A Supplemental Report Issued Following Hurricane Harvey

Examination of Selected Assertions by U.S. EPA in the Proposed Remedial Action Plan for the San Jacinto River Waste Pits Superfund Site

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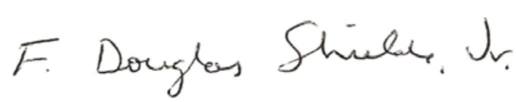

1 Introduction

In late 2016 I was engaged to provide comments on selected assertions within the Proposed Remedial Action Plan (PRAP, U.S. EPA 2016a) for the San Jacinto River Waste Pits Superfund Site (Site) regarding the long-term stability of the armored cap (TCRA Armored Cap), constructed as part of the Time Critical Removal Action (TCRA) at the Site in the face of fluvial and coastal processes. I was also asked to similarly consider the area located on a peninsula south of Interstate 10 (Southern Impoundment). My response to that request was completed on or about January 10, 2017 and submitted as part of the comments of McGinnes Industrial Maintenance Corporation and International Paper Company on the PRAP (*see* Appendix D of "Comments of International Paper Company and McGinnes Industrial Maintenance Corporation on U.S. Environmental Protection Agency Region 6 Proposed Remedial Action Plan," referred to herein as the "January 2017 Report"). More recently I was asked to re-examine my findings in light of new information and experience obtained as a result of Hurricane Harvey. This supplemental report details that re-examination. I do not repeat points made in the January 2017 Report.

I visited the Site and its environs on September 21, 2017. Locations visited and georeferenced digital photos taken on that date are indexed in Figure 1 (all Figures are grouped at the end of this document). In addition, I have examined stage (water level) and discharge (rate of water flow) data collected during the storm, Site monitoring data collected since the storm, satellite and aerial photos taken before, during and after the storm, and output from a hydrodynamic computer model (Anchor QEA 2010) that was used to simulate water depths and current velocities in the river corridor in which the Site is located during the flood event associated with the passage of Hurricane Harvey (Keith et al. 2017).

2 Hurricane Harvey hydrologic data

Hurricane Harvey was an extreme event and its occurrence creates an unusual opportunity to test assertions regarding long-term stability of the TCRA Armored Cap in the face of extreme hydrologic events and stresses. Since the storm stalled over the Texas Gulf Coast for several days, rainfall totals were unprecedented. High flow durations and magnitudes were extreme, and the relatively low level of storm surge produced higher hydraulic gradients than for storms with significant surge. Initial posts from the National Oceanic and Atmospheric Administration (NOAA) (https://www.climate.gov/news-features/event-tracker/reviewing-hurricane-harveys-catastrophic-rain-and-flooding, accessed 2017.09.27) regarding the magnitude of the rainfall event indicate it exceeded the 500-year event. "Houston observed two of its wettest five days ever on back to back days August 26 and 27." About 24 inches of rain fell in two days at Houston Hobby Airport. A total of 43.38 inches of rain were reported for Houston. Furthermore,

> … an official analysis of whether rainfall amounts in Harvey were a 1-in-500-year event or 1-in-1000 will have to wait for the time being. However, Dr. Sanja Perica, chief of the National Weather Service's Hydrometeorological Design Studies Center, has noted that preliminary estimates for the area suggest that some locations likely received rainfall amounts that have a 0.1 (one in a thousand) percent chance of occurring in any year.

> Analysis from other groups also came to similar conclusions. As noted by the Washington Post, in an analysis of the highest one-day rainfall amounts done by Shane Hubbard of the University of Wisconsin, such a large amount of rain falling over a one-day period has a 0.1% chance of occurring in any given year. Analysis of the five-day rainfall amounts by the company MetSat found that five-day rainfall totals on par with Harvey's had a 0.004% to 0.0002% chance[1] of occurring in any given year[2].

Discharge records for the Lake Houston Dam (*see* Figure 2a) indicated a peak discharge of 334,400 cubic feet per second on August 29, 2017. This discharge is about 82% of the value computed for the 0.2% chance (500-year return interval event) for this location (FEMA 2107). Stage measurements by the United States Geological Survey (USGS) and posted to the web by the National Weather Service at the U. S. Highway 90 bridge were incomplete, but indicated that the peak stage exceeded 28.5 ft, some 18.5 ft above flood stage (Figure 2b), and stage data collected by the USGS at the I-10 bridge which is immediately south of the TCRA Armored Cap, indicated that passage of the storm produced peak stages 12 ft above the base flow stage (Figure 2c).

3 Visual reconnaissance

On September 21, 2017, I visited the Site vicinity, including both the TCRA Armored Cap, the Southern Impoundment, and key locations where overbank flows and attendant erosion had been reported either following Hurricane Harvey or following the 1994 flood. Visible erosion in the area of the TCRA Armored Cap was minor, and reports of inspections of the underwater portions of the Armored Cap indicated very minor movement of protective stone (Keith 2017). No erosion was evident at the Southern Impoundment. Notable erosion, sand deposition, and damage to infrastructure (roads, bridges and buildings) was noted at three other locations, which were 1.25 to 4 miles from the TCRA Armored Cap as shown in Figure 1. The most notable erosion was associated with river overflow across meander necks through depressions or pools associated with inlets, pits and ponds left in the floodplain from aggregate mining, and lakes. However, there were no permanent river channel movements or avulsions associated with the Hurricane Harvey event.

