Alternatives Analysis

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Lake Houston Dam Improvements Project
SWG-2020-00271
Harris County, Texas

Prepared for Black and Veatch
On Behalf of Coastal Water Authority
Hollaway Project Number: 29-20

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Alternatives Analysis

INTRODUCTION

The Clean Water Act (CWA) Section 404(b)(1) guidelines (40 Code of Federal Regulations [CFR] 230) generally prohibit the discharge of fill material "if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences." The City of Houston, (COH, the Applicant), investigated numerous potential Onsite Alternatives, including the No Action Alternative and an Offsite Alternative, to determine which alternatives are practicable, and which among them is the Least Environmentally Damaging Practicable Alternative (LEDPA).

PROJECT NEED

The existing dam structure located along Lake Houston is nearly 70 years old and needs renovation to properly control water levels prior to, during, and following major storm events. Over the past ten years, Houston has been faced with increased weather extremes, including the worst drought seen in 60 years in 2011, to the worst rainstorm from a hurricane in United States history in 2017. During Hurricane Harvey, rainwater entered the lake at a rate of 430,000 cubic feet per second (cfs) causing the lake to reach elevations of approximately 53 ft (approximately seven ft higher than the available capacity). Due to the large, rapid influx of water, the lake was not able to quickly release water as it is designed to do, causing area homes, businesses, and public infrastructure to flood.

In response to Hurricane Harvey, the Federal Emergency Management Agency (FEMA) issued a federal disaster declaration [DR-4332-TX]) on August 25, 2017. Under this declaration, Harris County became eligible for both individual and public assistance. After obtaining approval from Congress in August 2019, FEMA awarded the first set of federal grants to the Applicant for a pair of large-scale flood mitigation projects, one being this proposed project.

PROJECT PURPOSE

The purpose of the project is to provide additional stability to the existing dam structure with improved controlled release capabilities to enable a rapid decrease of water levels in advance of storm events to reduce upstream and downstream flooding along Lake Houston, as well as, to continue to support the original project purpose of acting as the primary municipal water supply for the COH.

By improving the existing dam structure located on Lake Houston, floodwaters can be rapidly released under controlled circumstances, or stored to meet drinking water needs, thus turning storm events into a future benefit.

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ALTERNATIVES

During the design process, the Applicant evaluated numerous possible alternatives to determine which were practicable, and subsequently, which one represents the LEDPA that meets the purpose and need of the project. Including the no action alternative, the following eleven onsite and offsite alternatives were considered during the development and design of the proposed project:

1. No Action Alternative
2. Onsite Alternative 1
3. Onsite Alternative 1A
4. Onsite Alternative 1B
5. Offsite Alternative 2
6. Onsite Alternative 3A
7. Onsite Alternative 3B
8. Onsite Alternative 3C
9. Onsite Alternative 4
10. Onsite Alternative 4A (Preferred Alternative)
11. Onsite Alternative 4B

The Applicant developed the following siting criteria to be used in conjunction with the above-defined project purpose and need in evaluating the practicability of potential alternatives:

- Located along Lake Houston
- Proximity to existing Lake Houston dam structure
- Provides upstream and downstream benefits
- Provides additional discharge capability and structural integrity
- Reasonable construction timeline
- Costs within approved grant budget
- High Benefit to Cost Ratio (BCR)

According to FEMA, a beneficial cost occurs when a BCR is 1.0 or greater. A BCR is calculated by conducting a Benefit to Cost Analysis (BCA) utilizing the FEMA Toolkit that determines the future risk reduction benefits of a hazard mitigation project[i]. It should be noted that the BCAs completed were intended for screening purposes only to identify the project alternative with the highest cost-effectiveness.

The proposed project is water dependent and cannot avoid impacts to Waters of the United States (WOUS). However, extensive effort has been made to minimize impacts to WOUS, including wetlands, to the extent practicable. **Table 1** provides a summary of the alternative analysis with additional information regarding impacts to WOUS, including wetlands, threatened and endangered (T&E) species, cultural resources, and associated mitigation costs.

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Table 1: Alternative Comparison Matrix for Practicability

Topic	Category	1 **No Action Alternative**	2 **Onsite Alternative 1**	3 **Onsite Alternative 1A**	4 **Onsite Alternative 1B**	5 **Offsite Alternative 2**	6 **Onsite Alternative 3A**	7 **Onsite Alternative 3B**	8 **Onsite Alternative 3C**	9 **Onsite Alternative 4**	10 **Onsite Alternative 4A (Preferred)**	11 **Onsite Alternative 4B**
Availability	**Located along Lake Houston**	N/A Within reasonable proximity to the existing Lake Houston dam structure	N/A	**YES** This alternative occurs within the existing dam gates	**YES** This alternative occurs within the existing dam gates	**YES** This alternative occurs within the existing dam gates	**YES** This alternative occurs 3,400 ft west of the existing dam gates	**YES** This alternative occurs within the existing dam gates	**YES** This alternative occurs within the existing dam gates	**YES** This alternative occurs within the east embankment	**YES** This alternative occurs within the uncontrolled dam spillway	**YES** This alternative occurs within the existing dam gates
	Property acquisition is not required?	N/A	**YES**	**YES**	**YES**	NO A total of 57 ac of additional property would be required	**YES**	**YES**	**YES**	**YES**	**YES**	**YES**
Logistics and Safety	**Provides additional discharge capability and structural integrity?**	NO Structural integrity would remain as-is with no added capacity	NO 18 tainter gates would be added, no additional structural features would be added	**YES** Six tainter gates would be added, ogee crests would be included for increased structural stability	**YES** 14 tainter gates would be added, ogee crests would be included for increased structural stability	N/A 14 gates would be added, additional structural stability was not further developed	NO 14 tainter gates would be added, no additional structural features would be added	NO 2,600 ft of uncontrolled spillway would be added, no structural features would be added	N/A 2,600 ft of Obermeyer crest gates would be added, no structural changes are anticipated	**YES** 3,000 ft of Obermeyer gates would be added with additional fill in existing structure	**YES** 1,000 ft of Obermeyer gates would be added with additional fill in existing structure	**YES** 1,200 ft of Obermeyer gates would be added with additional fill in existing structure
	Provides upstream and downstream benefits?	NO Communities upstream and downstream would continue to be impacted by major storm events	N/A Potential benefits were not assessed for this alternative due to engineering issues	**YES** Water levels during large storm events would decrease by 0.5 ft upstream with no impacts downstream	**YES** Water levels during large storm events would decrease by 1.4 ft upstream with no impacts downstream	N/A Due to costs outside of the approved project budget, potential benefits were not assessed	N/A Due to high environmental impacts, potential benefits were not assessed	NO Limited flow depth would be enabled over the armored crest with limited flood reduction benefits	**YES** Water levels during large storm events would decrease by 2.1 ft upstream with no impacts downstream	**YES** Water levels during large storm events would decrease by 3.2 ft upstream and no impacts downstream	**YES** Water levels during large storm event would decrease by 1.3 ft upstream with no impacts downstream	**YES** Water levels during large storm event would decrease by 1.4 ft upstream with no impacts downstream
	Reasonable construction timeline?	N/A	N/A A construction timeline was not developed for this alternative due to engineering issues	**YES** Construction would last 12 to 18 months	NO Construction would last 24 to 30 months	NO Due to extensive environmental impacts, it is anticipated that a longer construction and permitting timeline will be required	N/A Due to extensive environmental impacts, a construction timeline was not developed	N/A Due to limited flood reduction benefits, a construction timeline was not developed	**YES** Construction would last 18 to 24 months	NO Construction would last five to six years	**YES** Construction would last 18 to 24 months	**NO** Construction would last 24 to 30 months
Cost	**Costs within approved project grant budget ($47.1 million)?**	N/A	N/A A cost was not developed for this alternative due to engineering issues	NO Total project cost is $47.3 million	NO Total project cost is $94.3 million	NO Total project costs exceed $90 million	N/A Due to extensive environmental impacts, a cost was not developed	N/A Due to limited flood reduction benefits, a cost was not developed	NO Total project cost is $210.5 million	NO Total project cost is $115 million	**YES** Total project cost is $34.3 million	**YES** Total project cost is $40.3 million
	High BCR (greater than 1.0)?	N/A	N/A Due to engineering issues, a BCR was not developed	**NO** The calculated BCR is 0.89	NO The calculated BCR is 0.85	N/A Due to costs exceeding $90 million, a BCR was not calculated	N/A Due to extensive environmental impacts, a BCR was not developed	N/A Due limited flood reduction benefits during floods, a BCR was not developed	NO The calculated BCR is 0.38	**YES** The calculated BCR is 1.02	**YES** The calculated BCR is 1.19	**YES** The calculated BCR is 1.11

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Topic	Category	1	2	3	4	5	6	7	8	9	10	11
		No Action Alternative	**Onsite Alternative 1**	**Onsite Alternative 1A**	**Onsite Alternative 1B**	**Offsite Alternative 2**	**Onsite Alternative 3A**	**Onsite Alternative 3B**	**Onsite Alternative 3C**	**Onsite Alternative 4**	**Onsite Alternative 4A (Preferred)**	**Onsite Alternative 4B**
Environmental	**Avoids impacts to Navigable Waters (i.e., open water, streams, and bayous)?**	**YES** No navigable waters affected	NO A total of 33.4 ac and 2,822 LF of open water and stream features would be impacted	NO A total of 1.0 ac and 437 LF of open water and stream features would be impacted	NO A total of 1.8 ac and 760 LF of open water and stream features would be impacted	NO A total of 24.0 ac and 4,518 LF of open water and stream features would be impacted	NO A total of 13.0 ac and 2,303 LF of open water and stream features would be impacted	**YES** No navigable waters affected	NO A total of 0.3 ac and 60 LF of open water and stream features would be impacted	NO A total of 18.2 ac of previously disturbed open water features would be impacted	NO A total of 4.0 ac of previously disturbed open water features would be impacted	NO A total of 11.4 ac of previously disturbed open water features would be impacted
	Avoids special aquatic site impacts (i.e., wetlands)?	**YES** No special aquatic sites impacted	NO A total of 14.3 ac would be impacted	**YES** No special aquatic sites impacted	**YES** No special aquatic sites impacted	NO A total of 35.6 ac would be impacted	NO A total of 4.0 ac would be impacted	**YES** No impacts anticipated	NO A total 0.4 ac would be impacted	**YES** No impacts anticipated	**YES** No impacts anticipated	**YES** No impacts anticipated
	Avoids impacts to federally protected species (i.e., T&E, MBTA, or BGEPA)?	**YES** No federally protected species affected	**YES** No federally protected species affected	**YES** No federally protected species affected	**YES** No federally protected species affected.	NO Bald eagles may be temporarily affected during construction activities	NO Bald eagles may be temporarily affected during construction activities	NO Bald eagles may be temporarily affected during construction activities	NO Bald eagles may be temporarily affected during construction activities	**YES** A previously observed bald eagle nest may be temporarily affected during construction activities	**YES** A previously observed bald eagle nest may be temporarily affected during construction activities	**YES** A previously observed bald eagle nest may be temporarily affected during construction activities
	Avoids impacts to state listed T&E species?	**YES** No state listed species affected	NO Sandbank pocketbook may be temporarily affected during construction activities	NO Sandbank pocketbook may be temporarily affected during construction activities	NO Sandbank pocketbook may be temporarily affected during construction activities	NO Multiple state listed T&E species may be temporarily affected during construction activities	NO Multiple state listed T&E species may be temporarily affected during construction activities	NO Sandbank pocketbook and Louisiana pigtoe may be temporarily affected during construction activities	NO Sandbank pocketbook and Louisiana pigtoe may be temporarily affected during construction activities	NO Sandbank pocketbook may be temporarily affected during construction activities	**YES** No state listed species affected	**YES** No state listed species affected
	Feasible costs for mitigating impacts to WOUS (Over $500,000)?	**YES** No costs would be incurred	NO An estimated $1,635,000 could be incurred	**YES** No costs would be incurred	**YES** No costs would be incurred	NO An estimated $3,673,800 could be incurred	NO An estimated $835,750 could be incurred	**YES** No costs would be incurred	**YES** At least $83,000 may be incurred	**YES** No costs would be incurred	**YES** No costs would be incurred	**YES** No costs would be incurred

Alternatives Analysis

1. NO ACTION ALTERNATIVE

The existing Lake Houston dam consists of a conventional Ambursen reinforced concrete slab and buttress spillway that spans approximately 5,877 feet (ft) in length across the southern portion of Lake Houston in northeast Houston, Harris County, Texas (**Exhibit 1: 2021 Aerial Photograph with the No Action Alternative**). An Ambursen or buttress dam is characterized by a solid, water-tight upstream side that is supported by a series of buttresses or supports. From the construction point of view, an Ambursen dam requires far less material because the structure is essentially hollow[2].

The dam was constructed and deliberately impounded beginning in 1954. Since its construction, the dam has been owned by the COH and operated by the Coastal Water Authority (CWA). The reservoir's main body of water is strategically located between the dam and the confluence of the San Jacinto River and is part of the San Jacinto watershed (Hydrologic Unit Code [HUC] 18070202). This watershed has a population over 197,570 people and drains 487 square miles[3]. Lake Houston was originally created to replace Sheldon Lake, the primary source of water for the city[4]. Lake Houston is a dependable supply of raw water for the nearby metropolitan area, with a water purification plant adjacent to the lake located at the west Lake Houston wastewater treatment plant. The COH and the San Jacinto River Authority (SJRA) pump water from Lake Houston for public and industrial water supply use that conveys 150 to 200 million gallons per day[5]. According to the Texas Water Development Board's (TWDB) 2011 volumetric survey, the lake encompasses a surface area of 11,282 acres (ac) with a total storage capacity of 134,122 ac-ft at its normal operating elevation of 42 ft Above Mean Sea Level (AMSL)[6].

