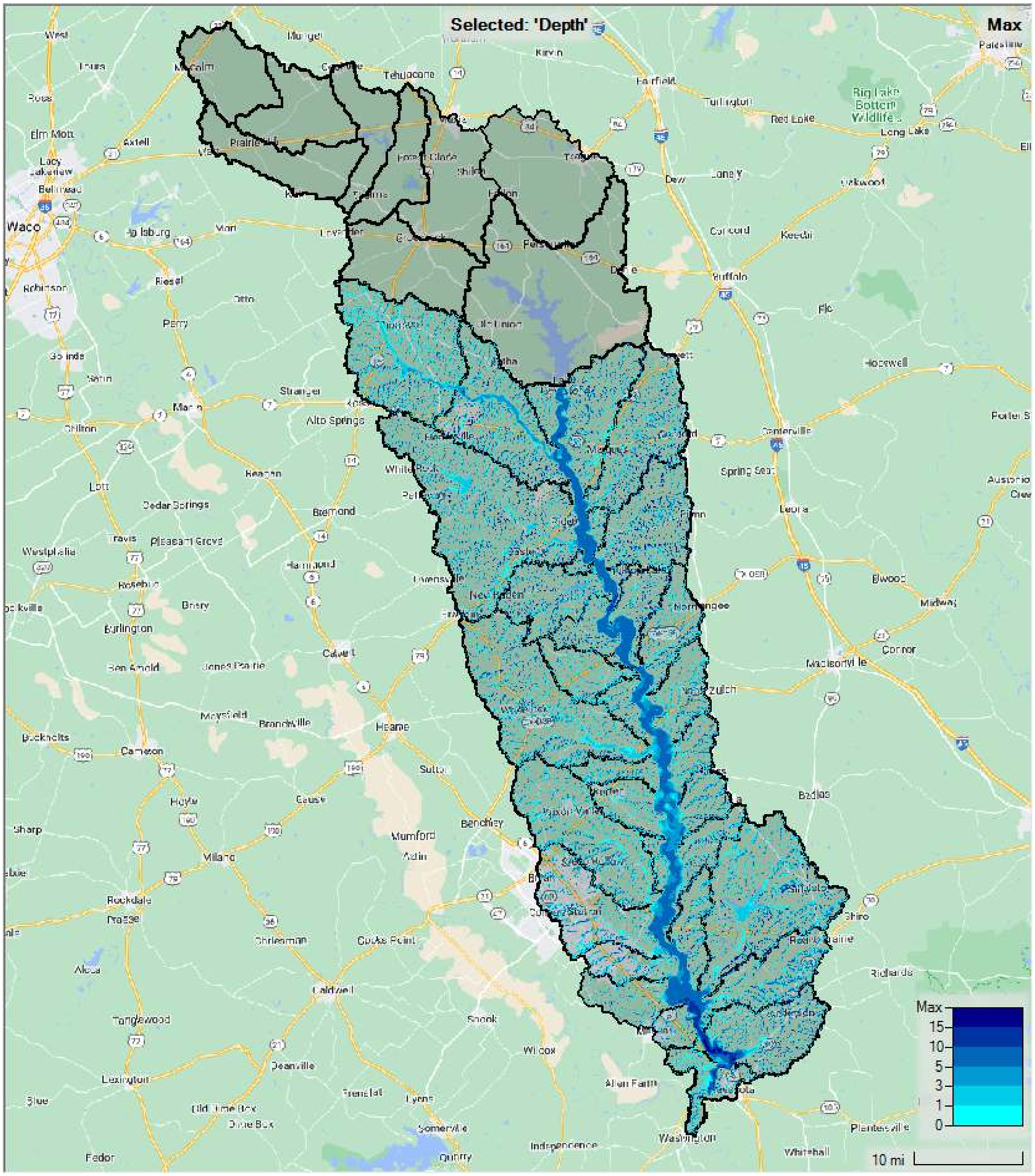




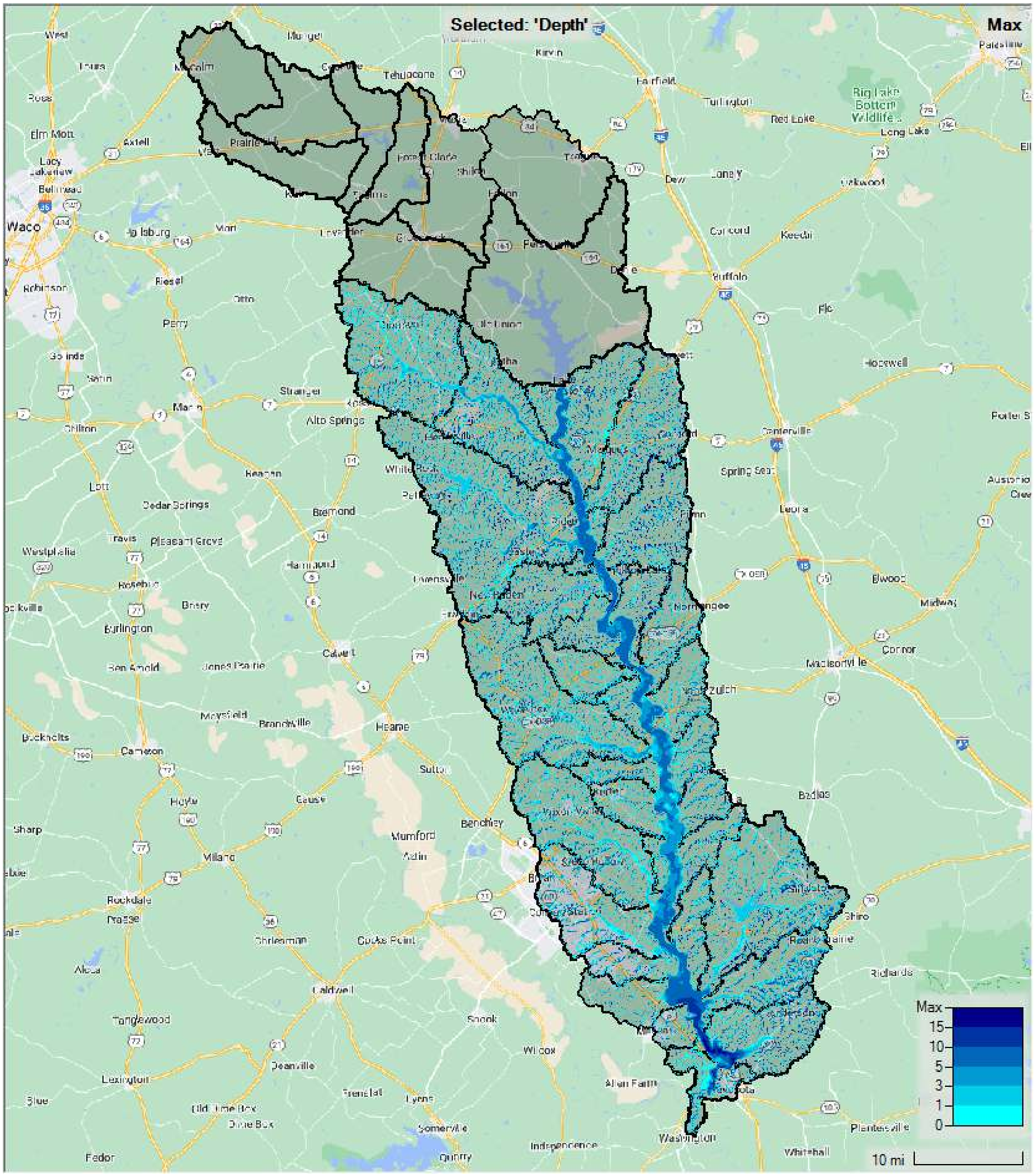
Model validation summary:

	April 2017		June 2021	
	8110500	8110800	8110500	8110800
Flow NSE	0.85	0.83	0.94	0.95
Qp diff (%)	4.6%	-11.1%	18.2%	13.6%
WSE diff (ft)	0.67	-1.48	0.337	-1.83