4 Satellite imagery and computer model

To supplement my January 2017 Report analysis of maps and aerial photographs, I examined two types of satellite imagery, both with nearly cloud-free coverage prior to and immediately after Hurricane Harvey:

1. Color infrared 10 meter resolution imagery from the Sentinel Satellite of the European Space Agency. Pre-flood coverage is from April 24, 2017 and post-flood is from October 1,

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[1] Equivalent to a probability of 1 in 25,000 to 1 in 500,000

[2] See http://metstat.com/hurricane-harvey-extraordinary-flooding-for-houston-and-surrounding-areas/ for additional information on rainfall event frequency estimates.

2017 (*see* Figure 3a-d). Stages recorded for the San Jacinto River at Sheldon, Texas for these dates were comparable, although subject to variation due to tides. Bankline change due to erosion and deposition is difficult to detect with this resolution, but major avulsions of the base flow channel would be readily evident, and none are apparent. Also, the color infrared image presents a strong contrast between water (bright blue) and sediment (bright white). Sediments deposited along the channel and floodplain during the Hurricane Harvey event are prominently depicted. Comparison of the pre- and post-flood images was facilitated by computer-generated contrast images that depicted regions of increased post-flood reflectivity in a bright yellow color (*see* Figures 4a-d).

2. Natural color 3 meter resolution imagery from the PlanetScope Scene coverage from planet.com. Pre-flood coverage was dated August 20, 2017 while post flood coverage from September 29, 2017 was used (*see* Figure 5). Stages recorded for the San Jacinto River at Sheldon, Texas for these dates were comparable, although subject to variation due to tides. Comparison was facilitated by a feature of the planet.com web page that allows scrolling back and forth through side-by-side adjacent images (Figure 5). Close-up images of specific locations where bank erosion was noted are provided in Figures 6a-c.
3. I also examined output from the 2D hydrodynamic model produced by Anchor QEA that was initially developed to support design of the TCRA Armored Cap. Specifically, the output I considered was for a recent simulation of the Hurricane Harvey flood event run to hindcast depths, velocities and shear stresses on the TCRA Armored Cap and its environs (Keith et al. 2017). A map of the reach in which the Site is located indicating maximum bed shear stresses computed by the hindcast model is provided in Figure 7.

Floodplains

Comparison of the color infrared images confirmed impressions made by the on-the-ground visual inspection (Figures 3 and 4). Channel activity was limited to a reach beginning about 2.3 miles below the Lake Houston Dam to about 5.3 miles below the dam and that reach begins about 1.9 miles above the existing TCRA Armored Cap (straight-line distances). Fresh sediment deposits were more common than erosion; both along the channel margins, in the form of mid-channel bars, and in overbank areas subjected to flow (Figures 3a-d and 4a-d). Floodplain erosion and deposition associated with overbank flows existed in the same locations (Rio Villa in Banana Bend oxbow and Highland Shores in Banana Bend) as for the 1994 flood (Figure 3c), which were described in my January 2017 Report. There was also some floodplain erosion associated with overbank flow about 1.25 miles due east of the TCRA Armored Cap (Figure 3d) that was noted in the on-the-ground reconnaissance (Figure 1). However, as in 1994, eroded overbank channels did not capture river baseflow, and the river returned to its pre-flood channel as the flood receded (Figure 3a).

Channel banks

No major bank erosion was noted. The alignments of concave banks on the outside of bends were stable. Comparison of pre- and post-flood satellite imagery indicated bank erosion at three locations between the Lake Houston Dam and Muleshoe Lake, which is about 4.3 miles (straight line distance) upstream from the TCRA Armored Cap (Figure 6a-c). Channel width changes were limited to a reach extending about 0.6 miles up- and downstream of the U. S.

Highway 90 bridge, about 5.2 miles northwest of the existing TCRA Armored Cap (Figure 6b and c). The lack of erosion and deposition in the reach in which the Site is located (Figures 3d and 4d) was consistent with output from a 2D hydrodynamic computer model that was used to simulate passage of the Hurricane Harvey event (hindcasting). Maximum simulated shear stresses along the shorelines and banks in this reach during the Hurricane Harvey event were generally well below 1 Pa = 0.02 lb/sq ft (Figure 7), implying that they were less than levels that would initiate erosion of floodplain soils (Fischenich 2001) and generally below reported levels needed to erode cohesive bank sediments (Clark and Wynn 2007, Enlow et al. 2017).

TCRA Armored Cap

The Anchor computer model hindcast the peak Hurricane Harvey storm hydraulic stresses on the TCRA Armored Cap and indicates that maximum current velocities approached but did not exceed those used in the TCRA design (depth-averaged current velocities of 6.9 ft/s simulated vs. 8.5 ft/s used in design) (Keith et al. 2017, Anchor QEA 2010). These results are consistent with the very minor displacement of stones in the TCRA Armored Cap that were detected following Hurricane Harvey.

5 Observations at the Site

Post-flood bathymetric surveys revealed 5-12 ft of scour in the river channel along the eastern side of the TCRA Armored Cap but outside the boundary of the cap and minor changes in the area of the Armored Cap itself (Keith and Verduin 2017). No impacts on the Southern Impoundment were noted.

6 Re-examination of January 2017 Report Findings

Dynamism of the San Jacinto River

As noted above, the flows associated with Hurricane Harvey represent a most extreme event and a historical worst case with regard to floodplain erosion. Coupled with the extreme total precipitation, the relatively low storm surge produced maximum hydraulic loadings along the river corridor. Despite this loading, severe erosion and deposition were limited to regions distant from the TCRA Armored Cap, and did not result in any changes in the alignment of the river channel.

