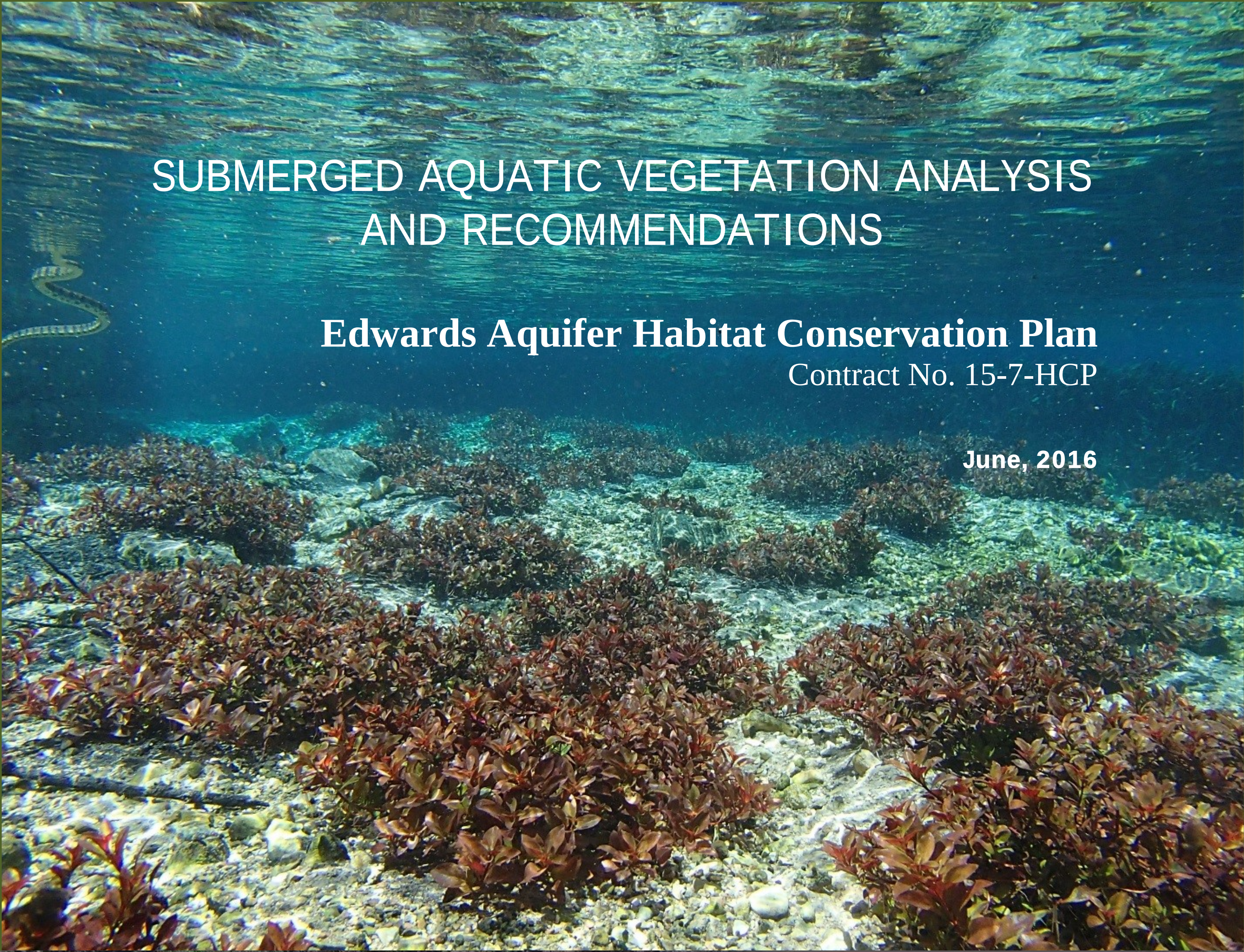

SUBMERGED AQUATIC VEGETATION ANALYSIS AND RECOMMENDATIONS

Edwards Aquifer Habitat Conservation Plan

Contract No. 15-7-HCP

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EXECUTIVE SUMMARY

The Edwards Aquifer Recovery Implementation Plan (EARIP) process led to development of the approved Habitat Conservation Plan (HCP) (EARIP 2011). The HCP provides for ecological monitoring, applied research, and mitigation and restoration activities with the aim of fostering high-quality habitat for the threatened and endangered species found in the Comal and San Marcos systems (EARIP 2011). After several years of HCP implementation of key restoration and protection measures, the program is at a key juncture of being able to effectively evaluate potential adaptive management activities or adjustments. Adaptive management in action consists of managers and researchers working together based on knowledge gained since implementation to evaluate and possibly adjust components based on the intent of the HCP which is to protect the threatened and endangered species within the framework of the incorporated HCP flow regime.

This project evaluated three of the major mitigation and restoration activities including native aquatic vegetation restoration in both the Comal and San Marcos systems, Texas wild rice restoration in the San Marcos system, and flow-split management in the Old Channel of the Comal River. Two primary objectives of this project were to use lessons learned from field experiences since implementation to potentially modify methodologies and submerged aquatic vegetation goals, if necessary, and to establish a timeline for submerged aquatic vegetation restoration (including Texas wild rice) with annual goals. Both objectives were performed to support the tracking of achievement of the HCP long-term biological goals. An additional adaptive management exercise described herein was an evaluation of the flow-split recommendations for the Old Channel of the Comal River.

AQUATIC VEGETATION RESTORATION

Since 2013, a wealth of information has been gained on the effectiveness of the HCP aquatic vegetation restoration program. Although not without challenges as noted in the lessons learned section and detailed in Appendix A, it has been proven that non-native vegetation removal can be highly successful in both systems. Over 5,000 m^2 of non-native *Hygrophila* from the Comal system and over 3,400 m^2 of non-native *Hydrilla* and 1,800 m^2 of non-native *Hygrophila* from the San Marcos system has been successfully removed from key restoration work areas. Additionally, propagation of and subsequent planting of native aquatic vegetation has been successful at varying degrees primarily relative to individual vegetative species and sustained persistence of coverage over time. Over the course of the Comal restoration project through 2015, over 36,000 native aquatic plants have been installed in the Comal system with sustained restoration of over 1,800 m^2 of native aquatic vegetation. Similarly, over the course of San Marcos restoration project through 2015, over 22,000 native aquatic plants (not counting Texas wild rice) have been planted in the San Marcos system with sustained restoration of over 700 m^2 of native aquatic vegetation. Additionally, in the San Marcos system, over 30,000 individual Texas wild rice plants were installed with a sustained restoration of over 3,600 m^2 through fall 2015. Sustained restoration represents vegetation that has persisted and was successfully growing as per this assessment and does not represent the total that was planted or the coverage that came and went over time due to factors such as cessation of gardening during low flows under Provision M of the Incidental Take Permit and scour from flooding.

Key lessons learned from the restoration teams that have direct application for this HCP mitigation measure moving forward include the utilization of system specific plant propagation techniques such as mobile underwater plant propagation trays in Comal and the combination of Texas wild rice production from seeds at the San Marcos Aquatic Resource Center to maintain genetic characteristics of transplanted plants and propagation of native plants within the raceways at the Freeman Aquatic Center in San Marcos. In addition, system specific non-native removal techniques such as the standardized 4-step removal and planting process adopted in Comal and the adaptive non-native removal and planting process adopted in San Marcos should be continued. Both approaches have been shown to be effective given the differences in species and system characteristics. Differences between the approaches reflect the differences in physical characteristics of the river system (e.g., Old Channel flow volume and depth compared to the main stem San Marcos River), contact recreation and access locations in the San Marcos, and non-native species differences (i.e., *Hydrilla* in the San Marcos). Both systems have taken and should continue to take advantage of riparian vegetation thinning to promote increased sunlight for native aquatic vegetation growth as part of riparian restoration efforts. It is proposed that these system specific methodologies be continued to maintain the effectiveness and efficiency of the aquatic vegetation restoration project. Additionally, as part of on-going adaptive management, future opportunities and application of alternative techniques will be explored relative to differences between restoration sites. Where practical, future alternative methodologies may be incorporated in either or both systems moving forward to enhance the success of this project.

In both systems, restoration work has been conducted on 6 of the 7 aquatic vegetation species (specific to each system) identified in the HCP long-term biological goals for the fountain darter. While present in the HCP long-term biological goals table for both systems, non-native aquatic vegetation is not presently being actively promoted or encouraged. During the development of the HCP, it was unknown how effective the non-native vegetation removal program and subsequent native aquatic vegetation reestablishment would be. As such, coverage of non-native vegetation was left in the HCP long-term biological goals table as it is documented as fountain darter habitat. However, in response to successful efforts of control, each restoration team conducted extensive removal on non-native aquatic vegetation from the long-term biological goal (LTBG) reaches and other work areas since HCP implementation.

The scope of work for this project requires the development of a restoration schedule with annual milestones specific to each vegetation species and monitoring reach to accomplish the vegetative biological goals associated with the fountain darter currently established in the HCP. Although not specifically included to meet fountain darter goals, the restoration schedule also includes meeting target Texas wild rice goals in the San Marcos River. With the knowledge gained since implementation, it is the professional opinion of the project team that it would not be ecologically responsible to implement a schedule to meet the original non-native vegetative goals in these systems in support of fountain darter targets. However, since that is a contractual requirement of this scope of work, the exercise was completed and provided herein. In this report, the project team presents the rationale behind and restoration schedules for the following three scenarios:

1) Scenario 1: Existing HCP aquatic vegetation goals
2) Scenario 2: Proposed modification to have only Native aquatic vegetation goals
3) Scenario 3: The second scenario coupled with a definition of “proportional expansion” to further protect the fountain darter in these systems and guide an efficient and effective use of HCP financial resources

For each Scenario, the schedules per system were developed in the context of current funding in the HCP for this mitigation measure. For all schedules presented herein, the post-2015 flood mapping conducted as part of the HCP biological monitoring program was used as the starting point. Finally, for all subsequent comparisons to the long-term aquatic vegetation goals, the project team recommends use of the Fall Comprehensive Event aquatic vegetation maps conducted and prepared as part of the HCP biological monitoring program.

To accomplish the existing Comal HCP long-term biological goals (Scenario 1) for fountain darter habitat, approximately 11,200 m^2 of an additional aquatic vegetation needs to be established. Of this amount, approximately 5,800 m^2 involves rooted aquatic vegetation with approximately 5,400 m^2 involving bryophytes. It must be highlighted that of the rooted aquatic vegetation, over 2,000 m^2 of non-native *Hygrophila* is needed to meet the goals. This is the same *Hygrophila* that has been actively removed to improve overall habitat conditions in the system. Is should also be noted, that target bryophyte coverage is not fully contingent on planting like rooted aquatic plants and amounts are highly variable within the Comal system, especially during drought. To accomplish the existing San Marcos HCP long-term biological goals (Scenario 1), approximately 6,150 m^2 of an additional aquatic vegetation needs to be established. Of this amount, approximately 725 m^2 is made up of non-native aquatic vegetation (*Hygrophila*, *Hydrilla*, and *Vallisneria*). Again, this is the same non-native vegetation that has been actively removed since the implementation of the HCP to improve overall habitat conditions in the San Marcos system. Ecologically, letting non-native aquatic vegetation grow back in to meet a target is not only difficult to propose, but allowing non-natives that have been successfully removed from areas to re-establish over time makes the accomplishment of the native vegetation goals more difficult.

As documented herein, it is not possible to meet the existing HCP long-term biological goals for vegetation coverage in all Comal or San Marcos reaches prior to 2027 using the existing HCP budget. The main shortcoming in the Comal system is relative to *Ludwigia* in the Old Channel reach. In fact, without significant riparian canopy removal and in channel modification, it is likely that the *Ludwigia* goal for the Old Channel reach may not be attainable regardless of budget. The major roadblocks in the San Marcos system are relative to *Ludwigia* and *Potamogeton* in the Spring Lake Dam reach; *Ludwigia*, *Potamogeton* and *Sagittaria* in the City Park reach; and *Ludwigia* and *Cabomba* in the I35 reach. In fact, based on the challenges noted throughout this document regarding competition between previously unseen Texas wild rice levels (as goals) and native aquatic vegetation historically encountered, recreation throughout the San Marcos River and on-going river channel adjustments toward a new equilibrium below Rio Vista dam, it may not be possible to ever meet the original HCP goals for aquatic vegetation in the San Marcos River.

Assuming one could meet the existing HCP vegetation goals in each system, work is still mandatory throughout the remainder of the system for two primary reasons. The first is that to sustain the aquatic plant coverage within the LTBG reaches, non-native vegetation removal (and replacement with natives) will be mandatory in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) in order to assure that non-native plants don't reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG reaches (beyond their defined aerial targets). This concern is especially germane to the San Marcos River where extensive beds of *Hydrilla* occur throughout the river where fragments are regularly dislodged from the extensive contact recreation. Secondly, work towards achieving the undefined HCP management objective of proportional expansion is required per the HCP. It is anticipated that the combination of these two factors coupled with trying to achieve the existing HCP vegetative goals will require the complete use of the annual HCP budget for this mitigation measure in each system through 2027 and beyond.

Upon detailed examinations of the three years of restoration activities, the project team proposes some modifications (Scenario 2) to the HCP long-term biological goals for consideration. The most notable revision for both systems is the proposed removal of all non-native aquatic vegetation from the fountain darter long-term biological goals. Additionally, one new native species (*Potamogeton*) is proposed for addition on the Comal system, while two new native species (*Heteranthera* and *Zizania texana* [Texas wild rice]) are proposed for addition on the San Marcos system. The rest of the proposed revisions on both systems are primarily adjustments in coverage per reach based on each restoration team's experience of what is anticipated to be feasible to accomplish and protective of the fountain darter.

In the Comal system, these adjustments result in a slight reduction (520 m^2) of overall aquatic vegetation in the LTBG reaches. It should be remembered that the HCP vegetation coverage goals were set based on the highest coverage of specific species in a given LTBG reach recorded since 2000, regardless of year, with subsequent adjustments for overall surface area within each LTBG reach. Based on three years of intensive restoration work in the system, it is the conclusion of the project team that not all of those original goals regarding surface area coverage are feasible. However, because of the increased value of native vegetation versus non-native vegetation, there is an overall increase in the potential number of fountain darters to be protected with these proposed modifications.

Under the proposed Comal LTBG reach Scenario 2, it is possible to increase the number of fountain darters protected while meeting the proposed revised HCP long-term biological goals for native vegetation coverage in all LTBG reaches by the conclusion of 2021. Although native vegetative goals could be met following 2021, continued gardening, propagation (at a reduced level compared to full production) and maintenance will be necessary to sustain this coverage over time and proportional expansion will need to be pursued. As proportional expansion is not formally defined, it is anticipated that the combination of meeting the proposed goals in the LTBG reaches, continued maintenance, and efforts toward proportional expansion will exhaust the annual budget for this mitigation measure each year in the Comal system.

In the San Marcos system, proposed adjustments result in a slight reduction (575 m^2) of overall aquatic vegetation in the LTBG reaches. Again, it is highlighted that the original vegetation goals were set based on the highest coverage of specific species in a given LTBG reach recorded since 2000, regardless of year, with subsequent adjustments for overall surface area within each

LTBG reach. Based on three years of intensive restoration work in the system and the required goals for Texas wild rice, it is the conclusion of the project team that not all of the original HCP goals are feasible. Unlike the Comal system, proposed adjustments to the San Marcos River goals needed to incorporate a key HCP decision and an evolving condition that was not fully understood during the development of the HCP. The first is relative to the City Park LTBG reach and the HCP decision to designate the City Park area as a focused recreation access point along the river. By design, recreation access in the San Marcos River is now being directed within certain highly recreated zones (e.g. City Park) to confine physical disturbance to the aquatic vegetation and avoidance of Texas wild rice stands and entrance to State Scientific Study areas. This HCP decision automatically forces a reduction in possible habitat in the City Park LTBG reach as it is not cost efficient or sustainable to plant native vegetation in areas that will be denuded by recreationalists each summer. Secondly, the evolving condition in the I35 LTBG reach revolves around the changing river hydraulics that has followed the reconstruction of Rio Vista Dam. Since that event, aquatic vegetation in the I35 LTBG reach has dramatically declined. The time line or channel configuration under which the San Marcos River below Rio Vista dam reaches its new dynamic equilibrium is at present unknown and not been estimated with applicable bed evolution modeling. Therefore, the project team does not feel that the existing HCP aquatic vegetation goals are achievable in the I35 LTBG reach.

In contrast, under the proposed San Marcos LTBG reach Scenario 2, it is possible to meet all the proposed revised HCP long-term biological goals for native vegetation coverage in all LTBG reaches by the conclusion of 2025. Although native vegetative goals are projected to be met following 2025, continued gardening, propagation (at a reduced level compared to full production) and maintenance will be necessary to sustain this coverage over time and proportional expansion will need to be pursued. As proportional expansion is not formally defined, it is anticipated that the combination of meeting the proposed goals in the LTBG reaches, continued maintenance, and efforts toward proportional expansion will exhaust the annual budget for this mitigation measure each year in the San Marcos system. Additionally, although the proposed native vegetation goals could be met, the reduction in overall vegetation in the LTBG reaches causes a slight decrease (15%) relative to the total number of darters protected (34,325 [original] versus 29,300 [proposed]). This slight reduction emphasizes the importance of defining the proportional expansion HCP management objective associated with the long-term biological goals in the San Marcos River.

As documented in the HCP and referenced above, the fountain darter long-term biological goals for each system also have a management objective that identifies extending aquatic vegetation restoration work beyond the LTBG reaches in equal proportion to efforts expended per study area. In the Comal system, this applies to both the Landa Lake and Old Channel LTBG reaches. In the San Marcos system, this includes all three (Spring Lake Dam, City Park, and I35) LTBG reaches. This objective is not formally defined in the HCP and thus, based on three years of restoration experience in these systems, the project team recommends the following for consideration. It is important to remember that although the main HCP goal is for the survival and recovery of the fountain darter in the wild, this is not the focus of the long-term biological goals. These goals are striving for conditions should they ever be achieved and maintained that would warrant the down listing or delisting of the species. As such, we propose the following as a definition of the "proportional expansion" of this work in each system. To meet this management objective, we recommend establishing known “Restoration reaches” in addition to the established LTBG reaches in each system. In addition to defining this HCP management objective for future comparison, this step was necessary to meet the scope of this project which involves the development of a restoration schedule that strives to accomplish and maintain the long-term biological goals and objectives.

The proposed three Restoration reaches for the Comal system represent a reach both upstream and downstream of the Landa Lake LTBG reach, as well as the entire stretch of the Old Channel from the Landa Lake dam to the existing LTBG reach. This expansion includes the majority of Landa Lake as well as the portion identified in the HCP Section 5.2.2.1 as the critically important Old Channel Environmental Restoration and Protection Area (ERPA). The HCP does not call for expansion in the Upper Spring Run LTBG reach nor New Channel LTBG reach given the higher levels of recreation in these reaches coupled with the potential for scour via flooding from either Blieder’s or Dry Comal creek’s, respectively. Similarly, we do not propose restoration activities downstream of the existing LTBG reach in the Old Channel. This area downstream is outside of the protection zone of maintaining suitable water temperatures (as modeled in the HCP) during low-flow conditions. Additionally, recreational activities are substantially increased in this downstream zone, especially in the Hinman Island drive portion of the river. Adding these three “Restoration reaches” in the Comal system adds approximately 30,000 m^2 of native aquatic vegetation and approximately 180,000 fountain daters for protection. To accomplish the proposed Comal system goals for both the LTBG and Restoration reaches (Scenario 3), approximately 2,500 m^2 of additional native aquatic vegetation would need to be established for the Restoration reaches. If this combined program (LTBG and Restoration) was implemented, it would possible to meet all the proposed revised HCP long-term biological goals for vegetation coverage in all LTBG reaches and Restoration reaches in the Comal system by the conclusion of 2023. It is anticipated that approximately one half of the annual HCP budget would be needed for this mitigation measure in the Comal system from 2024 through 2027 to maintain goals and management objectives.

The proposed five Restoration reaches in the San Marcos system represent reaches both upstream and downstream of the City Park LTBG reach, as well as the entire stretch of the river from downstream of the I35 LTBG reach to the I35 highway bridge. This expansion includes the majority of key fountain darter habitat areas between Spring Lake Dam and Rio Vista Dam, as well as nearly the entirety of the river from Rio Vista Dam to I35. We do not propose native aquatic vegetation restoration activities <u>specific</u> to fountain darters downstream of I35. Although fountain darters are found downstream of this area, we do not feel that the costs associated with repeated restoration in a reach so prone to flooding destruction is a practical use of HCP funding. However, per the established Texas wild rice HCP goals, restoration for Texas wild rice will continue downstream of I35. Adding these “Restoration reaches” in the San Marcos system adds over 9,000 m^2 of native aquatic vegetation and approximately 35,000 fountain darters for protection. To accomplish the proposed San Marcos system goals for both the LTBG and Restoration reaches (Scenario 3), the San Marcos restoration team needs to establish approximately 2,700 m^2 of additional native aquatic vegetation in the Restoration reaches. If this combined program (LTBG and Restoration) was implemented, it would be possible to meet all the proposed revised HCP long-term biological goals for vegetation coverage in all LTBG reaches and Restoration reaches in the San Marcos system by the conclusion of 2027 using the established HCP budget for this mitigation measure.

Restoration timelines for the accomplishment of the aquatic vegetation goals in both systems are presented individually for all three Scenarios in Section 3 and Appendix B. For successful implementation of these schedules, it is critical that concurrent aquatic plant propagation, gardening, and maintenance occur throughout the entire HCP timeline regardless of whether a certain species in a given reach during a given year has no defined coverage goal. It is important to understand that depending on the system, vegetation species, and particular reach, somewhere between 35 to 65% of the annual costs associated with this restoration effort involves non-native plant removal, aquatic gardening, and plant propagation. Without these key components, achieving and sustaining the native aquatic vegetation coverage presented in the HCP timeline would not be possible.

Upon accomplishment of coverage goals per reach, plant propagation (at a reduced level compared to full production) will still be necessary to supplement vegetation stands to sustain this coverage over time. This is particularly true under any post flood scour events that might reduce coverage below target goals. It also needs to be understood that although two of the three vegetation goal schedules only formally define targets in the LTBG reaches, it does not mean that aquatic gardening and maintenance does not need to occur outside of those areas. To sustain native aquatic plant coverage goals in these systems, non-native vegetation removal (and replacement with natives) will be mandatory in order to assure that non-native plants don't reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG or restored proportionally expanded areas.