Baseline scenario modeled flood depth (ft) for the April 2017 storm

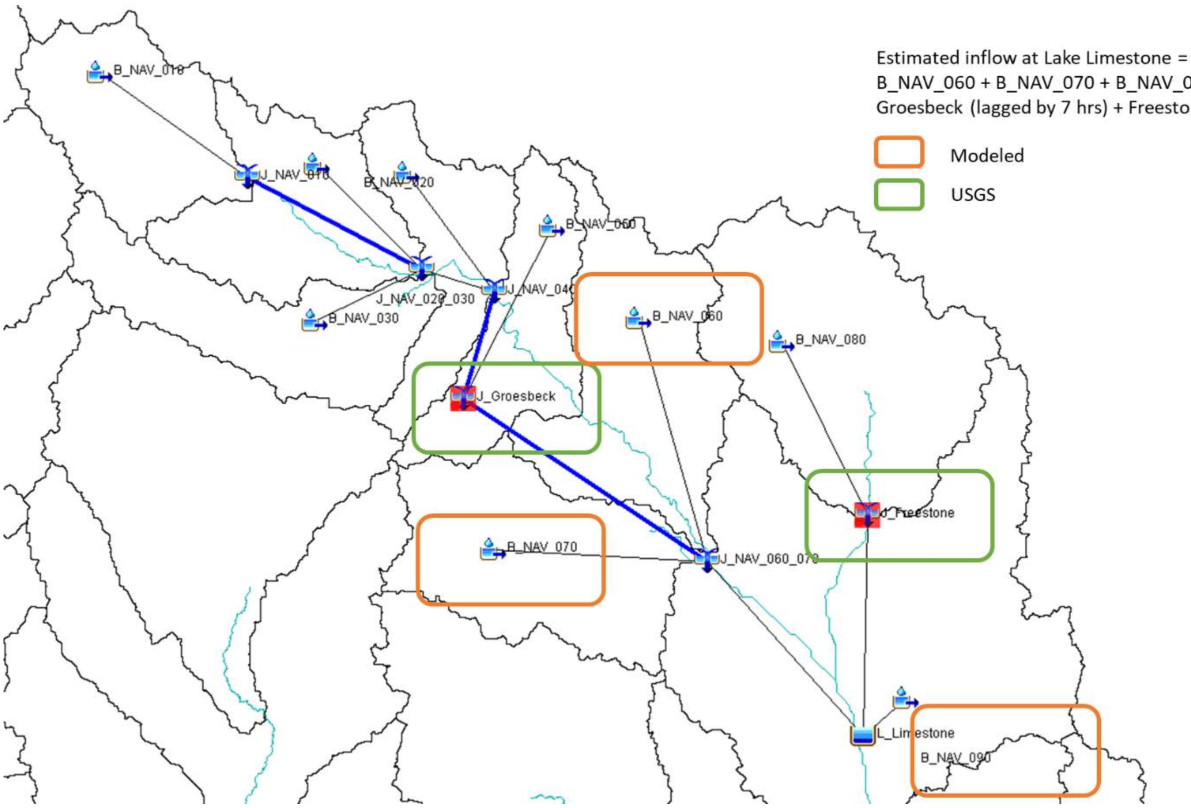


Baseline scenario modeled flood depth (ft) for the June 2021 storm

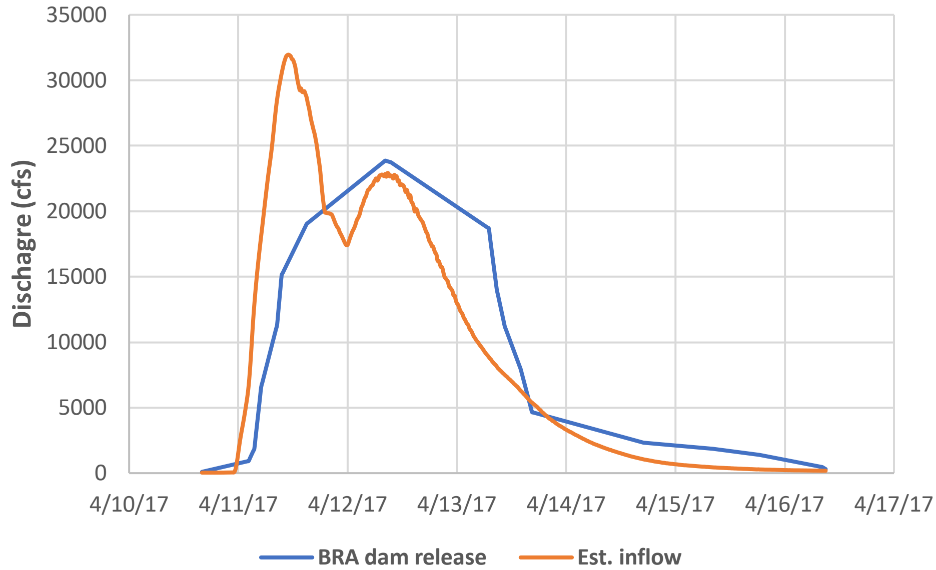


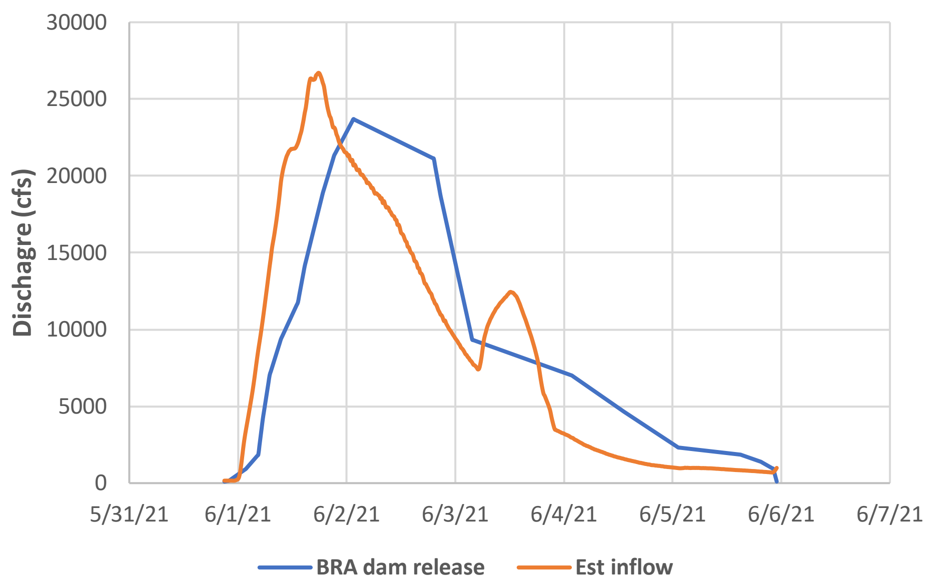
Appendix C: “No Dam” Scenario Development

Modified HEC-HMS model for the "no dam" scenario



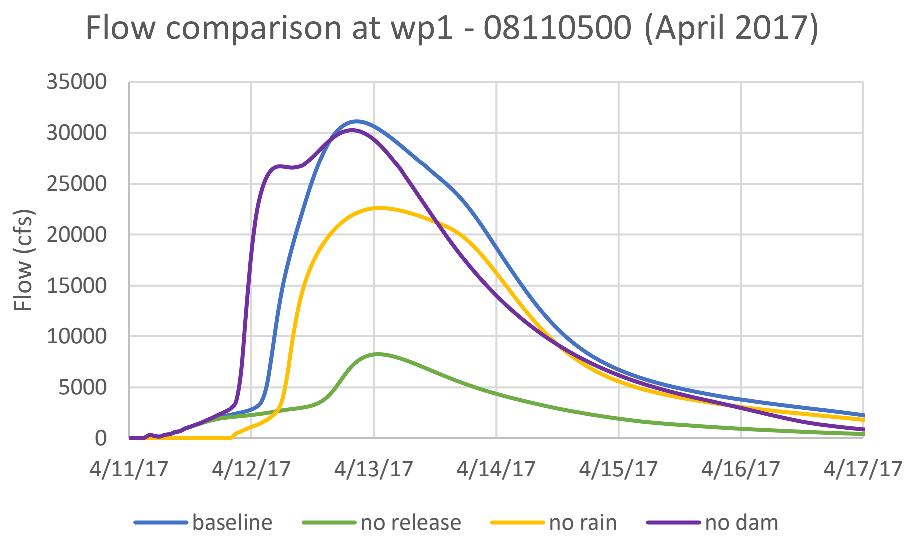
Estimated inflow at Lake Limestone for the April 2017 storm (top) and June 2021 storm (bottom)