Despite the severe test that Hurricane Harvey represented, the integrity of the TCRA Armored Cap itself was not compromised. Scour occurred in the river channel adjacent to the eastern border of the cap but did not impact the integrity of the Armored Cap itself. Furthermore, during a Spring 2016 high flow event, a similar but smaller scour zone developed immediately north of this one and was remediated using placement of geotextile and riprap. The 2016 work was not disturbed by Hurricane Harvey, showing the efficacy of these standard engineering measures (i.e., thickened toe, gradual slopes, adequate size and quality stone riprap, and well designed and placed geotextile) to protect a future enhanced cap at the Site.

Threat from ongoing fluvial processes

The PRAP asserts that, "These changes (i.e., loss of land at the waste pits site due to erosion and subsidence) will likely continue in the future." My examination of evidence available since Hurricane Harvey occurred yields no change in my earlier response to this assertion regarding changes due to land subsidence; my response remains that subsidence processes are no longer operative in locations within the Site. However, Hurricane Harvey represents a historical worst case with regard to floodplain erosion. Examination of the aforementioned pre- and post-flood satellite imagery did not reveal any land loss in the vicinity of the TCRA Armored Cap or the Southern Impoundment or in the river reach within which the Site is located (Bear Lake to Buffalo Bayou). Consistent with these results, storm impacts to the TCRA Armored Cap were minor, limited to extremely small areas, and occurred in areas in which smaller materials were called for as part of the TCRA Armored Cap design (Keith 2017). If the temporary TCRA Armored Cap, constructed using smaller materials and with less robust design withstood Hurricane Harvey, then a permanent cap (such as the one proposed by the USACE in the PRAP) that is well-engineered should provide adequate protection from future fluvial and coastal processes.

Utility of models

The PRAP asserted that computer models have limited utility in predicting future erosion and river channel changes. While I have no new information to add to my previous response on this point, I note that the actual data and observations produced by Hurricane Harvey are more valuable than computer simulations. The integrity of the TCRA Armored Cap in the face of this event, as noted above, should produce greater confidence in well-designed solutions for stabilization in place.

Uncertainty regarding future climate

Finally, the PRAP noted that, "Future storm intensity and flooding may be even more intense due to climate change, sea level rise, and continued urban development." The only amendment needed to my original response to this point is that even under a future climatic regime, the precipitation event associated with Hurricane Harvey was a rare, extreme event and therefore provides an indication of how a well-designed and constructed cap and associated perimeter protection would fare in future storms. In addition, future fluvial and coastal processes may be ameliorated by future sea level rise and natural sediment deposition as noted in my previous report.

7 References

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Keith, D. 2017. Post Hurricane Harvey Maintenance to the Time Critical Removal Action Armored Cap, San Jacinto River Waste Pits Superfund Site, Channelview, Texas. Letter dated September 15, 2017 to Gary Miller, Remedial Project Manager, U. S.EPA, Region 6, Dallas Texas. Anchor QEA, Ocean Springs, MS.

Keith, D. and Verduin, J. 2017. Plan for Armor Rock Placement Adjacent to the Time Critical Removal Action Armored Cap, San Jacinto River Waste Pits Superfund Site, Channelview, Texas. Letter dated September 21, 2017 to Gary Miller, Remedial Project Manager, U. S.EPA, Region 6, Dallas Texas. Anchor QEA, Ocean Springs, MS.

Figure 1. Locations inspected on 9/21/2017. Photographs represent observed extreme erosion.