Considering over 10,000 m^2 of non-native vegetation has been removed, nearly 90,000 native plants have been installed and over 6,000 m^2 of native aquatic vegetation sustained in the first three years of HCP restoration combined for both systems, with 2013 being a trial year, the proposed goals and timeline appear achievable with the following assumptions emphasized:

- Restoration efforts will proceed with no major setbacks or resets such as floods, dam or culvert repairs, etc.
- Anthropogenic factors such as recreational disturbances and urban runoff are managed.
- Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
- Non-native vegetation removal (and replacement with natives) will occur in upstream or adjacent areas outside of the LTBG reaches in order to mitigate reestablishment on non-natives.
- No significant interruptions in work due to HCP Provision M.
- Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation.
- Riparian restoration in the Old Channel of the Comal River is mandatory to accomplish the proposed goals.
- Mapping to compare against goals will be conducted annually each fall.

TEXAS WILD RICE

The project team presently supports the ranges of the Texas wild rice goals in the HCP but based on current knowledge projects that accomplishment may be constrained to the lower end of the range for Texas wild rice goals. The rationale for this projection is in part because of the competing goals of Texas wild rice and other native vegetation target aerial coverage present in some reaches of the San Marcos River. A conflict is inherently imposed on the restoration program as the HCP native vegetation restoration goals for the fountain darter were derived from the historically highest level of vegetation present over 10 years of monitoring. In contrast, the Texas wild rice goals were derived based on the potential for suitable habitat (depth, velocity, and substrate) for this species, independent of the HCP native aquatic vegetation goals for the fountain darter. When combined, there is not enough suitable habitat to accommodate the competing areal coverage for all aquatic vegetation species simultaneously. In addition, unknowns regarding future floods and the potential removal of Cape's Dam cause uncertainty on the ability to achieve sustained restoration of the goals and management objectives below I35. With those concerns noted, a comprehensive schedule is provided for Texas wild rice with projected accomplishment in 2026 assuming the current level of HCP funding and no system resets like major floods.

FLOW-SPLIT MANAGEMENT

Based on HCP activities conducted in the Old Channel since the inception of restoration coupled with biological monitoring conducted during the drought conditions of 2013 and 2014, we propose that adjustments be considered to the current HCP flow-split recommendations. A detailed discussion of the rationale behind this decision is presented in Section 2.3. In summary, when the HCP was under development, *Hygrophila* dominated the Old Channel LTBG reach and the success of the proposed native aquatic vegetation restoration was an unknown. As such, a decision was made by the HCP Biological working group to incorporate a flow-split recommendation that exhibited more of a stream hydrology characteristic to try and improve conditions in the Old Channel. Following three years of restoration work and continued monitoring, it is that decision that is being revisited in this report.

As part of the HCP, in the spring of 2014 the City of New Braunfels completed the repair of the larger culvert from Landa Lake to the Old Channel of the Comal River while sealing off the two original smaller culverts. This allowed for full functionality of the large culvert, and at that time, the City of New Braunfels began operating according to the HCP flow-split recommendations. Prior to culvert repair and operation, the Sediment Island had been removed and native aquatic vegetation including *Ludwigia* was successfully restored in 2013 in its former footprint. Since the culvert repair and operation we have observed areas of native aquatic vegetation, including the former Sediment Island area, becoming scoured and severely reduced in cover. The scour action typically was a consequence of rapidly changing water velocity or sustained high water velocities in the 70 to 80 cfs range.

A second observation that happened during the biological monitoring of Comal Springs riffle beetles during the extensive 2014 drought raised another concern with the original flow-split recommendations. In summer 2014, total system discharge declined below 70 cfs in the Comal River, a condition not experienced since prior to the inception of the biological monitoring program in 2000. Operations according to the flow-split table mandated that a 50 cfs (Old Channel) to 20 cfs (New Channel) split occur. As such, the City of New Braunfels adjusted to accommodate that recommendation. In doing so, a large amount of Comal Springs riffle beetle habitat in the Spring Island area became exposed. Knowing that native aquatic vegetation in the Old Channel does very well at 40 cfs (pre-2003) coupled with the successful restoration of native aquatic vegetation since 2013 in the Old Channel, we feel that an adjustment to the flow-split recommendations when total system discharge declines below 150 cfs to 50 cfs is warranted to protect riffle beetle habitat in the Spring Island area. Based on the knowledge gained on upper end scour at 70 to 80 cfs, and the exposure of Comal Springs riffle beetle habitat below the 150 cfs flow-split distribution, Table 35 (Section 3.2) presents the proposed adjustments to the flow-split recommendations.

ADAPTIVE MANAGEMENT

In summary, this review, lessons learned, assessment, and scheduling exercise provided valuable information for consideration in the HCP adaptive management process. The recommendations presented in this document represent the combined experience and consensus of both the Comal and San Marcos restoration teams. In addition to proposed modifications or clarifications to certain HCP long-term biological goals or objectives, the project team recommends that should these recommendations and schedules be implemented, they formally be revisited every two years. The importance of a periodic reassessment is to ensure the implemented recommendations are providing the protection that was projected, schedules are in fact feasible, and an opportunity is provided to account and/or adjust for unforeseen circumstances. Finally, we also recommend that the HCP long-term biological goals be formally revisited every five years to assess whether those goals are continuing to meet the intent of the HCP.

1.0 OVERVIEW

The Habitat Conservation Plan (HCP) developed as part of the Edwards Aquifer Recovery Implementation Plan (EARIP) provides for ecological monitoring, applied research, and mitigation and restoration activities with the aim of fostering high-quality habitat for the threatened and endangered species found in the Comal and San Marcos systems (EARIP 2011). After three plus years of HCP implementation, it had become evident that certain mitigation and restoration measures would benefit from a detailed evaluation of goals, objectives, and timelines for accomplishment within the context of the term of the HCP. This is the definition of adaptive management in action with managers and researchers working together based on knowledge gained since implementation to evaluate and possibly adjust components based on the original intent of the HCP which is to protect the threatened and endangered species within the framework of the incorporated HCP flow regime.

This project takes a detailed look at three of the major mitigation and restoration activities including native aquatic vegetation restoration in both the Comal and San Marcos systems, Texas wild rice restoration in the San Marcos system, and flow-split management in the Old Channel of the Comal River. As stated in the scope of work for this project, the purpose of this effort was to generate information and data for evaluating potential changes to vegetation restoration, in the Comal and San Marcos Rivers, to achieve the Edward's Aquifer HCP Long-term Biological Goals through the HCP Adaptive Management process. The two primary objectives of this project were 1) to use lessons learned from field experience in the first three years of implementation to potentially modify methodologies and submerged aquatic vegetation goals, if necessary, and 2) to establish a timeline for submerged aquatic vegetation restoration (including Texas wild rice), with annual goals. Both objectives are being performed to support the tracking of achievement of the HCP long-term biological goals.

An additional objective of this adaptive management exercise was to evaluate the flow-split recommendations for the Old Channel of the Comal River based on knowledge gained over the past few years of implementation following the culvert repairs in Spring 2014.

2.0 BASELINE EVALUATION

2.1 Vegetation Restoration Lessons Learned

Literature and processes for restoring aquatic vegetation within wetlands and marshes is commonplace and some work has been done with propagating and restoring sea grasses in estuaries and aquatic plants in reservoirs. However, little information was available during the development and initial implementation of the HCP aquatic vegetation restoration measure for the propagation and restoration of submersed aquatic plants in spring-fed rivers. The aquatic plant restoration activities currently active in the Comal and San Marcos rivers are unique in many respects. Few rivers in the United States possess the aquatic diversity of these two water bodies and currently no similar large-scale restoration project has been identified to use as a comparison or template. Therefore, both restoration teams relied on broader aquatic vegetation restoration literature, published literature on aquatic vegetation life histories, and on-going application of adaptive management principals to assess the effectiveness of applied specific removal and propagation methodologies.

The Comal and San Marcos river aquatic plant restoration efforts have experienced both unique and shared challenges between the tasks of removing invasive aquatic plant species, propagating and transplanting sufficient amounts of native plant material and maintaining restored locations despite drought, flood, human recreation and other circumstances. The success of these efforts in each system to date reflects a combination of creative thinking and sustained hard work by the respective restoration teams. As outlined in the HCP, three species of aquatic plants (*Ludwigia repens*, *Cabomba caroliniana* and *Sagittaria platyphylla*) were pre-selected as targets for the aquatic restoration efforts based on fountain darter use collected from over a decade of intense biological monitoring. While these species were chosen based on their preferred use by the fountain darter other factors such as ease in propagation, availability of propagules, and planting techniques (e.g., size and density) were not initially taken into account.

To better understand the basis of existing success, challenges encountered and overcome and the challenges which remain the following system-specific sections (further detailed in Appendix A) provide results to date, detailed descriptions of methodologies employed or tried, noted challenges the project teams faced and some challenges which remain to be solved in the future.

2.1.1 Comal System

As part of the HCP, scientists with BIO-WEST, Inc. and researchers from Baylor University's Center for Reservoir and Aquatic Systems Research ("Baylor") (Comal restoration team) developed and implemented a native aquatic vegetation restoration plan for Landa Lake and the Old Channel within the City of New Braunfels, Texas (BIO-WEST 2013). The intent of this HCP measure is to maintain high-quality habitat for the endangered fountain darter *Etheostoma fonticola* by both increasing the amount of available habitat and by improving the quality of the existing habitat. This habitat restoration measure is a key element in striving to meet the HCP long-term biological goals for the fountain darter as discussed further in Section 2.

The main project areas for vegetation restoration work to date include the general extent of the Landa Lake HCP biological monitoring study reach and a stretch of the Old Channel of the Comal River bounded on the upstream side by the Landa Lake outflow to the downstream-most extent of the Old Channel HCP biological monitoring study reach (Figure 1). The selected Old Channel restoration area was identified in HCP Section 5.2.2.1 as the critically important Environmental Restoration and Protection Area (ERPA).

Figure 1. Location of the Landa Lake and Old Channel restoration areas (Red). Green indicates the extent of 2013 and 2014 restoration activities in the Old Channel, yellow represents extent for 2015 activities, and dark blue indicates areas of future invasive vegetation removal and habitat restoration in the Old Channel.

In 2013 the Comal restoration team determined a path forward for the aquatic vegetation restoration project by conducting site assessments to gage habitat quality within the project areas and by analyzing historical accounts in order to determine previous expanses of native vegetation. The historical analysis supported the theory that many pockets of native vegetation in Landa Lake and the Old Channel had been replaced by non-native aquatic plant species, and that the areas slated for restoration could, following restoration activities, once again support native plant communities. Using the full-system aquatic vegetation mapping completed for the HCP biological monitoring in February 2013, the Comal restoration team created baseline aquatic vegetation maps of the Landa Lake and Old Channel restoration areas. These 2013 maps showed that the range for *Ludwigia repens* (*Ludwigia*) (native aquatic vegetation) was very limited in the Landa Lake and Old Channel restoration areas (Table 1). In contrast in 2013, *Hygrophila polysperma* (*Hygrophila*) (non-native aquatic vegetation) was the dominant submersed aquatic plant species in the Old Channel restoration stretch of the Comal River covering approximately 27 % of the total area (Table 1).

Table 1. Aquatic vegetation species and area coverage present in 2013 within the two Project Areas prior to HCP restoration activities.

Aquatic Plant Species	Area (m^2)	% of Total Area within Project Area
Landa Lake Project Area (47,889 m^2)		
Bryophytes*	7,019.9	14.7%
Cabomba Ɨ	2,713.1 (344.1)	5.7%
Hygrophila	522.9	1.1%
Justicia	6.4	0.01%
Ludwigia	191.7	0.4%
Nuphar	2,715.9	5.7%
Sagittaria	3,461.6	7.2%
Vallisneria	21,192.1	44.2%
Bare substrate	10,065.4	21%
Old Channel Project Area (8,050 m^2)		
Cabomba	117.3	1.6%
Colocasia	164.1	2%
Hydrocotyle	2.2	0.02%
Hygrophila	2,177.4	27%
Justicia	372.2	4.6%
Ludwigia	123.7	1.5%
Nuphar	70.3	0.9%
Sagittaria	281.6	3.5%
Vallisneria	1,132.7	14.1%
Zizaniopsis	130.7	1.6%
Bare substrate	3,477.8	43.2%

*Presented as bryophytes mapped as the dominant vegetation. An additional 1,026.8 m^2 of bryophytes is overlying other mapped vegetation types.
Ɨ This number has since been modified from previous reports. Number in parentheses removes the large amount of *Cabomba* located within Pecan Island side channel. This number (344.1) should be considered the baseline number for *Cabomba* in the Landa Lake restoration area.

In order to identify target native species for restoration, the project team initially looked at several factors, including the quality of habitat the species provides for the fountain darter, historical and current distribution of the species in the system, and the suitability of the species for propagation. Based on these factors the Comal restoration team, in 2013, identified three target native species—*Ludwigia*, *Cabomba*, and *Sagittaria*—and their corresponding habitat types for use in restoration activities. All three species are identified in the HCP long-term biological goals for the fountain darter in the Comal system.

Two additional native aquatic plants were used in 2014 (*Potamogeton illinoensis* and nonvascular bryophytes/aquatic mosses). Bryophytes are identified in the HCP long-term biological goals for the fountain darter in the Comal system, while *Potamogeton* is not. This species was added to the restoration program based on the knowledge gained in the Old Channel restoration reach in 2013. Upon successful removal of the Sediment Island (discussed in Appendix A) and replanting of native aquatic vegetation in the footprint of the former island, the introduction of *Ludwigia*, *Sagittaria*, and *Cabomba* went well. However, as the water velocity in the upstream portion of this area and again just upstream of the golf course bridge is very swift, it was noted over the course of 2013, that *Ludwigia* was unable to support itself in this habitat type. This swift habitat is highly suitable for *Potamogeton* and thus this native aquatic vegetation species was used to provide a velocity shelter in these areas for other native vegetation. The use of *Potamogeton* for this purpose has been highly successful since 2014.

Restoration efforts in 2015 included the addition of the vascular *Vallisneria neotropicalis* and submerged *Justicia americana*. *Vallisneria* is identified in the HCP long-term biological goals for the fountain darter in the Comal system, but *Justicia* is not. Similar to *Potamogeton* as described above, *Justicia* amounts used were low and focused on providing velocity buffers to protect other native plants targeted for restoration. As such, five of the seven aquatic vegetation species identified in the HCP long-term biological goals for the fountain darter in the Comal system are actively being planted in the system. A type of unidentified filamentous algae which historically occurred in the early 2000s in the Old Channel was included in the long-term biological goals but has been absent from the Old Channel stretch of river for nearly a decade. The sparse distribution of this algae in the Comal system and complexities of trying to establish an algae via restoration has led the team to avoid this species to date. The other aquatic vegetation species unaccounted for in the HCP long-term biological goals table is the non-native *Hygrophila*. During the development of the HCP, it was unknown how effective the non-native vegetation removal program and subsequent native aquatic vegetation reestablishment would be. As such, a level of *Hygrophila* was left in the HCP long-term biological goals table as it does provide fountain darter habitat.

Since 2013, a wealth of information has been gained on the effectiveness of the restoration program. Based on a comparison of 2013 mapping data to late 2015 map data, the Comal restoration team has successfully removed over 4,000 m^2 of non-native *Hygrophila* from the system translating to over 99% in both the Upper Spring Run and Landa Lake restoration areas, and approximately 84% of the non-native *Hygrophila* from the Old Channel restoration area (Table 2). During removal efforts in 2014, it was observed that a large amount *Hygrophila* fragments originated from the spring-fed swimming pool and moved downstream through the Old Channel restoration area. Upon further inspection, the gravel bottom of the spring fed swimming pool was noted to be approximately 80% covered with *Hygrophila*. A large amount of fragmentation was occurring from this growth as swimmers tore *Hygrophila* stems and discharge washed these propagules downstream. As a result, the restoration team recommended that removal of *Hygrophila* from the swimming pool was necessary in order to eliminate this source of fragments and prevent re-colonization of *Hygrophila* downstream in the Old Channel restoration area. Due to the large amount of *Hygrophila* in the pool and the extent of its establishment, it was determined that removal of gravelly bottom material by an excavator machine would quickly and most efficiently eliminate *Hygrophila* from the pool. Removal of *Hygrophila* from the swimming pool occurred from April 6 to April 8, 2015, and consisted of removal of 3 to 4 inches of pool bottom gravel across two thirds of the pool bottom. The material was hauled to a secure location contained within silt fencing and allowed to dry. After removal of bottom material, the pool was revisited occasionally throughout the summer, whereupon any remaining *Hygrophila* fragments were removed. This additional effort removed an estimated 970 m^2 of *Hygrophila* adding to the total documented in Table 2.

Table 2. Coverage of *Hygrophila* (m^2) in the Comal system between 2013 and 2015.

	Coverage of *Hygrophila* (m^2)			
	Upper Spring Run	**Landa Lake**	**Old Channel**	***Total***
2013	763	522	3,411	4,696
2015	1	2	531	534
% reduction in reach	> 99%	> 99%	84%	89%

Over the course of Comal restoration project through 2015, over 36,000 native aquatic plants have been installed in the Comal system (Table 3).

Table 3. Number of individual plants installed in the Comal system between 2013 and 2015.

	Old Channel	**Landa Lake**	***Total***
Ludwigia	9,688	8,009	17,697
Sagittaria	6,048	1,947	7,995
Cabomba	2,915	4,953	7,868
Potamogeton	27	0	27
Justicia	20	0	20
Vallisneria	2,000	1,225	3,225
Total	20,698	16,134	36,832

At present (February 2016), the Comal restoration team has sustained restoration of 1,858 m^2 of native vegetation that has persisted within the Landa Lake and Old Channel restoration work areas (Table 4). We state “sustained restoration”, because this represents vegetation that has persisted up to February 2016. Table 4 does not represent the total that was planted nor the coverage that came and went over time, only what was present as of February 2016 and successfully growing. For a detailed examination of the variability in success and challenges over time, please refer to the Aquatic Vegetation Restoration stand-alone annual reports (BIO-WEST 2013, 2014a, and 2015a) submitted to the City of New Braunfels as part of the HCP.

Table 4. Native Aquatic Vegetation (m^2) planted and sustained since 2013.

	Old Channel	**Landa Lake**	***Total***
Ludwigia	617	607	1,224
Sagittaria	218	114	332
Cabomba	45	102	147
Potamogeton	73	-	73
Justicia	17	-	17
Vallisneria	3	62	65
Total	973	885	1,858

Figures 2 and 3 show the aquatic vegetation distribution and coverage in the Landa Lake Restoration reach over time, starting with pre-restoration (Spring 2013) and then annually each fall from 2013 through 2015. Figures 4 and 5 document the aquatic vegetation distribution and coverage in the Old Channel restoration reach over time starting with pre-restoration (Spring 2013) and then annually each fall from 2013 through 2015.

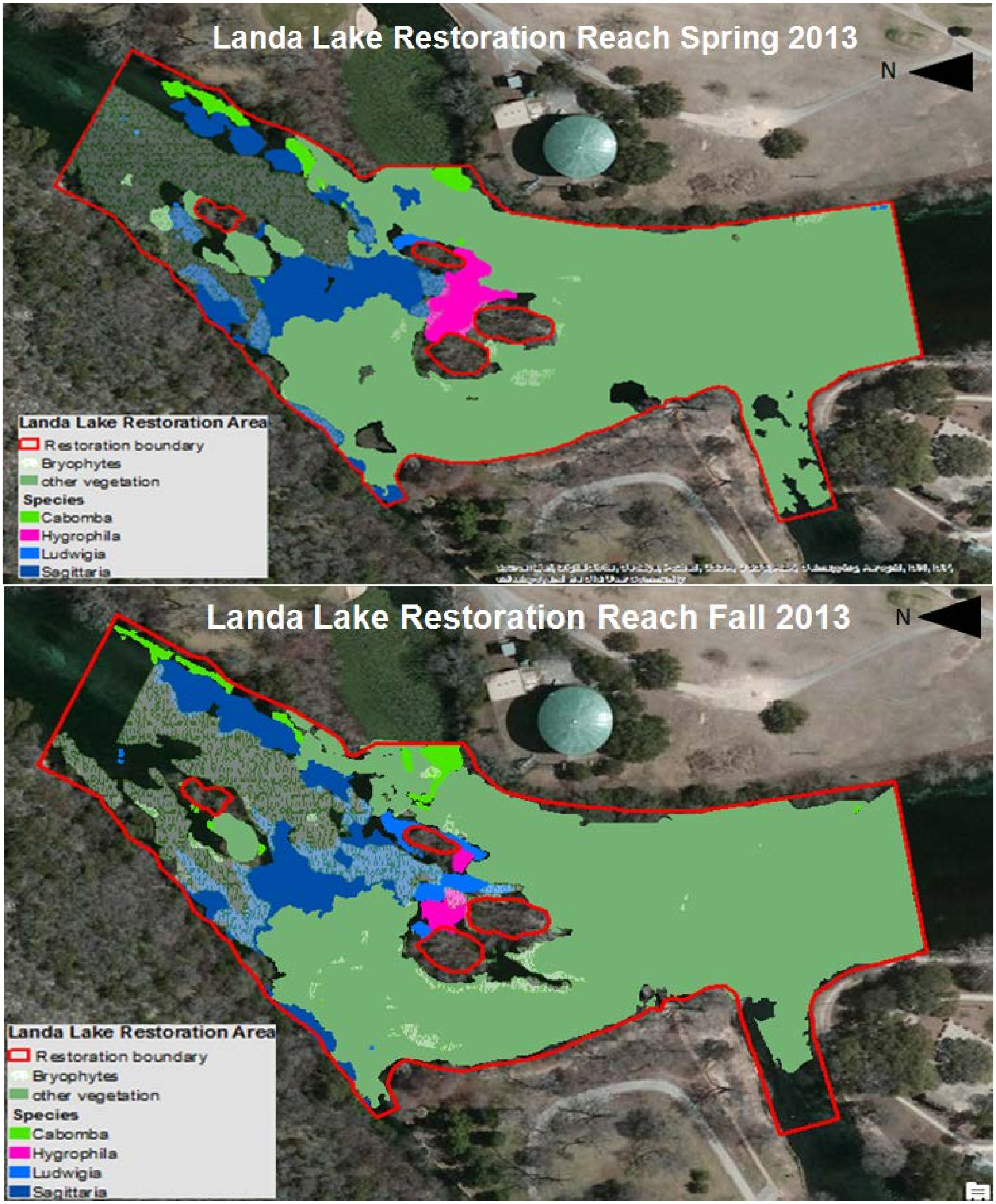

Figure 2. Landa Lake Restoration reach aquatic vegetation map Spring 2013 (Top) and Fall 2013 (Bottom).