The spillway has a maximum crest elevation of 66 ft AMSL with an overflow diffusion grill that discharges water into a stilling pool. The spillway is flanked by two compacted earth-filled embankments; one to the left (the east embankment) that is 4,000 ft long, and one to the right (the west embankment) that is 4,600 ft long, both with a maximum height of 48 ft. Water release is controlled by two tainter gates (each 18 ft by 20.5 ft) and two flashboards (18 ft by 5 ft) located between 3,000 ft of open spillways to the east and the west embankment (**Figure 1**).

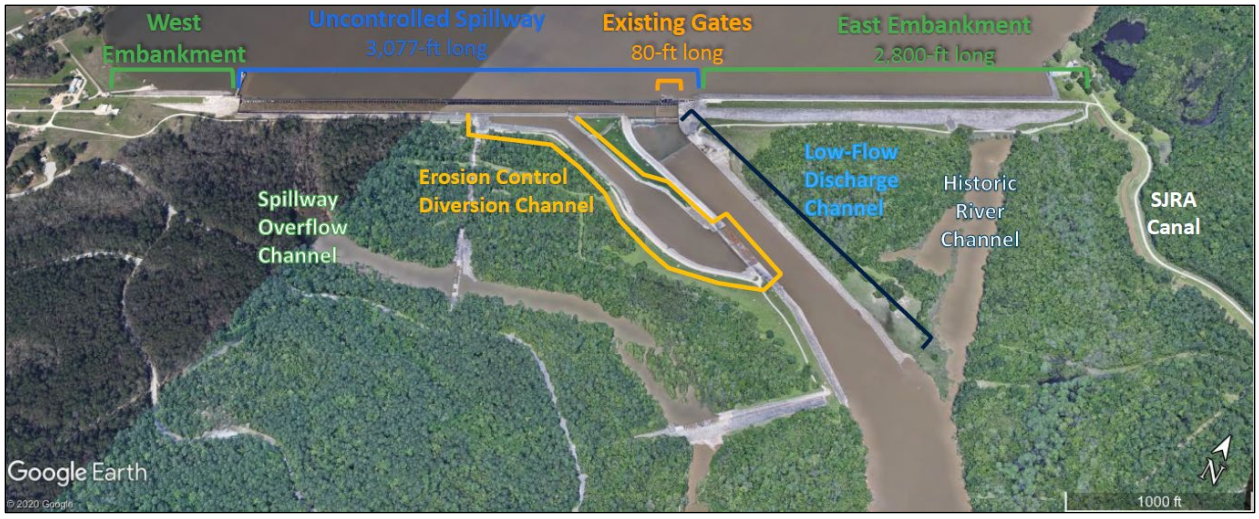

Figure 1: Existing Lake Houston Dam Structure

During an initial study conducted by Freese and Nichols, Inc. (FNI) in 2008, engineers assessed the current condition of the Ambursen spillway, its functionality, structural integrity, hydraulic flow, and if it complied with current Texas storm guidelines. Probable Maximum Flood (PMF) models were assessed, and the engineers recognized the dam was operating at 578,500 cfs as opposed to the 700,000 cfs it was originally designed to discharge[7]. A total of 32 potential dam safety issues were identified. Of the 32, 15 issues could be easily resolved with maintenance only actions, with the remaining 17 issues needing resolution include addressing the sliding stability of the spillway, pressure relief systems, drainage, tailwater, and uplift occurring under the slab downstream from the gated spillway structure[8], all of which require engineering design and construction.

These underlying issues were exposed during Hurricane Harvey in 2017, where rainwater caused the lake to reach elevations of approximately 53.1 ft[9]. Due to the large influx of water in a short amount of time, the dam spillway was not able to release water (as it is designed to) fast enough, causing seven ft of water to flow over the dam structure flooding area homes, businesses, and public infrastructure. According to damage maps prepared by Harris County Flood Control District (HCFCD), the Kingwood area in upper Lake Houston suffered the most damage, totaling 4,484 Harris County homes, not including businesses or homes located along Lake Houston in Montgomery County[10]. Numerous hurricanes and tropical storms continue to hit the Texas coast and sweep across the Atlantic and Gulf Coast regions in increased frequency and turbulence with 30 tropical depressions, 29 storms, 12 hurricanes, and five major hurricanes occurring in 2020[11].

By not adding additional controlled release structures and stability features, communities, companies, and much-needed public infrastructure within the San Jacinto watershed would continue to be at risk of flooding and permanent damage from severe storms. The dam would continue to degrade over time, causing additional risks to the public.

The No Action Alternative would result in no direct impacts to WOUS, including wetlands, T&E species or their habitats. The No Action Alternative may cause indirect impacts to natural resources if the spillways are not adequately managed. High velocity flood water may cause upstream and downstream impacts to Lake Conroe, the San Jacinto River, and habitats utilized by bald eagles, migratory birds, and other wildlife.

2. ONSITE ALTERNATIVE 1

Onsite Alternative 1 consists of approximately 41 ac of COH property located along the eastern portion of the Lake Houston dam. This alternative includes the existing Lake Houston dam with tainter gates, rip-rap, stilling basins, and mowed and maintained herbaceous upland habitat (**Exhibit 2: 2021 Aerial Photograph with Onsite Alternative 1**). No additional Right-of-Way (ROW) or property acquisition would be needed for this alternative.

This alternative includes a modification to the existing stilling basin and bays located within existing tainter gates and along approximately 355 ft of the east embankment of the Lake Houston dam. This Onsite Alternative would provide 18 additional gates within the east embankment of the Ambursen spillway structure, as well as modify the existing gated spillway and adjacent slab-and-buttress bays (**Figure 2**).

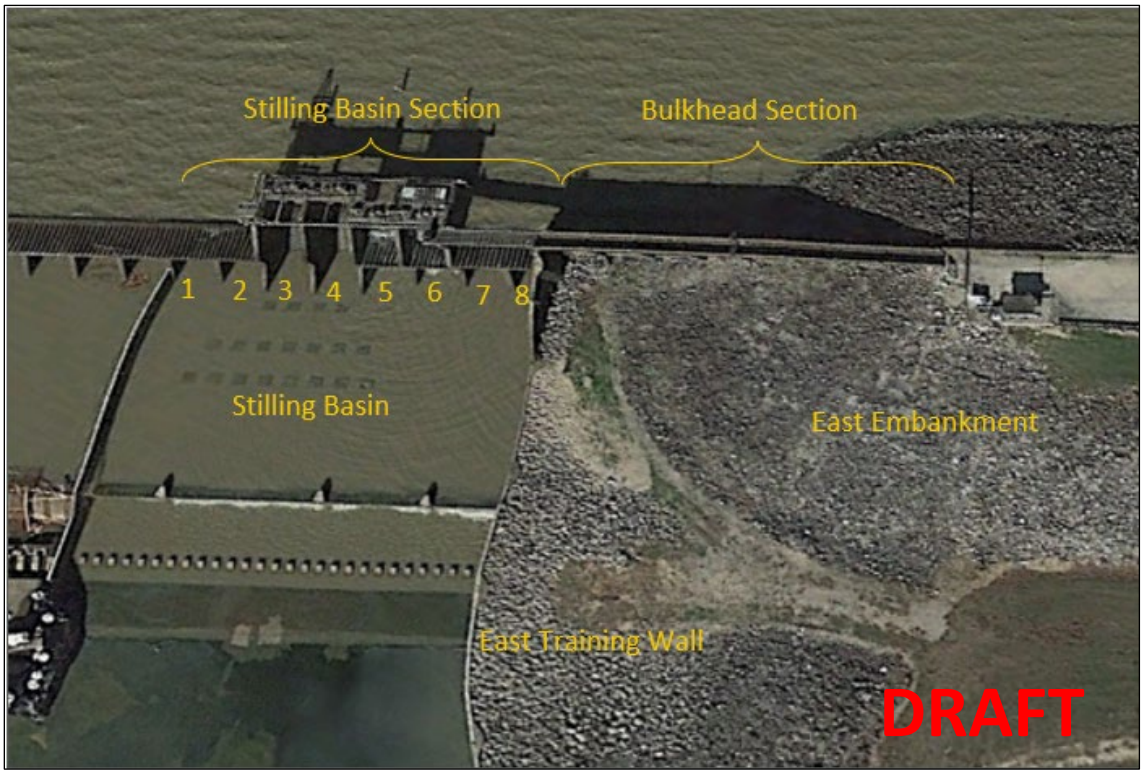

Figure 2: Depiction of Onsite Alternative 1

Onsite Alternative 1 was originally presented in the 2018 FNI alternatives memorandum[12]. FNI proposed the addition of up to ten, 18 ft wide x 20 ft tall tainter gates within the existing Ambursen bays, including as many as eight bays in the bulkhead section. This alternative was intended to minimize cost by working within the existing structure footprint, repurposing as much of the existing structure as possible. This approach would save costs on construction material quantities and dewatering efforts.

The potential impacts would primarily occur within Lake Houston and would impact approximately 2,822 LF of the San Jacinto River. Onsite Alternative 1 would also impact 14.3 ac of forested and herbaceous wetlands. This alternative would require an estimated $1,635,000 worth of credits from an USACE-approved mitigation bank.

No federally listed T&E species or their habitat would be impacted by this alternative. There is also no federally designated critical habitat at or in the vicinity of this location. The state-listed sandbank pocketbook (*Lampsilis satura*) is the only species that may be affected by this alternative during the construction; however, these impacts could be easily avoided by obtaining an Aquatic Resources Relocation Plan (ARRP) from Texas Parks and Wildlife Department (TPWD). An ARRP would enable a qualified, permitted malacologist to relocate mussels to a TPWD approved location outside of construction work zones.

3. ONSITE ALTERNATIVE 1A

Onsite Alternative 1A is a modification to the existing stilling basin and bays immediately adjacent to the existing tainter gates along the Lake Houston dam. This alternative occurs primarily on

previously developed land consisting of the Lake Houston dam, stilling basin, riprap, Lake Houston, and a small portion of the San Jacinto River (**Exhibit 3: 2021 Aerial Photograph with Onsite Alternative 1A**). No additional ROW would be required with this alternative.

Onsite Alternative 1A would modify the six 20 ft wide bays within the spillway section to add mass concrete ogee crests and tainter gates within the existing bay footprint that would improve its structural integrity (**Figure 3**). The existing concrete structure would be modified to increase the elevation of the east embankment with minor regrading. All proposed work associated with this alternative would take place within existing COH and CWA property and would not require any additional ROW or land acquisition.

Figure 3: Depiction of Onsite Alternative 1A

The construction of this alternative would include a cofferdam with sheet piles constructed around the existing tainter gates. Divers and underwater jet blasters would clean and roughen the existing surface of the existing slab and install the vertical framework to an elevation of 20.0 ft to contain tremie concrete. Once the tremie is installed, concrete would be placed under the existing sloped slab to create mass concrete blocks. These concrete blocks would be placed in front of each bay to further stabilize the dam structure where the new tainter gates will be installed. Hydro-mechanical equipment including gates, hoists, drums, and motor controls would also be installed to control the water flow within the tainter gates.

When considering this alternative, Onsite Alternative 1A would provide a lower cost option that would discharge into the main channel of the San Jacinto River downstream of the dam. This alternative would result in decreased Water Surface Elevation (WSEL) of 0.53 ft during the event of a 100-year storm within Lake Houston. The upstream WSEL would decrease by an average of 0.53 ft and the downstream impacts would not see significant change, other than minor direct impacts limited to the COH property.

Onsite Alternative 1A meets the need for stabilizing the dam structure and rapidly reducing WSEL within Lake Houston. However, additional storage of water is not achieved with this alternative. The stabilization features would be limited to the construction area covering approximately 175 LF along the existing structure.

Onsite Alternative 1A has the smallest project footprint, consisting of less than two acres of previously disturbed habitats. The potential impacts would primarily occur within Lake Houston and would only impact approximately 437 LF of the San Jacinto River. Most of the impacts to the San Jacinto River would occur in previously disturbed substrates consisting of concrete and rip-rap. No wetlands or other special aquatic sites would be impacted by this alternative and would therefore, not require wetland mitigation.

No federally designated critical habitat or federally listed T&E species would be impacted by this alternative. The sandbank pocketbook is the only state-listed species that may be affected by this alternative during the construction of the tainter gates and use of the cofferdam. These impacts could be avoided by obtaining an ARRP from TPWD to enable qualified, permitted malacologists to relocate mussels to an approved location outside of construction work zones.

The estimated timeline to construct Onsite Alternative 1A is approximately 12 to 18 months. This timeline may be impacted by seasonal weather, including the rainy season, cold weather, and hurricane season. Due to the complex cofferdam configuration needed to construct Onsite Alternative 1A, there is also a potential risk of poor performance and failure of the temporary cofferdam.

Onsite Alternative 1A is anticipated to cost approximately $47,300,000 in construction costs, operations and management (O&M), and other extraneous potential cost risks. Based on the BCA, this alternative would result in an overall cost benefit of $44,000,000 with a BCR of 0.89, making this alternative not cost effective.

Overall, Onsite Alternative 1A has limited impacts to the environment; however, due to the complicated nature of the cofferdam, limited costs benefits, limited additional capacity, and constructability this alternative was dismissed. Onsite Alternative 1A is not the LEDPA.

4. ONSITE ALTERNATIVE 1B

Onsite Alternative 1B is located within existing COH property along the eastern portion of the Lake Houston dam. This alternative includes the existing Lake Houston dam, riprap, stilling basins, and mowed and maintained herbaceous upland habitat (**Exhibit 4: 2021 Aerial Photograph with Onsite Alternative 1B**). No additional ROW would be required with this alternative.