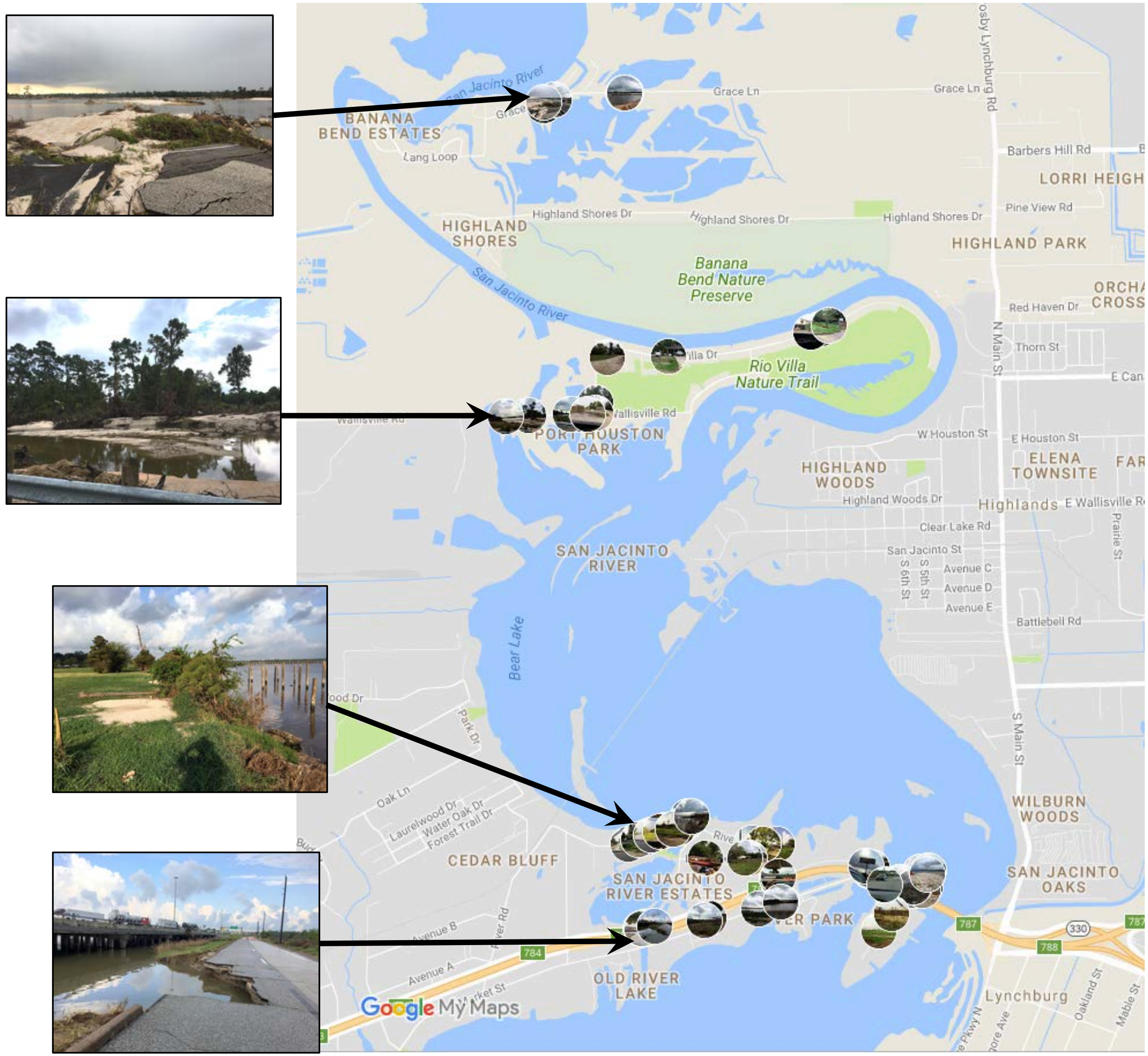
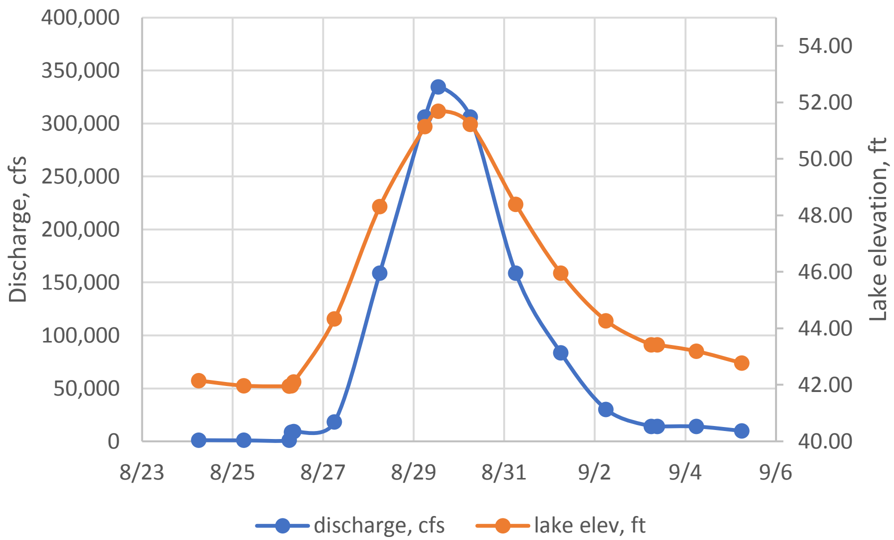
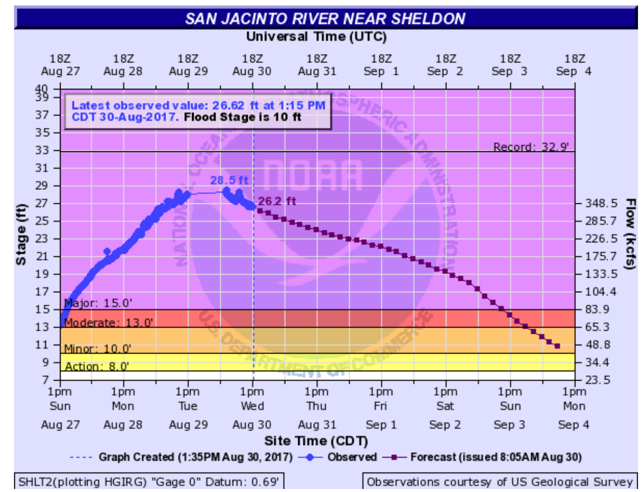


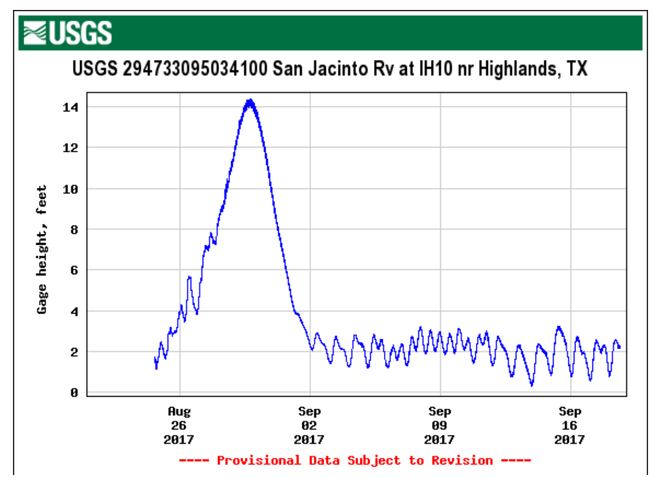
Figure 2. Stage and discharge data for San Jacinto River during Hurricane Harvey.



a. Lake Houston Dam discharges and Lake Houston stage from Coastal Water Authority (CWA).