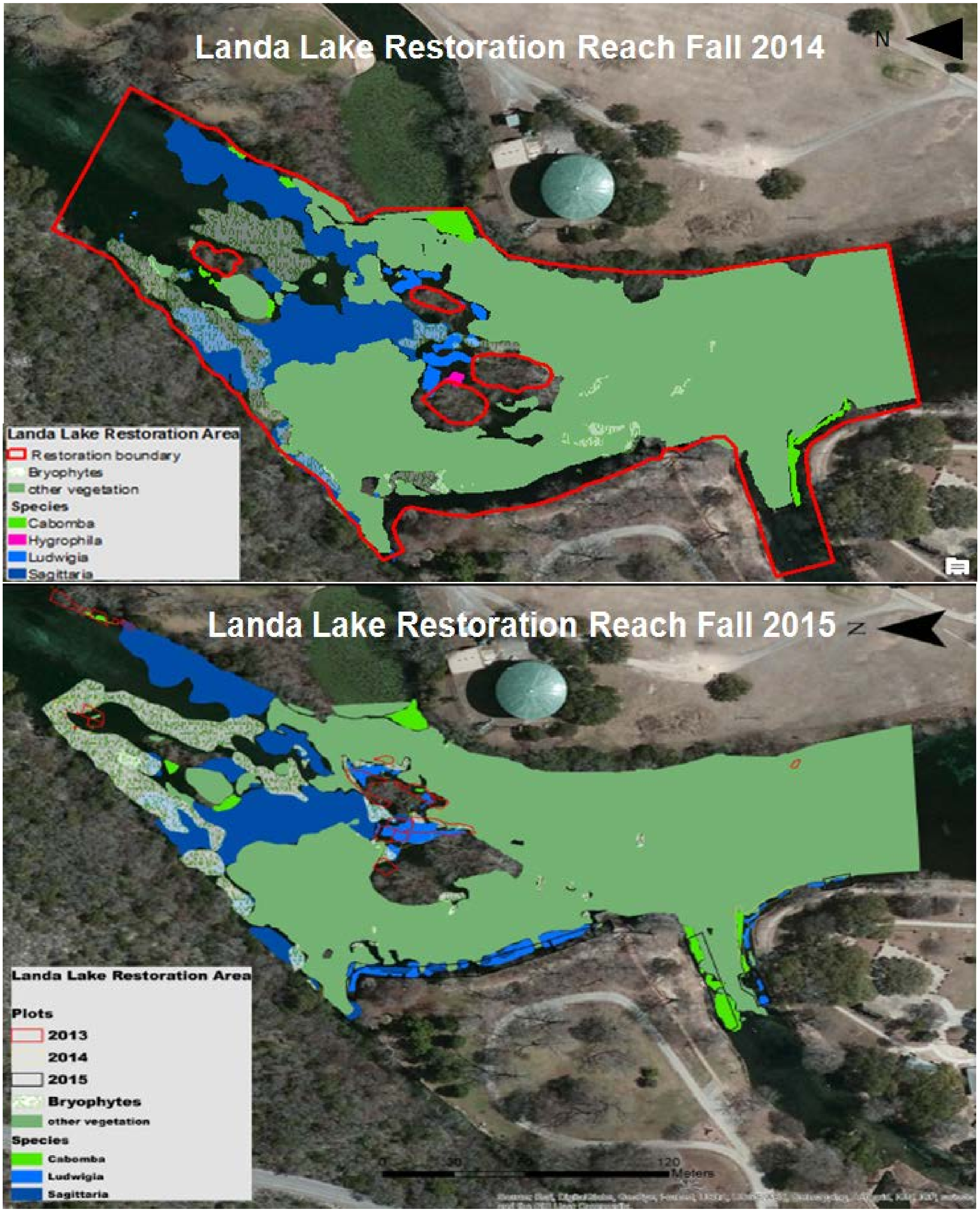

Figure 3. Landa Lake Restoration reach aquatic vegetation map Fall 2014 (Top) and Fall 2015 (Bottom).

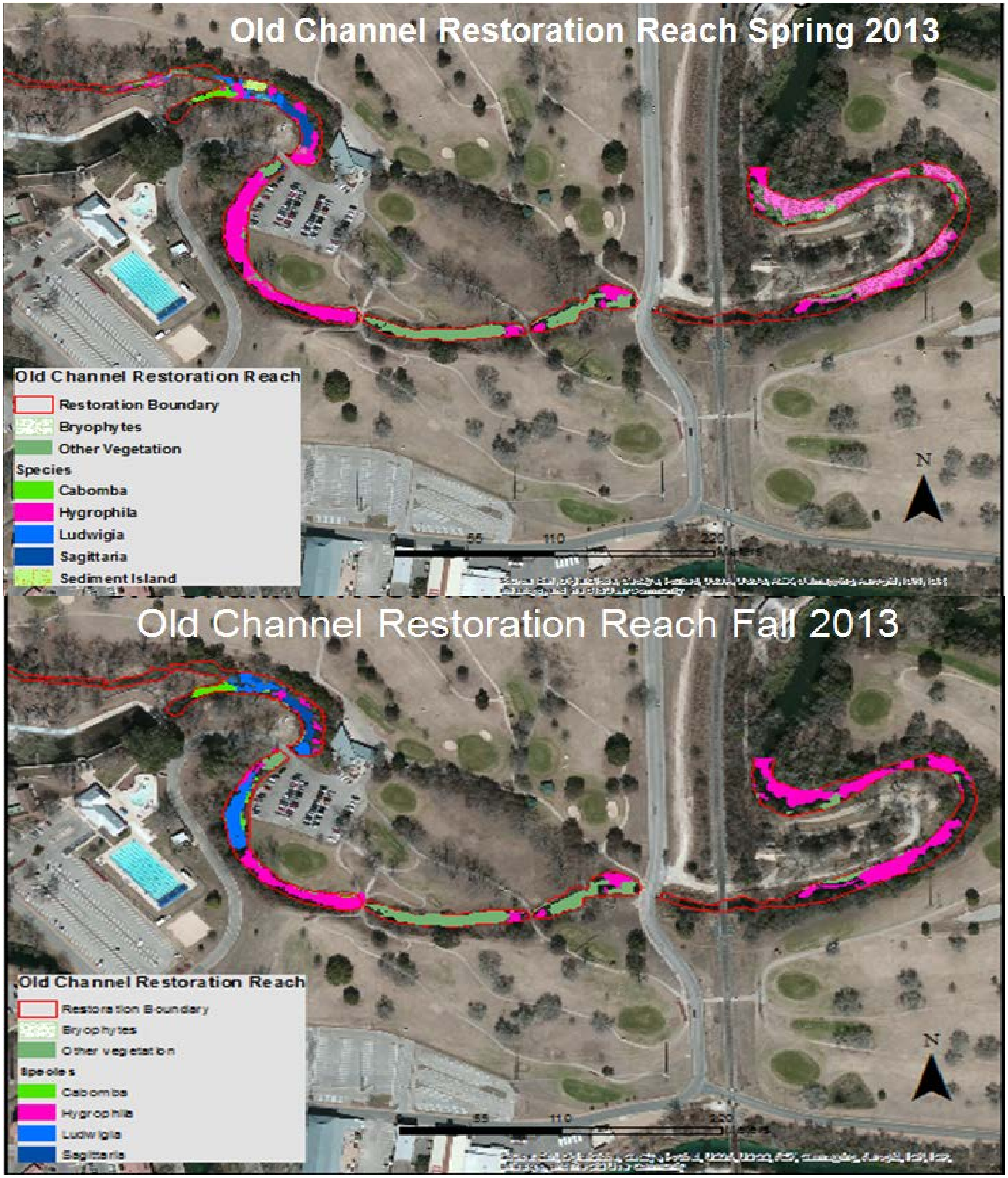

Figure 4. Old Channel Restoration reach aquatic vegetation map Spring 2013 (Top) and Fall 2013 (Bottom).

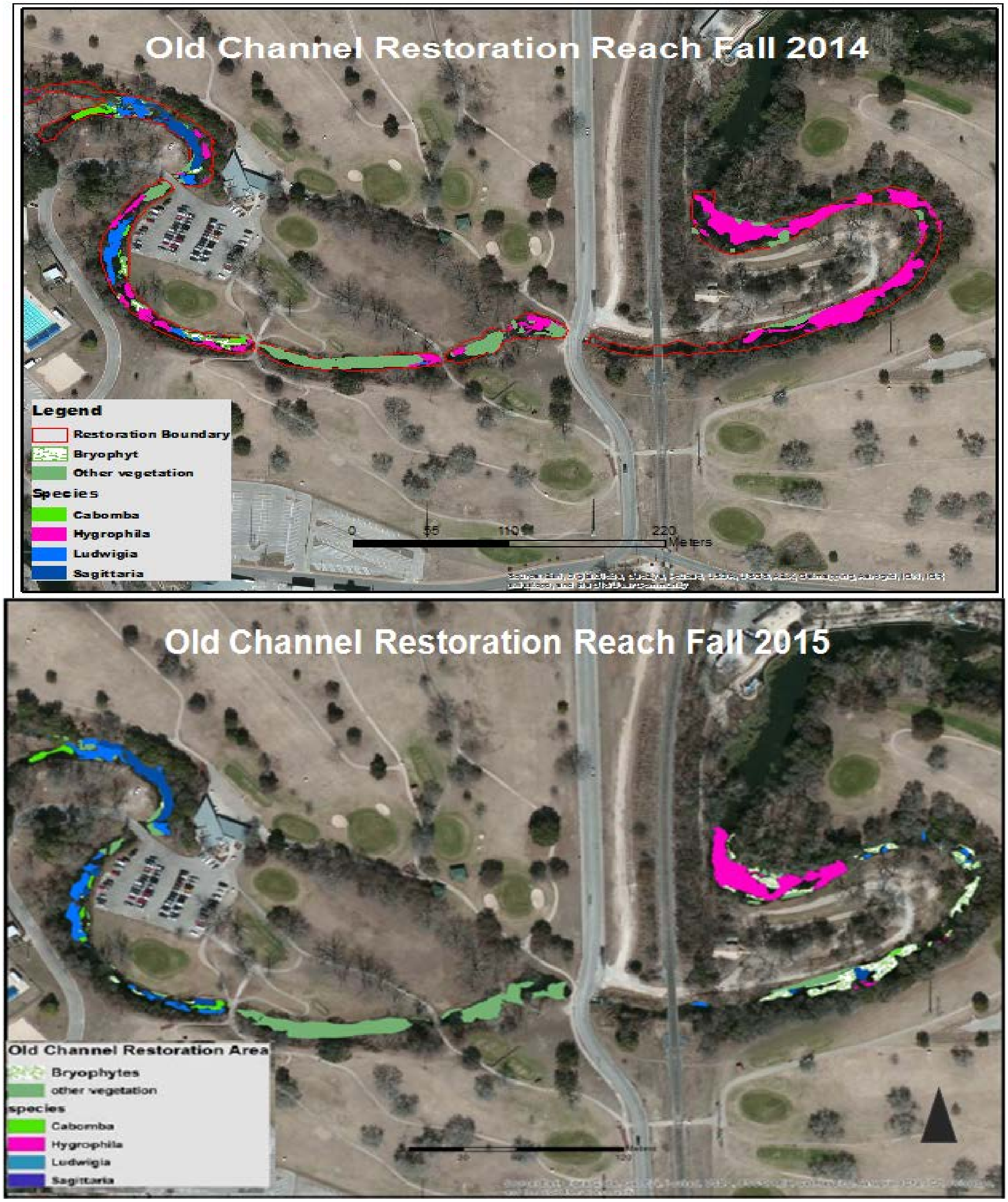

Figure 5. Old Channel Restoration reach aquatic vegetation map Fall 2014 (Top) and Fall 2015 (Bottom).

2.1.2 San Marcos River

As part of the HCP, Texas State University and City of San Marcos scientists (San Marcos restoration team) developed and implemented a native aquatic vegetation restoration plan for the San Marcos River. The intent of this HCP measure is to maintain high-quality habitat for the fountain darter by both increasing the amount of available habitat and by improving the quality of the existing habitat. This habitat restoration measure is a key element in striving to meet the HCP long-term biological goals for the fountain darter in the San Marcos system as discussed further in Section 2.2.

Aquatic vegetation restoration to date has targeted four San Marcos River reaches (Sewell Park, Below Sewell Park through City Park, Bicentennial Park, and Cypress Island-Rio Vista Park) from Spring 2013 through Fall 2015 (Figure 6) and has primarily targeted Texas wild rice to date. It is also important to understand that native aquatic vegetation restoration work in the San Marcos River was conducted in harmony with Texas wild rice enhancement and sediment removal as well as in coordination with other HCP measures such as State Scientific Study Areas (SSAs), riparian enhancement, and recreation river access control. Early efforts and locations focused on evaluation of non-native removal methods and planting strategies to achieve restoration targets including native plant propagation techniques (e.g., racenes, tillers). This also included coordination with the San Marcos Aquatic Resource Center propagation of Texas wild rice from seed stocks to be used in plantings intended to ensure maintenance of genetics within target river reaches.

The San Marcos restoration team agreed to implement these measures with a goal of meeting HCP long-term biological goals while maintaining a sustainable ‘recreation corridor’ (Hardy et al., 2015: http://dx.doi.org/10.1080/23249676.2015.1090352). For example, the City of San Marcos requested that native plantings use low height species to maximize water depth within the recreation corridor when possible. The location of the SSAs relative to long-term biological goal (LTBG) reaches and adjacent riparian restoration actions including recreation access control measures also influenced work site selection, timing, and method(s) utilized. Efforts were made during the riparian restoration actions to consider opening the skyline for more light penetration (e.g., Tolman 2014). Additionally, state permits for sediment removal restricted implementation of that measure to two sites prior to 2015. Finally, implementation was undertaken from an upstream to downstream strategy, given the dominance of the flow field on plant colonization strategies in riverine systems and the extensive areal coverage of non-native vegetation which was greater than ~ 75 percent in the San Marcos River as compared to approximately 25 percent in the Comal River.

Adhering to the upstream to downstream progression approach to restoration implementation, no aquatic vegetation restoration work below Rio Vista Dam has been targeted to date. Some experimental planting of Texas wild rice did occur below I35 but these plants were subsequently lost in the October 2015 flood event. The team’s strategy within the San Marcos River is to now shift toward other native aquatic species to meet HCP target goals concurrently with Texas wild rice targets.

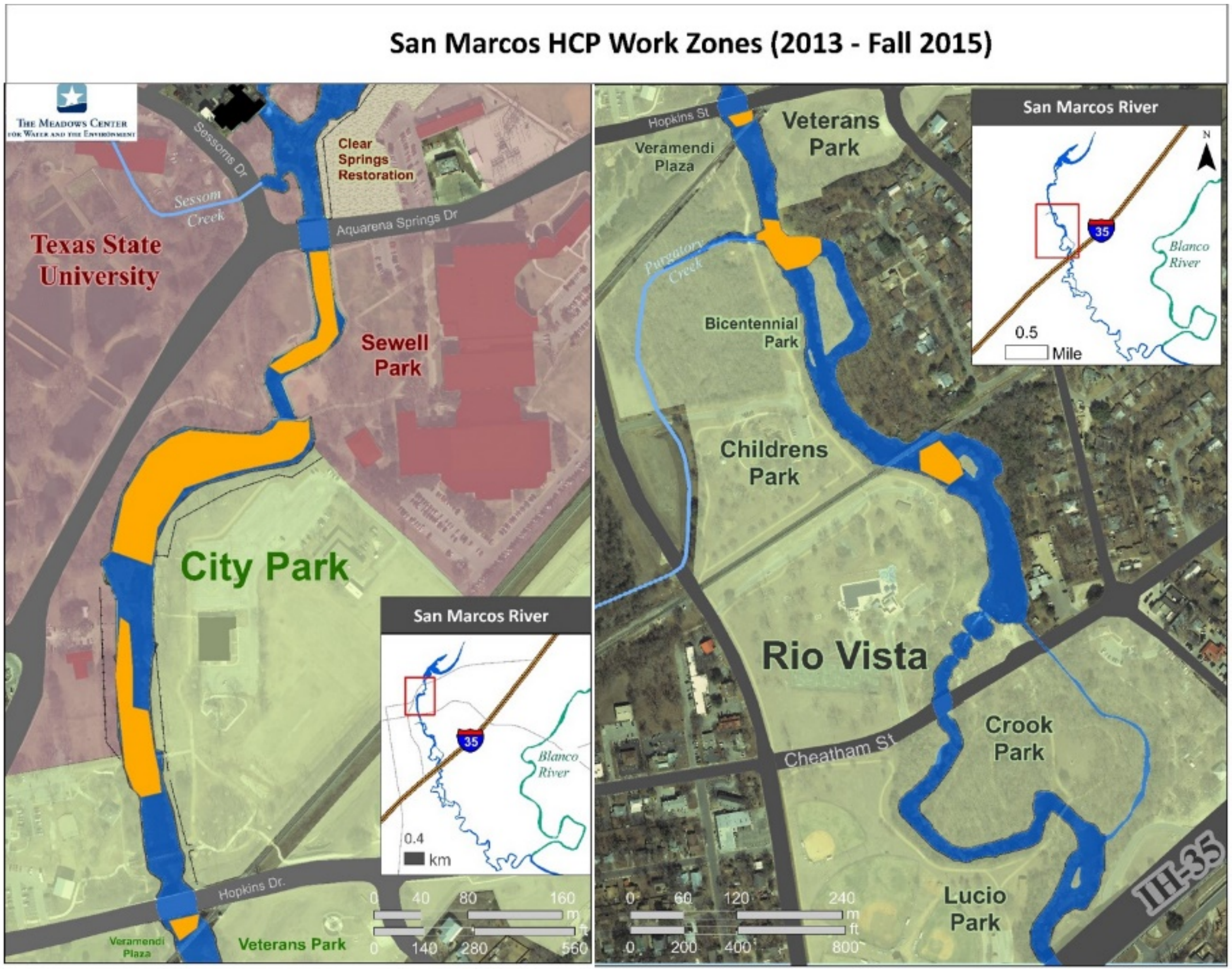

Figure 6. San Marcos River work zones between 2013 and 2015.

Since the implementation of the HCP, a wealth of information has been gained in the San Marcos system on the effectiveness of the aquatic vegetation restoration program. A major component of successful native vegetation restoration is effective removal and subsequent maintenance of non-native vegetation. Based on a comparison of 2013 mapping data to late 2015 map data, the San Marcos restoration team has successfully removed over 3,400 m^2 of non-native *Hydrilla* and 1,835 m^2 of non-native *Hygrophila* from the work zones, in addition to smaller quantities of other non-native vegetation in these work areas. Table 5 denotes the change in aerial coverage of non-native aquatic vegetation species in the restoration reaches from spring 2013 to October 2015. As discussed in detail in Appendix A, once an area was denuded of non-native aquatic vegetation, the area was replanted with native aquatic vegetation, and in some treatment areas and conditions, additional maintenance gardening was undertaken.

The strategy for non-native plant removal, planting, and maintenance in the San Marcos system has been shown to be effective but differs from that employed in the Comal in that instead of a standardized 4-step process, the San Marcos team parallel the steps but adjusts efforts in each step based on site characteristics and vegetation conditions. For example, removal of *Hydrilla* and leaving the area exposed was found to result in significant re-colonization from adjacent vegetation beds. Vegetated areas were revisited systematically and gardening was undertaken only as needed to support growth.

Table 5. Area (m^2) of non-native vegetation species in the San Marcos River among reaches in the San Marcos River prior to restoration efforts (Spring 2013), at the end of year one (Fall 2013), year two (November 2014), and year three (November 2015) of restoration activities. NA indicates where no vegetation coverage estimates were calculated in a section since no restoration work was completed during that time period.

Reach	Species	Spring 2013	Fall 2013	2014	2015
Upper Sewell Park	*Hydrilla verticillata*	258	69	116	37
	Hygrophila polysperma	64	36	38	8.9
	Vallisneria spiralis	0	72	10	0
Lower Sewell Park	*Hydrilla verticillata*	134	12	73	55
	Hygrophila polysperma	242	122	201	6.4
	Nasturtium officinale	32	0	0	0
	Vallisneria spiralis	2.4	4.4	3	0
Below Sewell Park - City Park	*Hydrilla verticillata*	857	145	1,034	237
	Hygrophila polysperma	1,484	998	795	531
	Nasturtium officinale	30	4.7	112	0
	Eichhornia	84	0	17	0
City Park entire	*Hydrilla verticillata*	1,466	NA	NA	308
	Hygrophila polysperma	586	NA	NA	192
	Nasturtium officinale	2	NA	NA	0
	Vallisneria spiralis	2	NA	NA	0
Lower City Park	*Hydrilla verticillata*	562	NA	340	85
	Hygrophila polysperma	333	NA	236	135
Bicentennial Park – Purgatory Creek	*Hydrilla verticillata*	59	NA	NA	66
	Hygrophila polysperma	28	NA	NA	0
Rio Vista – Cypress Island	*Hydrilla verticillata*	1,007	NA	NA	156
	Hygrophila polysperma	2.5	NA	NA	0

Over the course of San Marcos restoration project through 2015, over 52,500 native aquatic plants have been planted in the San Marcos system (Table 6). Of these, approximately 60% (30,431) were Texas wild rice.

Table 6. Number of individuals planted among reaches in the San Marcos River 2013- 2015.

Species	San Marcos River Reach					
	Upper Sewell Park	Lower Sewell Park	Below Sewell Park - City Park	Bicentennial Park -Purgatory Creek	Cypress Island-Rio vista	Total
Ludwigia repens	94	2,563	8,854	0	768	12,279
Heteranthera dubia	0	622	2,644	0	2,544	5,810
Zizania texana	125	1,761	20,409	384	7,752	30,431
Sagittaria	48	626	2,681	133	305	3,792
Potamogeton	0	55	178	0	0	233
Hydrocotyle	0	0	42	0	0	42

Through fall 2015, the San Marcos restoration team has sustained restoration of 4,367 m^2 of native vegetation that has persisted within the designated work areas (Table 7). Of this value, approximately 80% is represented by Texas wild rice. We state "sustained restoration" in Table 7 because this represents vegetation that persisted at a given point in time (Fall 2015 in this case). It is important to note that Table 7 does not represent the coverage present after the intense flooding on the San Marcos system in late 2015. Those numbers are discussed in Section 3 and used for the development of the restoration schedule. However, we do not feel it is appropriate to penalize successful sustained restoration with an uncontrollable major flooding event while describing program accomplishments. Additionally, Table 7 does not represent the total that was planted or the coverage that came and went over time. Understandingly it is important to document that variability in native vegetation growth and distribution and thus, coverage over time per reach is presented in Table 8.

Table 7. Native Aquatic Vegetation sustained restoration per reach since 2013.

	Upper Sewell Park	**Lower Sewell Park**	**Below Sewell Park - City Park**	**City Park entire**	**City Park lower**	**Bicentennial Park - Purgatory Creek**	**Cypress Island-Rio vista**	**Total**
Ludwigia	-	-	-	-	-	-	-	-
Heteranthera	-	-	-	0.3	0.3	-	63	64
Zizania texana	374	535	1,041	964	578	13	123	3,628
Sagittaria	7.2	-	663	-	-	-	4.9	675
Potamogeton	-	-	-	-	-	-	-	-
Hydrocotyle	-	-	-	-	-	-	-	-
Total	381.2	535.0	1,704.0	964.3	578.3	13.0	190.9	4,367

Table 8. Area (m^2) of native vegetation species within restoration reaches of the San Marcos prior to restoration efforts (Spring 2013), at end of year one (Fall 2013), year two (November 2014), and year three (November 2015) of removal and planting activities. NA indicates where no vegetation coverage estimates were calculated in a section since no restoration work was completed during that time period.