This alternative includes all components from Onsite Alternative 1A plus the modification of the 160 ft long concrete bulkhead to include eight tainter gates embedded in the embankment immediately east of the existing spillway, for a total of 14 new tainter gates (**Figure 3**). A new 200 ft long cut-off wall would be sunk into the embankment along the dam axis to the east of the modified bulkhead bays. The embankment would be set back to the east 160 ft to accommodate

the new bays and a new 160 ft wide stilling basin. An extension of the downstream channel would be added to convey flows along the existing discharge channel alignment.

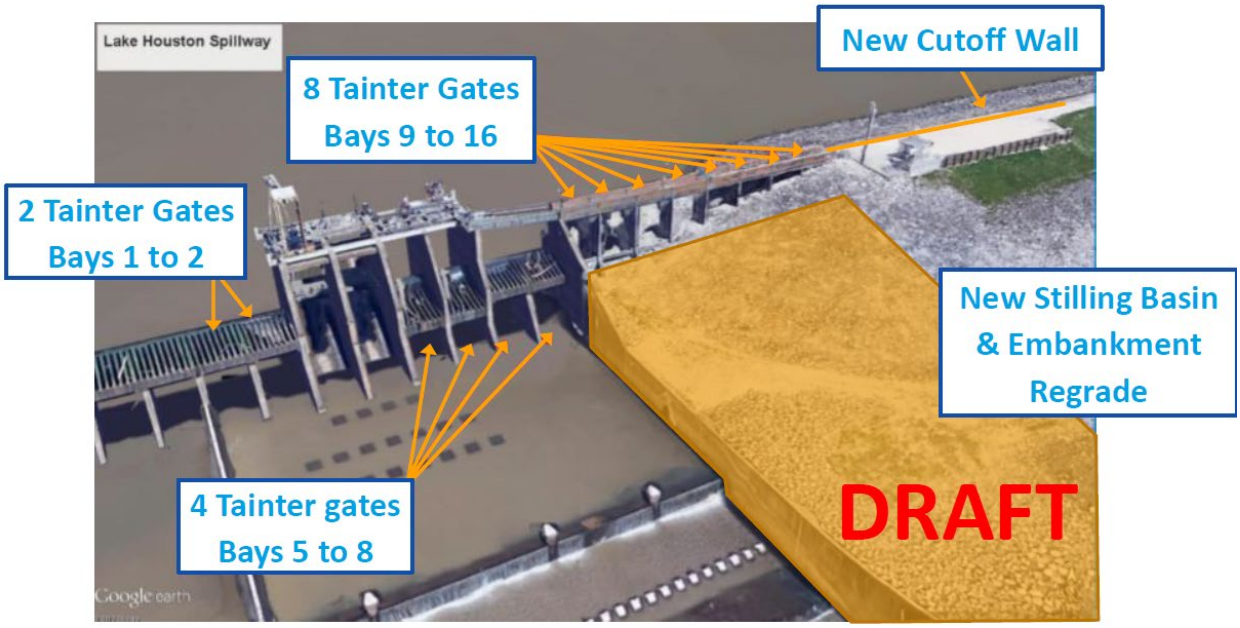

Figure 4: Depiction of Onsite Alternative 1B

Onsite Alternative 1B would reduce the WSEL by a maximum of 1.43 ft upstream, bringing the Lake Houston elevation to 49.15 ft during a 100-year storm. Potential downstream impacts would not be significant, limited only to the COH property, adjacent to the Lake Houston dam structure.

Stabilization features would include extended and reinforced buttress walls. To construct this alternative, a cofferdam with granular fill and sheet piles constructed around the existing tainter gates.

Onsite Alternative 1B has a project footprint that consists of approximately seven acres of previously disturbed habitat along the existing dam structure. The potential impacts would primarily occur within Lake Houston and would only impact approximately 760 LF of the San Jacinto River. Most of the impacts to the San Jacinto River would occur in previously disturbed substrates. No wetlands or other special aquatic sites would be impacted by this alternative and would therefore not require wetland mitigation.

Similar to Onsite Alternative 1A, no federally listed T&E species or federally designated critical habitat would be impacted by this alternative. The state-listed sandbank pocketbook is the only listed species that may be affected by this alternative during the construction of the tainter gates and use of the cofferdam. These impacts could be avoided by obtaining an ARRP from TPWD to enable qualified, permitted malacologists to relocate mussels to an approved location outside of construction work zones.

It would take approximately 24 to 30 months to construct Onsite Alternative 1B. Similar to Onsite Alternative 1A, this estimated timeframe may be impacted by seasonal weather including the rainy season, cold weather, and hurricane season. Due to the more complex cofferdam configuration needed to construct Onsite Alternative 1B, there is also a potential risk of poor performance and failure of the temporary cofferdam.

Onsite Alternative 1B is anticipated to cost approximately $94,300,000 in construction costs, O&M, and other extraneous potential cost risks. Based on the BCA, this alternative would result in an overall cost benefit of $84,750,000 with a BCR of 0.85. According to FEMA, a beneficial cost occurs when a BCR is 1.0 or greater, making this alternative not cost effective.

Although Onsite Alternative 1B would provide a cost option that would further stabilize the dam and enable rapidly reducing the WSEL within Lake Houston, this Alternative 1B is not LEDPA due to length of time to construct and not being cost-effective.

5. OFFSITE ALTERNATIVE 2

Offsite Alternative 2 covers approximately 220 ac and is located east of the existing Lake Houston dam and east of the existing COH property. This alternative would include private and COH-owned property and would require 57 ac of additional ROW. This alternative consists mostly of undeveloped land, including deciduous upland forests, wetland deciduous forests, mixed pine forest, cypress tupelo swamps, sloughs, emergent wetlands, ephemeral streams, a portion of the San Jacinto River, and Lake Houston (**Exhibit 5: 2021 Aerial Photograph with Offsite Alternative 2**).

Offsite Alternative 2 was originally developed in the FNI alternatives memorandum as an “offsite” alternative for a new 14-gate structure that minimized risk while maximizing discharge capacity[13]. Due to its location east of the San Jacinto River, this alternative requires an expansive conveyance channel and siphon structure to redirect flows from the intake structure back into the San Jacinto River. Offsite Alternative 2 is shown in **Figure 5**.

Figure 5: Depiction of Offsite Alternative 2

Offsite Alternative 2 has the largest project footprint, consisting of approximately 220 ac of undeveloped habitat adjacent to the existing dam structure. This alternative would result in impacts to cypress tupelo swamps, sloughs, forested wetlands, and streams. There would also be additional impacts to the San Jacinto River. The total impacts to WOUS would be a minimum of 35.6 ac to wetlands, 24 ac of open water and 4,518 LF of streams. Estimated mitigation costs for these impacts would be a minimum of $3,673,800 at a USACE approved mitigation bank.

No federally designated critical habitat or federally listed T&E species would be impacted by this alternative. This alternative may impact state-listed species, such as the alligator snapping turtle *(Macrochelys temminckii*), Louisiana pig toe (*Pleuobema reddellii*), Rafinesque's big eared bat (*Corynorhinus rafinesquii*), sandbank pocketbook, swallow-tailed kite (*Elanoides forficatus*), white-faced ibis (*Plegadis chihi*), and the wood stork (*Mycteria americana*). Coordination and consultation with TPWD would be recommended to develop Best Management Practices (BMP) to minimize and avoid impacts to state-listed species to the extent practicable. Although no bald eagles' nests or bald eagles were observed within the limits of this alternative, potential habitat exists. Bald eagles may be temporarily affected during construction activities.

During the initial scoping of Offsite Alternative 2, costs were anticipated to be approximately $90,000,000 for construction, not including O&M, extraneous costs, property acquisition or easements, mitigation, additional coordination, or maintenance of this alternative. Offsite Alternative 2 was not advanced beyond conceptual development because of high cost and the significant environmental impacts associated with the large structure footprint and channel alignment through quality wetlands.

Due to significant impacts anticipated to the surrounding environment and impracticably high construction costs, Offsite Alternative 2 is not the LEDPA.

6. ONSITE ALTERNATIVE 3A

Onsite Alternative 3A consists of 24 ac and is located along the eastern edge of the existing Lake Houston dam within existing CWA and COH Property. The land consists primarily of the west embankment and undeveloped land south of the of the spillway structure. No additional ROW would be required. This alternative would impact herbaceous uplands, riprap, herbaceous wetlands, forested wetlands, an intermittent stream, and the San Jacinto River (**Exhibit 6: 2021 Aerial Photograph with Onsite Alternative 3A**).

Onsite Alternative 3A includes the construction of a new 500 ft concrete spillway and new gated structure including 14 tainter gates with an armored stilling basin. The stilling basin would be sited within the San Jacinto River to maximize the hydraulics provided by the existing channel, as well as to minimize potential environmental impacts (**Figure 6**).

Figure 6: Depiction of Onsite Alternative 3A

Onsite Alternative 3A would directly impact approximately 4.0 ac of forested and emergent wetlands, 13.0 ac of open water, and 2,303 LF of streams (primarily the San Jacinto River). Estimated mitigation costs for these impacts would cost a minimum of $835,750 at a USACE approved mitigation bank.

This alternative would not impact any federally designated critical habitat or federally listed T&E species. There are multiple, state-listed protected species that this alternative may impact, such as the alligator snapping turtle, Louisiana pig toe, Rafinesque's big eared bat, sandbank pocketbook, swallow-tailed kite, white-faced ibis, and the wood stork. During field visits, a small rookery of snowy egrets (*Egretta thula*), roseate spoonbills (*Platalea ajaja*), and great blue herons (*Ardea herodias*) was observed near the banks of the San Jacinto River. Coordination and consultation with TPWD would be recommended to ensure state-listed species were not impacted to the extent practicable. Although no bald eagles' nests or bald eagles were observed within the limits of this alternative, potential habitat exists. Bald eagles may be temporarily affected during construction activities.

Due to the significant environmental impacts associated Onsite Alternative 3A, this alternative was not advanced beyond conceptual development. Onsite Alternative 3A is not the LEDPA.

7. ONSITE ALTERNATIVE 3B

Onsite Alternative 3B is located on 15 ac along the eastern edge of the existing Lake Houston dam within existing CWA and COH Property, therefore no additional ROW or property acquisition would be needed for this alternative. The land consists primarily of herbaceous uplands and riprap on the east embankment. A small portion of this alternative would also have minor impacts to

forested wetlands and the San Jacinto River (**Exhibit 7: 2021 Aerial Photograph with Onsite Alternative 3B**).

Onsite Alternative 3B features a 2,600 ft wide uncontrolled spillway composed of a concrete-armored embankment to allow passive discharge from the reservoir whenever the WSEL is above the normal pool (**Figure 7**). This alternative provides limited flow depth over the armored crest, thereby limiting the hydraulic capacity. This alternative, lacking technical merit in terms of flooding benefit, was further modified to develop Onsite Alternative 3C.

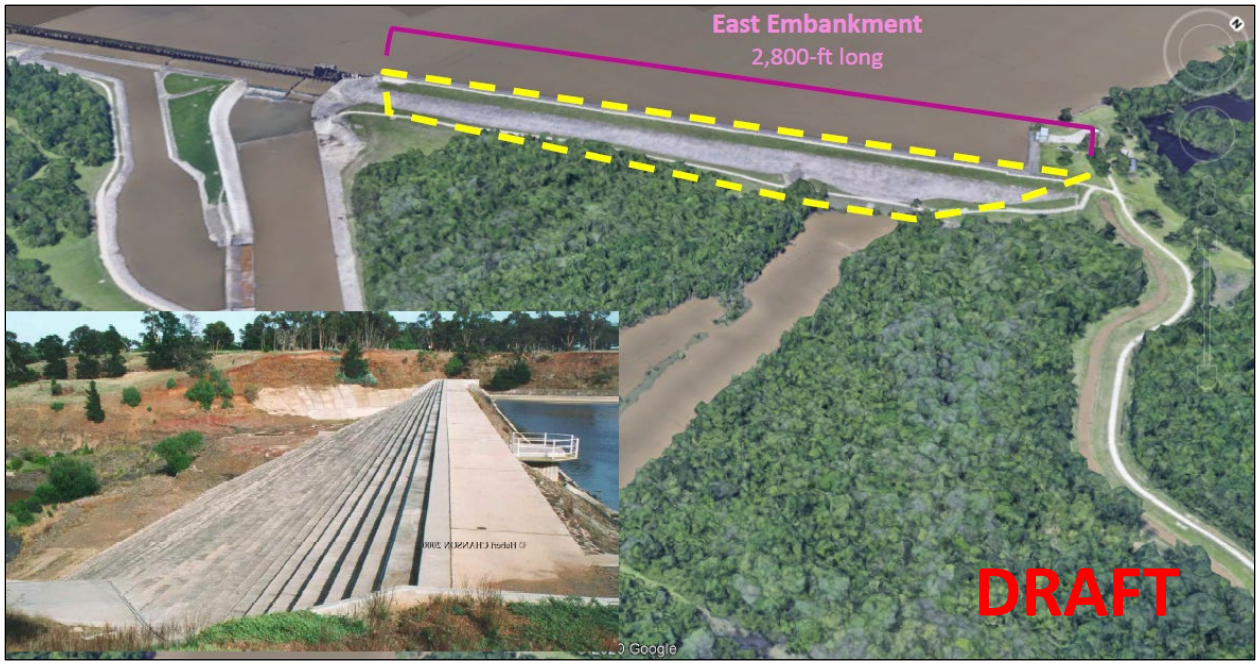

Figure 7: Depiction of Alternative 3B

Onsite Alternative 3B would impact previously disturbed habitat located along the existing dam structure primarily within Lake Houston. No wetlands or other special aquatic sites would be impacted by this alternative and would therefore, not require wetland mitigation.