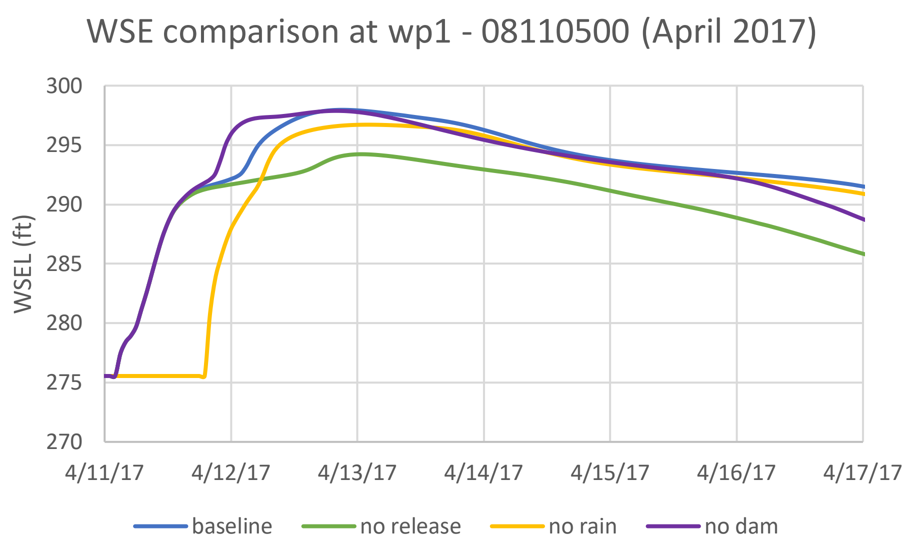


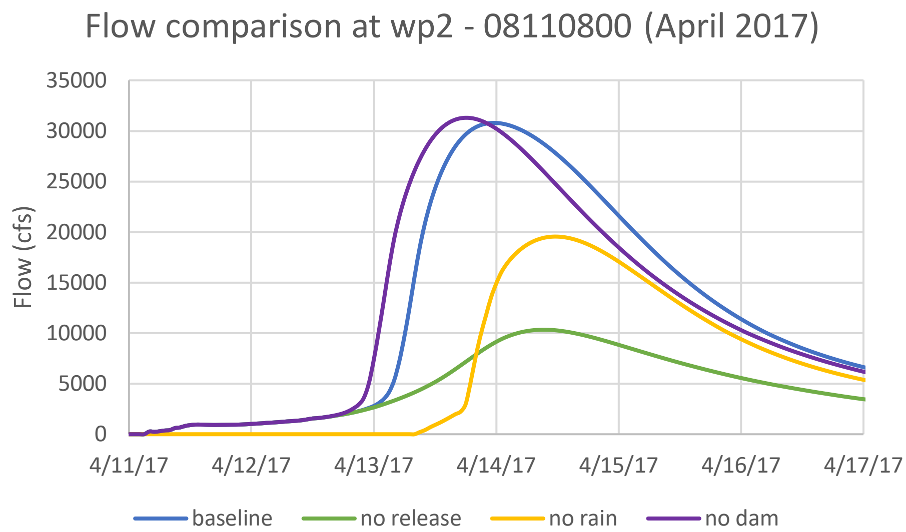


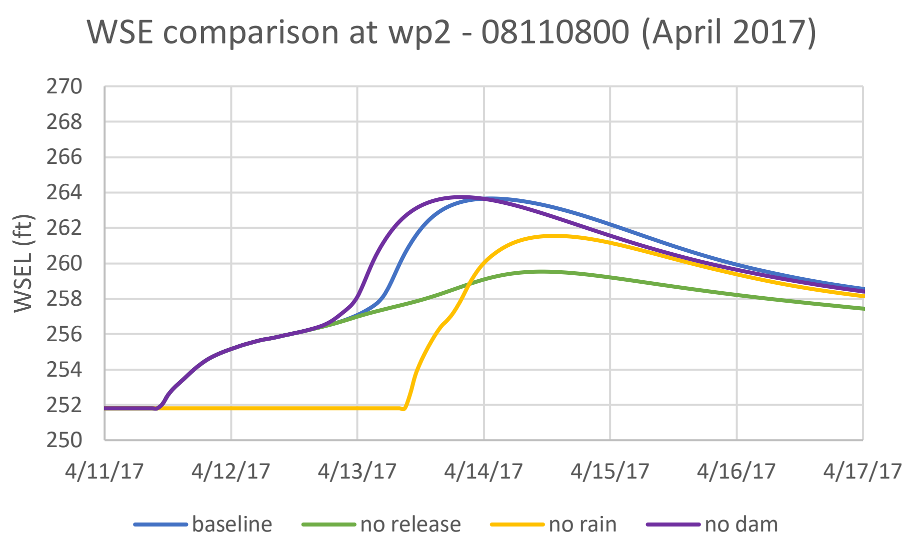
Appendix D: Scenario Comparison

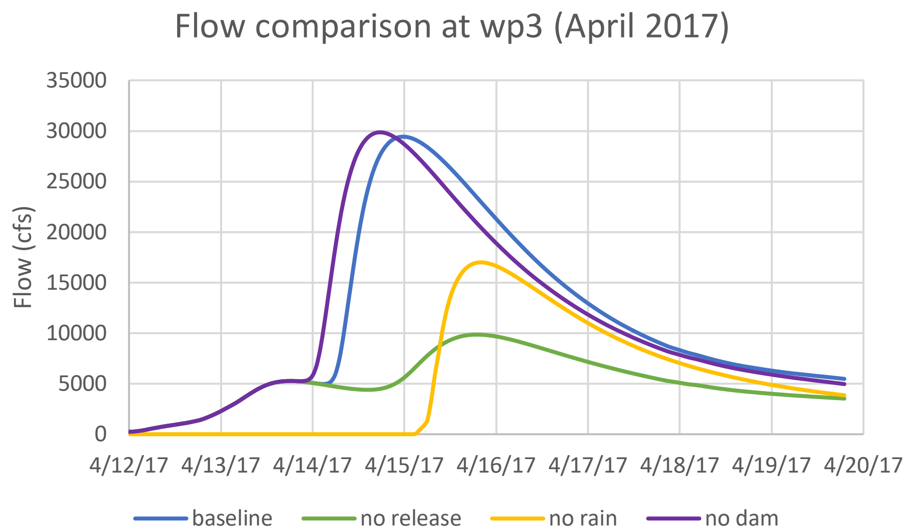
Flow and WSE comparison of modeled baseline scenarios for the April 2017 storm






Flow comparison at wp2 - 08110800 (April 2017)
Flow (cfs)
35000
30000
25000
20000
15000
10000
5000
0
4/11/17
4/12/17
4/13/17
4/14/17
4/15/17
4/16/17
4/17/17
baseline
no release
no rain
no dam


WSE comparison at wp2 - 08110800 (April 2017)
WSEL (ft)
270
268
266
264
262
260
258
256
254
252
250
4/11/17
4/12/17
4/13/17
4/14/17
4/15/17
4/16/17
4/17/17
baseline
no release
no rain
no dam


Flow comparison at wp3 (April 2017)
Flow (cfs)
35000
30000
25000
20000
15000
10000
5000
0
4/12/17
4/13/17
4/14/17
4/15/17
4/16/17
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4/18/17
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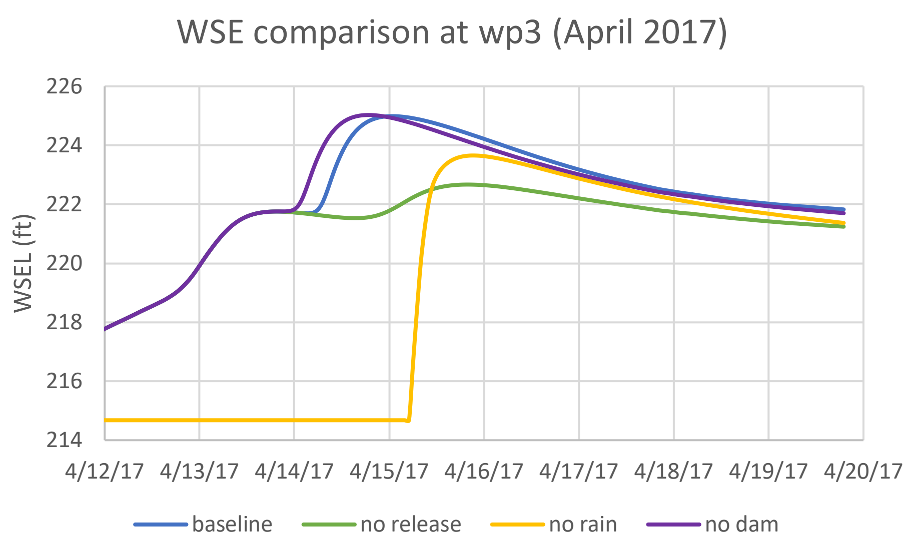
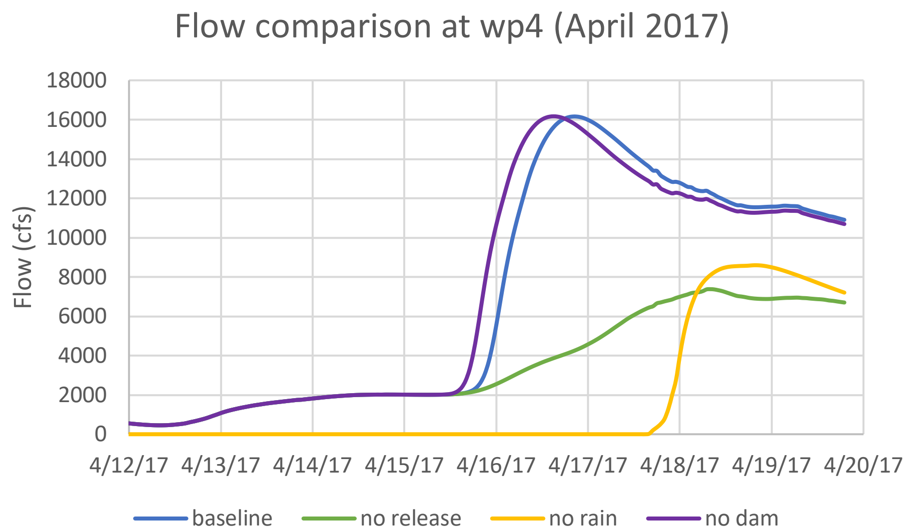
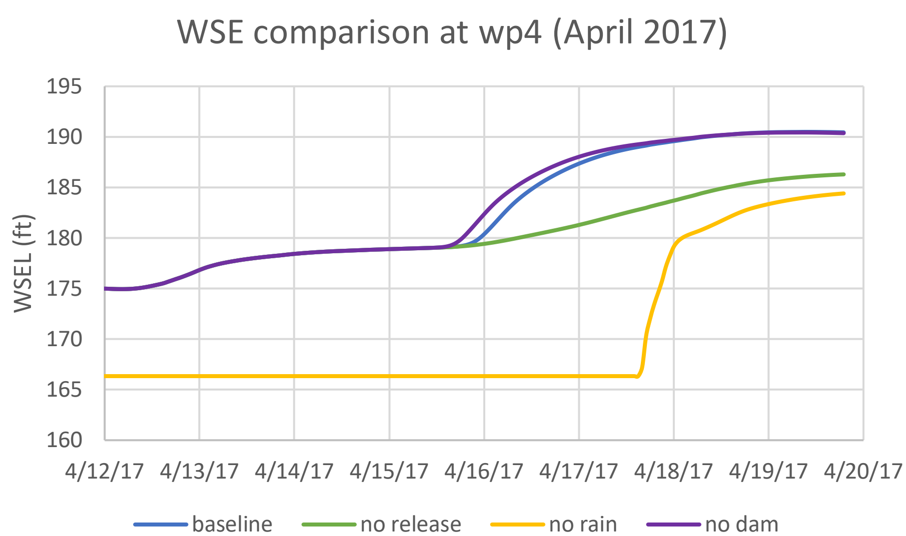
4/20/17
baseline
no release
no rain
no dam