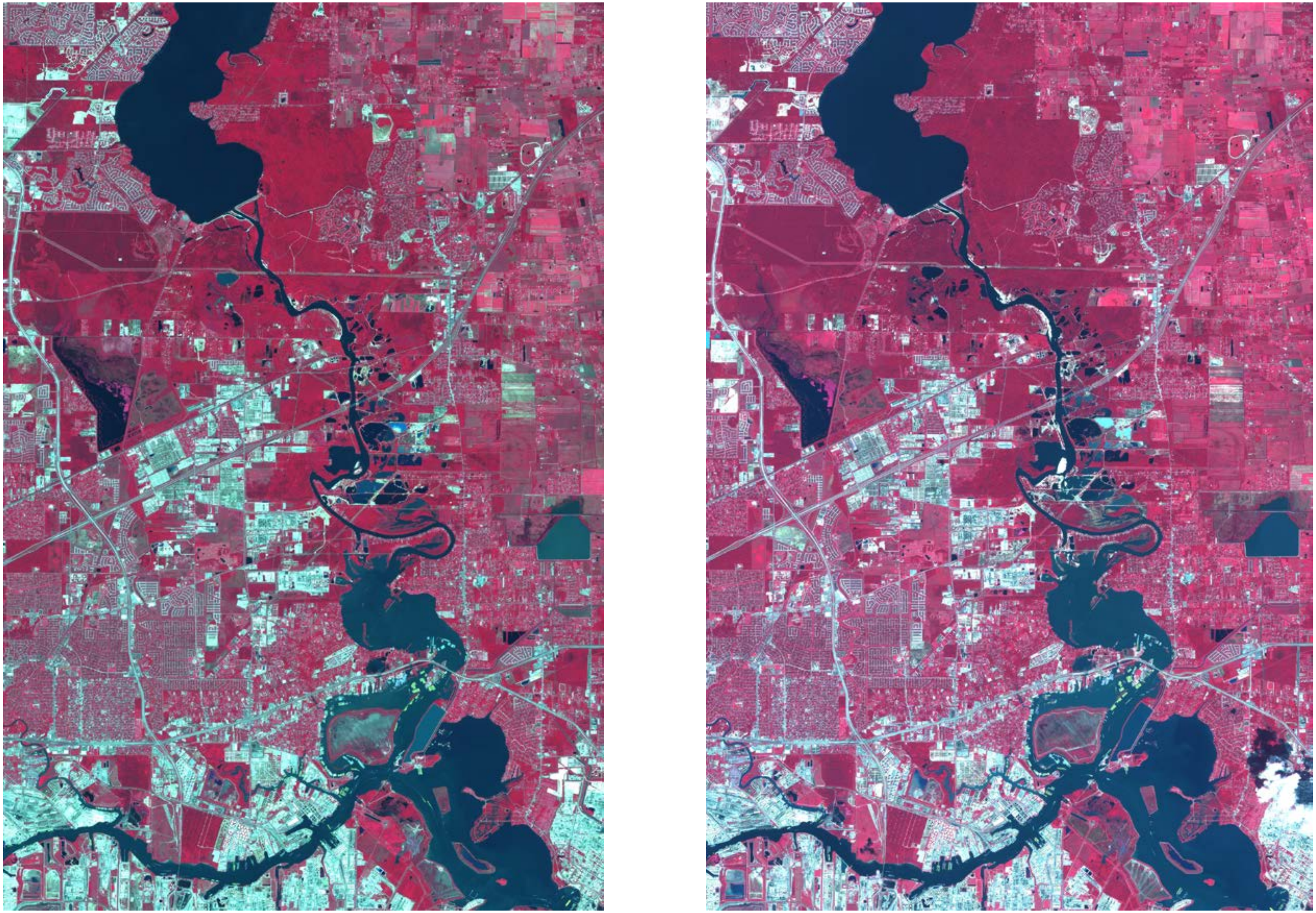


b. San Jacinto River stages at US Highway 90 bridge from National Weather Service.



c. San Jacinto River stages at Interstate Highway 10 bridge from USGS.

Figure 3. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Color infrared imagery from Sentinel, European Space Agency.