Reach	Species	Spring 2013	Fall 2013	2014	2015
Upper Sewell Park	*Zizania texana*	199	260	360	573
	Sagittaria platyphylla	2.7	18	7.0	9.9
	Potamogeton illinoensis	164	193	127	0
	Hydrocotyle	55	55	98	10
	Ludwigia repens	0	1.2	0	0
Lower Sewell Park	*Zizania texana*	666	786	839	1,201
	Sagittaria platyphylla	21	32	38	1.6
	Heteranthera dubia	0	0	71	0
	Potamogeton illinoensis	208	101	193	88
	Cabomba caroliniana	45	52	21	14
	Ludwigia repens	0	14	31	0
	Zizaniopsis	154	0	0	0
Below Sewell Park - City Park	*Zizania texana*	1,212	1,464	1,963	2,253
	Sagittaria platyphylla	22	108	376	685
	Heteranthera dubia	0	3.6	19	0
	Potamogeton illinoensis	770	765	336	170
	Hydrocotyle	23	8.2	34	15
	Cabomba caroliniana	11	45	5.89	0
	Zizaniopsis	16	0	0	0
	Ludwigia repens	0	56	16	0
City Park entire	*Zizania texana*	384	NA	NA	1,348
	Sagittaria platyphylla	18	NA	NA	0
	Heteranthera dubia	0	NA	NA	0.3
	Potamogeton illinoensis	254	NA	NA	180
City Park lower	*Zizania texana*	182	NA	532	760
	Sagittaria platyphylla	13	NA	32	0
	Heteranthera dubia	0	NA	63	0.3
	Potamogeton illinoensis	215	NA	104	115
Bicentennial Park – Purgatory Creek	*Zizania texana*	0	NA	NA	13
	Sagittaria platyphylla	100	NA	NA	7.9
	Potamogeton illinoensis	10	NA	NA	0
	Cabomba caroliniana	107	NA	NA	0
Rio Vista – Cypress Island	*Zizania texana*	0	NA	NA	123
	Sagittaria platyphylla	0	NA	NA	4.9
	Heteranthera dubia	0	NA	NA	63

Figures 7 through 11 show the aquatic vegetation distribution and coverage in the Upper Sewell Park (Figure 7), Lower Sewell Park (Figure 8), Below Sewell Park through City Park (Figure 9), Bicentennial Park (Figure 10), and Rio Vista-Cypress Island (Figure 11) over time, starting with pre-restoration (Spring 2013) and then annually each fall from 2013 through 2015. Each figure is accompanied by a brief description of HCP activities and observations since the inception of the restoration effort.

Spring Lake Dam/Upper Sewell Park: Aquatic vegetation mapping results for this section of river are provided in Figure 7. It should be noted that the Spring Lake Dam LTBG reach only received limited non-native plant removal and native planting in 2013 by design. In this section of the river, the primary efforts were associated with recreation access control along the eastern side of the stream through riparian restoration/fencing and establishment of an SSA. The recreation corridor extended from the west side of the channel (i.e., below Salt Grass) without restriction of shore access while recreation was "excluded" within the SSA established from the eastern spillway along river left downstream to Aquarena Springs Drive. The targeted removal of the sediment delta at the confluence with Sessom Creek and subsequent aquatic plantings were deferred while bank stabilization was undertaken and again deferred due to flooding events which damaged the bank stabilization structures. Monitoring results show that the large area immediately adjacent to the western shoreline at Sessom Creek becomes seasonally denuded of aquatic vegetation due to intense contact recreation and at present will not be targeted for aquatic vegetation restoration actions (i.e., planting) unless recreation access is curtailed. Monitoring results also clearly show that the passive measures of riparian fencing and instream SSA signage were effective in promoting and retaining native aquatic vegetation growth including expansion of Texas wild rice. Under existing recreation access along the western shoreline, we believe the eastern spillway and the SSA on river left represent the only pragmatic areas in which the biological goals in the Spring Lake Dam LTBG reach can be targeted unless river access along the western shoreline line above the confluence with Sessom Creek is curtailed.

Lower Sewell Park: Figure 8 provides the vegetation monitoring results from lower Sewell Park. The recreation corridor was defined along river left (the eastern stream margin) where the majority of river access takes place by Texas State students. The aquatic vegetation strip along river right (the western stream margin), including the sediment island below University Bridge, was retained to inhibit river access from the western stream margin. Interpretive signs were established at the two river access steps along the western stream margin to deter river access at these locations. Non-native plant removal extended from University Bridge downstream through Sewell Park to just upstream of the second walking bridge (Figure 8). Removal of large areas containing non-native vegetation (e.g. cut grass from the sediment island below University Bridge), buffer strips around Texas wild rice stands, and gardening within Texas wild rice stands were undertaken in this reach followed by a variety of planting strategies (e.g., species, number, and density of plants). In addition, this area was covered by the education and outreach efforts of the City of San Marcos HCP Conservation Crew as part of the passive restoration efforts. The monitoring results show that the implementation of the San Marcos teams restoration strategy for removal of nonnative plants, subsequent native plantings and gardening were effective in expanding Texas wild rice and other native species. This was accomplished with overall reductions in the nonnative aerial coverage while maintaining the recreation corridor. Conservation Crew outreach at Sewell Park was effective in minimizing river access from the western shoreline and subsequent damage to the aquatic vegetation. Our results suggest that the targeted restoration along the western shoreline will continue to expand native species with a reduction in non-natives. Our results also suggest that the ~2-meter-wide recreation corridor along the eastern retaining wall (river left) will not sustain aquatic vegetation during the recreation season and this area has been excluded in deriving overall restoration targets in this section of river.

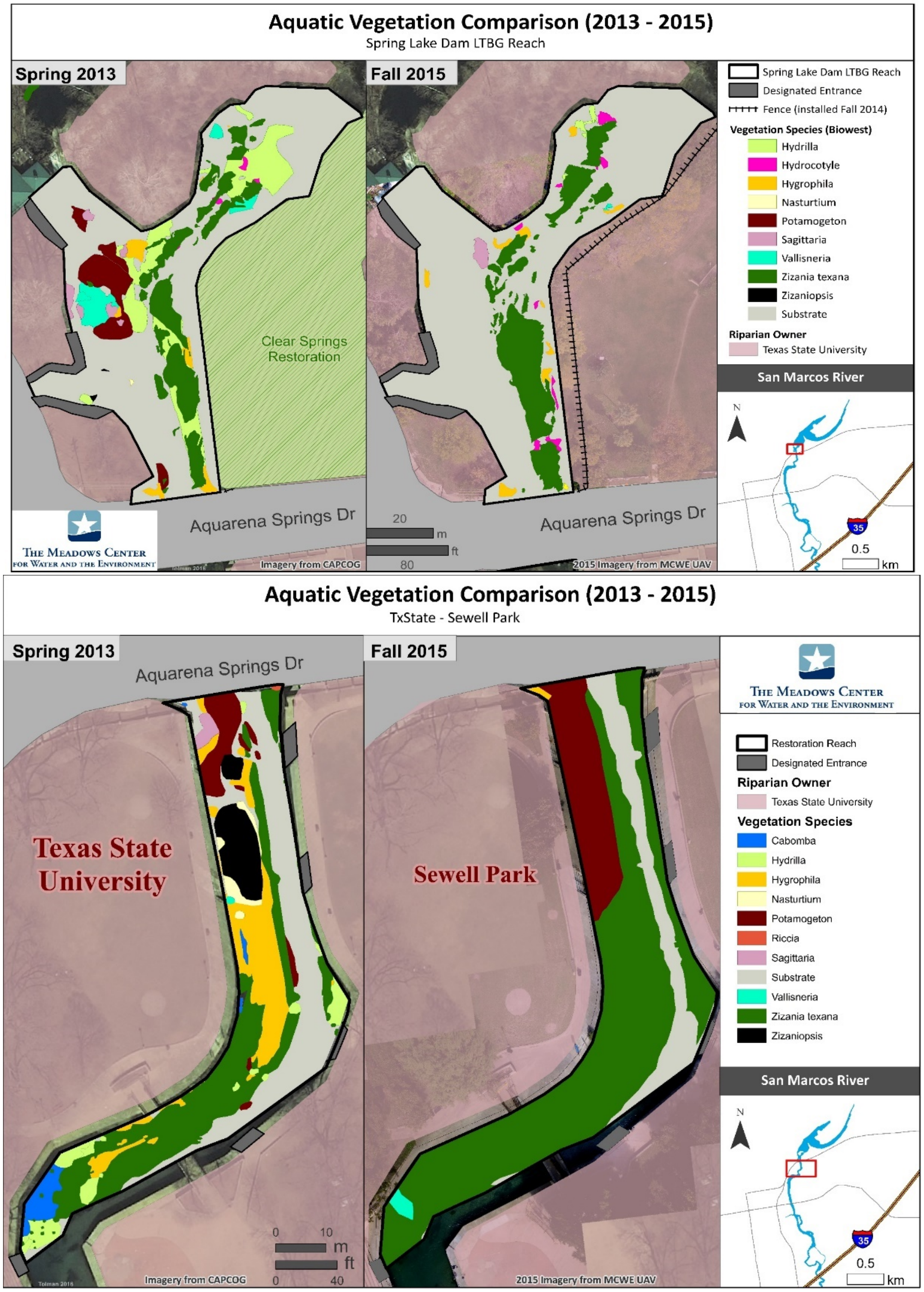

Figure 7. Changes in vegetation composition and distribution from spring 2013 to fall 2015 in the Spring Lake Dam LTBG reach (top) and upper Sewell Park work zone (bottom).

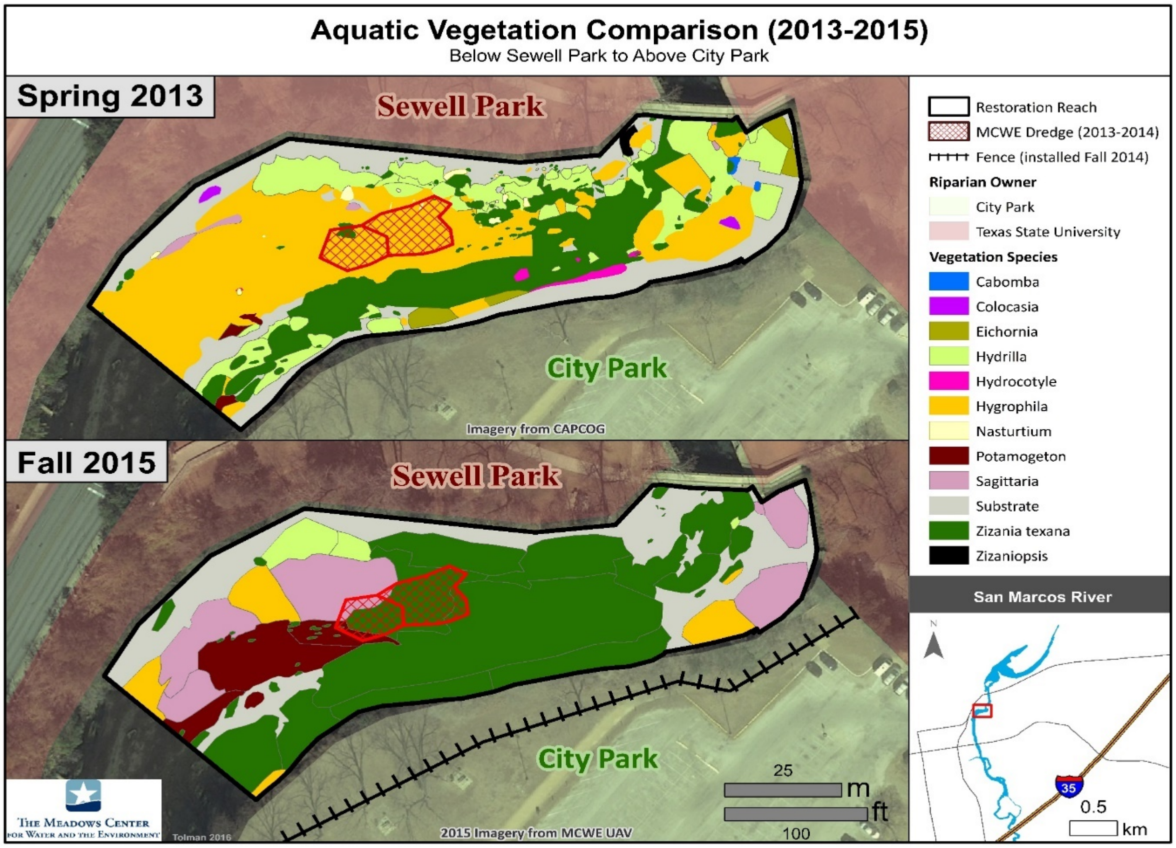

Figure 8. Changes in vegetation composition and distribution from spring 2013 to fall 2015 in the Lower Sewell Park work zone.

__Below Sewell Park through City Park:__ Aquatic vegetation monitoring results for the San Marcos River are provided for the upper end of City Park and at the lower end of City Park (Figure 9). The recreation corridor at the upper end of City Park follows the flow path on river left past the Texas State outdoor recreation access dock just downstream of the second walking bridge and extends along river left into City Park. The lower area (end of City Park) does not have a recreation corridor defined. The middle section of this reach adjacent to Dog Beach on the western shoreline and the Lion's Club tube rental access area (western stream margin) were excluded from nonnative removal and native plantings given the seasonal removal of aquatic vegetation due to contact recreation. Passive measures in this upper reach included the designation of the SSA on river right, just downstream of the second walking bridge in Sewell Park (Figure 9). River access in this upper area was also nominally blocked by riparian restoration fencing on the eastern side of the channel downstream to the Lions Club access area. Recreation access along the western shoreline is inhibited due to vegetation and steep banks. In addition, public education and outreach by the Conservation Crew focused on Dog Beach and Lions Club tube rental areas. For both these sections of river, methods for removing nonnative aquatic vegetation included, removing large monotypic stands, creating buffer strips around native species, and gardening within Texas wild rice stands. Removal methods were followed by subsequent planting of Texas wild rice and other native species using multiple planting techniques and where/when necessary, repeated gardening.

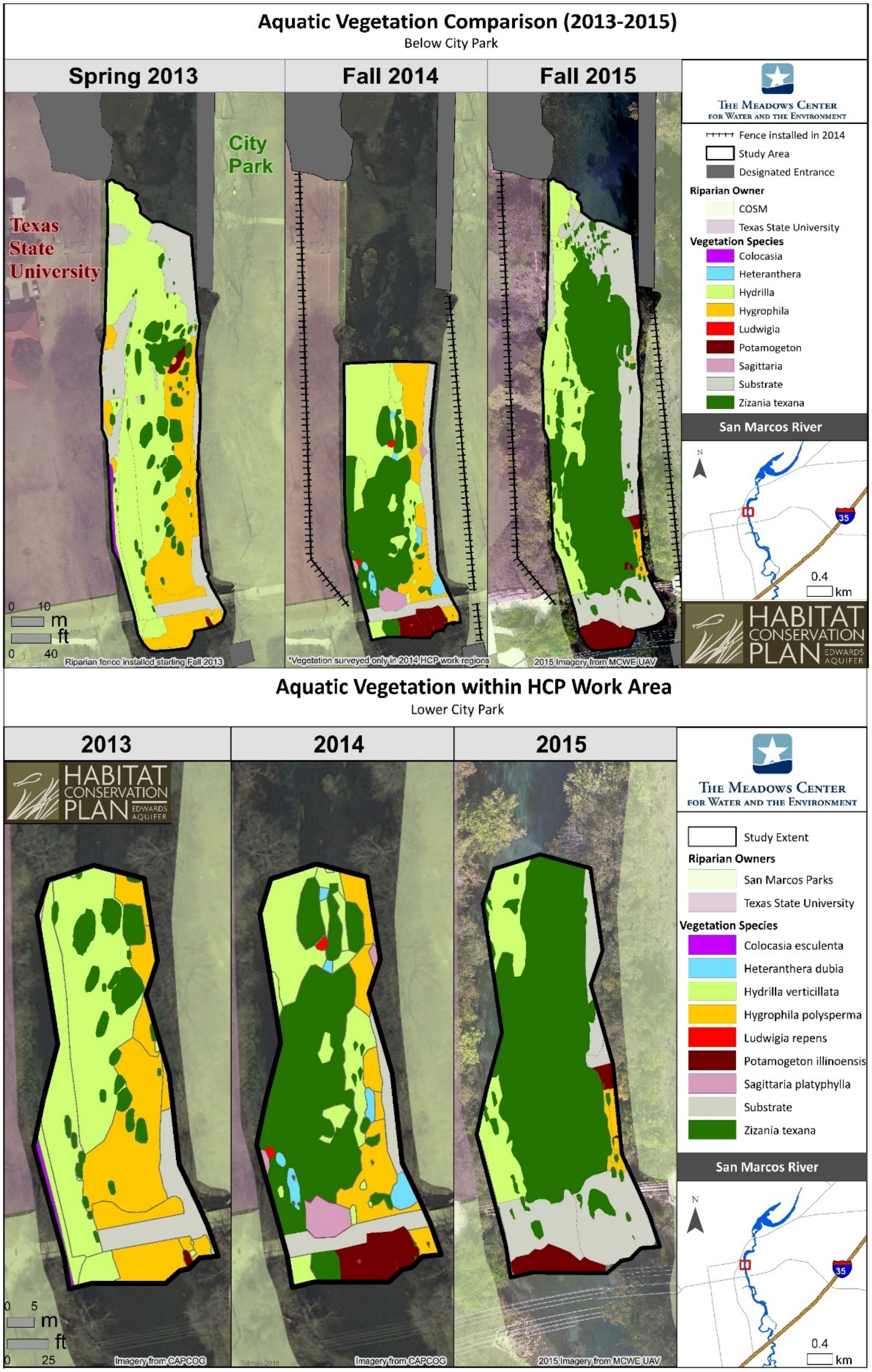

Figure 9. Changes in vegetation composition and distribution from spring 2013 through fall 2105 through the City Park work zone.

The monitoring results indicate that non-native removal and subsequent planting of native aquatic vegetation utilizing an adaptive restoration strategy are effective in this reach of river. We note, that our monitoring data clearly indicates that voluntary expansion of Texas wild rice has extended downstream from the upper end of City Park where upstream Texas wild rice planting were conducted. The monitoring data also shows that the river section adjacent to Dog Beach and the Lions Club tube rental will not sustain aquatic vegetation during the recreation season and this area has been excluded in deriving overall restoration targets in this section of river.

Bicentennial Park: The vegetation monitoring results for the Bicentennial Park section of the San Marcos River are provided in Figure 10. Fine sediment accumulations at the confluence area of Purgatory Creek were excavated in conjunction with the removal of nonnative aquatic plants. Passive restoration efforts included the establishment of the SSA on river right just downstream of the Purgatory Creek confluence and restriction of river access on river right (western stream margin) due to riparian restoration and fencing. The recreation corridor was retained on river left between the island and the SSA. This area was also engaged via efforts of the Conservation Crew for public education and outreach. Active restoration measures included non-native vegetation removal in large areas followed by planting Texas wild rice and other target native aquatic species using multiple methods. The monitoring results indicate that non-native removal and subsequent planting of native aquatic vegetation utilizing an adaptive restoration strategy are effective in this reach of river. These results showed that fine sediment removal in conjunction with Texas wild rice and other native species plantings expanded the native areal coverage in this area.

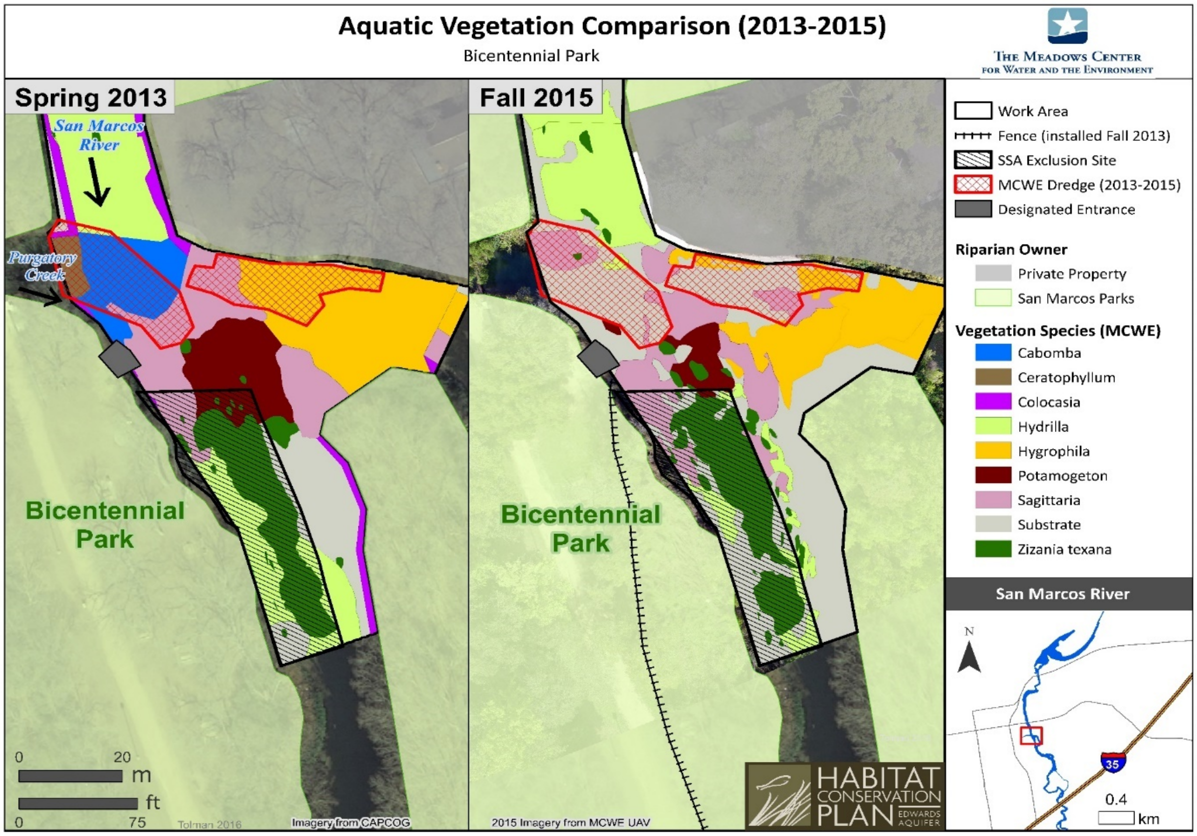

Figure 10. Changes in vegetation composition and distribution from spring 2013 to fall 2015 in the Bicentennial Park work zone.