WSE comparison at wp3 (April 2017)
WSEL (ft)
226
224
222
220
218
216
214
4/12/17
4/13/17
4/14/17
4/15/17
4/16/17
4/17/17
4/18/17
4/19/17
4/20/17
baseline
no release
no rain
no dam

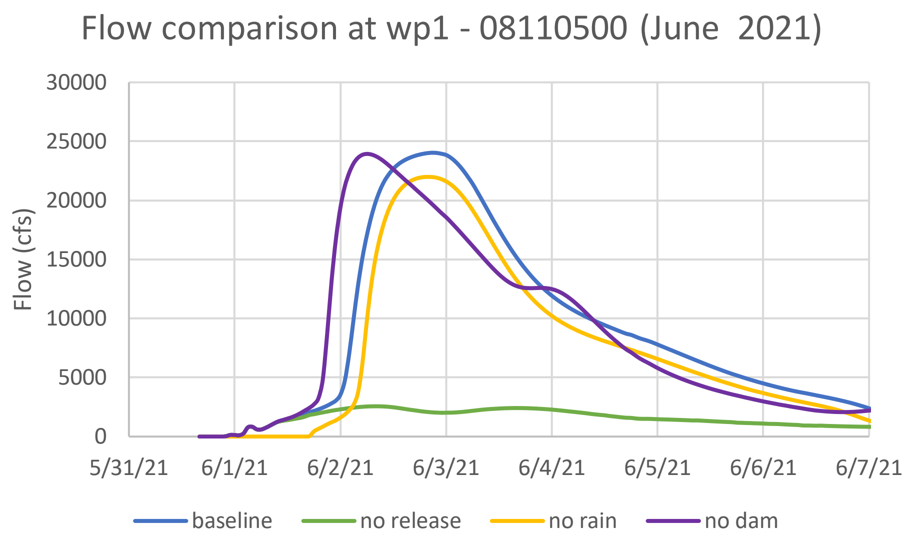


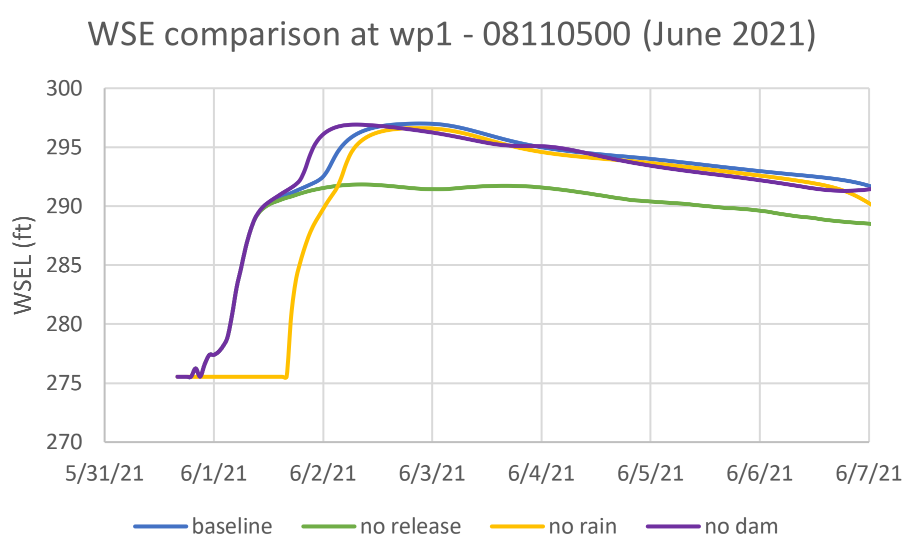
Flow comparison at wp4 (April 2017)
Flow (cfs)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
4/12/17
4/13/17
4/14/17
4/15/17
4/16/17
4/17/17
4/18/17
4/19/17
4/20/17
baseline
no release
no rain
no dam

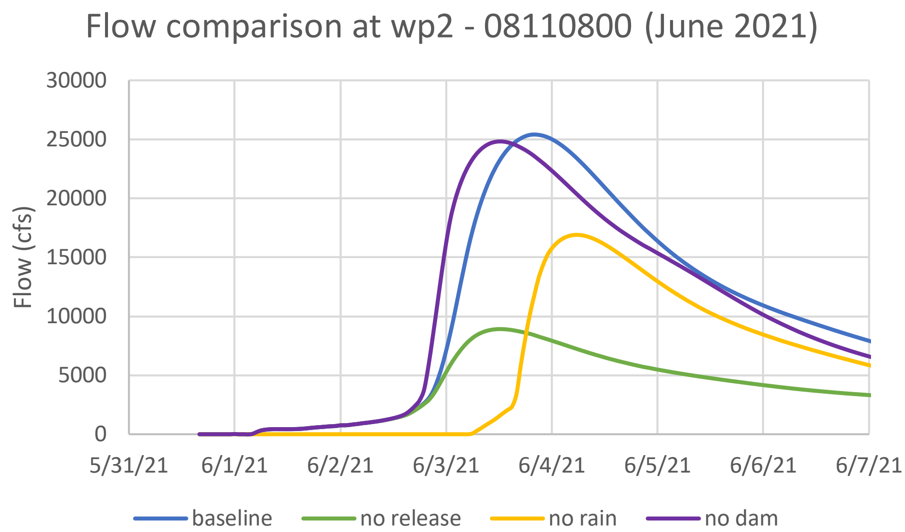


WSE comparison at wp4 (April 2017)
WSEL (ft)
195
190
185
180
175
170
165
160
4/12/17
4/13/17
4/14/17
4/15/17
4/16/17
4/17/17
4/18/17
4/19/17
4/20/17
baseline
no release
no rain
no dam

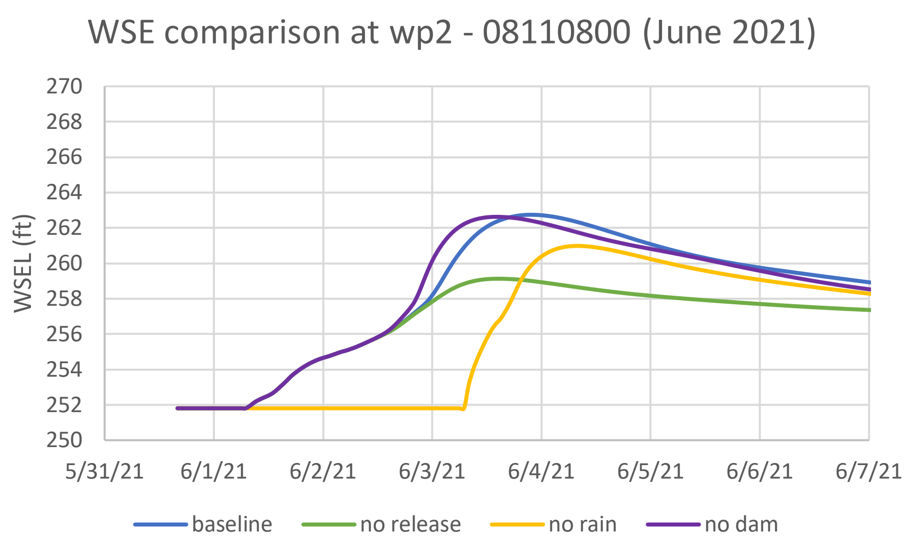
Flow and WSE comparison of modeled baseline scenarios for the June 2021 storm