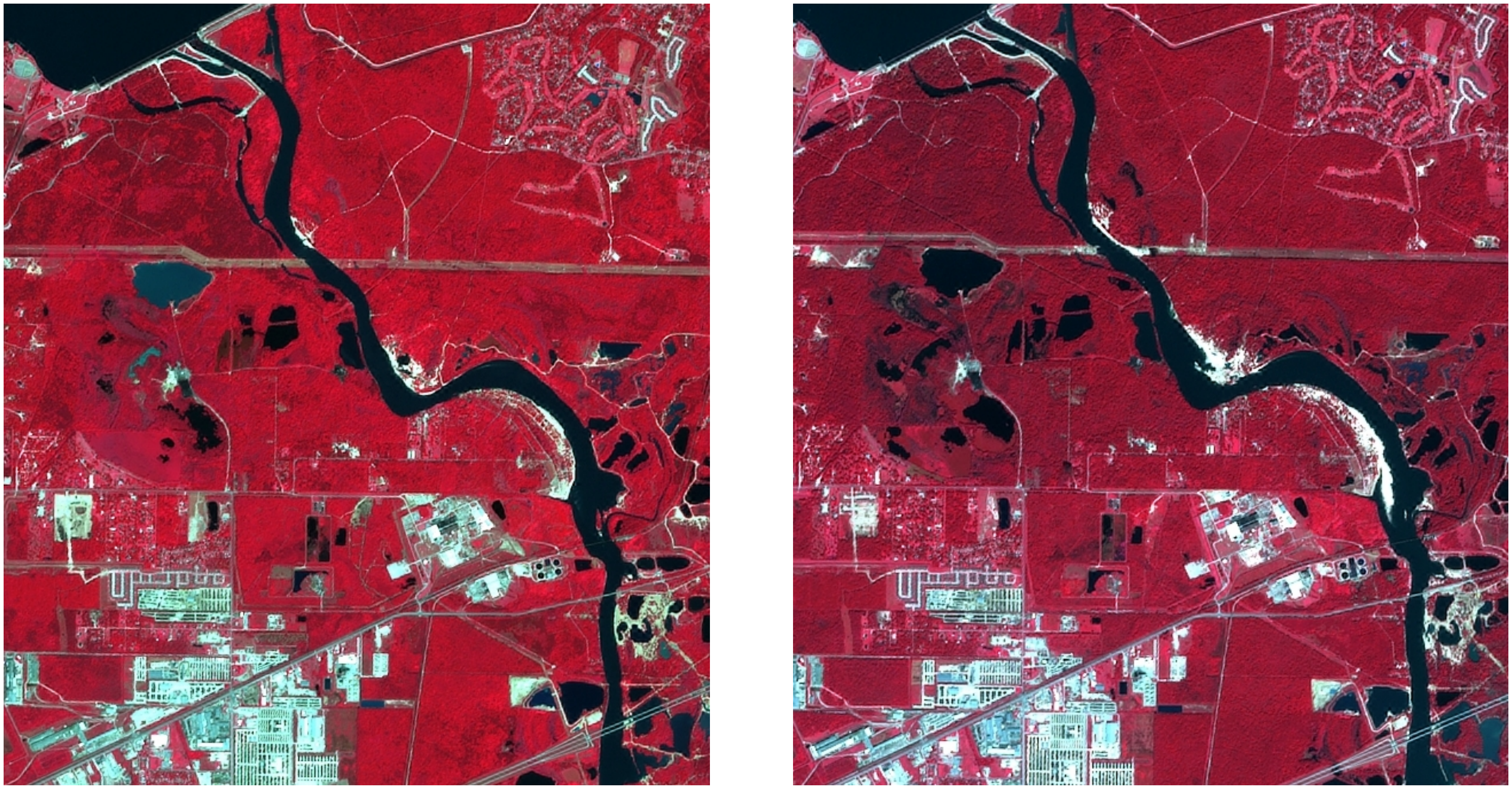


April 24, 2017

October 24, 2017

a. Lake Houston Dam to Buffalo Bayou

Figure 3. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Color infrared imagery from Sentinel, European Space Agency.



April 24, 2017

October 1, 2017

b. Lake Houston Dam to US Highway 90

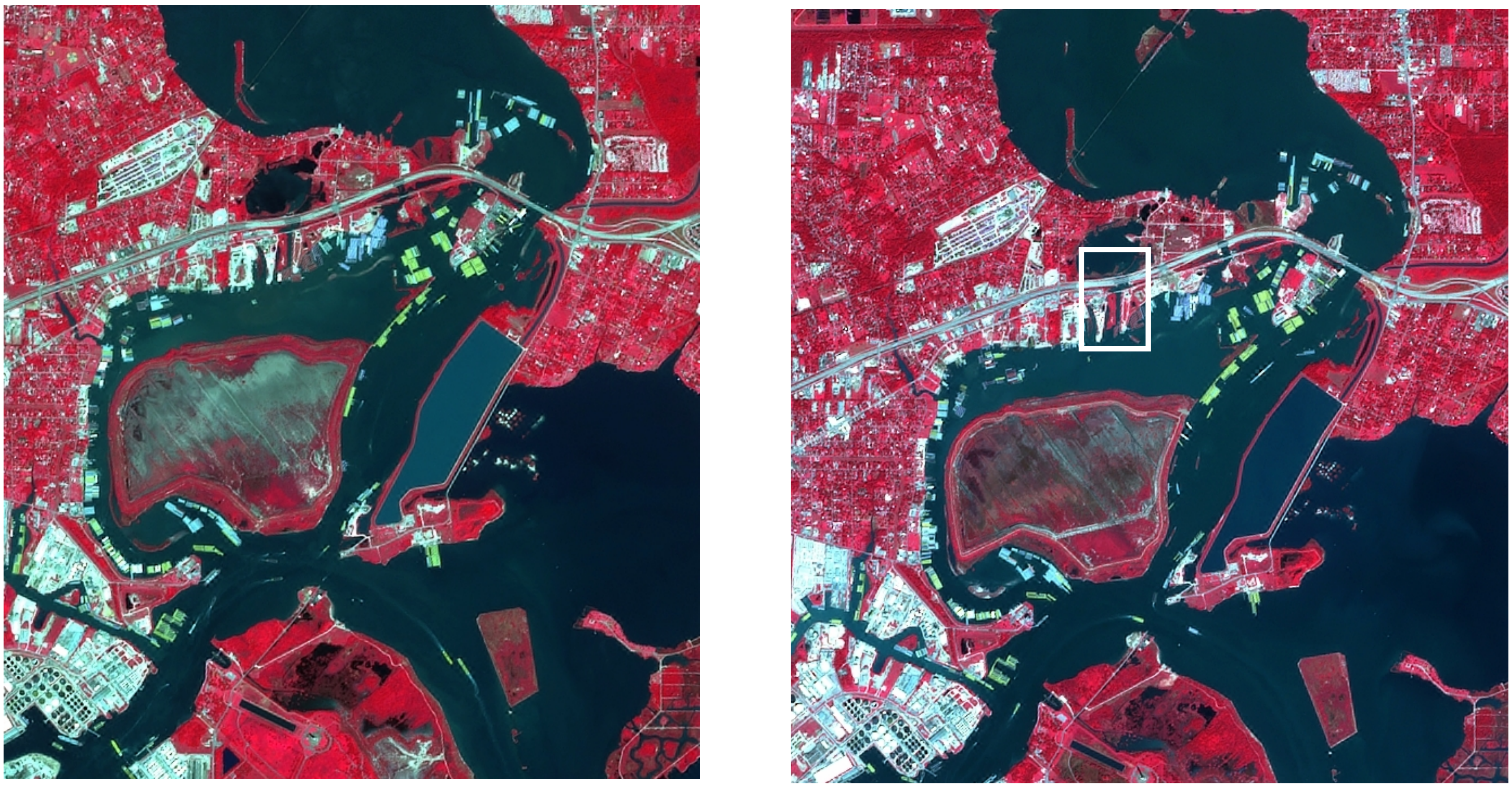
Figure 3. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Color infrared imagery from Sentinel, European Space Agency.