<u>Cypress Island-Rio Vista Park:</u> In 2015, restoration efforts extended downstream into the Cypress Island – Rio Vista area (Figure 11). No defined recreation corridor was defined in this area given channel properties. Passive measures primarily were focused on public education and outreach conducted by the Conservation Crew. Active restoration measures included nonnative vegetation removal in large areas followed by planting Texas wild rice and other target native species using multiple methods under an adaptive restoration strategy. The monitoring results indicate that at present, non-native removal and subsequent planting of native aquatic vegetation are effective in this section of river.

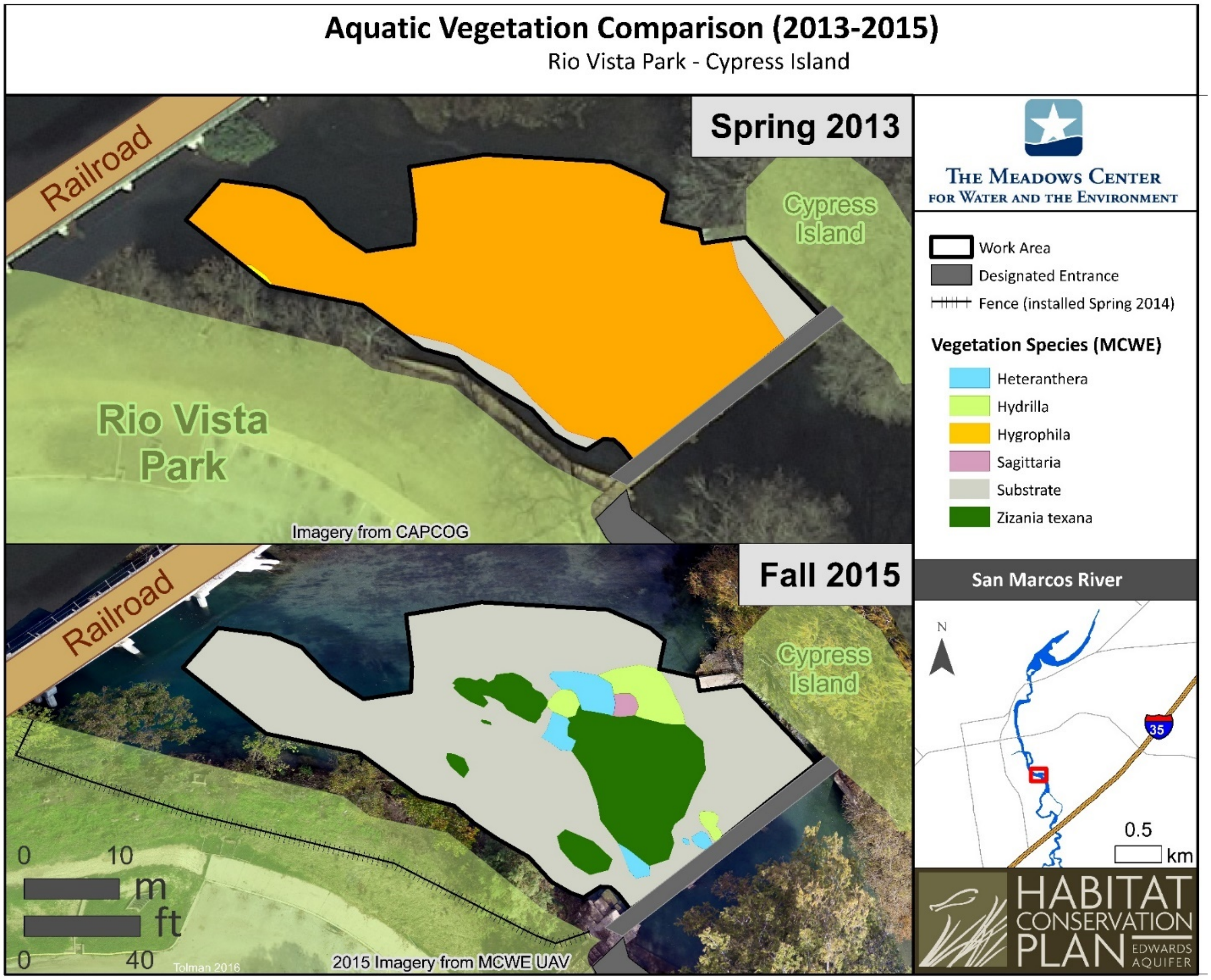

Figure 11. Changes in vegetation composition and distribution from spring 2013 to fall 2015 in the Cypress Island – Rio Vista work zone.

2.1.3 Lessons learned per system and future application

Over the course of the first three years of HCP implementation, many challenges have been confronted relative to the native aquatic vegetation restoration program in both systems. Detailed descriptions of lessons learned and challenges faced since project inception are presented in Appendix A. In summary, key lessons learned from the restoration teams that have direct application moving forward are as follows:

- ***In-system native plant propagation.*** This practice has been highly successful in both river systems. In the Comal system, using Mobile Underwater Plant Propagation Trays (MUPPTs) in Landa Lake has been shown to be effective for the growth of robust aquatic plants for restoration activities. Similar success has been achieved in the Texas State University (TSU) raceways at the Freeman Aquatic Building (FAB). This includes both successful harvesting of Texas wild rice racemes (tillers), other native plant fragments, and grow out of Texas wild plants produced from seed at the San Marcos Aquatic Resource Center (SMARC). Growing the plants in the system tends to reduce the grow out time allowing a quicker turn around for use in restoration. Additionally, in-system grow out reduces the opportunity for stress to the plant during the initial establishment, grow out and ultimate transplant. The project team recommends that these system specific propagation efforts continue in both systems.
- ***Non-native removal and native aquatic vegetation planting.*** In the Comal system, multiple clearing events of non-native vegetation occur with a 2 to 3-week grace period before final clearing and subsequent planting. Over time a high level of success for non-native plant removal has involved a 4-step method. This involves a) the initial clearing, b) a second more detailed clearing approximately 1-week later, c) a 2 to 3-week grace period to let the area settle, roots to start to grow, and sediment to dissipate on its own, and d) a final detailed clearing extracting all roots from the area. Upon completion of this adaptive 4-step method, native plants are installed in to the cleared and open area. In the San Marcos system, a similar adaptive process to non-native removal that reflects the site characteristics and in particular the presence and dynamics of *Hydrilla* (which is not present in the Comal system) has been demonstrated to be very effective. The project team recommends that these system specific removal and planting efforts continue in both systems.
- ***Aquatic gardening.*** Another technique essential to the success of the restoration activities is extensive gardening following planting. In the Comal, aquatic gardening is conducted approximately every 2 weeks following planting until the native vegetation establishes greater than 75% coverage at which time gardening is reduced to once per month. Following near 100% coverage, gardening is conducted on an as needed basis. In the San Marcos, the adaptive restoration approach implements gardening on an as needed basis based on monitoring of the planted area. The time interval or frequency of gardening and the total length of time to conduct the gardening is determined by the response of the plants. These aquatic gardening approaches will be continued within each system moving forward in support of sustained native aquatic vegetation restoration in both systems.
- ***Conjunctive riparian restoration.*** Both restoration teams have noted that the success of native aquatic vegetation in certain areas of the river may be impacted by competitive advantages of non-native aquatic vegetation due to shading effects. In many instances, this has to do with shading along edges where non-native plants are more successful in lower light conditions relative to native plants. This has been specifically addressed in terms of Texas wild rice in the San Marcos based on modeling of seasonal light dynamics due to the riparian canopy. Those analyses have supported guidance of the selection of native riparian species planted after non-native removal to facilitate greater light penetration to the river surface. We recommend that the

evaluation of native aquatic plant restoration success continue to consider and address the role of riparian shading dynamics.

- ***Monitoring.*** In the San Marcos system, monitoring of non-native removal and native aquatic vegetation establishment using simple drone technology has been demonstrated to be successful, generates a highly accurate visual/archival photographic records that produce highly accurate polygons in GIS suitable for documenting changes over both space and time. Species identification are verified using ground truth measurements with GPS. Images are captured of an area prior to non-native aquatic vegetation removal, after non-native aquatic vegetation removal, and after subsequent planting of native aquatic plants. This includes monitoring the effectiveness over time after gardening and system changes that can occur after flood events. We recommend that this process be implemented to the degree practical in both systems moving forward.

As noted above and further described in Appendix A, these restoration activities will continue to be implemented moving forward. Furthermore, the on-going application of adaptive management principals employed by both teams in the evaluation of alternative methods given site specific characteristics will continue to be explored and implemented where practical to enhance the success of the native aquatic vegetation restoration project.

2.2 Long-term Biological Goals Comparison

2.2.1 Native Aquatic Vegetation and Fountain Darters

2.2.1.1 Comal System

For the Comal system, the HCP states:

> "The long-term biological goals for the fountain darter at Comal Springs are quantified as areal coverage of aquatic vegetation (habitat) within four representative reaches of the Comal system (Upper Spring run [upstream most portion of the system to Spring Island], Landa Lake [Spring Island to the outflow to Old and New channels], Old Channel, and New Channel) and fountain darter density (population measurement) per aquatic vegetation type. (Figure 4-1). The habitat-based and population measurement goals are presented in Table 4-1 and include proposed aquatic vegetation restoration efforts. The population measurement goal is to maintain the median densities of fountain darters observed per aquatic vegetation type per system at a level greater than or equal to that observed over the past 10 years in the EAA Variable Flow Study monitoring."

In addition, the Comal system has a key management objective relative to aquatic vegetation restoration in two of the four long-term biological goal (LTBG) reaches that states, "Active native vegetation restoration and protection will be implemented in Landa Lake and the Old Channel. Restoration activities will extend beyond the study reaches in equal proportion to effort expended per study area in relation to the total area of Landa Lake and Old Channel." This clause has never been formally defined and will be discussed later in this report. Table 9 presents the aquatic vegetation coverage and fountain darter density goals and Figure 12 shows the four LTBG reaches both taken directly from the HCP.

Table 9. Long-term biological goals for the fountain darter in the Comal System (HCP Table 4-1)

Fountain darter habitat (aquatic vegetation) in meters squared (HCP Table 4-1)							
Study Reach	Bryophytes	*Hygrophila*	Fil Algae	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	1,850	650		150		600	
Landa Lake	4,000	250		900	500	1,250	13,500
Old Channel	150	200	300	1,500			
New Channel	150	1,350			350		
Total	6,150	2,450	300	2,550	850	1,850	13,500
Fountain darter median density (number/m^2)							
	Bryophytes	*Hygrophila*	Fil Algae	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
	20	4	14	7	7	1	1

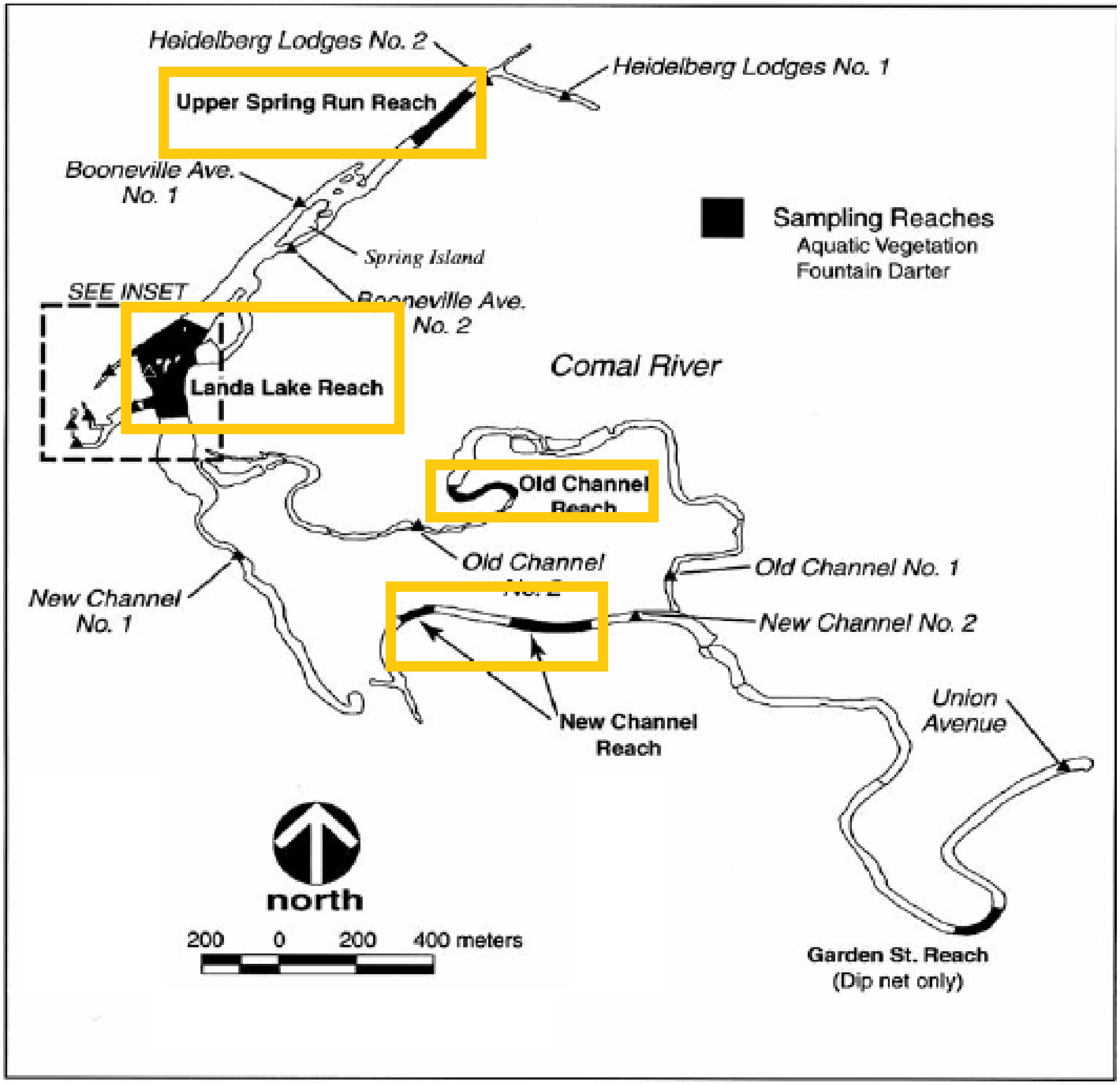

Figure 12. Long-term biological goal (LTBG) reaches for the Comal system specified in the HCP (modified from HCP Figure 4-1). Shaded areas within orange rectangles represent four designated reaches.

Restoration work has been conducted on 6 of the 7 aquatic vegetation species identified in the HCP long-term biological goals for the fountain darter in the Comal system. This includes 5 native aquatic vegetation species that are actively being planted in the Comal system. A type of unidentified filamentous algae which historically occurred in the early 2000s in the Old Channel was included in the long-term biological goals but has been absent from that Old Channel stretch of river for nearly a decade. The sparse distribution of this alga in the Comal system and the anticipated complexities of trying to establish an alga via restoration led the team to avoid this species to date. While present in the HCP long-term biological goals table *Hygrophila* is not being actively promoted or encouraged. Instead, in response to successful efforts of control, the team decided that extensive removal from the Comal system would be optimal. As noted in

Section 2.1, during the development of the HCP, it was unknown how effective the non-native vegetation removal program and subsequent native aquatic vegetation reestablishment would be. As such, coverage of *Hygrophila* was left in the HCP long-term biological goals table as it does provide fountain darter habitat.

Table 10 provides a comparison of the aquatic vegetation coverage specified in the HCP relative to the Fall 2015 coverage present in the system based on data collected by the HCP biological monitoring program from the LTBG reaches (Figure 12). In the table, a positive number represents where a goal is already being met, whereas a negative number identifies where restoration work within the LTBG reaches still needs to be accomplished. As discussed in Section 2.1.1, bryophytes are not rooted and thus have varied greatly depending on time of year and flow regime being experienced. *Hygrophila* has been successfully removed well below the goals in 3 of the 4 LTBG reaches with the remaining amounts in the Old Channel to be addressed in 2016. No work has been done on filamentous algae to date as essentially none of this vegetation remains in the Old Channel, whereas significant progress has been made on both *Ludwigia* and *Cabomba*. *Sagittaria* is currently above the goals in both reaches it is present in and *Vallisneria* was reduced during the City of New Braunfels walls project affecting the total amount of coverage relative to the goals.

The project team examined the long-term biological goals in greater detail to include an assessment of fountain darter density goals. An expansion of the fountain darter median density goals per vegetation type presented in Table 9 were simply multiplied against the total coverage of each vegetation type. For example, the median fountain darter density of 7 darters per m^2 for *Ludwigia* was multiplied by 2,550 (total m^2 of *Ludwigia* in the long-term biological goals) for a total 17,850 fountain darters. Similar calculations were made across all vegetation types in the long-term biological goals (Table 9) and resulted in a total of 176,150 fountain darters (Table 11). Understanding that the establishment of the long-term aquatic vegetation (habitat) goals for the fountain darter are for the protection of the fountain darter, the team used this projected abundance information in association with aquatic vegetation coverage goals (m^2) when addressing issues identified above and proposed revised goals for consideration. Table 11 presents the existing long-term biological goals for the fountain darter in the Comal system.

Table 10. Comparison of Fall 2015 aquatic vegetation coverage within the long-term biological goal (LTBG) reaches to the HCP goals for the fountain darter in the Comal System.

FALL 2015 COVERAGE WITHIN HCP LONG-TERM BIOLOGICAL GOAL REACHES

Fountain darter habitat (aquatic vegetation) in meters squared (m^2) fall 2015							
Study Reach	Bryophytes	*Hygrophila*	Fil Algae	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	281		0	6	10	898	
Landa Lake	1,692			437	287	2,621	12,255
Old Channel	214	920		26			
New Channel	214	796		79	3,511		
Total	2,401	1,716	0	547	3,807	3,519	12,255

HCP LONG-TERM BIOLOGICAL GOAL REACHES AND GOALS

Fountain darter habitat (aquatic vegetation) in meters squared (HCP Table 4-1)							
Study Reach	Bryophytes	*Hygrophila*	Fil Algae	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	1,850	650		150		600	
Landa Lake	4,000	250		900	500	1,250	13,500
Old Channel	150	200	300	1,500			
New Channel	150	1,350			350		
Total	6,150	2,450	300	2,550	850	1,850	13,500

DIFFERENCES BETWEEN FALL 2015 AND HCP VEGETATION GOALS

Fountain darter habitat (aquatic vegetation) in meters squared - Comparison							
Study Reach	Bryophytes[A]	*Hygrophila*	Fil Algae	*Ludwigia*[B]	*Cabomba*[B]	*Sagittaria*	*Vallisneria*
Upper Spring Run	-1,569	-650		-144		298	
Landa Lake	-2,308	-250		-463	-213	1,371	-1,245
Old Channel	64	720	-300	-1,474			
New Channel	64	-554			3,161		
Total	-3,749	-734	-300	-2,003	2,957	1,669	-1,245

[A] Bryophytes are transient

[B] Riparian restoration necessary to meet this goal in the Old Channel

Table 11. Existing long-term biological goals for the fountain darter in the Comal System.

HCP LONG-TERM BIOLOGICAL GOAL (LTBG) REACHES AND GOALS

Fountain darter habitat (aquatic vegetation) in meters squared (HCP Table 4-1)								
Study Reach	Bryophytes	*Hygrophila*	Fil Algae	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	*TOTAL*
Upper Spring Run	1,850	650		150		600		3,250
Landa Lake	4,000	250		900	500	1,250	13,500	20,400
Old Channel	150	200	300	1,500				2,150
New Channel	150	1,350			350			1,850
Total	6,150	2,450	300	2,550	850	1,850	13,500	27,650
Fountain darter median density (number/m^2)								
	Bryophytes 20	*Hygrophila* 4	Fil Algae 14	*Ludwigia* 7	*Cabomba* 7	*Sagittaria* 1	*Vallisneria* 1	*TOTAL*
# darters * veg total	123,000	9,800	4,200	17,850	5,950	1,850	13,500	176,150

2.2.1.2 San Marcos System

For the San Marcos system, the HCP states:

> "The long-term biological goals for the fountain darter are quantified as areal coverage of habitat within three representative river reaches of the San Marcos system (Figure 4-3) and fountain darter density (population measurement) per aquatic vegetation type. These habitat-based and population measurement goals are presented in Table 4-21. The population measurement goal is to maintain greater than or equal to the median densities observed per aquatic vegetation type per system over the past 10 years of EAA Variable Flow Study monitoring."

In addition, the San Marcos system has a key management objective relative to aquatic vegetation restoration in all three designated reaches that states, "Active native vegetation restoration and protection will be implemented in all three representative study reaches. Restoration activities will extend beyond the study reaches in equal proportion to effort expended per study reach in relation to the total river segment." Similar to the Comal system, this proportional expansion clause in the San Marcos River has never been formally defined and will be discussed later in this report. Table 12 presents the aquatic vegetation coverage and fountain darter density goals and Figure 13 shows the three LTBG reaches both taken directly from the HCP.