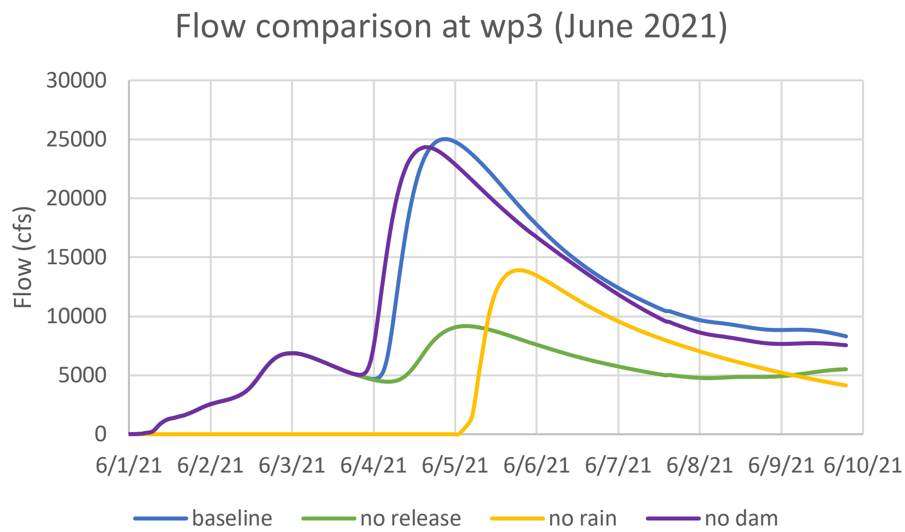




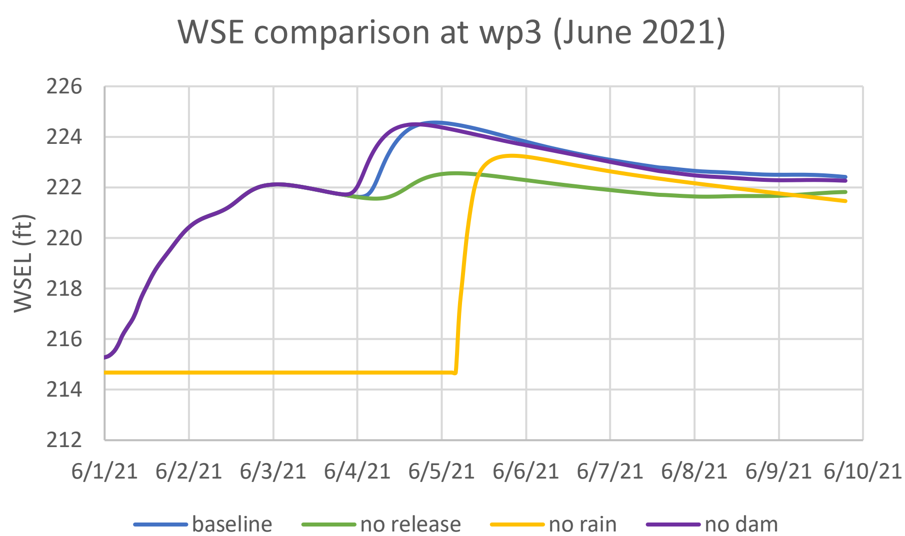
Flow comparison at wp2 - 08110800 (June 2021)
Flow (cfs)
30000
25000
20000
15000
10000
5000
0
5/31/21
6/1/21
6/2/21
6/3/21
6/4/21
6/5/21
6/6/21
6/7/21
baseline
no release
no rain
no dam



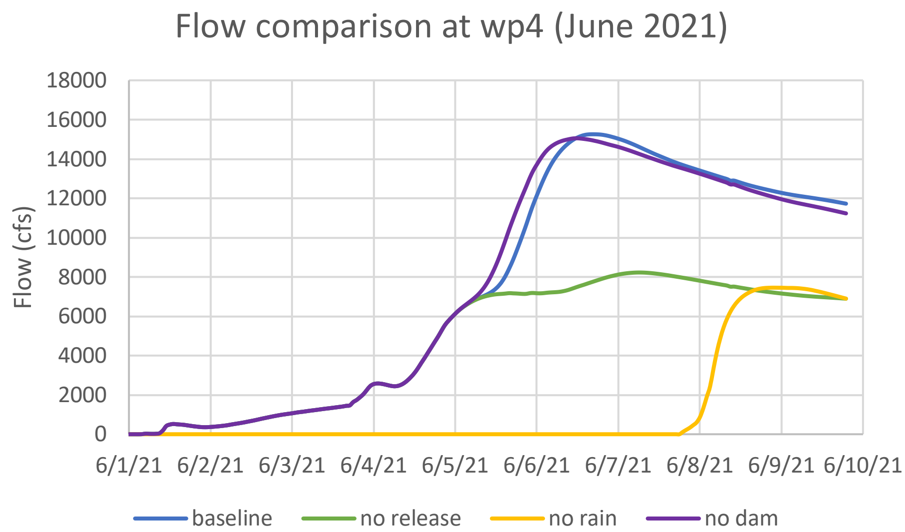
WSE comparison at wp2 - 08110800 (June 2021)
WSEL (ft)
270
268
266
264
262
260
258
256
254
252
250
5/31/21
6/1/21
6/2/21
6/3/21
6/4/21
6/5/21
6/6/21
6/7/21
baseline
no release
no rain
no dam

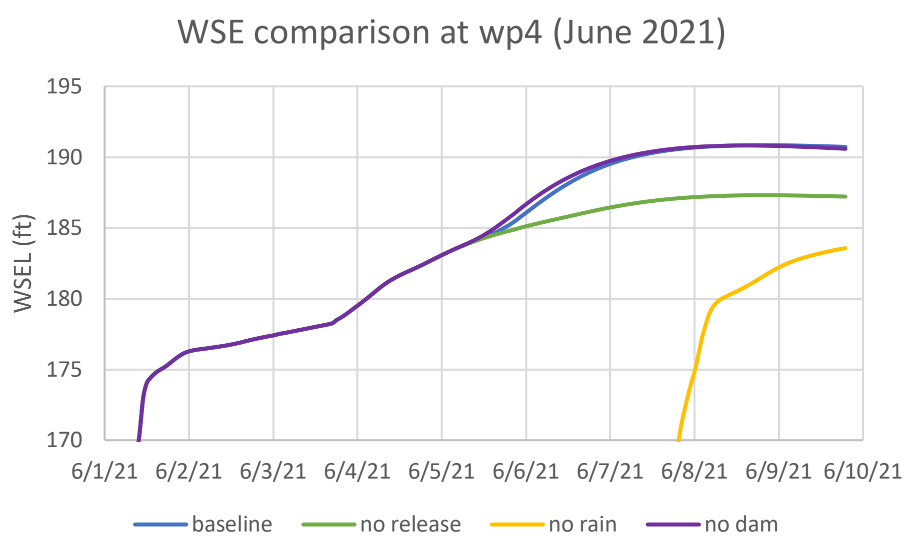


Flow comparison at wp3 (June 2021)
30000
25000
20000
15000
10000
5000
0
Flow (cfs)
6/1/21
6/2/21
6/3/21
6/4/21
6/5/21
6/6/21
6/7/21
6/8/21
6/9/21
6/10/21
baseline
no release
no rain
no dam



WSE comparison at wp3 (June 2021)
226
224
222
220
218
216
214
212
WSEL (ft)
6/1/21
6/2/21
6/3/21
6/4/21
6/5/21
6/6/21
6/7/21
6/8/21
6/9/21
6/10/21
baseline
no release
no rain
no dam


Flow comparison at wp4 (June 2021)
Flow (cfs)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
6/1/21
6/2/21
6/3/21
6/4/21
6/5/21
6/6/21
6/7/21
6/8/21
6/9/21
6/10/21
baseline
no release
no rain
no dam


WSE comparison at wp4 (June 2021)
WSEL (ft)
195
190
185
180
175
170
6/1/21
6/2/21
6/3/21
6/4/21
6/5/21
6/6/21
6/7/21
6/8/21
6/9/21
6/10/21
baseline
no release
no rain
no dam

Modeled Qp and WSEmax for the April 2017 storm (values denoted by * indicate values at the end of simulation)

Watch point	Baseline		No release		No rain		No dam	
	Qp (cfs)	WSEmax (ft)	Qp (cfs)	WSEmax (ft)	Qp (cfs)	WSEmax (ft)	Qp (cfs)	WSEmax (ft)
1	31115	297.96	8244	294.23	22610	296.71	30251	297.88
2	30785	263.66	10334	259.53	19544	261.55	31297	263.74
3	29422	224.99	9851	222.67	16994	223.65	29852	225.03
4	16158	190.50	7378	186.29*	8594	184.41*	16170	190.43

Modeled Qp and WSEmax for the June 2021 storm (values denoted by * indicate values at the end of simulation)

Watch point	Baseline		No release		No rain		No dam	
	Qp (cfs)	WSEmax (ft)	Qp (cfs)	WSEmax (ft)	Qp (cfs)	WSEmax (ft)	Qp (cfs)	WSEmax (ft)
1	24037	297.01	2566	291.84	21990	296.62	23940	296.92
2	25407	262.74	9360*	259.13*	16897	260.98	24818	262.63
3	25018	224.57	9166	222.56	13904	223.25	24327	224.50
4	15256	190.84	8226	187.31	7454	183.57	15051	190.82

Modeled peak flow timing and peak stage timing for the April 2017 storm (values denoted by * indicate values at the end of simulation)

Watchpoint	Baseline		No release		No rain		No dam	
	Qp	WSEmax	Qp	WSEmax	Qp	WSEmax	Qp	WSEmax
1	4/12/17 21:00	4/12/17 21:00	4/13/17 1:00	4/13/17 1:00	4/13/17 1:00	4/13/17 2:00	4/12/17 20:00	4/12/17 20:00
2	4/14/17 0:00	4/14/17 1:00	4/14/17 9:00	4/14/17 11:00	4/14/17 12:00	4/14/17 13:00	4/13/17 18:00	4/13/17 20:00
3	4/15/17 0:00	4/15/17 1:00	4/15/17 19:00	4/15/17 20:00	4/15/17 20:00	4/15/17 21:00	4/14/17 18:00	4/14/17 19:00
4	4/16/17 20:00	4/19/17 9:00	4/18/17 8:00	4/19/17 19:00*	4/18/17 20:00	4/19/17 19:00*	4/16/17 15:00	4/19/17 9:00

Modeled peak flow timing and peak stage timing for the June 2021 storm (values denoted by * indicate values at the end of simulation)

Watchpoint	Baseline		No release		No rain		No dam	
	Qp	WSEmax	Qp	WSEmax	Qp	WSEmax	Qp	WSEmax
1	6/2/21 21:00	6/2/21 21:00	6/2/21 8:00	6/2/21 8:00	6/2/21 20:00	6/2/21 21:00	6/2/21 6:00	6/2/21 7:00
2	6/3/21 20:00	6/3/21 22:00	6/9/21 19:00*	6/9/21 19:00*	6/4/21 6:00	6/4/21 8:00	6/3/21 12:00	6/3/21 14:00
3	6/4/21 21:00	6/4/21 22:00	6/5/21 3:00	6/5/21 4:00	6/5/21 19:00	6/5/21 20:00	6/4/21 16:00	6/4/21 17:00
4	6/6/21 17:00	6/8/21 18:00	6/7/21 6:00	6/8/21 19:00	6/8/21 22:00	6/9/21 19:00*	6/6/21 12:00	6/8/21 14:00