April 24, 2017

October 1, 2017

c. US Highway 90 to Bear Lake. White rectangles in October image highlight floodplain erosion and deposition.

Figure 3. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Color infrared imagery from Sentinel, European Space Agency.

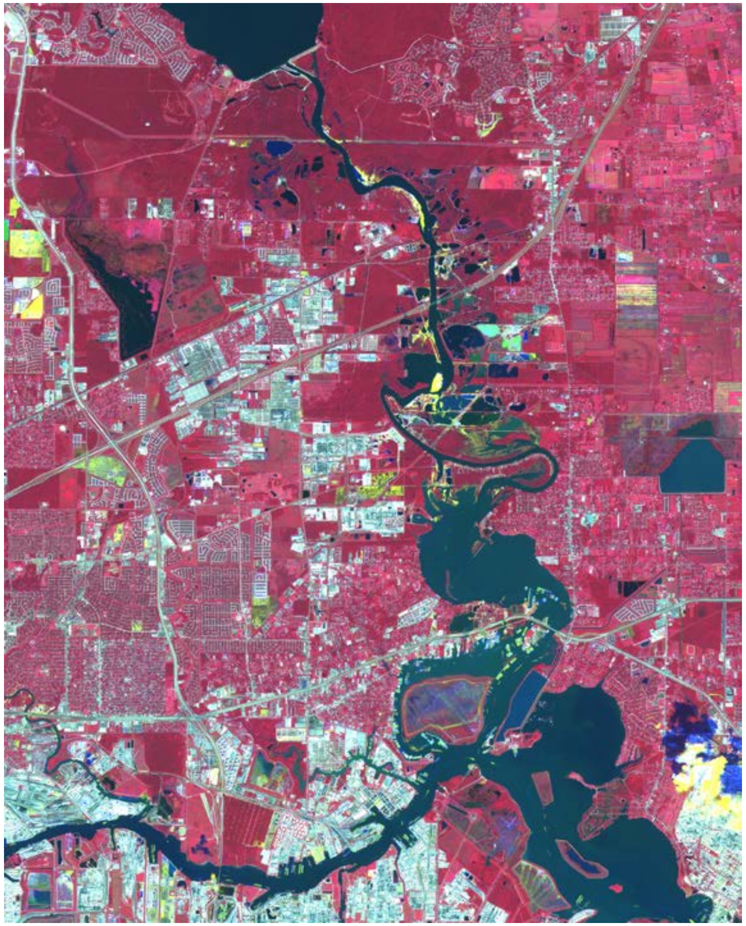


April 24, 2017

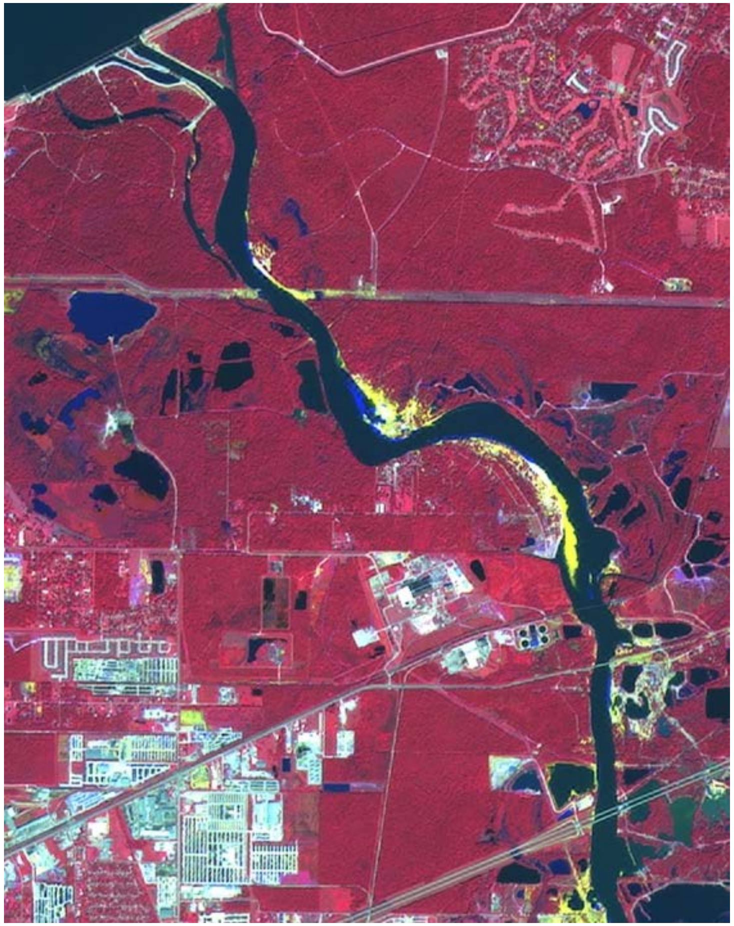
October 1, 2017

d. Bear Lake to Buffalo Bayou. White rectangle on October image highlights floodplain erosion noted in on-the-ground field reconnaissance.