Similar to Onsite Alternative 1A and 1B, no federally listed T&E species or their habitat would be impacted by this alternative. There is also no federally designated critical habitat impacted by this alternative. The state-listed sandbank pocketbook is the only state-listed-species that may be affected by this alternative during construction activities. These impacts could be easily avoided by obtaining an ARRP from TPWD to enable qualified, permitted malacologists to relocate mussels to an approved location outside of construction work zones. Although no bald eagles' nests or bald eagles were observed within the limits of this alternative, potential habitat exists. Bald eagles may be temporarily affected during construction activities.

Although impacts to the environment are minimal with this alternative, it would not meet the purpose or need of the project with limited flood reduction benefits. Onsite Alternative 3B is not the LEDPA.

8. ONSITE ALTERNATIVE 3C

Onsite Alternative 3C is located on 30 ac along the eastern embankment of the existing Lake Houston dam on CWA and COH Property. No additional Right of Way (ROW) or property acquisition would be needed for this alternative. This alternative would include direct impacts to herbaceous uplands and riprap along the east embankment. Potential additional downstream impacts from this alternative may affect a mosaic of forested wetlands, emergent wetlands, and the San Jacinto River (**Exhibit 8: 2021 Aerial Photograph with Onsite Alternative 3C**).

Onsite Alternative 3C closely resembles Onsite Alternative 3B, except that it incorporates 2,600 LF of 4 ft high controlled Obermeyer spillway gates along the eastern portion of the embankment-supported overflow spillway. The controlled Obermeyer spillway gates would provide an additional 1.5 ft of freeboard above normal conditions which is typically at an WSEL of 42.5 ft. Approximately 50 percent of the existing embankment section would need to be removed to lower the crest from an elevation of roughly 60.5 ft to 40.0 ft. Due to the significant quantity of excavated materials, an offsite disposal area would be required. The downstream toe would contain an energy dissipation structure and riprap to reduce flow velocities and to prevent scour to the downstream extents of the San Jacinto River (**Figure 8**).

Figure 8: Depiction of Onsite Alternative 3C

Onsite Alternative 3C is characterized by the inclusion of controlled Obermeyer spillway gates. Obermeyer gates offer low weight, long gate section lengths, and low structural impact, and have been proven to be a cost-effective spillway gate solution. Installing the controlled Obermeyer crest gates would reduce the 100-year WSEL by approximately 2.15 ft.

Onsite Alternative 3C would be located on 0.3 ac of previously disturbed open water habitats within Lake Houston and would only impact approximately 60 LF of the San Jacinto River. Direct impacts to wetlands would consist of 0.4 ac to forested wetlands; however, there is a high potential for more indirect potential impacts to wetlands downstream consisting of a mosaic of forested wetlands, emergent wetlands, and the San Jacinto River during major storm events.

No federally listed T&E species or their habitat would be directly impacted by this alternative. There is also no federally designated critical habitat within this alternative. The sandbank pocketbook and Louisiana pigtoe are the only state-listed species that may be affected by this alternative during construction activities. These impacts could be avoided by obtaining an ARRP from TPWD to would enable qualified, permitted malacologists to relocate mussels to an approved location outside of construction work zones. During major storm events, large swaths of forested habitat may be flooded with the potential to impact bald eagles, nesting migratory birds, and roosting bats. Although no bald eagles' nests or bald eagles were observed within the limits of this alternative, potential habitat exists. Bald eagles may be temporarily affected during construction activities.

It would take approximately 18 to 24 months to construct Onsite Alternative 3C. This estimated timeframe may be impacted by seasonal weather including the rainy season, cold weather, and hurricane season. This alternative would enable the existing uncontrolled spillway structure to have limited use during construction. Due to this alternative's location near the San Jacinto River, there is a high likelihood for groundwater control to be an issue during construction activities with the potential to cause delays.

Onsite Alternative 3C is anticipated to cost approximately $210,500,000 in construction costs, O&M, and other extraneous potential cost risks. Based on the BCA, this alternative would result in an overall cost benefit of $81,000,000 with a BCR of 0.38. According to the FEMA a beneficial cost occurs when a BCR is 1.0 or greater, making this alternative not cost effective.

Although direct impacts to the environment are minimal with this alternative there is a higher potential for indirect impacts to the environment. Additionally, since the project would not benefit the surrounding communities due to the large costs, Onsite Alternative 3C is not the LEDPA.

9. ONSITE ALTERNATIVE 4

Onsite Alternative 4 is located on 30 ac along the western embankment of the existing Lake Houston dam on CWA and COH property. No additional Right of Way (ROW) or property acquisition would be needed for this alternative. This alternative would reconstruct approximately 3,000 ft of the uncontrolled Ambursen spillway. This alternative would impact concrete, riprap, and Lake Houston (**Figure 9** and **Exhibit 9: 2021 Aerial Photograph with Onsite Alternative 4**).

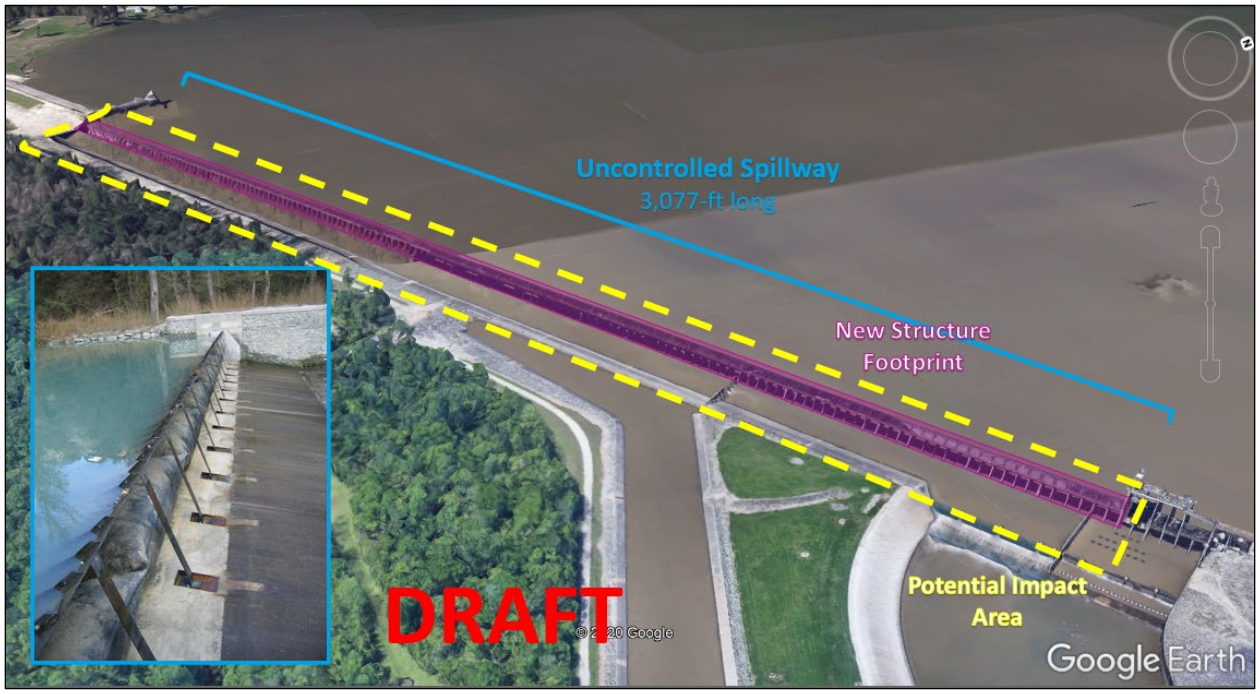

Figure 9: Depiction of Onsite Alternative 4

Similar to Onsite Alternative 3C, Onsite Alternative 4 incorporates the inclusion of controlled Obermeyer spillway gates along the uncontrolled Ambursen spillway section. The new hydraulically controlled Obermeyer spillway gates would be 3.5 ft high and offer discharge a WSEL of 39.0 ft. Onsite Alternative 4 also incorporates stabilization features of the Ambursen spillway, which is necessary for implementation of the proposed modifications.

The 100-year WSEL upstream would be reduced by about a maximum of 3.2 ft. The upstream flooding impacts for the 100-year storm with Onsite Alternative 4 implemented would be like the impacts corresponding to a flooding event during the typical 10- or 25-year storms.

Onsite Alternative 4 would primarily occur on previously disturbed habitats along the existing Ambursen dam structure. Approximately 18.2 ac of impacts would occur to Lake Houston and the San Jacinto River. Most of the impacts would occur in previously disturbed concrete substrates. No wetlands or other special aquatic sites would be impacted by this alternative and would therefore, not require wetland mitigation.

No federally listed T&E species or their habitat would be impacted by this alternative. There is also no designated critical habitat within this alternative. The state-listed sandbank pocketbook is the only state-listed species that may be affected by this alternative during construction activities; however, these impacts could be avoided by obtaining an ARRP that would enable qualified, permitted malacologists to relocate mussels to an approved location outside of construction work zones. During the field surveys, there was a bald eagle nest located approximately 600 ft south of this alternative. During the nesting period, this may cause construction delays or warrant the use of a USFWS consultation and/or permit.

It would take approximately five to six years to construct Onsite Alternative 4. This estimated timeframe may be impacted by seasonal weather including the rainy season, cold weather, and hurricane season. Additionally, while construction is going on and around the existing uncontrolled Ambursen spillway, these features would not be operational, and present potential risks including unsafe working conditions, damage of equipment, or partially completed work. Although the proposed design is complex, the structure would be further stabilized and offer great flood reduction benefits.

Onsite Alternative 4 is anticipated to cost approximately $115,000,000 in construction costs, O&M, and other extraneous potential cost risks. Based on the BCA, this alternative would result in an overall cost benefit of $123,000,000 with a BCR of 1.02. According to FEMA, a beneficial cost occurs when a BCR is 1.0 or greater, making this alternative cost effective.

Although impacts to the environment are minimal with this alternative, due to the extended period of time it would take to construct this project and the costs exceeding the approved project grant budget, Onsite Alternative 4 is not the LEDPA.

10. ONSITE ALTERNATIVE 4A (PREFERRED ALTERNATIVE)

Onsite Alternative 4A is located along the western embankment of the existing Lake Houston dam on CWA and COH property. No additional Right of Way (ROW) or property acquisition would be needed for this alternative. This alternative would reconstruct approximately 1,000 ft of the uncontrolled Ambursen spillway with habitats consisting primarily of concrete and riprap (**Exhibit 10: 2021 Aerial Photograph with Onsite Alternative 4A**).

Onsite Alternative 4A would construct new Obermeyer gates spanning approximately 1,000 LF along the eastern portion of the existing Lake Houston dam structure. Currently, this area consists of the uncontrolled Ambursen spillway that spans approximately 3,077 LF. To accomplish this, the existing crest would be lowered approximately 3.5 ft and fitted with an Obermeyer gate structure. The dam would be accessed via barge with the necessary equipment mounted on top and ferried from an upland laydown yard on COH property.

A downstream and upstream cofferdam would be installed mechanically, with assistance from divers. The cofferdam would be installed in 220 ft increments that would enable the construction of a single 200 ft crest gate. This constructed barrier would be hopscotched across the 1,000 ft length of the Ambursen section where new Obermeyer spillway gates are proposed. The frame would be anchored to the existing concrete face slab mechanically over a rubberized water stop at contact points to reduce water seepage. The temporary bulkheads would wrap around the ends of the framed structure to prevent water from entering the bulkheads (**Figure X**).

Alternatives Analysis

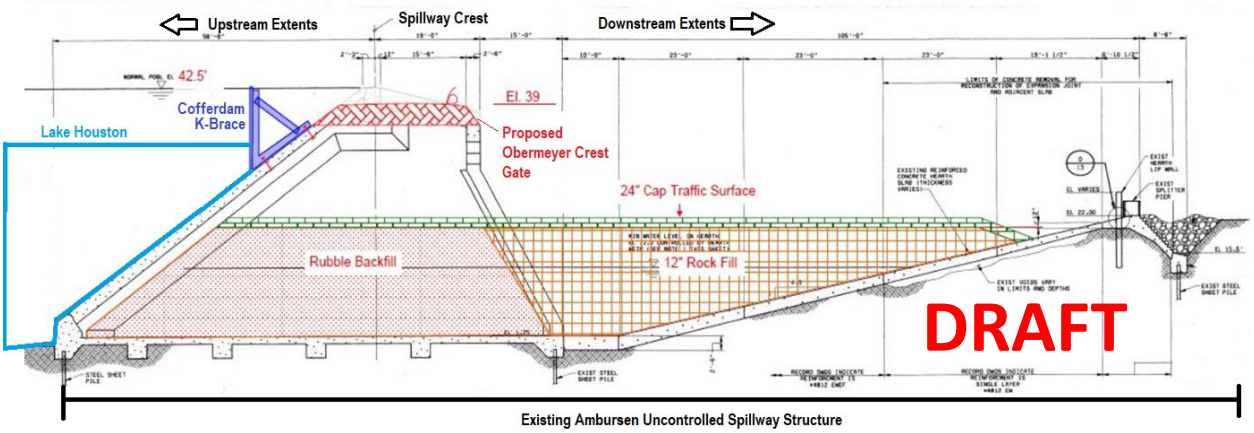

Figure 10: Draft cross section with temporary cofferdam

According to H&H modeling, this improvement would result in a drop of 1.2 ft WSEL during a 100-year storm. **Table 2**, below, provides a summary of the benefits and impacts associated with Onsite Alternative 4A. To maximize the upstream benefits and minimize the downstream impacts, the project would allow a gradual, tiered opening.