Qp difference (%) against baseline for the April 2017 storm (negative values indicate lower peak flows compared to baseline)

Watchpoint	No release	No rain	No dam
1	-73.5%	-27.3%	-2.8%
2	-66.4%	-36.5%	1.7%
3	-66.5%	-42.2%	1.5%
4	-54.3%	-46.8%	0.1%

Qp difference (%) against baseline for the June 2021 storm (negative values indicate lower peak flows compared to baseline)

Watchpoint	No release	No rain	No dam
1	-89.3%	-8.5%	-0.4%
2	-63.2%	-33.5%	-2.3%
3	-63.4%	-44.4%	-2.8%
4	-46.1%	-51.1%	-1.3%

WSEmax difference (ft) against baseline for the April 2017 storm (negative values indicate lower WSEmax compared to baseline)

Watchpoint	No release	No rain	No dam

1	-3.74	-1.25	-0.09
2	-4.13	-2.11	0.08
3	-2.32	-1.33	0.04
4	-4.21	-6.09	-0.06

WSEmax difference (ft) against baseline for the June 2021 storm (negative values indicate lower WSEmax compared to baseline)

Watchpoint	No release	No rain	No dam
1	-5.17	-0.38	-0.09
2	-3.61	-1.76	-0.12
3	-2.01	-1.31	-0.07
4	-3.54	-7.28	-0.02

Peak time difference (hours) against baseline at selected watchpoints – April 2017 storm (negative values indicate earlier peak times compared to baseline)

Watchpoint	No release		No rain		No dam	
	Qp	WSEmax	Qp	WSEmax	Qp	WSEmax
1	4	4	4	5	-1	-1
2	9	10	12	12	-6	-5
3	19	19	20	20	-6	-6
4	36	10	48	10	-5	0

Peak time difference (hours) against baseline at selected watchpoints – June 2021 storm (negative values indicate earlier peak times compared to baseline)

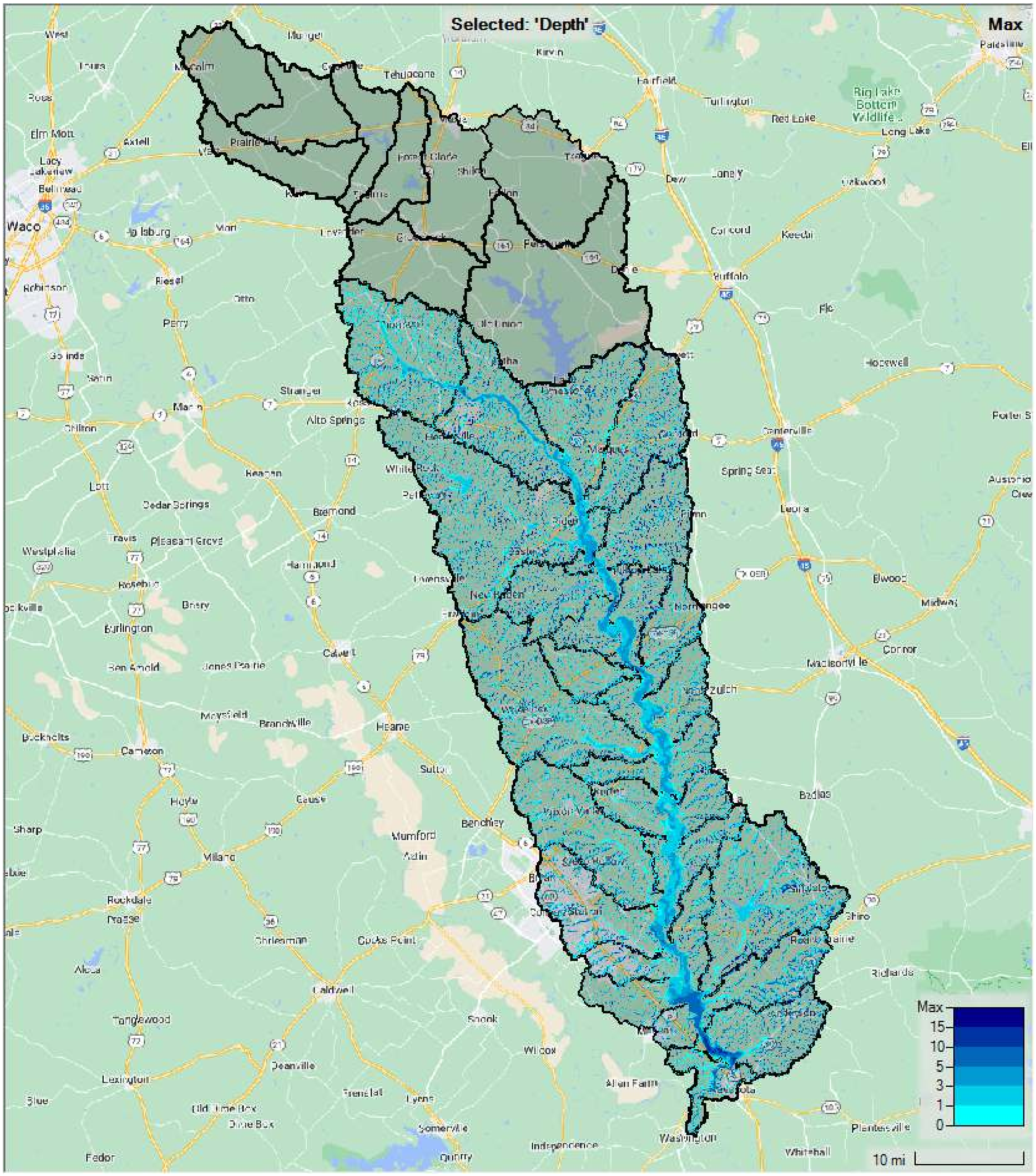
Watchpoint	No release		No rain		No dam	
	Qp	WSEmax	Qp	WSEmax	Qp	WSEmax
1	-13	-13	-1	0	-15	-14
2	143	141	10	10	-8	-8
3	6	6	22	22	-5	-5

4	13	1	53	25	-5	-4

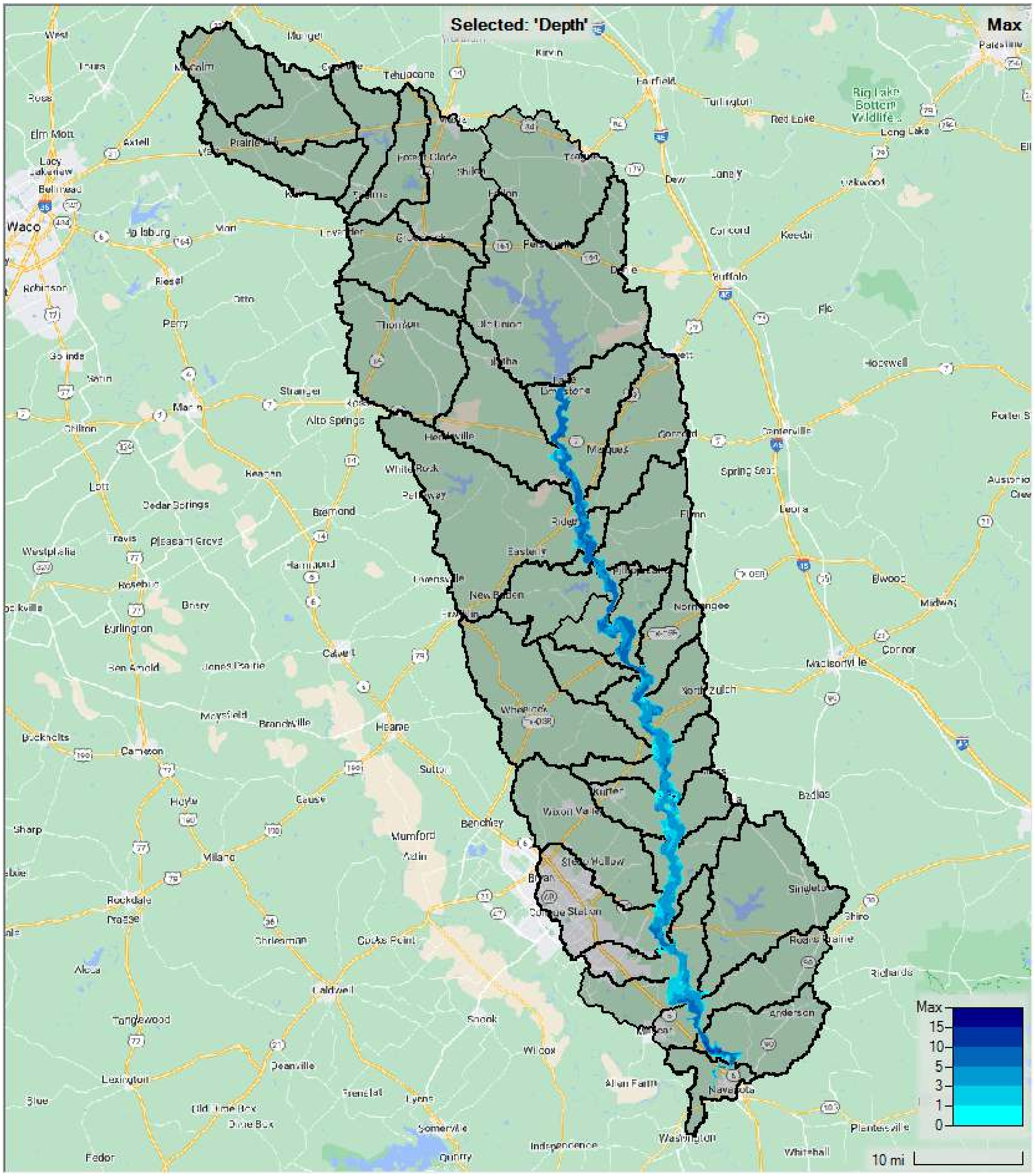
Inundation (WSE above flood stage) duration in hours for Watchpoints 1 (Gage 08110500) and 2 (Gage 08110800)