Figure 4. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Color infrared imagery from Sentinel, European Space Agency. Yellow indicates increase in reflectivity between April 24, 2017 and October 1, 2017 images.



a. Lake Houston Dam to Buffalo Bayou



b. Lake Houston Dam to US Highway 90

Figure 4. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Color infrared imagery from Sentinel, European Space Agency. Yellow indicates increase in reflectivity between April 24, 2017 and October 1, 2017 images.

c. US Highway 90 to Bear Lake

d. Bear Lake to Buffalo Bayou

Figure 5. Examination of pre- and post-flood satellite imagery using compare feature on planet.com

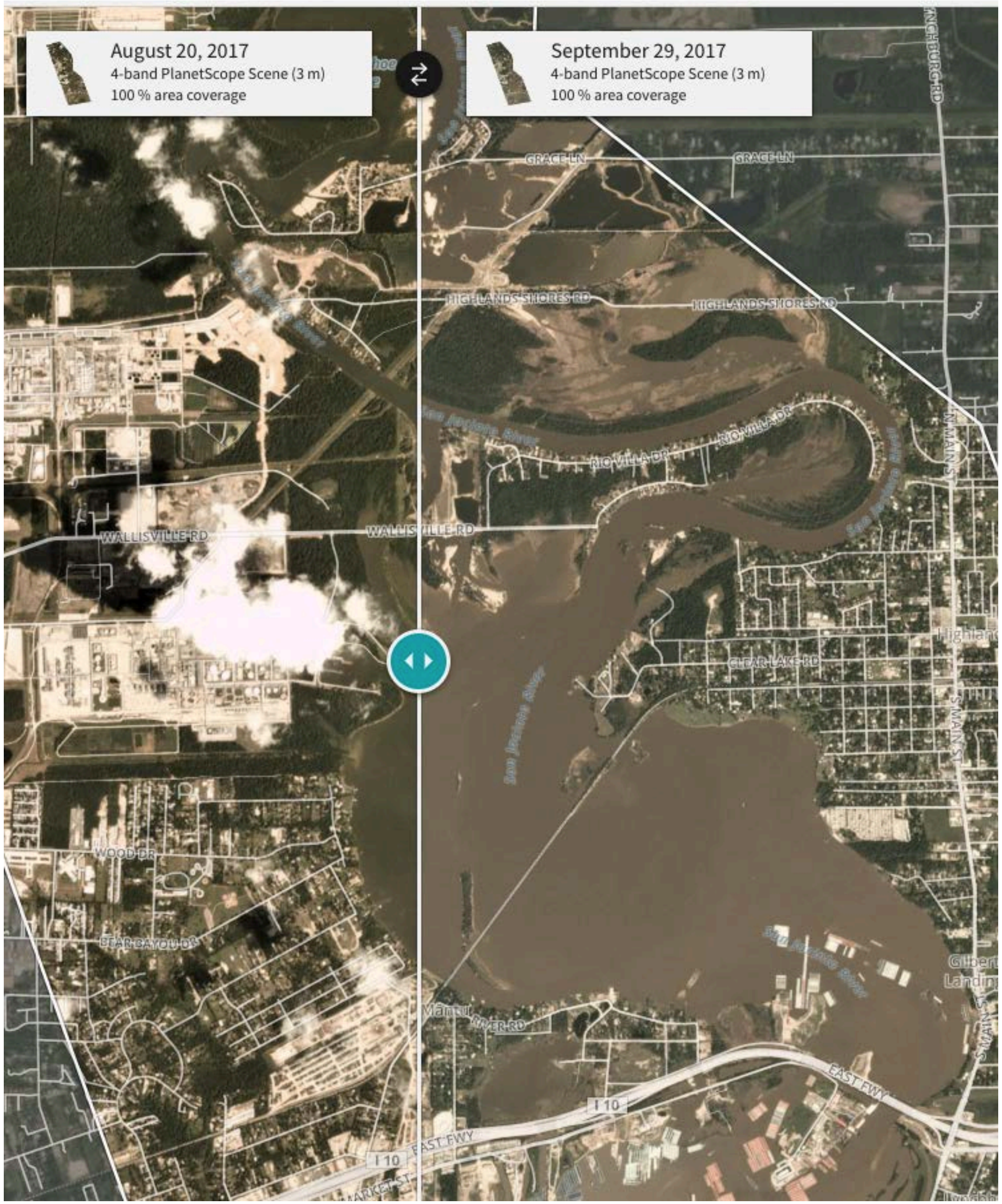


Figure 6. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Natural color infrared imagery from 4-band PlanetScope Scene (3m). Red rectangle shows area of bank erosion and deposition.

a. Bank erosion on east bank about 2.2 miles SE of Lake Houston Dam.

Figure 6. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Natural color infrared imagery from 4-band PlanetScope Scene (3m). Red rectangle shows area of bank erosion and deposition.

b. Bank erosion on east bank about 4.0 miles SE of Lake Houston Dam.

Figure 6. Comparison of pre- and post-flood coverage of San Jacinto River, Texas. Natural color infrared imagery from 4-band PlanetScope Scene (3m). Red rectangle shows area of bank erosion and deposition.

c. Bank erosion on west bank about 4.9 miles SE of Lake Houston Dam.

Figure 7. Simulated maximum total bed shear stress during Hurricane Harvey using Lake Houston Dam flow for calibration. Anchor QEA (unpublished).