Table 12. Long-term biological goals for the fountain darter in the San Marcos System (HCP Table 4-21)

Fountain darter habitat (aquatic vegetation) in meters squared (m^2) HCP Table 4-21							
Study reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring lake Dam	50	200	25	100	1,000	100	125
City Park	200	1,000	50	500	2,000	300	50
IH-35	50	200	300	100	300	100	25
Total	300	1,400	375	700	3,300	500	200
Fountain darter median density (number/m^2)							
	Hygrophila	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
	4	7	7	5	5	1	1

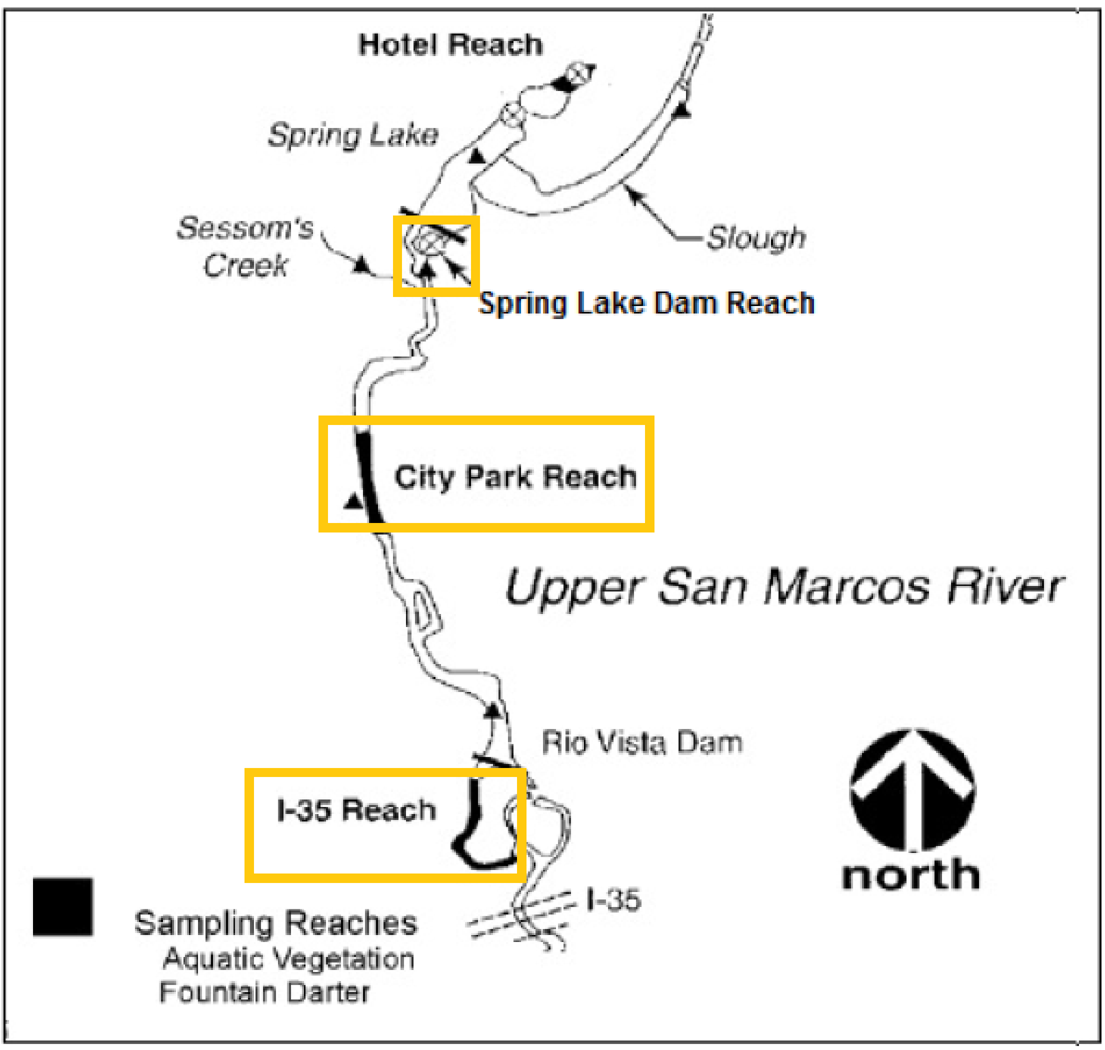

Figure 13. Long-term biological goal reaches for the San Marcos system specified in the HCP (modified from HCP Figure 4-3). Shaded areas within orange rectangles represent three designated reaches.

Restoration work has been conducted on 6 of the 7 aquatic vegetation species identified in the HCP long-term biological goals for the fountain darter in the San Marcos system. This includes three native vegetation species that are actively being planted in the San Marcos system. *Cabomba* is the only native species not planted to date in the San Marcos River as culture techniques have been less effective than for other native species thus far. The other three aquatic vegetation species in the HCP long-term biological goals table not being actively planted are all non-natives (*Hygrophila*, *Hydrilla*, and *Vallisneria*). Restoration for these non-native species consists of extensive removal from the system. As noted in Section 2.1, during the development of the HCP, it was unknown how effective the non-native vegetation removal program and subsequent native aquatic vegetation reestablishment would be. As such, coverage of these three non-natives was left in the HCP long-term biological goals table as they do provide fountain darter habitat.

Table 13 provides a comparison of the aquatic vegetation coverage specified in the HCP relative to the Fall 2015 coverage present in the system based on data collected by the HCP biological monitoring program from the LTBG reaches (Figure 13). It is important to recognize in the evaluation of the data presented in Table 13 that the City of San Marcos and Texas State University consciously focused initial restoration efforts on Texas wild rice and not specifically on all the species listed in Table 13. Transitioning to targeting the other native species listed in Table 13 is anticipated to occur as Texas wild rice areal coverage is met in each reach moving in an upstream to downstream direction. Furthermore, it needs to be understood that the San Marcos system was(is) dominated by non-native vegetation (> 75%) and the restoration team realized that the success of meeting the vegetation goals within the LTBG reaches would require extensive non-native vegetation removal efforts upstream of these reaches, especially for *Hydrilla*.

In the table, a positive number represents where a goal is already being met, whereas a negative number identifies where restoration work within the LTBG reaches still needs to be accomplished. On face value this table is misleading in that a lot of the restoration work to date on the San Marcos River has been conducted outside of the LTBG reaches for reasons outlined above and more fully in Section 2.1.2. Regardless, this table is necessary to guide development of the schedules discussed in Section 3. In summary, *Hygrophila* and *Hydrilla* have been successfully removed and are near or below the goals in both the Spring Lake Dam and I35 LTBG reaches. Significant progress with Texas wild rice has been made throughout the San Marcos River including the LTBG reaches. Although not on as large of a scale, successful restoration of *Heteranthera* and *Sagittaria* has been shown in the San Marcos River. Only limited success has been documented for *Ludwigia* and *Potamogeton* thus far primarily as a function of focused effort on other species.

The project team examined the long-term biological goals in greater detail to include an assessment of fountain darter density goals. An expansion of the fountain darter median density goals per vegetation type presented in Table 12 were simply multiplied against the total coverage of each vegetation type. For example, the median fountain darter density of 5 darters per m^2 for *Potamogeton* was multiplied by 3,300 (total m^2 of *Potamogeton* in the long-term biological goals) for a total 16,500 fountain darters. This calculation was made across all vegetation types in the long-term biological goals (Table 12) and resulted in a total of 34,325 fountain darters

(Table 14). Understanding that the establishment of the long-term aquatic vegetation (habitat) goals for the fountain darter are for the protection of the fountain darter, the team used this projected abundance information in association with aquatic vegetation coverage goals (m^2) when evaluating proposed revisions for consideration. Table 14 presents the existing long-term biological goals for the fountain darter in the San Marcos system.

Table 13. Comparison of Fall 2015 aquatic vegetation coverage within the long-term biological goal (LTBG) reaches to the HCP goals for the fountain darter in the San Marcos System.

FALL 2015 COVERAGE WITHIN HCP LONG-TERM BIOLOGICAL GOAL REACHES

Fountain darter habitat (aquatic vegetation) in meters squared (m^2) fall 2015							
Study reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring lake Dam	58	1		30		21	3
City Park	640	5		1,098	107	128	5
IH-35	26		22	41		0	
Total	724	7	22	1,169	107	150	7

HCP LONG-TERM BIOLOGICAL GOAL REACHES AND GOALS

Fountain darter habitat (aquatic vegetation) in meters squared (m^2) HCP Table 4-21							
Study reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring lake Dam	50	200	25	100	1,000	100	125
City Park	200	1,000	50	500	2,000	300	50
IH-35	50	200	300	100	300	100	25
Total	300	1,400	375	700	3,300	500	200

DIFFERENCES BETWEEN FALL 2015 AND HCP VEGETATION GOALS

Fountain darter habitat (aquatic vegetation) in meters squared (m^2) Comparison							
Study reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring lake Dam	8	-199	-25	-70	-1,000	-79	-122
City Park	440	-995	-50	598	-1,893	-172	-45
IH-35	-24	-200	-278	-59	-300	-100	-25
Total	424	-1,393	-353	469	-3,193	-350	-193

Table 14. Existing long-term biological goals for the fountain darter in the San Marcos System.

HCP LONG-TERM BIOLOGICAL GOAL REACHES AND GOALS

Fountain darter habitat (aquatic vegetation) in meters squared (m^2) HCP Table 4-21								
Study reach	*Hygrophila*	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*	*TOTAL*
Spring lake Dam	50	200	25	100	1,000	100	125	1,600
City Park	200	1,000	50	500	2,000	300	50	4,100
IH-35	50	200	300	100	300	100	25	1,075
Total	300	1,400	375	700	3,300	500	200	6,775
Fountain darter median density (number/m^2)								
	Hygrophila 4	*Ludwigia* 7	*Cabomba* 7	*Hydrilla* 5	*Potamogeton* 5	*Sagittaria* 1	*Vallisneria* 1	*TOTAL*
# darters * veg total	1,200	9,800	2,625	3,500	16,500	500	200	34,325

2.2.2 Texas wild rice

Table 15 presents the long-term biological goals for Texas wild rice specified in the HCP.

Table 15. HCP long-term biological goals (Table 4-10 from HCP).

TABLE 4-10
LONG-TERM BIOLOGICAL GOAL FOR TEXAS WILD-RICE

River Segment	Areal Coverage (m^2)	Reach Percentage of Total Areal Coverage
Spring Lake	1,000 – 1,500	n/a
Spring Lake Dam to Rio Vista Dam	5,810 – 9,245	83 – 66
Rio Vista Dam to IH-35	910 – 1,650	13 – 12
Downstream of IH-35	280 – 3,055	4 – 22
TOTAL	8000 – 15,450	100

The long-term biological goals for Texas wild rice are accompanied by three management objectives which are paraphrased below from the HCP:

- Minimum Texas wild rice coverage per segment (500 m^2 - Spring Lake, 2,490 m^2 - Spring Lake Dam to Rio Vista Dam, 390 m^2 – Rio Vista Dam to IH35, and 120 m^2 – Downstream of IH35) during drought of record like conditions (It should be noted that management objectives are different from the goals, as evident by these minimum numbers being below the goal range in each of the segments shown in Table 15);
- Recreation awareness throughout the whole river at all flows with designated control in certain high quality habitat areas below 100 cfs; and
- Active restoration and Texas wild rice expansion efforts and long-term monitoring.

Texas wild rice restoration efforts conducted between spring 2013 through early 2016 has resulted in an expansion estimated at 2,795 m^2 within the combined LTBG reaches and proposed Restoration reaches in the San Marcos River (Table 16). Successful expansion of Texas wild rice has been observed in each restoration reach with the greatest expansion observed in the reach below Sewell Park through City Park. We attribute this success to both passive and active restoration measures implemented within the San Marcos River as described in Appendix A.

Table 16. Area calculations for Texas wild rice amongst Restoration reaches (encompassing LTBG reaches) from spring 2013 to early 2016.

River segment	Spring 2013	Fall 2014	Aug 2015	2016
Spring Lake	31	30	NA	31
Spring Lake Dam – Rio Vista Dam	4,015	5,716	6,938	6,220
Rio Vista Dam – IH 35	401	335	385	85
Downstream of IH35	109	121	28	0
Totals	**4,556**	**6,202**	**7,351**	**6,336**

Full system maps for Texas wild rice showing Pre-restoration 2013, summer 2013, summer 2014, summer 2015 (pre-flood) and immediately post flood (December 2015) full aerial coverage are presented in Appendix C. A summary of this coverage is presented in Figure 14.

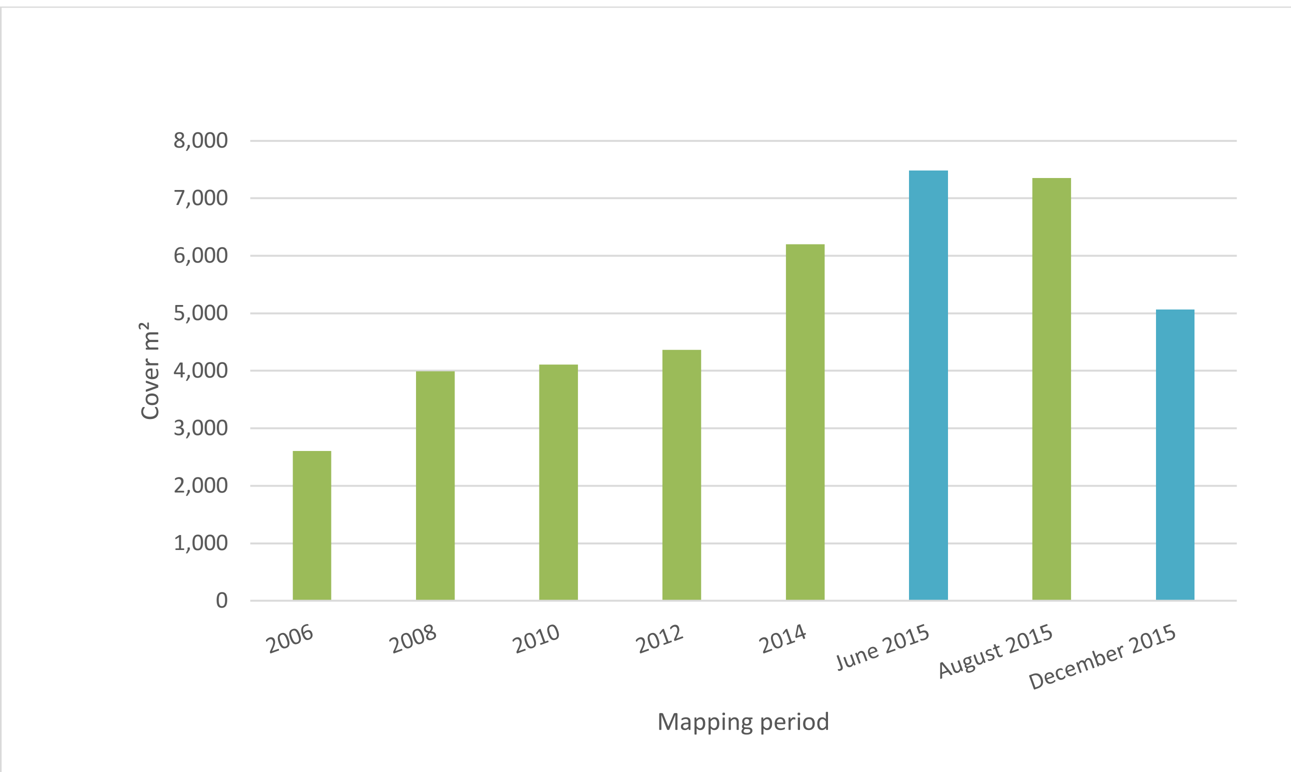

Figure 14. Total surface area of Texas wild rice stands across selected years in the San Marcos River. Blue represents high-flow Critical Period mapping efforts (BIO-WEST 2016).

Table 17 displays the current coverage of Texas wild rice, proposed goals, and amounts needed to accomplish the goals. It should be noted that restoration actions in Spring Lake proper were evaluated and the Slough Arm was discounted due to lack of velocity, unsuitable substrates, and scouring during floods. In addition, identified locations within Spring Lake proper were screened for potential cultural resource issues necessary to work within these areas. Work in Spring Lake is currently targeted for the fall of 2016.

Table 17. Current Texas wild rice coverage among river segments (m^2), long-term goals for Texas wild rice among river segments, and aerial coverage needed to obtain goals.

River segment	Current (2016)	Goals	Needed
Spring Lake	31	1,000	969
Spring Lake Dam – Rio Vista Dam	6,220	5,810	met
Rio Vista Dam – IH 35	85	910	825
Downstream of IH35	0	280	280
Totals	**6,336**	**8,000**	**1,664**

2.3 Old Channel Flow Split Evaluation

Table 18 shows the HCP flow-split recommendations in the HCP. Based on restoration activities conducted in the Old Channel since the inception of restoration coupled with biological monitoring conducted during the drought conditions of 2013 and 2014, we recommend that adjustments be considered to the current HCP flow-split recommendations. In order to assess our proposed adjustments, it is imperative to understand the development of the original recommendations and why they are a concern at this time.

Until 2003, the Old Channel LTBG reach was the most stable habitat in the Comal River being supplied water via a structure (two small culverts) that regulated flow through this section at approximately 40 cfs (P. Connor, USFWS, pers. comm.). In 2000-2002 this reach was dominated by filamentous algae, which provided the highest density of fountain darters of any aquatic vegetation type at that time. Also common in the Old Channel LTBG reach was a non-native species of the genus *Ceratopteris*. In 2002, the USFWS installed an additional culvert between the dam and the Old Channel to supplement the two existing smaller culverts. The original culverts coupled with the smaller swimming pool culvert had the capacity to convey approximately 40 cfs down the Old Channel. This “New” culvert significantly increased the volume of water that could be released directly to the Old Channel. Operationally the New culvert was not significantly opened until late fall 2002 upon a high rainfall event, unknowingly at the time resulting in a cascade of effects on the aquatic vegetation community of the Old Channel LTBG reach.

Table 18. HCP flow-split management recommendations for the Old and New Channels of the Comal River.

TABLE 5-3
FLOW-SPLIT MANAGEMENT FOR OLD AND NEW CHANNELS

Total Comal	Old Channel (cfs)		New Channel (cfs)	
Springflow (cfs)	Fall, Winter	Spring, Summer	Fall, Winter	Spring, Summer
350+	80	60	270+	290+
300	80	60	220	240
250	80	60	170	190
200	70	60	130	140
150	60		90	
100	60		40	
80	50		30	
70	50		20	
60	40		20	
50	40		10	
40	30		10	
30	20		10	

Figure 15 shows the measured discharge in the Old Channel taken just downstream of Elizabeth Street via EAA's long-term biological monitoring program. This hydraulic data collection was added in Spring 2003 because of the concern posed by installation and subsequent operation of the New culvert and altering the previously stable flow regime of the Old Channel. At that time, no USGS gage on the Old Channel existed.

In 2003, the *Ceratopteris* abundance remained approximately the same as in previous years with some fluctuation in total coverage, but the filamentous algae virtually disappeared beginning in the fall of 2002 and remained very low throughout 2003. At the same time, small patches of *Hygrophila* became established by the fall 2002 sample and some *Ludwigia* appeared by the spring 2003 sample. At that time, both species appeared to be growing at about the same rate, but *Hygrophila* remained slightly more abundant since it started to establish a few months before the *Ludwigia* appeared. By mid-2003, these plants had largely covered the areas that had previously been covered with filamentous algae. This change in vegetation community corresponded with culvert operation in late 2002 and early 2003. Discharge measurements in the Old Channel conducted for the biological monitoring program (Figure 15) were 114.5 cfs during the spring 2003 sample and over 93 cfs in each of the latter two samples in 2003. This extended period of higher discharges proceeded in changing the aquatic vegetation community in this reach.

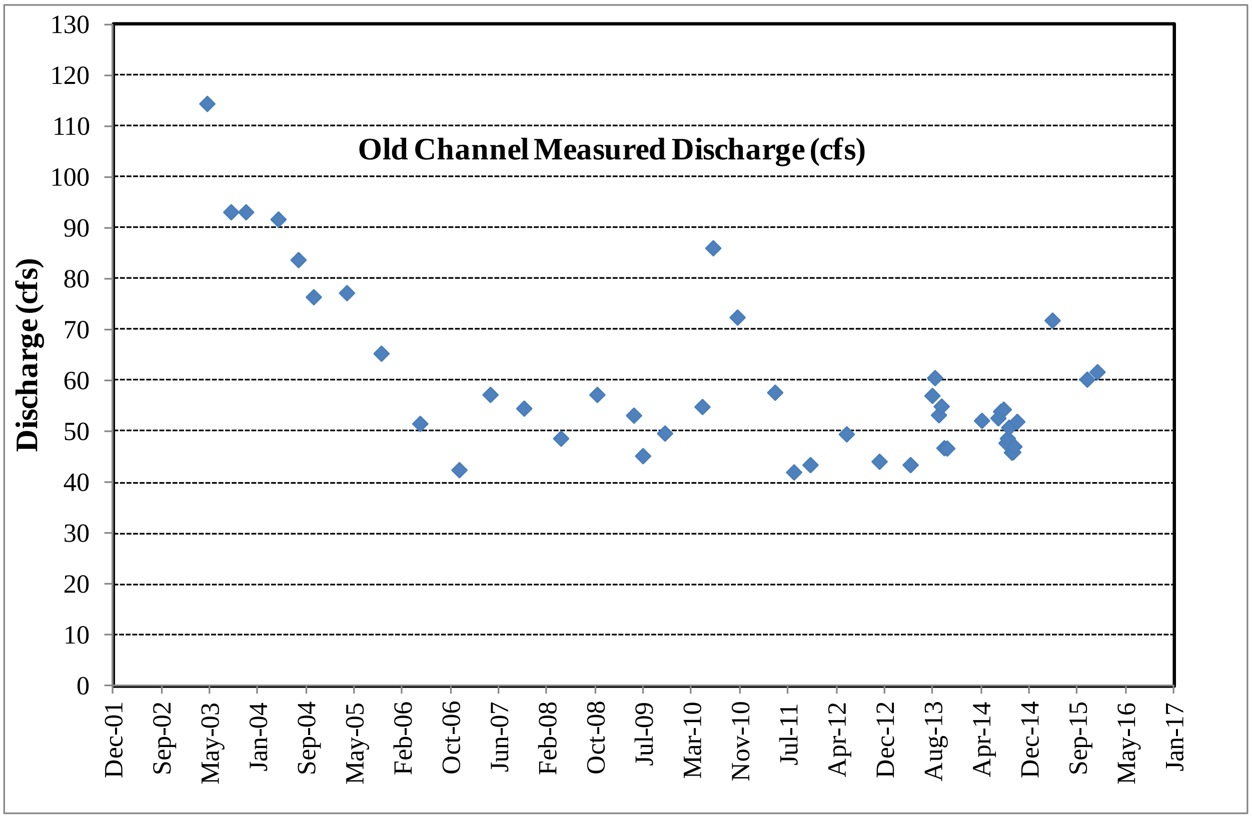

Figure 15. Measured discharge in the Old Channel of the Comal River below Elizabeth Street via long-term biological monitoring.

The changes in this section of the Old Channel were significant because of the importance of filamentous algae to fountain darters. An excerpt from the 2003 Annual Biological Monitoring Report states:

> "Future sampling of fountain darters in the new vegetation will determine whether the channel will continue to support the densities of fountain darters that had been sampled in 2000-2002 or if the new vegetation types will reduce the densities to those observed in other areas. Continued monitoring will be important to determine whether filamentous algae will return in areas that have not been covered with *Hygrophila* and *Ludwigia* and to determine how much area will be covered with these two plant types. The filamentous algae was very susceptible to flushing flows during flood events and has remained low while flows are higher than normal in 2003. If flows return to the 40cfs estimate made by the USFWS, conditions may allow for the return of filamentous algae in the reach. It will also be important to monitor the relative proportion of each of the two "new" plant types because *Ludwigia* supports a much greater density of fountain darters than *Hygrophila*. If, like in other areas, the *Hygrophila* eventually comes to dominate the reach, the habitat quality for fountain darters will decrease substantially compared to conditions observed in 2000-2002." (BIO-WEST 2004).