Watchpoint	April 2017		June 2021	
	Baseline	No dam	Baseline	No dam
1	137	119	190	199
2	63	64	62	64

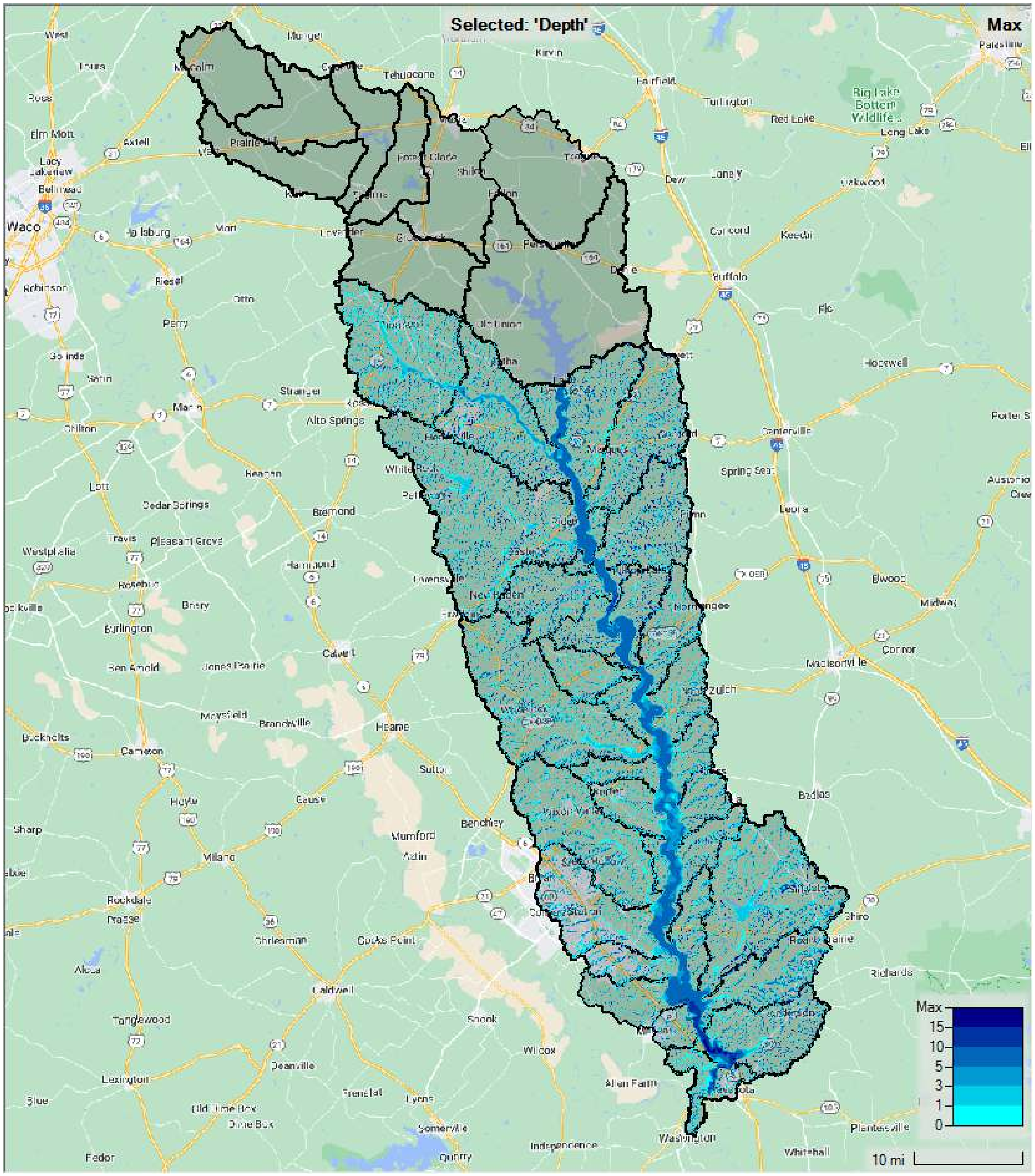
“No release” scenario modeled flood depth (ft) for the April 2017 storm



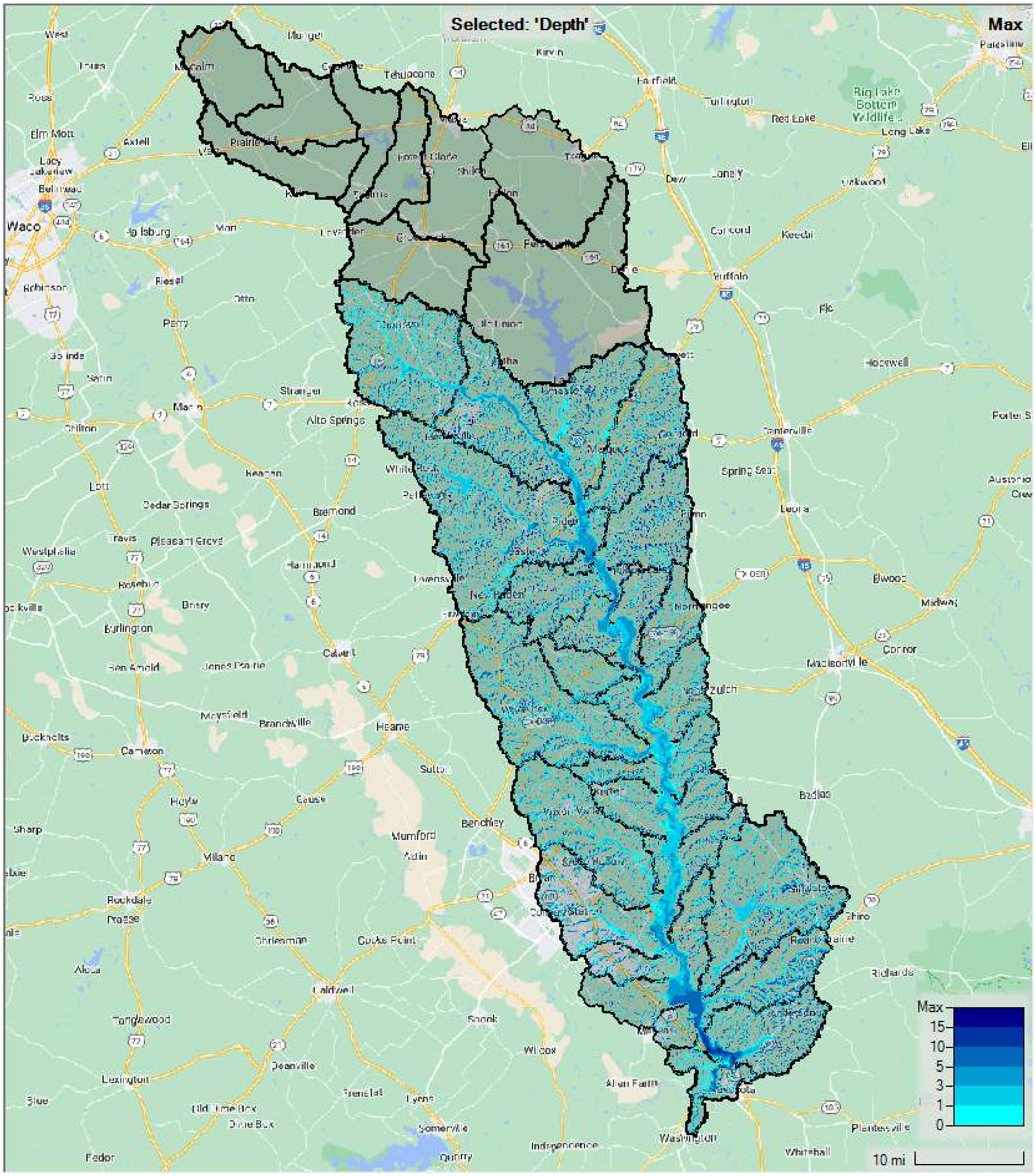
“No rain” scenario modeled flood depth (ft) for the April 2017 storm