Table 2: Onsite Alternative 4A benefits and impacts summary (100-year)

Location (Upstream (US); Downstream (DS))	US Benefit (-) or DS Impact (+) (ft)
Lake Houston Spillway (US)	-1.22
FM 1960 (US)	-1.04
Lake Houston Parkway (US)	-0.54
Luce Bayou Confluence (US)	-0.95
Lake Houston Property (DS)	+1.30
San Jacinto River (DS)	0.00
Buffalo Bayou (DS)	0.00

Onsite Alternative 4A would primarily occur on 3.75 ac of open water that have been previously disturbed, concrete substrates of Lake Houston and the San Jacinto River.

No wetlands or other special aquatic sites would be impacted by this alternative and would therefore, not require wetland mitigation.

No federally listed T&E species or their habitat would be impacted by this alternative. There is no federally designated critical habitat within this alternative. During the field surveys, there was a bald eagle nest located approximately 600 ft south of this alternative. During the nesting period, this may cause construction delays or warrant additional coordination with USFWS.

It would take approximately 18 to 24 months to construct Onsite Alternative 4A. This estimated timeframe may be impacted by seasonal weather including the rainy season, cold weather, and hurricane season. Additionally, while construction is going on in and around the existing uncontrolled Ambursen spillway, these features would not be operational, and present potential risks including unsafe working conditions, damage of equipment, or partially completed work.

Onsite Alternative 4A is anticipated to cost approximately $34,300,000 in construction costs, O&M, and other extraneous potential cost risks. Based on the BCA, this alternative would result in an overall cost benefit of $40,900,000. In terms of benefits Onsite Alternative 4A had the highest BCR of all alternatives, at 1.19.

Due to minimal impacts to the environment, low project costs, high flood reduction benefits, improved upstream benefits, lack of downstream impacts, and anticipated project construction schedules, Onsite Alternative 4A is the LEDPA.

11. ONSITE ALTERNATIVE 4B

Onsite Alternative 4B is located on 4 ac along the western embankment of the existing Lake Houston dam on CWA and COH property. No additional ROW would be required. This alternative would reconstruct approximately 1,200 ft of the uncontrolled Ambursen spillway consisting primarily of concrete and riprap (**Exhibit 11: 2021 Aerial Photograph with Onsite Alternative 4B**).

Onsite Alternative 4B would include the construction of new Obermeyer gates spanning approximately 1,200 LF along the eastern portion of the existing Lake Houston dam structure. Currently, this area consists of the uncontrolled Ambursen spillway that spans approximately 3,077 LF. To accomplish this, the existing crest would be lowered approximately 3.5 ft and fitted with an Obermeyer gate structure. The dam would be accessed via barge with the necessary equipment mounted on top and ferried from an upland laydown yard on the COH's property.

A downstream and upstream cofferdam would be installed similarly to Onsite Alternative 4A and would be hopscotched across the 1,200 ft length of the Ambursen section where new Obermeyer spillway gates are proposed. Additional fill material would be installed within the hollow Ambursen structure for the 1,200 ft (**Figure 11**).

Alternatives Analysis

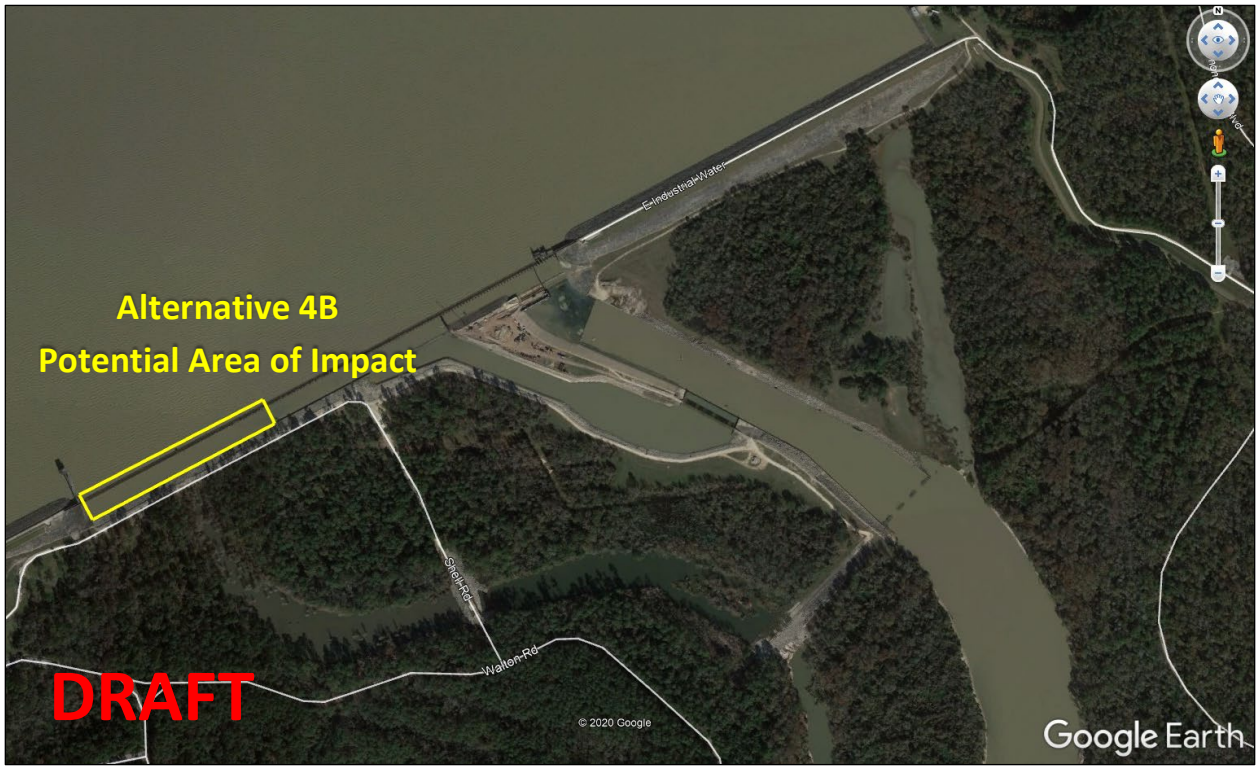

Figure 11: Depiction of Onsite Alternative 4B

According to H&H modeling, this improvement would result in a drop of 1.4 ft WSEL during a 100-year storm. The project would also allow a gradual tiered opening.

Onsite Alternative 4B would primarily occur on previously disturbed habitats within the existing Ambursen dam structure. The potential impacts would occur primarily to 11.4 ac of previously disturbed concrete substrates of Lake Houston and the San Jacinto River. No wetlands or other special aquatic sites would be impacted by this alternative and would therefore, not require wetland mitigation.

No federally listed T&E species or their habitat would be impacted by this alternative. There is also no federally designated critical habitat within this alternative. During the field surveys, there was a bald eagle nest located approximately 600 ft south of this alternative. During the nesting period, this may cause construction delays or warrant additional coordination with USFWS.

It would take approximately 24 to 30 months to construct Onsite Alternative 4B. This estimated timeframe may be impacted by seasonal weather including the rainy season, cold weather, and hurricane season. The existing uncontrolled Ambursen spillway would not be operational during construction, thus presenting potential risks including unsafe working conditions, damage of equipment, or partially completed work.

Onsite Alternative 4B is anticipated to cost approximately $40,300,000 in construction costs, O&M, and other extraneous potential cost risks. Based on the BCA, this alternative would result in an overall cost benefit of $44,600,000, with a BCR at 1.11.

Although impacts to the environment are minimal with this alternative, due to the extended period of time it would take to construct this project, Onsite Alternative 4B is not the LEDPA.

DETERMINATION OF THE LEDPA

After developing and analyzing the proposed project siting criteria for the purpose and need of the proposed project, the Applicant has concluded that Onsite Alternative 4A is the Preferred Alternative and the LEDPA.

The goal of the project is to maximize benefit upstream of Lake Houston while minimizing impacts downstream of the dam during a 100-year storm event. Through the Alternatives Analysis, it was confirmed that a delayed, controlled opening of Obermeyer crest gates is the most cost efficient and effective way to minimize impacts caused by severe storms. By enabling a gradual, tiered opening would ensure a more gradual release of floodwaters and reduce impacts that might result with a rapid, immediate opening of the gates.

In this analysis, nine onsite alternatives and one offsite alternative were considered, in addition to the No Action Alternative. The No Action Alternative does not fulfill the Applicant's purpose or need. If the project is not developed, the community would suffer from flooding to both upstream and downstream regions. The surrounding community would also not realize the benefits associated with Onsite Alternative 4A (Preferred Alternative).

Onsite Alternative 1 meets the need for rapidly reducing WSEL within Lake Houston. However, Onsite Alternative 1 offers limited flood reduction benefit with high potential of structural risks. Due to these risks and limited benefits, Onsite Alternative 1 is not practicable and would not satisfy the purpose and need of the project. To capture a range of potential benefits and mitigate structural risks through varied levels of structural modification, the project team subdivided Alternative 1 into two sub-alternatives: Onsite Alternative 1A and Onsite Alternative 1B.

Overall, Onsite Alternative 1A had limited impacts to the environment and is cost effective. However, due to the complicated nature of the construction of the cofferdam, limited additional capacity, and constructability, this alternative was dismissed. Onsite Alternative 1A and 1B had limited impacts to the environment but scored low with a BCR below 1.0. Both Onsite Alternative 1A and Onsite Alternative 1B are not the LEDPA, as they do not meet the purpose and need of the project.

Offsite Alternative 2 is not practicable because it is beyond the approved project grant budget allocated and would require additional private property acquisition that would further drive up costs.

Offsite Alternative 2 would result in the most impacts to state-listed T&E species and special aquatic resources compared to other alternatives, as well as other impacts to resources considered in the public interest. No other offsite alternatives were considered due to the need to improve the existing structure at the confluence of the San Jacinto River.

After review of Onsite Alternatives 3A, 3B, 3C, 4, and 4B, the Applicant concluded that there are no feasible onsite alternatives that would satisfy the purpose and need of the project while

reducing the upstream and downstream impacts, being cost effective, limiting construction time to realize the benefits of the project, and limiting environmental impact than Onsite Alternative 4A (Preferred Alternative). Onsite Alternative 4A (Preferred Alternative) thus reflects the LEDPA, as it is consistent with the project purpose and need.

Onsite Alternative 4A (Preferred Alternative) would provide flood reduction benefits to the community while minimizing impacts to WOUS, including wetlands. This alternative also scored the highest during the BCA, making this alternative the most cost-effective project. Onsite Alternative 4A (Preferred Alternative) scored the highest for value when compared to other higher-ranking alternatives, such as Onsite Alternative 1A and Onsite Alternative 4B. The value score was the highest when considering cost and non-cost factors (dam safety, environmental impacts, water supply, operations, flood risk reductions, and constructability).

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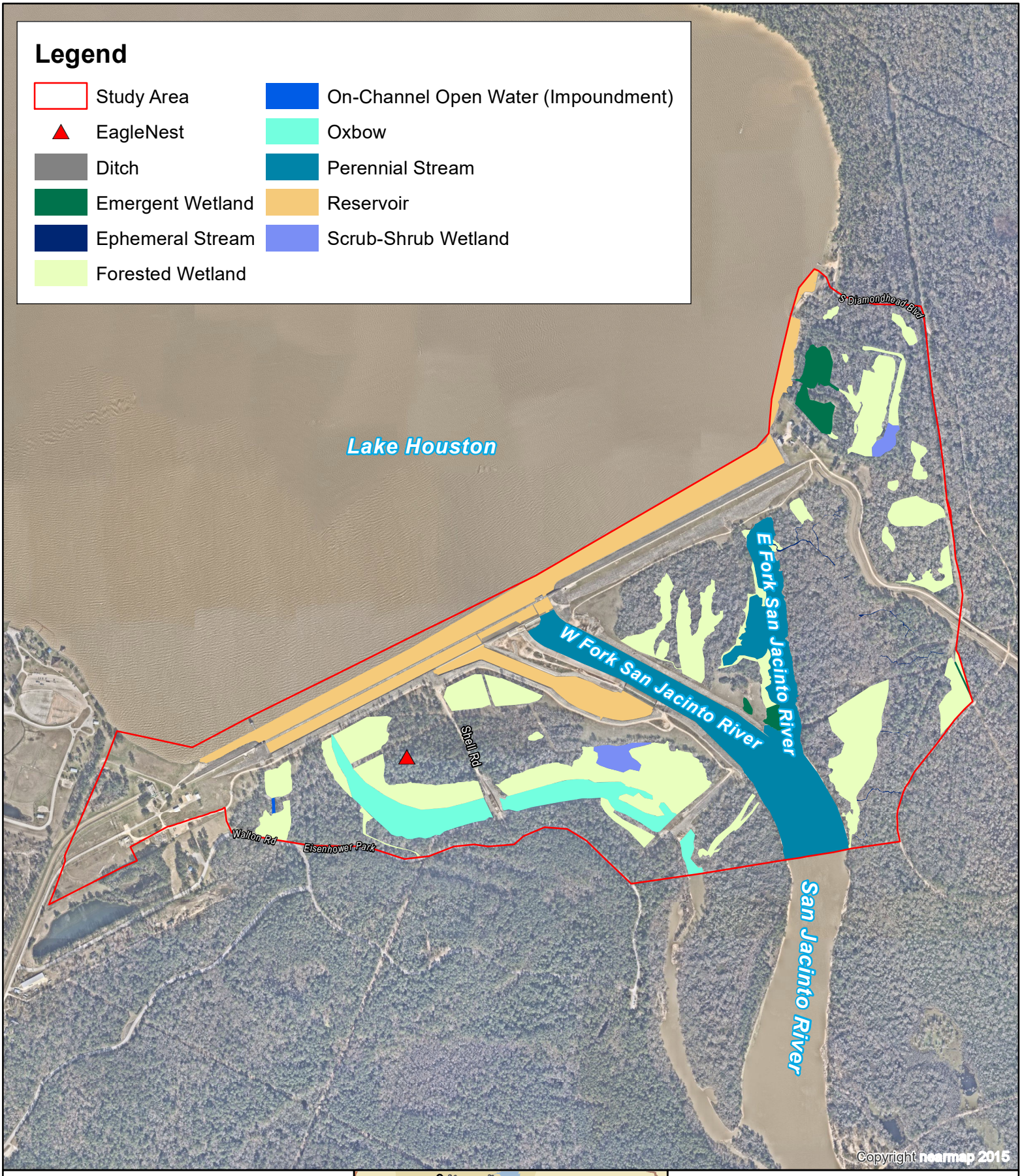