In fact, those predictions proved true in that nearly the entirety of the Old Channel LTBG reach was converted to *Hygrophila* over the next several years and ultimately the fountain darter population within this reach showed a corresponding decline (Figure 16). Over the 16 years of EAA sponsored biological monitoring only two fisheries biologists have collected these fountain darter data including Dr. Tom Brandt (USFWS SMARC) and Brad Littrell (BIO-WEST) with an overlapping training period with both scientists jointly participating in sampling from 2006 to 2008. For comparison, Figure 17 shows the results from the same dip net sampling conducted for the fountain darter in Spring Island reach of the Comal system for this same time period. No other Comal study reach exhibits as dramatic a change as what was observed in the Old Channel when *Hygrophila* became dominant.

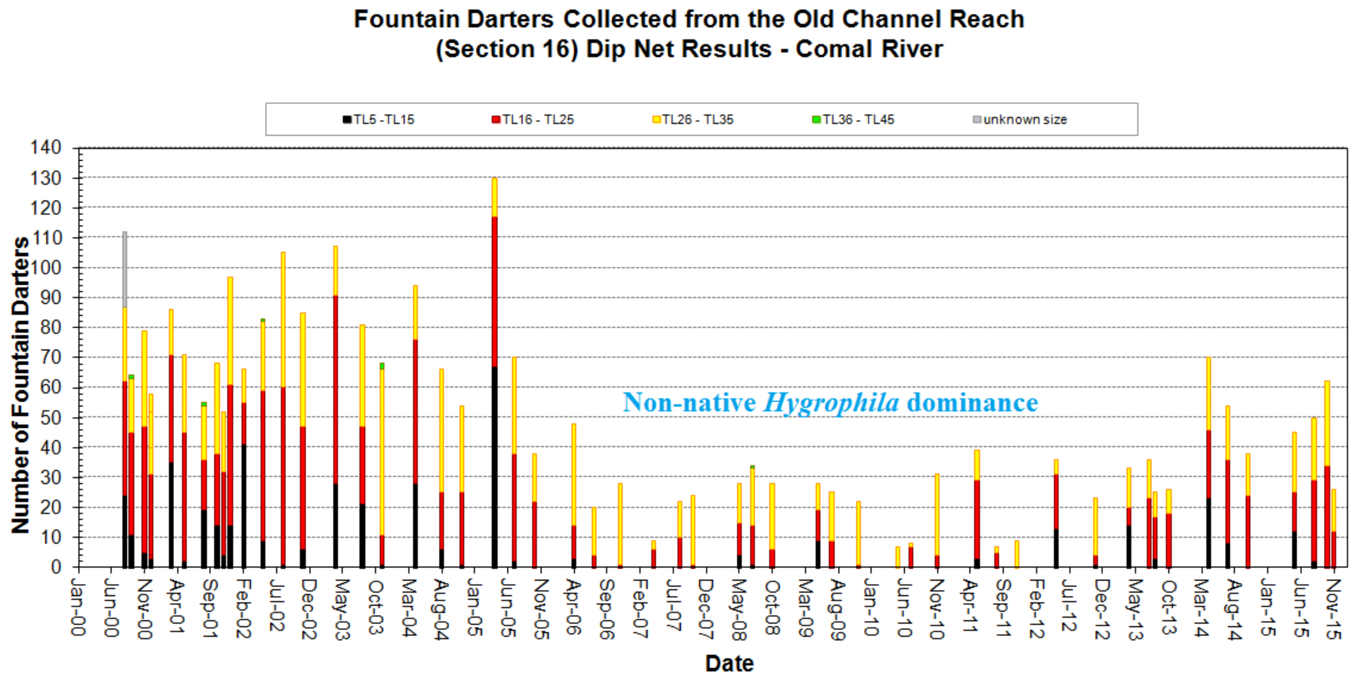

Figure 16. Fountain darter dip net sample results in the Old Channel of the Comal River (BIO-WEST 2016).

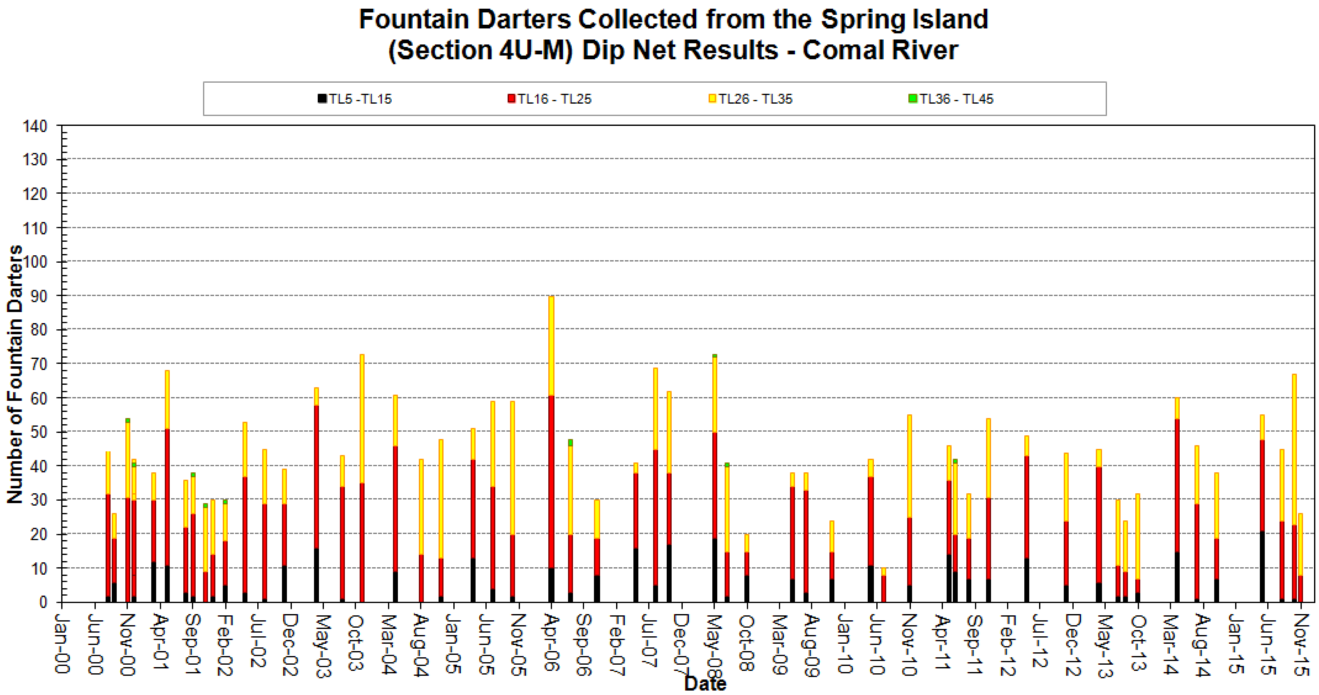

Figure 17. Fountain darter dip net sample results in the Spring Island area of the Comal River (BIO-WEST 2016).

When the HCP was under development, *Hygrophila* dominated the Old Channel study reach and the success of the proposed native aquatic vegetation restoration was an unknown. As such, the decision was made by the Biological working group to incorporate a flow-split recommendation that exhibited more of a stream hydrology characteristic to try and improve conditions in the Old Channel. Following three years of restoration work and continued monitoring, it is that decision that is being revisited in this section.

As a specific HCP mitigation measure, in the spring of 2014 the City of New Braunfels completed the repair of the larger culvert while sealing off the two original smaller culverts. This allowed for full functionality of the large culvert, and at that time, the City of New Braunfels began operating according to the flow-split recommendations (Table 18) in the HCP. In addition, USGS installed and started operating the Old Channel gage (USGS 08168913 Comal Rv (oc) nr Landa Lk, New Braunfels, TX) in 2013. Figure 18 shows the results from the Old Channel USGS gaging station from 2013 to early 2016. The original provisional data in 2013 was taken during a calibration phase and are not reflective of the low-flow conditions being experienced in the overall system during that time. However, starting in late 2013 to early 2014, the USGS Old Channel gage measurements correspond with total system discharge as well as biological monitoring program measurements. The completion of repairs and subsequent flow variability following the functionality of the culvert is quite evident in Figure 18 and is highlighted by the start of the orange box.

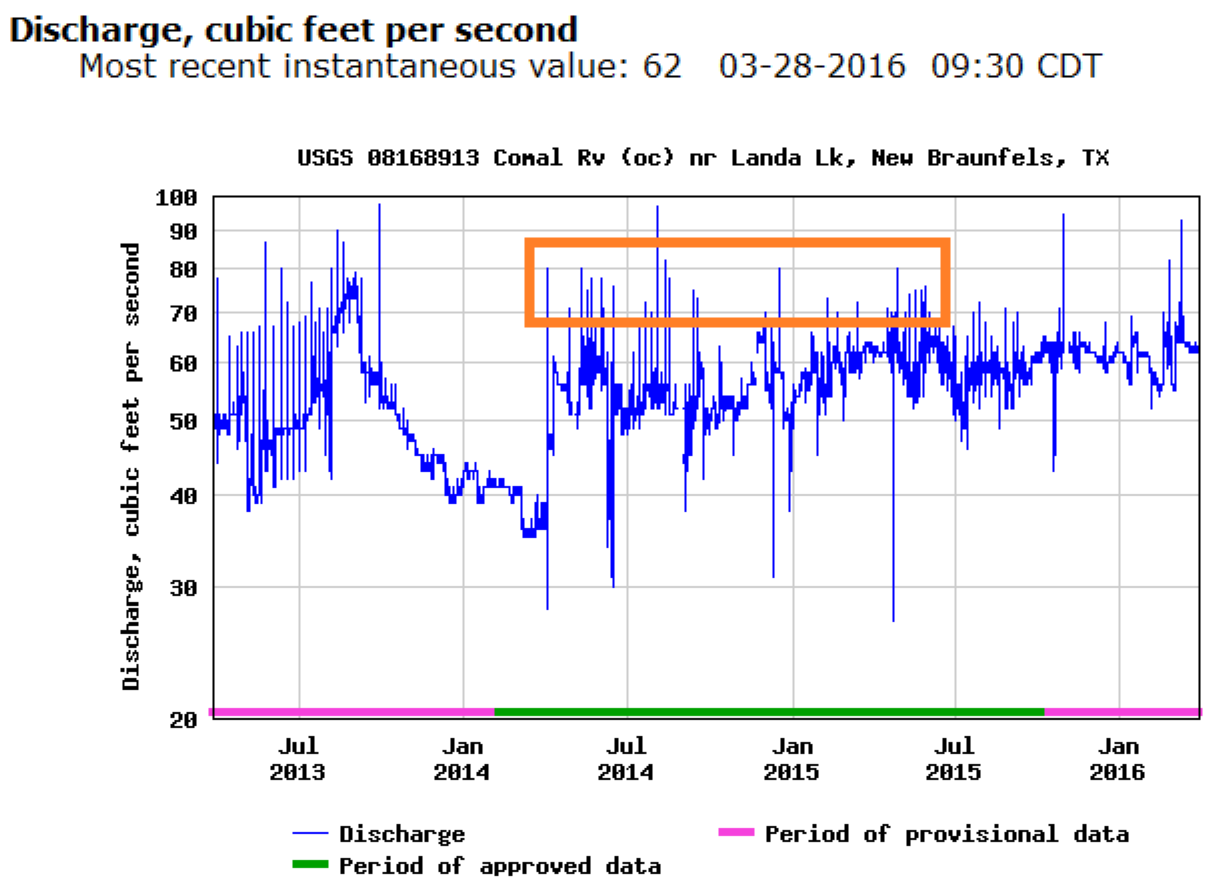

Figure 18. Old channel discharge reported at USGS gage 08168913.

Prior to culvert repairs, the Sediment Island had been removed and native aquatic vegetation including *Ludwigia* was successfully restored in 2013 in its former footprint (Figure 19, top). Since the culvert repair we have observed areas of vegetation, including the former Sediment Island area, becoming scoured and severely reduced in cover (Figure 19, bottom). The scour action typically was a consequence of rapidly changing water velocity or sustained high water velocities in the 70 to 80 cfs range. While stream adapted aquatic plants can withstand some velocity range there is a maximum threshold which once crossed damages steams, leaves and undermines roots. Broadleaved upright growing species such as *Ludwigia* have a lower velocity threshold compared to narrow leaved and thicker stemmed aquatic plants such as *Potamogeton* and *Justicia*. While aquatic plants such as *Ludwigia* can eventually adapt to increases in velocities by growing thicker root masses or senescing long stems so they stay short and prostrate abrupt velocity changes do not provide plants the time to produce adapted growth structures and can dislocate loose sediment leading to root undermining. This action can rip out large sections of plants before their growth adaptations and ability to adjust. Aquatic plant growth has been most affected by velocity in the Sediment Island area but other planted locations within the first 1,000 feet of the Old Channel have notably expanded and retracted from large continuous stands to smaller individual patches seemingly as a result in abrupt changes in water velocities.

Figure 19. *Ludwigia* in the former Sediment Island footprint during Spring 2013 (top) and Spring 2015 (bottom).

While considered a “constant” flow channel the Old Channel has been subjected to perturbations in water flow during the course of restoration activities. These perturbations can be attributed to culvert repair, draining of the spring-fed swimming pool, clearing of vegetation mats blocking the culverts, and storm water runoff from the golf course and golf course parking lot. The Old Channel has seen two major flood events since restoration began in 2013 and these events seem to have had little effect upon the aquatic vegetation most likely because these overbanking events displaced water velocities outside of the river channel. Therefore, damage to aquatic plants from increased velocity is most likely to occur when discharge is directed and concentrated within the river channel. Based on the knowledge gained regarding in channel scour over the course of HCP monitoring, we propose an upper limit of 65 cfs for consideration.

A second observation that happened during the biological monitoring of Comal Springs riffle beetles during the extensive 2014 drought caused another reason for concern with the original flow-split recommendations. In summer 2014, total system discharge declined to below 70 cfs in the Comal River, a condition not experienced since prior to the inception of the biological monitoring program in 2000. Operations according to the flow-split table mandated that a 50 cfs (Old Channel) to 20 cfs (New Channel) split occur. As such, the City of New Braunfels adjusted to accommodate that recommendation. In doing so, a large amount of Comal Springs riffle beetle habitat in the Spring Island area became exposed (Figure 20). Knowing that native aquatic vegetation in the Old Channel does very well at 40 cfs (pre-2003) coupled with the successful restoration of native aquatic vegetation since 2013 in the Old Channel, we feel that an adjustment to the flow-split when total system discharge declines below 150 cfs to 50 cfs is warranted to protect riffle beetle habitat in the Spring Island area.

Figure 20. Exposed Comal Spring riffle beetle habitat in the Spring Island area of the Comal River during late summer 2014 (BIO-WEST 2015b).

3.0 RESTORATION SCHEDULE AND RECOMMENDATIONS

As introduced in the Executive Summary, a major objective of this evaluation was to establish a timeline for submerged aquatic vegetation restoration (including Texas wild rice) with annual goals for the term of the HCP. The purpose of this timeline is to assist in the development of annual work plans but more importantly to assist with tracking progress towards meeting of HCP long-term biological goals.

3.1 Aquatic Vegetation Restoration Schedule

The scope of work for this project requires the development of a restoration schedule with annual milestones specific to each vegetation species and monitoring reach to accomplish the vegetative biological goals specific to the fountain darter currently established in the HCP. It is clear why the original long-term monitoring biological goals included non-native aquatic vegetation species. They indeed provide fountain darter habitat and their successful removal and subsequent reestablishment of native aquatic vegetation was unproven at that time. However, since program implementation, a wealth of information has been gained on the effectiveness of the HCP aquatic vegetation restoration program. With this knowledge, it is the professional opinion of the project team that it would not be ecologically responsible to implement a schedule to meet the original non-native vegetative goals in these systems. However, since that is a contractual requirement of this scope of work, the exercise was completed and presented herein for both systems.

The existing HCP long-term biological goals for the established LTBG reaches are identified in Tables 9 and 12 for the Comal and San Marcos systems, respectively. In this section, the project team presents the rationale behind and presents restoration schedules for the following three scenarios:

1) Scenario 1: Existing HCP aquatic vegetation goals
2) Scenario 2: Proposed modification to have only Native aquatic vegetation goals
3) Scenario 3: The second scenario coupled with a definition of “proportional expansion” to further protect the fountain darter in these systems and guide an efficient and effective use of HCP financial resources

All schedules were developed in the context of current funding in the HCP for this mitigation measure. For all schedules presented herein, the post-2015 flood mapping conducted as part of the HCP biological monitoring program was used. Finally, for all subsequent comparisons to the long-term aquatic vegetation goals, the project team recommends use of the Fall Comprehensive Event aquatic vegetation maps conducted and prepared as part of the HCP biological monitoring program.

3.1.1 Comal System

3.1.1.1 Existing HCP Aquatic Vegetation Goals

An evaluation of Table 19 reveals that to accomplish the existing Comal long-term biological goals, approximately 11,200 m^2 of an additional aquatic vegetation needs to be established. Of this amount, approximately 5,800 m^2 involves rooted aquatic vegetation with approximately 5,400 m^2 involving bryophytes. The first thing to note is that of the rooted aquatic vegetation, over 2,000 m^2 of *Hygrophila* is needed to meet the existing goals. This is the same *Hygrophila* that has been actively removed via the HCP to improve overall habitat conditions in the system. As such, no active planting of *Hygrophila* is proposed to meet the goal. Rather, the restoration team would simply stop gardening activities in certain discrete areas to allow this non-native plant to re-grow in these reaches but only until it meets the existing long-term biological goal. Ecologically, not only is this difficult to propose, but practically it makes the accomplishment of the native vegetation goals more difficult as will be documented later in this section.

Table 19. Existing (top), HCP Goals (middle), and Difference (bottom) in aerial coverage of aquatic vegetation in the Comal system long-term biological goal (LTBG) reaches.

EXISTING EAHCP vegetation species and aerial coverage in long-term biological goal reaches (POST FLOOD 2015)

Study Reach	Bryophytes	*Hygrophila*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	36	0	1	2	825	
Landa Lake	729	0	474	240	2,759	12,012
Old Channel	3	536	7			
New Channel		241	31	2,397		

EAHCP existing goals for vegetation species and aerial coverage in long-term biological goal reaches.

Study Reach	Bryophytes	*Hygrophila*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	1,850	650	150	0	600	0
Landa Lake	4,000	250	900	500	1,250	13,500
Old Channel	150	200	1,500	0	0	0
New Channel	150	1,350	0	350	0	0

DIFFERENCE between current EAHCP vegetation aerial coverage and existing vegetation goal by long-term biological goal reach.

Study Reach	Bryophytes	*Hygrophila*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	-1,814	-650	-149	2	225	0
Landa Lake	-3,271	-250	-426	-261	1,509	-1,488
Old Channel	-147	336	-1,493	0	0	0
New Channel	-150	-1,109	31	2,047	0	0

To determine a level of effort required to achieve cover goals of each rooted native aquatic plant species, coverage of each target species was averaged across the four quarterly mapping events in 2015 in Landa Lake and the Old Channel. To provide an estimated number of plants required per m^2 this average cover was divided by the total number of plants planted per species across three years of restoration activity. This provides an estimated number of plants per species to be planted in order to provide 1 m^2 of cover.

Average # of plants needed for 1 m^2 (estimated from averaged 2015 sustained coverage)

16-17	*Ludwigia*
14-19	*Cabomba*
12	*Sagittaria*

To create a schedule of restoration activities to reach the proposed goals within the LTBG reaches we took into consideration the number of plants needed, the number of plants that could be provided, and HCP annual budget allowances. However, since aquatic plant growth is highly variable throughout a year and from year to year as well as between locations, it needs to be clear that this is very much an estimated timeline. This timeline also assumes that restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc. This also assumes anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth. As previously mentioned, allowing the non-native *Hygrophila* to regain a foothold in the system (to meet its goal) will only make the attempted achievement of the other species goals more difficult.

When developing such a timeline each target plant species requires different considerations. For instance, the propagation of *Ludwigia* on an annual basis is mostly limited to between 6,000 and 7,000 plants per year. This number is based on the number of MUPPT turnovers which can be accomplished within one year which in turn is limited by the growing season. Typically, six MUPPT turnovers occur in a year from March to August with *Ludwigia* in the MUPPTs requiring three weeks to become mature. In comparison restoration of *Cabomba* and *Sagittaria* is not as limited since a large supply is currently present in the Old Channel or Landa Lake, but is more time consuming per planting effort than *Ludwigia* since these plants have to be collected, bundled or cut before being planted.

For the Old Channel LTBG meeting the existing cover goals of *Ludwigia* and *Cabomba* is highly dependent upon coinciding littoral and riparian restoration as much of the Old Channel has dense riparian canopy cover inhibiting native aquatic plant establishment. It is estimated that at least 700 m^2 of additional planting area can be provided by reducing non-native riparian canopy cover. Existing cover goals are also dependent upon providing additional planting area by channel modification, velocity buffers, or other means to increase suitable habitat for *Ludwigia* and *Cabomba*. Meeting existing goals in the Landa Lake LTBG reach is a bit less challenging for rooted vegetation, but will require some modifications to the existing aquatic plant community. Existing suitable areas for planting of *Ludwigia* and *Cabomba* in Landa Lake have mostly been planted out in the past three years. Any additional cover of these two species may require translocation of other native vegetation types as well as removal of littoral vegetation such as elephant ear, and some riparian canopy modifications especially along the Eastern shoreline where *Cabomba* has been difficult to establish. Landa Lake is dominated by *Vallisneria* and *Sagittaria* which has expanded recently with drought recovery and will most likely continue to compete for growing space with *Ludwigia* and *Cabomba*. Therefore, a timeline to meet coverage goals for *Ludwigia* and *Cabomba* in Landa Lake is dependent not only on the pace at which plants can be propagated and planted or translocated but the pace at which vegetation translocation or removal or other modifications can be made to provide new planting areas.

In the Upper Spring Run and New Channel LTBG reaches aquatic vegetation goals again face challenges. Any increase in aquatic vegetation cover in the Upper Spring Run could be potentially subjected to removal by property owners in an attempt to keep the stream bed area clear for swimming and recreation. The use of exclosures (similar to San Marcos SSAs) to protect some limited amounts of vegetation might be an option if amenable to the City of New Braunfels and property owners. Aquatic vegetation in the Upper Spring Run is also severely impacted by floods as well as low flows. Understanding these limitations and the approved HCP flow regime, maintaining these Upper Spring Run LTBG reach goals will be difficult during an extended low flow event. In the New Channel LTBG reach promoting and maintaining existing native vegetation with some supplemental planting is expected to be sufficient effort to meet the goals of this area. In order to accomplish the existing HCP long-term biological goals in the New Channel LTBG reach, the main activity will be no activity other than to allow non-native *Hygrophila* to expand again in the system.