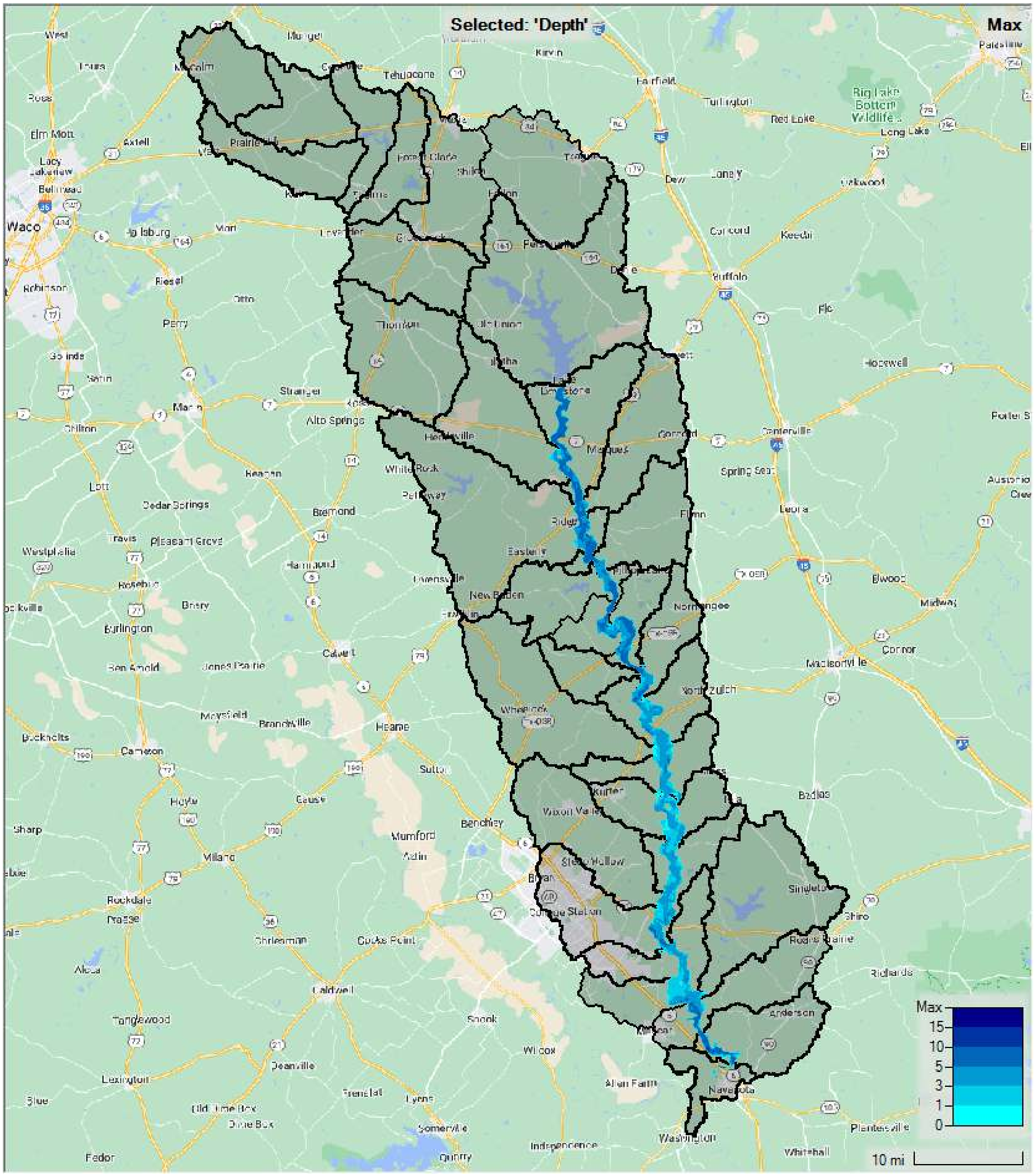
“No dam” scenario modeled flood depth (ft) for the April 2017 storm



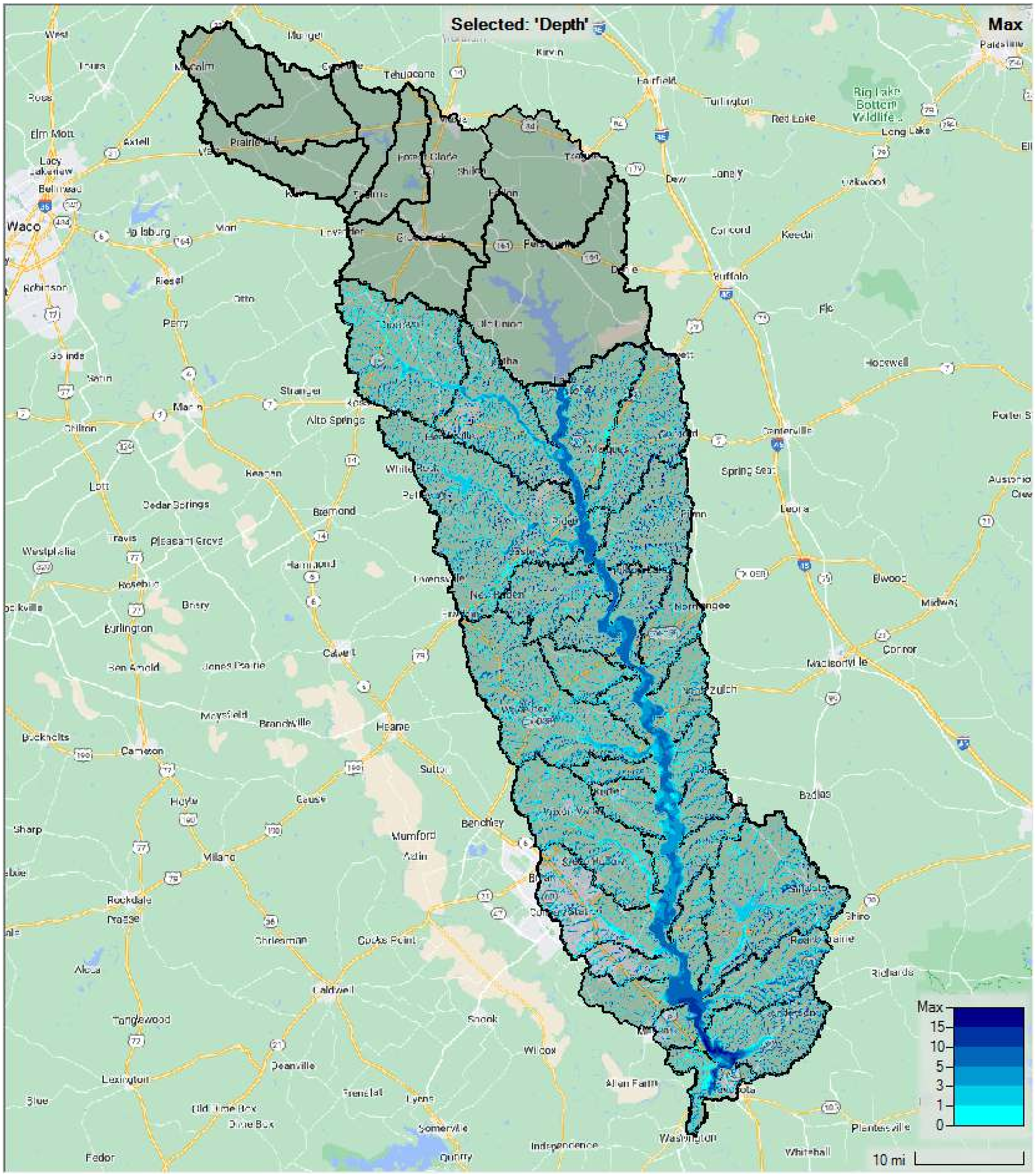
“No release” scenario modeled flood depth (ft) for the June 2021 storm



“No rain” scenario modeled flood depth (ft) for the June 2021 storm



“No dam” scenario modeled flood depth (ft) for the June 2021 storm



[i] Hydrologic Engineering Center. (2022). HEC-RAS River Analysis System (Version 6.2) [Software]. Available from https://www.hec.usace.army.mil/software/hec-ras/

[ii] The National Map Download Client. (n.d.) *Terrain: 2018 Light Detection and Ranging (LIDAR).* [Data set]. U.S. Geological Survey. https://apps.nationalmap.gov/downloader/

[iii] Multi-Resolution Land Characteristics Consortium Viewer. (n.d.) *2016 National Land Cover Database.* [Data set]. Multi-Resolution Land Characteristics Consortium. https://www.mrlc.gov/viewer/

[iv] Soil Survey Staff, Natural Resources Conservation Service. (n.d.) *Soil Data Access: Soil Survey Geographic (SSURGO) Database.* [Data set]. United States Department of Agriculture. https://sdmdataaccess.sc.egov.usda.gov

[v] A. Juan, personal communication, 2022

[vi] U.S. Geological Survey. (n.d.) *USGS 08110500 Navasota Rv nr Easterly, TX.* National Water Information System data (USGS Water Data for the Nation). https://nwis.waterdata.usgs.gov/usa/nwis/peak/?site_no=08110500; U.S. Geological Survey. (n.d.) *USGS 08110800 Navasota Rv at Old San Antonio Rd nr Bryan, TX*. National Water Information System data (USGS Water Data for the Nation). https://nwis.waterdata.usgs.gov/usa/nwis/peak/?site_no=08110800

[vii] Kalyanapu, A.J., Burian, S.J., & McPherson, T.N. (2009). Effect of land use-based surface roughness on hydrologic model output. *Journal of Spatial Hydrology*, *9*(2), 51-71.

[viii] Rawls, W.J., Brakensiek, D.L. and Miller, N. (1983). Green-Ampt infiltration parameters from soils data. *Journal of hydraulic engineering*, *109*(1), 62-70. https://doi.org/10.1061/(ASCE)0733-9429(1983)109:1(62)

[ix] Halff Associates. (2019). *Lower Brazos Flood Protection Planning Study for the Brazos River Authority.* https://brazos.org/Project-Updates/Lower-Brazos-Floodplain-Protection-Planning-Study

[x] U.S. Geological Survey (2022). *Navasota Rv abv Grosbeck, TX*. https://waterdata.usgs.gov/monitoring-location/08110325

[xi] U.S. Geological Survey (2022). *Navasota Rv nr Freestone, TX*. https://waterdata.usgs.gov/monitoring-location/08110430