Exhibit 1: 2021 Aerial Photograph with the No Action Alternative

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021 Created: 5/26/2021

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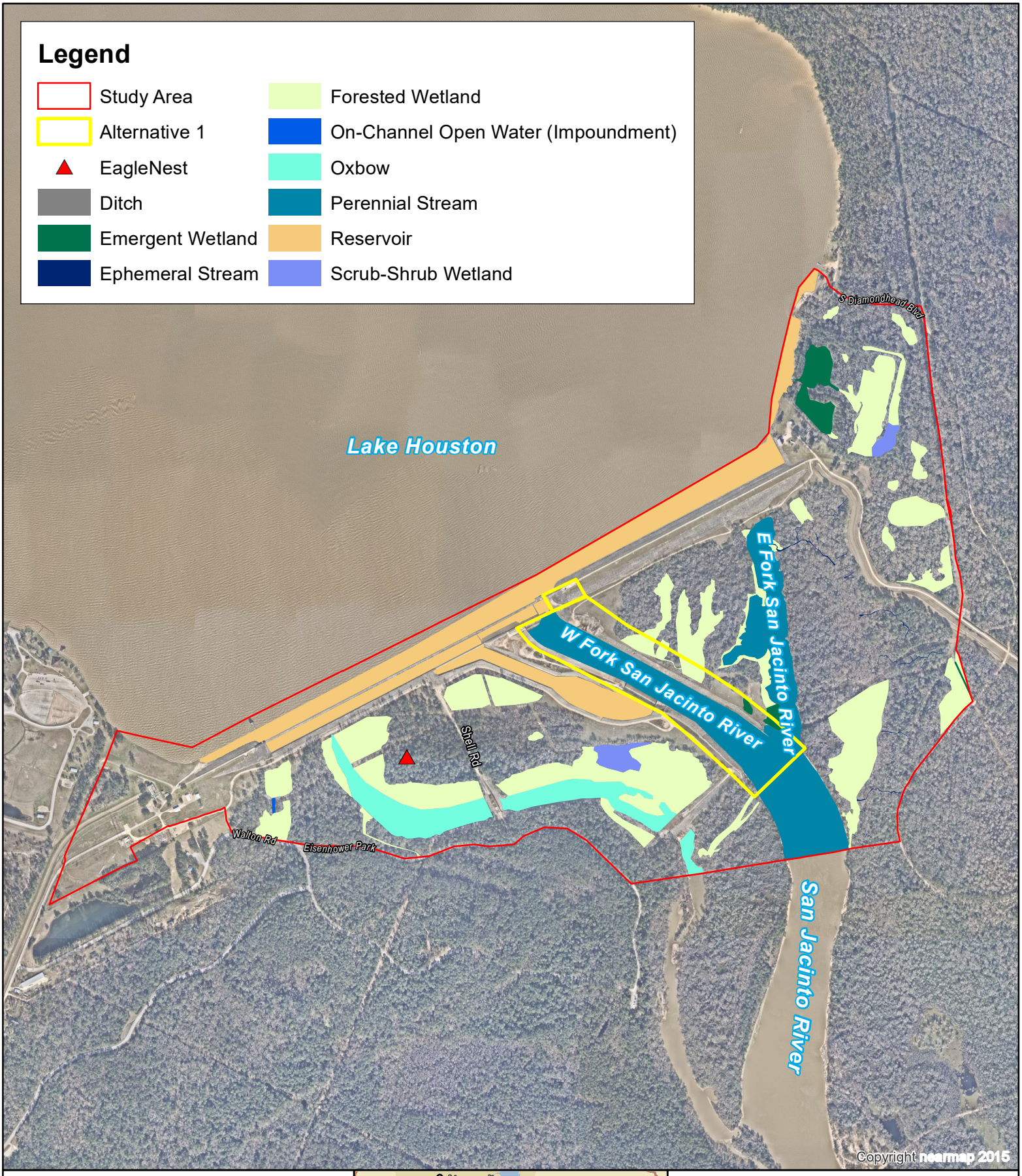

Exhibit 2: 2021 Aerial Photograph with Onsite Alternative 1

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021 Created: 5/26/2021

HOLLAWAY
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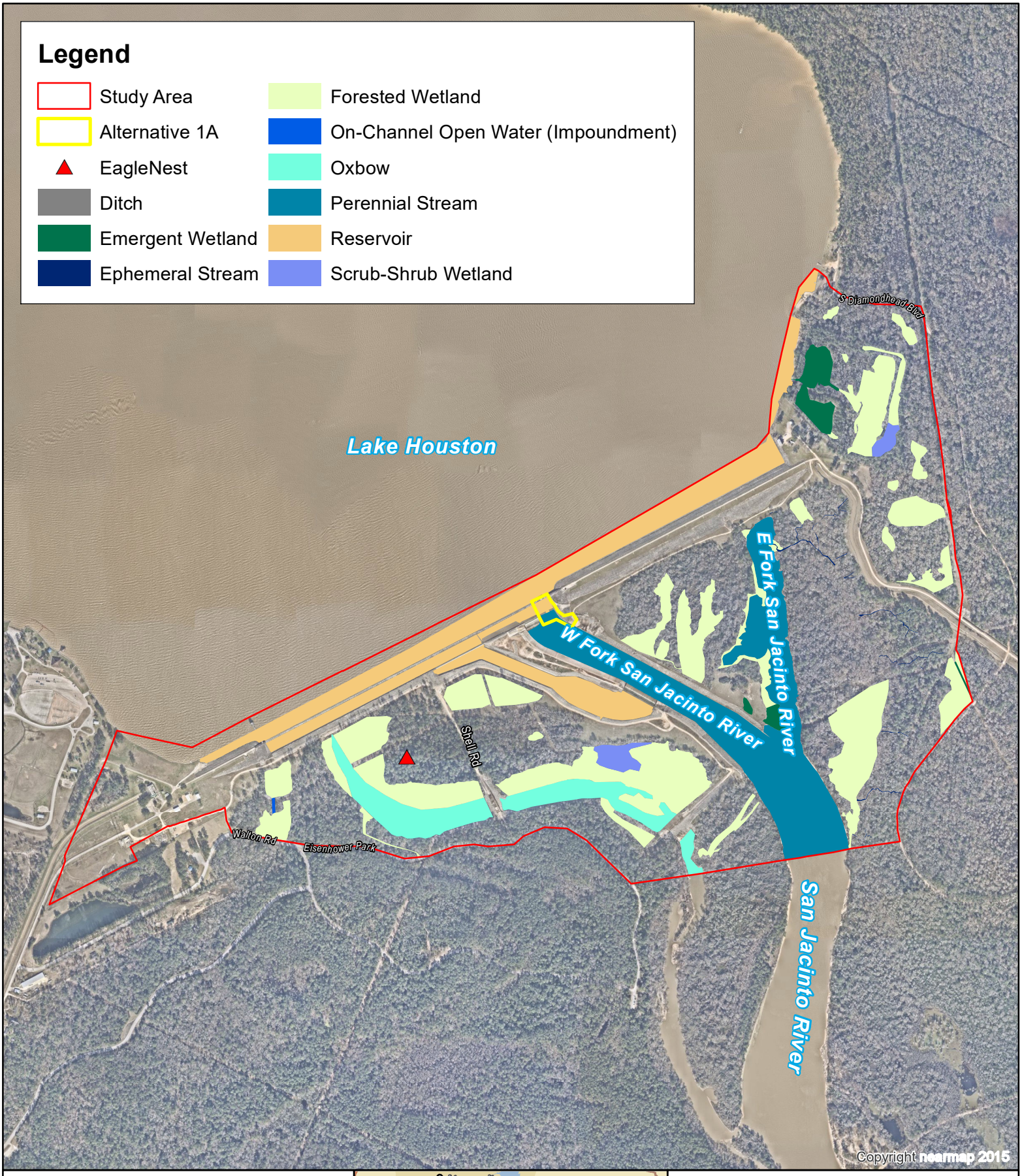

Exhibit 3: 2021 Aerial Photograph with Onsite Alternative 1A

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

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ENVIRONMENTAL + COMMUNICATIONS

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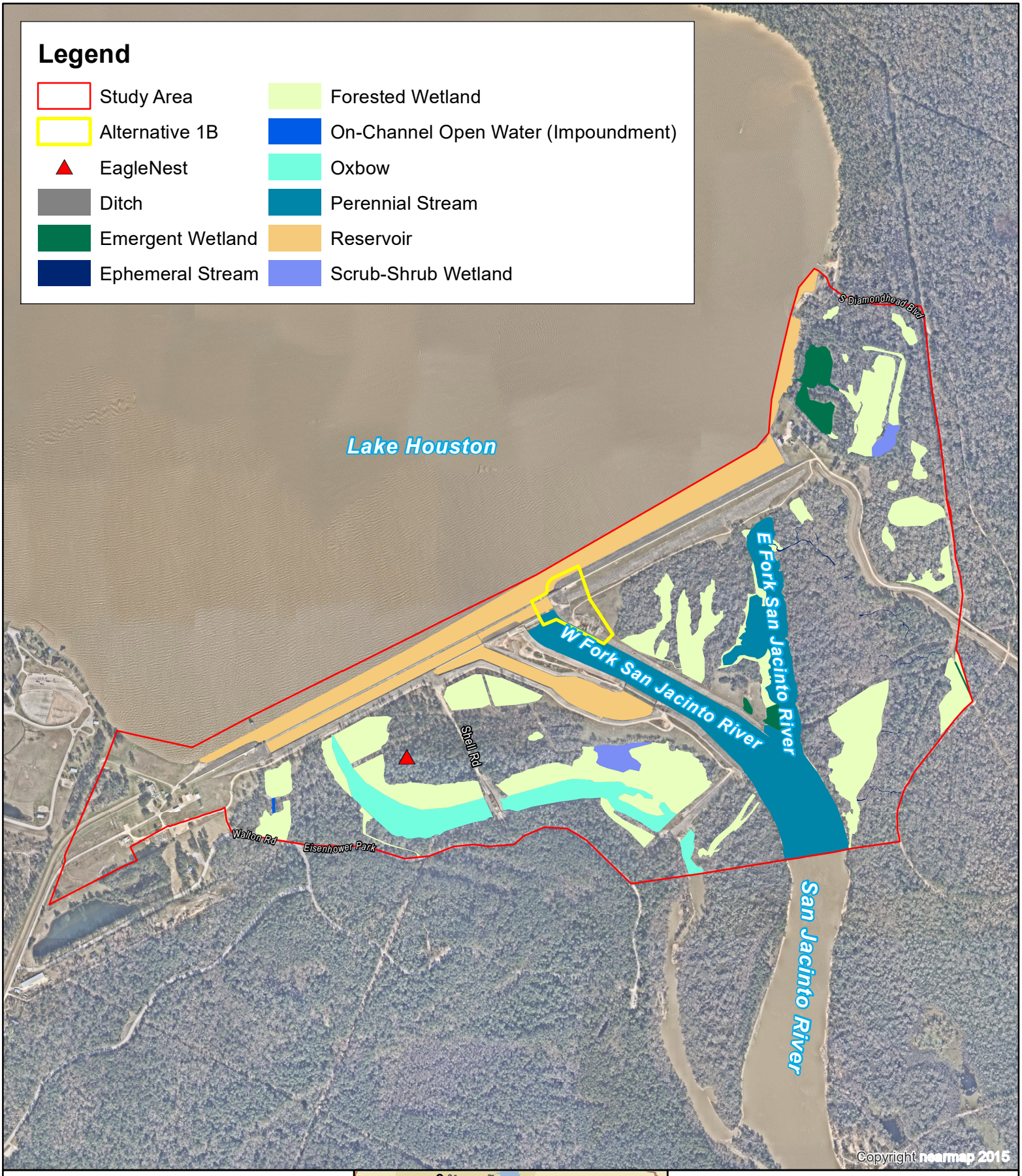

Exhibit 4: 2021 Aerial Photograph with Onsite Alternative 1B

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

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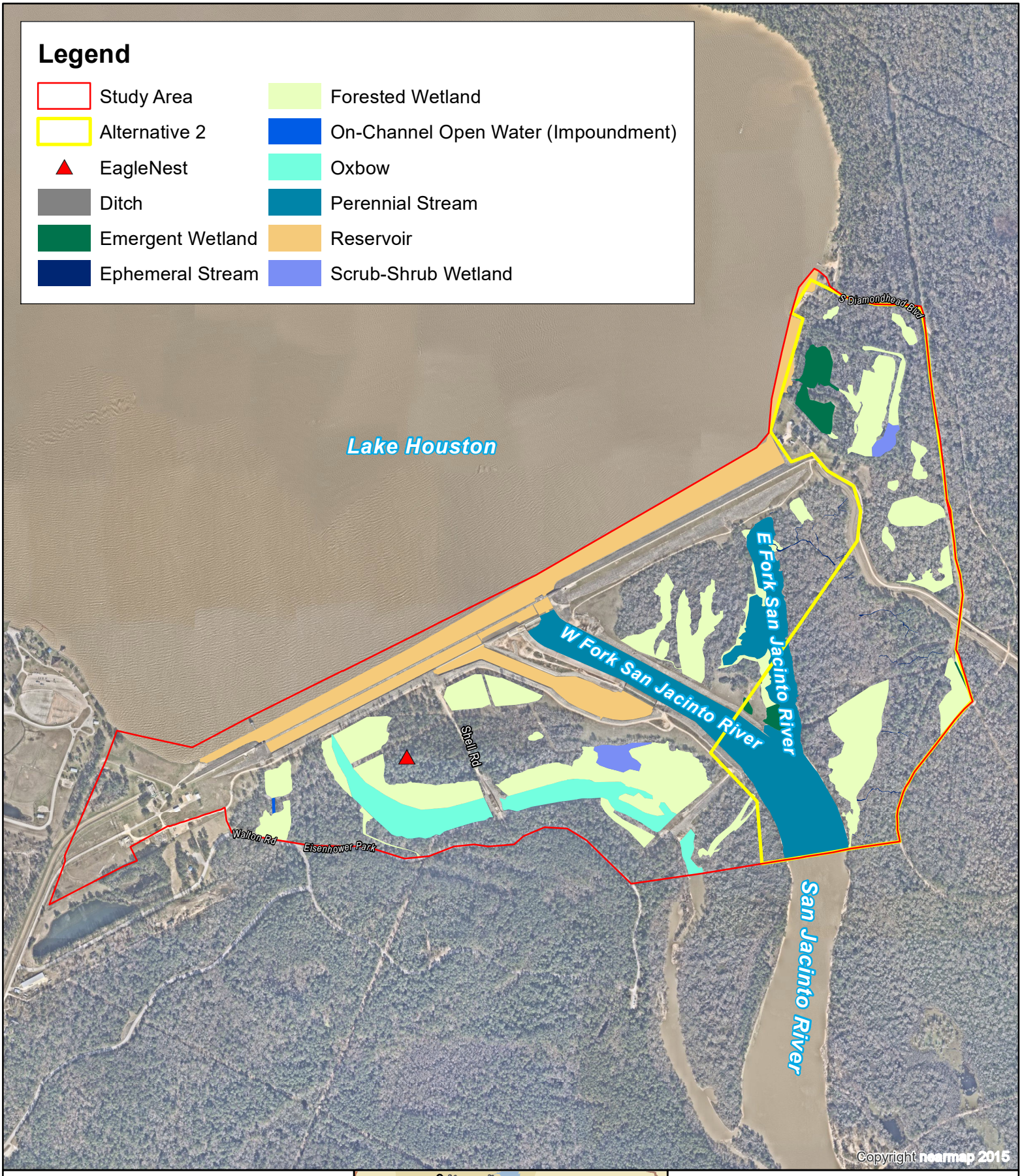

Exhibit 5: 2021 Aerial Photograph with Offsite Alternative 2

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021 Created: 5/26/2021

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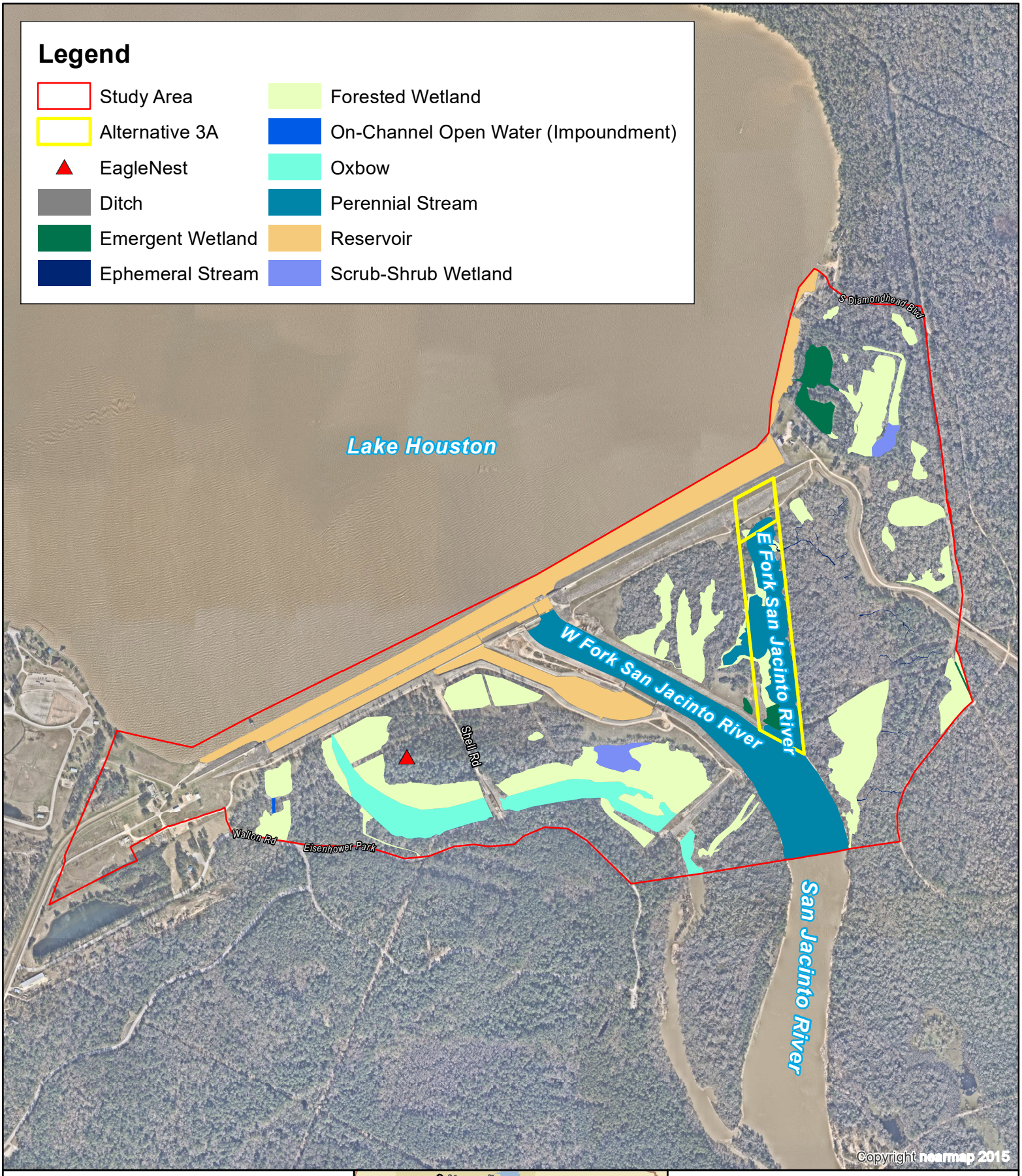

Exhibit 6: 2021 Aerial Photograph with Onsite Alternative 3A

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

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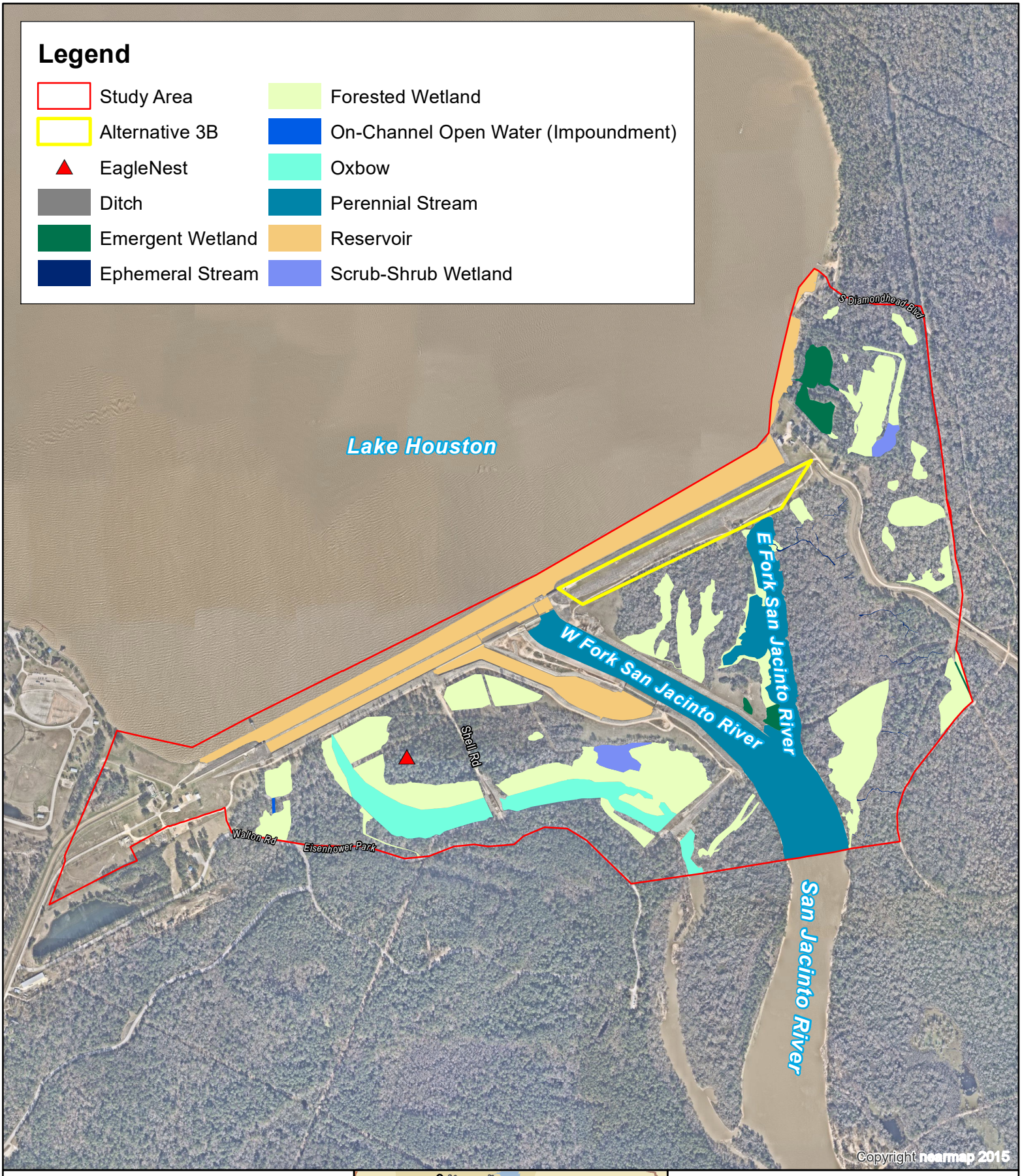

Exhibit 7: 2021 Aerial Photograph with Onsite Alternative 3B

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

HOLLAWAY
ENVIRONMENTAL + COMMUNICATIONS

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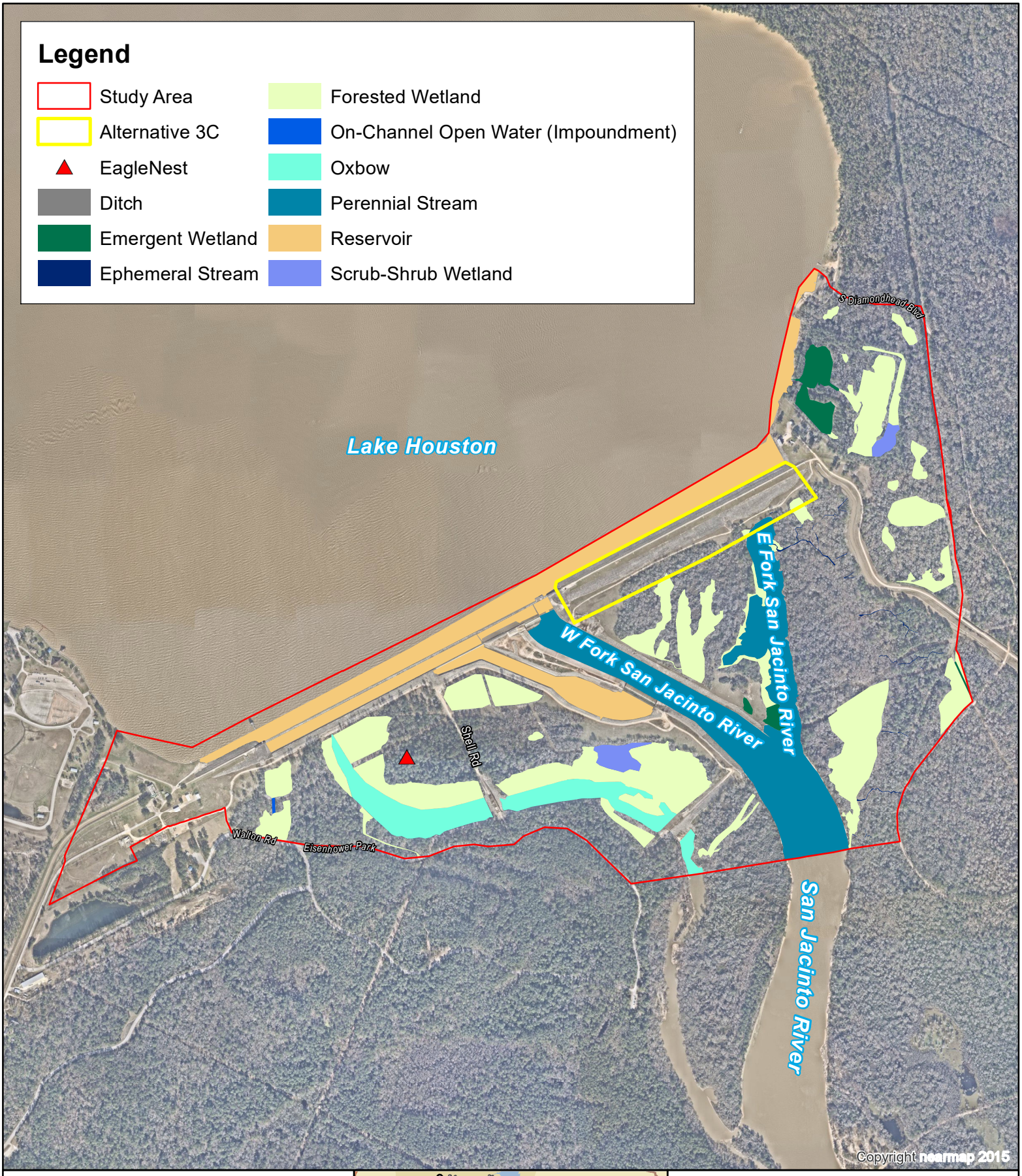

Exhibit 8: 2021 Aerial Photograph with Onsite Alternative 3C

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

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ENVIRONMENTAL + COMMUNICATIONS

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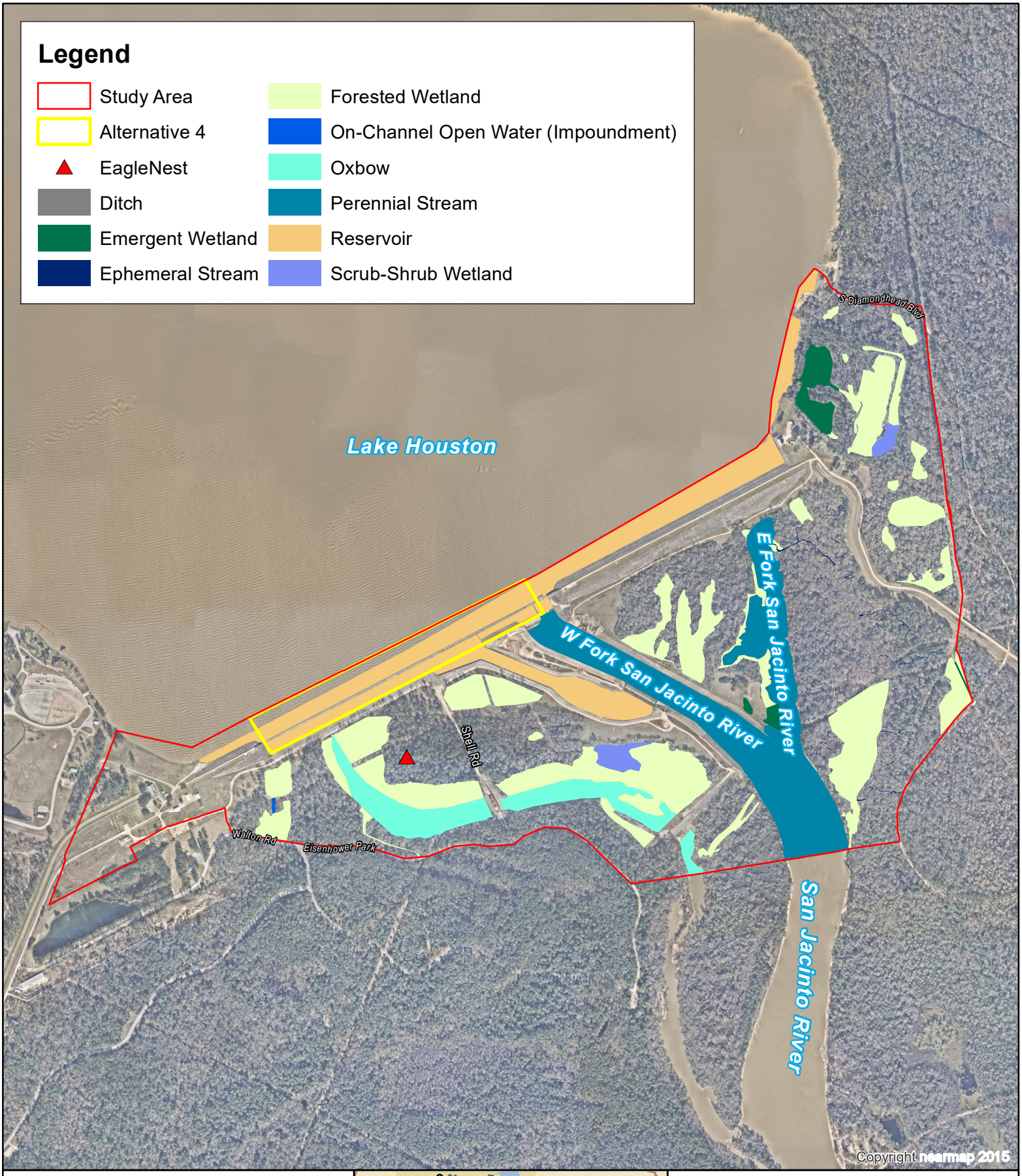

Exhibit 9: 2021 Aerial Photograph with Onsite Alternative 4

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

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ENVIRONMENTAL + COMMUNICATIONS

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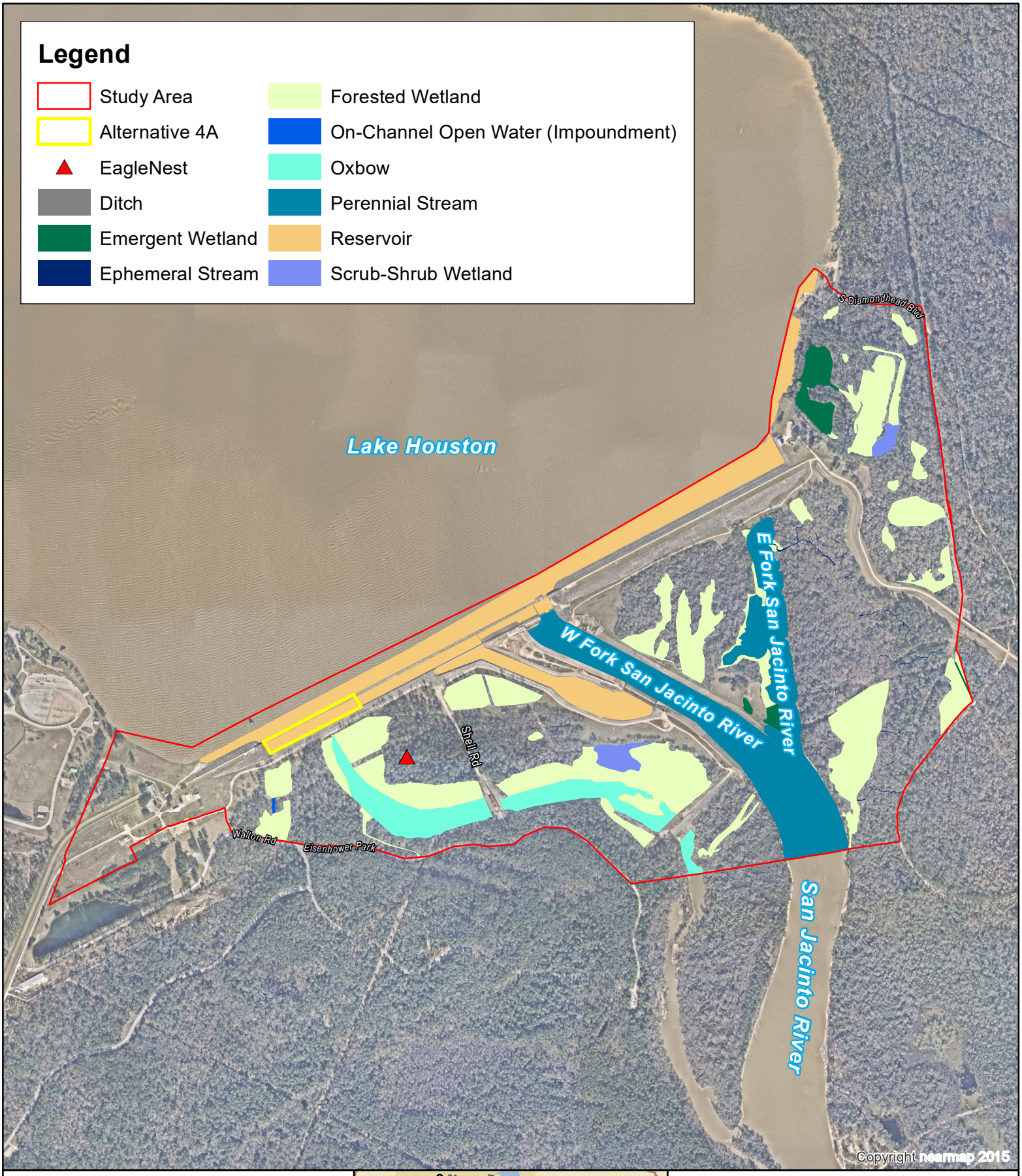

Exhibit 10: 2021 Aerial Photograph with Onsite Alternative 4A

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

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ENVIRONMENTAL + COMMUNICATIONS

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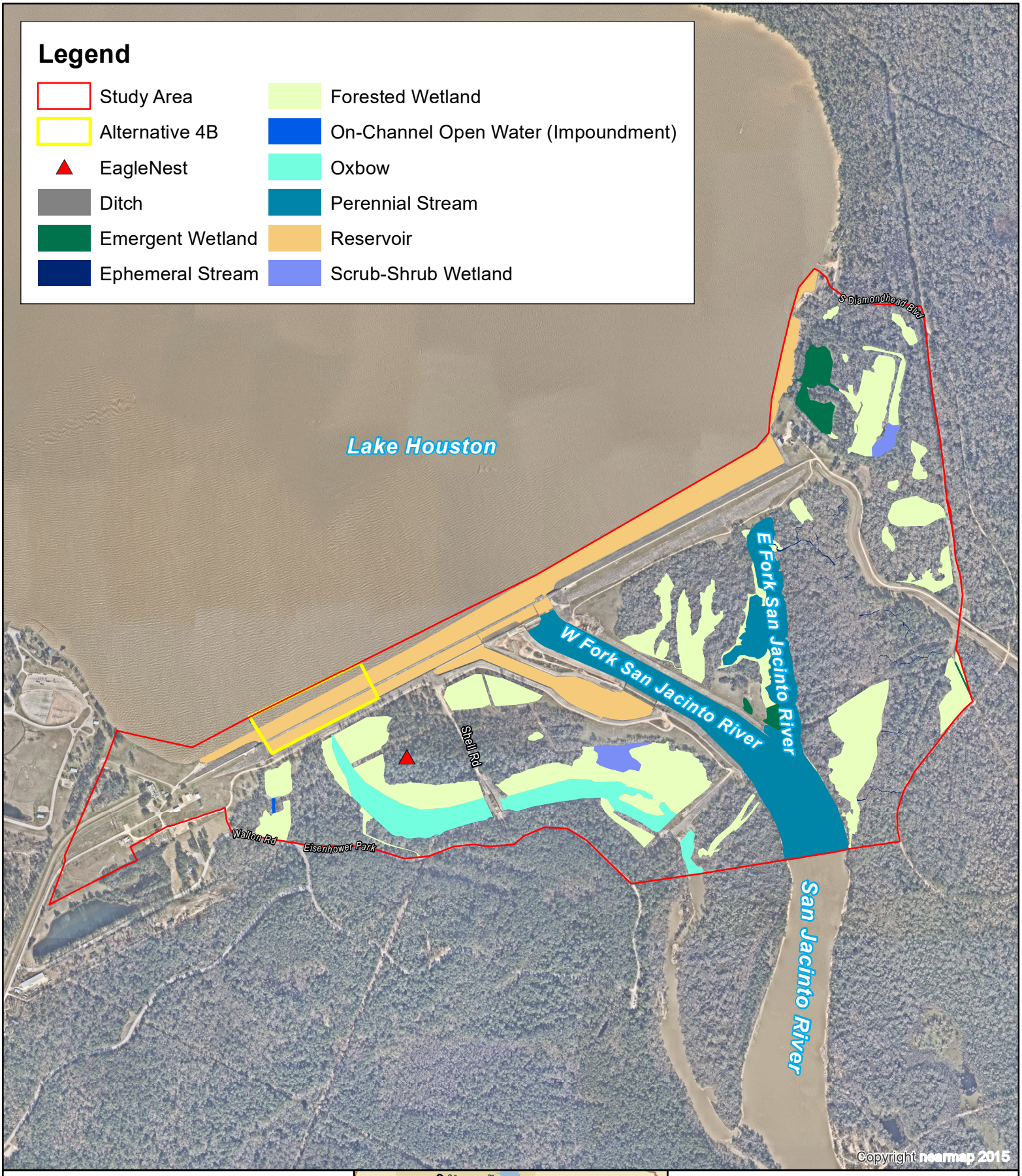

Exhibit 11: 2021 Aerial Photograph with Onsite Alternative 4B

Lake Houston Dam Spillway Improvement
SWG-2020-00271
Harris County, Texas

Date of Aerial: 1/27/2021
Created: 5/26/2021

HOLLAWAY
ENVIRONMENTAL + COMMUNICATIONS

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0 490 980
Feet