Bryophytes are highly transitory and cannot be “planted” into restoration locations as other types of vegetation therefore calculating effort and a timeline to meet coverage goals for this vegetation type across all LTBG reaches is difficult. To accomplish restoration goals, specific areas will be designated and kept devoid of other rooted vegetation types each year where bryophytes can be encouraged to colonize. Bryophytes will also colonize within some areas of restored vegetation, however, allowing bryophyte cover to increase too much comes at a cost of shading out and killing other native plant species. To track goal achievement for this non-rooted vegetation type, mapping of these designated areas will occur on an annual basis each fall.

Table 20 (Appendix B, Table B1) outlines the proposed restoration timeline for the accomplishment of the rooted aquatic vegetation ***existing*** HCP goals in the Comal system. For successful implementation of this schedule, it is critical that concurrent aquatic plant propagation, gardening, and maintenance occur throughout the HCP timeline. As evident in Table 20, it is not possible to meet all the existing HCP long-term biological goals for vegetation coverage in all reaches prior to 2027 using the existing HCP budget. The main shortcoming is relative to *Ludwigia* in the Old Channel reach. In fact, without significant riparian canopy removal and in channel modification, it is likely that the *Ludwigia* goal for the Old Channel reach is not attainable regardless of budget. It should be remembered that the existing HCP vegetation coverage goals were set based on the highest coverage of specific species in a given LTBG reach recorded since 2000, regardless of year, with subsequent adjustment for overall surface area within that reach. Based on three years of intensive restoration work in the system, it has been documented that in certain areas of the river, in particular high shade areas, native vegetation replacement of non-native vegetation is not achievable on a 1 to 1 ratio.

Upon accomplishment of coverage goals per 3 of the 4 reaches, plant propagation (at a reduced level compared to full production) will still be necessary to supplement vegetation stands to sustain this coverage over time. It also needs to be understood that although the Table 20 schedule only addresses work in the LTBG reaches, it does not mean that aquatic gardening and maintenance does not need to occur in other parts of the system. Under this option, work is mandatory in the remainder of the system for two primary reasons. The first is that to sustain the aquatic plant coverage within the LTBG reaches, non-native vegetation removal (and replacement with natives) will be required in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) in order to assure that non-native plants don't reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG reaches (beyond their defined aerial targets). Secondly, work towards achieving the undefined management objective of proportional expansion is required per the HCP. It is anticipated that the combination of these two factors will require the complete use of the annual HCP budget for this mitigation measure through 2027.

Table 20. Proposed restoration timeline designed to meet the **existing HCP** rooted aquatic vegetation goals over time in the Comal system.

REACHES	SPECIES	Meters squared of aquatic vegetation (m^2)			HCP TERM TIMELINE *											TOTAL
		Current (2016)	Goal	Needed	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																
Landa Lake	*Ludwigia*	474	900	426	125	60	60	90	95							430
	Cabomba	240	500	260	60	50	40	50	60							260
	Sagittaria	2,759	1,250	0												0
	Vallisneria	12,012	13,500	1,488	160	150	150	150	150	130	120	120	120	120	120	1490
	Hygrophila	0	250	250	10	15	25	25	25	25	25	25	25	25	25	250
Old Channel	*Ludwigia*	7	1,500	1,493	150	150	150	125	125	100	75	75	75	75	75	1175
	Filamentous algae	0	200	200	25	20	20	20	20	20	15	15	15	15	15	200
	Hygrophila	450	200	0												0
New Channel	*Cabomba*	2,397	350	0												0
	Hygrophila	796	1,350	554	50	50	50	50	50	50	50	50	50	50	55	555
Upper Spring Run	*Ludwigia*	1	150	149	25	25	15	15	15	15	15	15	10			150
	Hygrophila	2	650	648	50	50	50	50	50	50	50	50	50	100	100	650
	Sagittaria	825	600	0												0

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**

Red shaded boxes represent non-native vegetation which will not be planted. It will simply be allowed to reestablish in isolated areas to meet the existing HCP goals.

Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc.

2) Anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth.

3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.

4) Non-native vegetation removal (and replacement with natives) will occur in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) outside of the LTBG and Restoration reaches in order to assure that non-native plants don't reestablish.

5) Riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

6) No significant interuptions due to HCP Provision M.

7) Mapping to compare against goals will be conducted annually each Fall.

3.1.1.2 Proposed revisions to all Native Vegetation

Based on three years of successful non-native vegetation species removal and subsequent establishment of native vegetation, the elimination of all non-native vegetation species from the long-term biological goals is recommended. As described above, the long-term biological goals for the fountain darter are for the protection of the fountain darter, not specific aquatic vegetation types. Maintaining a diverse community of native aquatic vegetation not only benefits the fountain darter but the entire aquatic ecosystem. Upon assessment by the Comal restoration team, the following issues were identified per species:

- *Hygrophila* has been successfully removed well below the goals in 3 of the 4 LTBG reaches with the remaining amounts in the Old Channel to be addressed in 2016. Because of the experienced success, we recommend removing this non-native species entirely from the HCP goals. However, this poses an issue in that 2,450 m^2 of fountain darter habitat is being removed from the system (on paper) and thus needs replacement by a similar amount of same quality native habitat, or possibly a lesser amount of higher quality fountain darter habitat as long as the resulting number of fountain darters remains neutral;
- No work has been done on filamentous algae and since essentially none of this remains in the Old Channel, we recommend removing this vegetation type from the goals. An elimination of 300 m^2 of fountain darter habitat (again on paper), would result in the need to make this up with other native vegetation types known to harbor fountain darters;
- Significant progress has been made on both *Ludwigia* and *Cabomba*, but the Comal restoration team is concerned that meeting the existing HCP goals in the Old Channel will not be possible without significant riparian restoration to thin out non-native tree canopy coverage or remove those non-native trees to allow more sunlight to reach the water;
- *Vallisneria* was reduced during the City of New Braunfels walls project. The areas affected were subsequently replanted with higher quality fountain darter habitat (*Ludwigia* and *Cabomba*) in an effort to diversify the vegetation community in Landa Lake. The success of that restoration was impressive and thus, we feel the overall amount of *Vallisneria* in the Landa Lake reach could be reduced to support other native vegetation establishment in this reach. This would result in an adjustment downward to the *Vallisneria* goal in the Landa Lake LTBG reach.

The most notable revision is the proposed removal of *Hygrophila* from the long-term biological goals. Additionally, one new native species (*Potamogeton*) is proposed for addition as it is a known habitat type for the fountain darter. The rest of the proposed revisions are merely adjustments in coverage per reach based on the restoration team's experience of what is anticipated to be feasible to accomplish in the Comal system. As shown in Table 11 and Table 21, the proposed revisions result in a slight reduction (520 m^2) of overall aquatic vegetation in the Comal LTBG reaches. However, because of the increased value of native vegetation versus non-native vegetation, there is an overall increase in the potential number of fountain darters to be protected (176,718 [proposed, Table 21] versus 176,150 [original] Table 13). Table 21 presents the proposed long-term biological goals for the fountain darter in the Comal system.

Table 21. Proposed Revised long-term biological goals for the fountain darter in the Comal System.

PROPOSED REVISED HCP GOALS FOR ESTABLISHED LTBG REACHES

Fountain darter habitat (aquatic vegetation) in meters squared (m^2)							TOTAL
Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	
Upper Spring Run	1,750		25	25	850		2,650
Landa Lake	3,950	25	900	500	2,250	12,500	20,125
Old Channel	550		425	180	450		1,605
New Channel	150		100	2,500			2,750
Total	6,400	25	1,450	3,205	3,550	12,500	27,130
Fountain darter median density (number/m^2)							
	Bryophytes 20	*Potamogeton* 3.3	*Ludwigia* 7	*Cabomba* 7	*Sagittaria* 1	*Vallisneria* 1	*TOTAL*
# darters * veg total	128,000	83	10,150	22,435	3,550	12,500	176,718

An evaluation of Table 22 reveals that to accomplish the proposed revised Comal long-term biological goals, approximately 8,100 m^2 of an additional aquatic vegetation needs to be established. Of this amount, approximately 2,500 m^2 involves rooted aquatic vegetation with approximately 5,600 m^2 involving bryophytes.

Table 22. Existing (top), Proposed (middle), and Difference (bottom) in aerial coverage of native aquatic vegetation in the Comal system long-term biological goal (LTBG) reaches.

EXISTING EAHCP vegetation species and aerial coverage in long-term biological goal reaches (POST FLOOD 2015)

Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	36		1	2	825	
Landa Lake	729		474	240	2,759	12,012
Old Channel	3		7			
New Channel			31	2,397		

PROPOSED EAHCP goals for vegetation species and aerial coverage in long-term biological goal reaches.

Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	1,750		25	25	850	
Landa Lake	3,950	25	900	500	2,250	12,500
Old Channel	550		425	180	450	
New Channel	150		100	2,500		

DIFFERENCE between current EAHCP vegetation aerial coverage and proposed vegetation goal by long-term biological goal reach.

Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	-1,714		-24	-23	-25	
Landa Lake	-3,221	-25	-426	-261	509	-488
Old Channel	-547		-418	-180	-450	
New Channel	-150		-69	-103		

Table 23 (Appendix B, Table B2) outlines the proposed restoration timeline for the accomplishment of the proposed revised rooted aquatic vegetation goals in the Comal system. For successful implementation of this schedule, it is critical that concurrent aquatic plant propagation, gardening, and maintenance occur throughout the HCP timeline. As evident in Table 23, under this scenario it is possible to meet all the proposed revised HCP long-term biological goals for rooted vegetation coverage in all LTBG reaches by the conclusion of 2021. With that said, upon accomplishment of coverage goals per reach, plant propagation (at a reduced level compared to full production) will still be necessary to supplement vegetation stands to sustain this coverage over time. It also needs to be understood that although the Table 23 schedule only addresses work in the LTBG reaches, it does not mean that aquatic gardening and maintenance does not need to occur in other parts of the system. As with the existing option, work under this revised scenario is mandatory in the remainder of the Comal system for the same two primary reasons. The first is that to sustain the aquatic plant coverage within the LTBG reaches, non-native vegetation removal (and replacement with natives) will be required in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) in order to assure

that non-native plants don't reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG reaches (beyond their defined aerial targets). Secondly, work towards achieving the undefined management objective of proportional expansion is required per the HCP. Similar to the existing option, it is anticipated that the combination of these two factors will require the complete use of the annual HCP budget for this mitigation measure through 2027.

Table 23. Proposed restoration timeline designed to meet the **proposed HCP** rooted aquatic vegetation goals over time in the Comal system.

REACHES	SPECIES	Meters squared of aquatic vegetation (m^2)			HCP TERM TIMELINE *											TOTAL
		Current (2016)	Goal	Needed	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																
Landa Lake	*Ludwigia*	474	900	426	100	100	100	105	25							430
	Cabomba	240	500	260	60	60	60	40	40							260
	Sagittaria	2,759	2,250	0												0
	Vallisneria	12,012	12,500	488	100	100	100	100	90							490
	Potamogeton	0	25	25	5	5	5	5	5							25
Old Channel	*Ludwigia*	7	425	418	100	100	100	100	20							420
	Cabomba	0	180	180	75	30	30	25	20							180
	Sagittaria	0	450	450	150	75	75	75	75							450
New Channel	*Ludwigia*	31	100	69		25	25	20								70
	Cabomba	2,397	2,500	103		35	35	35								105
	Sagittaria	0	0	0												0
Upper Spring Run	*Ludwigia*	1	25	24		10	10	5								25
	Cabomba	2	25	23		10	10	5								25
	Sagittaria	825	850	25		10	10	5								25

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the proposed revised LTBG reach goals.**
Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc.

2) Anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth.

3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.

4) Non-native vegetation removal (and replacement with natives) will occur in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) outside of the LTBG and Restoration reaches in order to assure that non-native plants don't reestablish.

5) Riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

6) No significant interuptions due to HCP Provision M.

7) Mapping to compare against goals will be conducted annually each Fall.

3.1.1.3 Proposed Proportional Expansion Definition using Restoration Reaches

As introduced in Section 2, the fountain darter long-term biological goals for the Comal system also have a management objective that identifies extending aquatic vegetation restoration work beyond the LTBG reaches in equal proportion to effort expended per study area in relation to the total area of Landa Lake and Old Channel. This objective is not formally defined in the HCP and thus, based on three years of restoration experience in the Comal system, we suggest the following clarification to proportional expansion. Although the main HCP goal is for the survival and recovery of the fountain darter in the wild, this is not the focus of the long-term biological goals. These goals are striving for conditions should they ever be achieved and maintained that would warrant the down listing or delisting of the species. As such, we recommend the following as a definition of the “proportional expansion” of this work in the Landa Lake and Old Channel sections of the Comal system.

To meet this management objective, we recommend establishing known “Restoration reaches” in addition to the established LTBG reaches. The proposed three Restoration reaches are shown in Figure 21 and represent a reach both upstream and downstream of the Landa Lake LTBG, as well as the entire stretch of the Old Channel from the Landa Lake dam to the existing LTBG reach. This expansion includes the majority of Landa Lake as well as the portion identified in the HCP Section 5.2.2.1 as the critically important Old Channel Environmental Restoration and Protection Area (ERPA). Gardening and maintaining these Restoration reaches to keep them free of invasive *Hygrophila* will also help protect the LTBG reaches as well as provide a larger propagule source for native plants and increase the diversity of the native plant community in the Comal River.

The HCP does not call for expansion in the Upper Spring Run LTBG reach nor New Channel LTBG reach given the higher levels of recreation in these reaches coupled with the potential for scour via flooding from either Blieder’s or Dry Comal creek’s, respectively. Similarly, we do not propose restoration activities downstream of the existing LTBG reach in the Old Channel. This area downstream is outside of the protection zone of maintaining suitable water temperatures (as modeled in the HCP) during low-flow conditions. Additionally, recreational activities are substantially increased in this downstream zone, especially in the Hinman Island drive portion of the river.

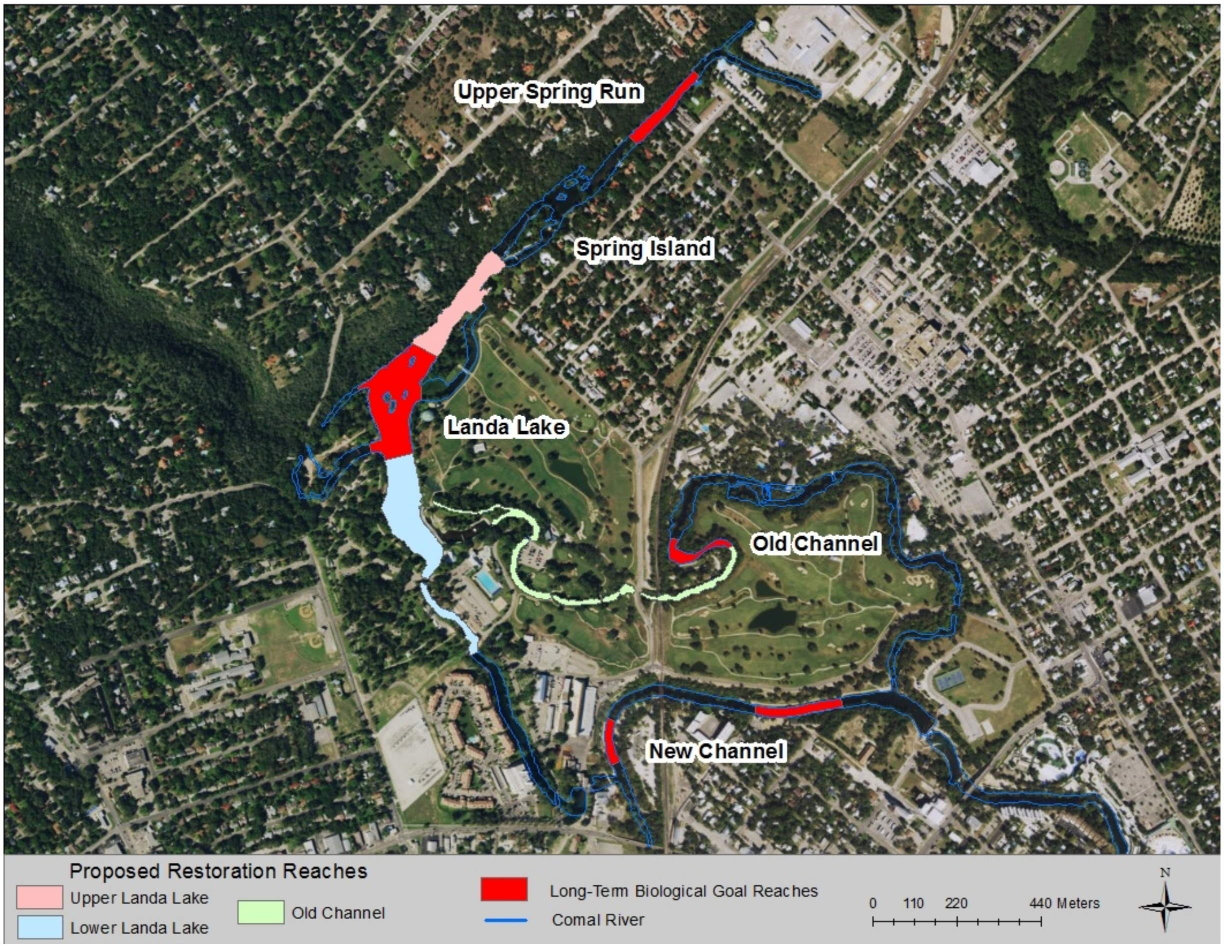

Figure 21. Long-term biological goal reaches and proposed "restoration reaches" for the Comal system.

Table 24 presents the proposed native aquatic vegetation goals and resulting fountain darter totals using the same 15 years of fountain darter drop net data. As evident in Table 24, adding these "Restoration reaches" adds over 30,000 m^2 of native aquatic vegetation and over 180,000 fountain daters. In addition to defining this HCP management objective for future comparison and more efficient use of HCP financial resources, this step is necessary to fully address the scope of this project which involves the development of a restoration schedule that strives to accomplish and maintain the long-term biological goals and objectives within the context of the HCP allocated budget.

Table 24. Proposed restoration reaches to define "proportional expansion" in the Comal System.

PROPOSED RESTORATION REACHES TO DEFINE "PROPORTIONAL" APPLICATION

Fountain darter habitat (aquatic vegetation) in meters squared (m^2)							TOTAL
Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	
Landa Lake UP[A]	5,500		25	250	250		6,025
Landa Lake DOWN[B]	500		50	125	100	22,500	23,275
Old Channel UP[C]	1,250	100	850	200	750	750	3,900
Total	7,250	100	925	575	1,100	23,250	33,200
Fountain darter median density (number/m^2)							
	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	
	20	3.3	7	7	1	1	*TOTAL*
# darters * veg total	145,000	330	6,475	4,025	1,100	23,250	180,180

[A] Landa Lake LTBG reach to downstream boundary of Spring Island

[B] Landa Lake LTBG reach to weir across from City of New Braunfels Park Office

[C] Old Channel from LTBG reach upstream to Landa Lake Dam

An evaluation of Table 25 reveals that to accomplish the proposed proportional expansion management objective, approximately 2,500 m^2 of an additional aquatic vegetation needs to be established. Of this amount, approximately 1,000 m^2 involves rooted aquatic vegetation with approximately 1,500 m^2 involving bryophytes. Table 26 (Appendix B, Table B3) outlines the proposed restoration timeline for the accomplishment of the combination (LTBG reaches and Restoration reaches) of proposed revised rooted aquatic vegetation goals in the Comal system. For successful implementation of this schedule, it is critical that concurrent aquatic plant propagation, gardening, and maintenance occur throughout the HCP timeline. As evident in Table 26, under this scenario it is possible to meet all the proposed revised HCP long-term biological goals for rooted vegetation coverage in all LTBG reaches and Restoration reaches by the conclusion of 2023.

Upon accomplishment of coverage goals per reach, plant propagation (at a reduced level compared to full production) will still be necessary to supplement vegetation stands to sustain this coverage over time. It also needs to be understood that although the schedule only addresses work in the LTBG and Restoration reaches, it does not mean that aquatic gardening and maintenance does not need to occur outside of those areas. To sustain the aquatic plant coverage within the LTBG and Restoration reaches, non-native vegetation removal (and replacement with natives) will be mandatory in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) in order to assure that non-native plants don't reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG and designated Restoration reaches. Finally, as noted throughout this section, the importance of riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

Table 25. Existing (top), Proposed (middle), and Difference (bottom) in aerial coverage of native aquatic vegetation in the Comal system proposed Restoration reaches.

EXISTING EAHCP vegetation species and aerial coverage in restoration reaches (POST FLOOD 2015)

Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	***TOTAL***
Landa Lake Upper	5,036		0	150	50		5,236
Landa Lake Lower	228		5	100	7	24,500	24,840
Old Channel ERPA	510	73	618	119	591	715	2,626

PROPOSED EAHCP goals for vegetation species and aerial coverage in restoration reaches.

Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	***TOTAL***
Landa Lake Upper	5,500		25	250	250		6,025
Landa Lake Lower	500		50	125	100	22,500	23,275
Old Channel ERPA	1,250	100	850	200	750	750	3,900

DIFFERENCE between current EAHCP vegetation aerial coverage and proposed vegetation goal by restoration reach.

Study Reach	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*	***TOTAL***
Landa Lake Upper	-464		-25	-100	-200		-789
Landa Lake Lower	-272		-45	-25	-93	2,000	1,565
Old Channel ERPA	-740	-27	-232	-81	-159	-35	-1,274

The LTBG reaches of Landa Lake and the Old Channel as well as the Old Channel ERPA are considered the highest priority areas. We therefore propose concentrating planting efforts in these three reaches first to the extent budget allows. Upon successful implementation in these priority areas, the plan is to then shift some focus over to the Upper Spring Run and New Channel LTBG reaches and ultimately the Landa Lake upper and lower Restoration reaches.

Considering over 5,000 m^2 of non-native *Hygrophila* has been removed, nearly 37,000 plants have been installed and approximately 1,850 m^2 of native aquatic vegetation sustained in the first three years of restoration, with 2013 being a trial year, the proposed goals and timeline in Table 26 appear achievable with assumptions noted. Overall, the combined scenario is anticipated to achieve the aquatic vegetation goals in the LTBG reaches as well as accomplish the associated management objective of proportional expansion specified in the HCP by the conclusion of 2023. Upon these accomplishments, it is estimated that approximately ½ of the annual HCP budget for this measure will be needed yearly from 2024 to 2027 to maintain these conditions.

Table 26. Proposed restoration timeline designed to meet the **Combined proposed HCP** rooted aquatic vegetation goals over time in the Comal system.

REACHES	SPECIES	Meters squared of aquatic vegetation (m^2)			HCP TERM TIMELINE *											TOTAL
		Current (2016)	Goal	Needed	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																
Landa Lake	*Ludwigia*	474	900	426	75	75	75	105	35	35	30					430
	Cabomba	240	500	260	50	50	50	30	30	25	25					260
	Sagittaria	2,759	2,250	0												0
	Vallisneria	12,012	12,500	488	100	100	75	75	75	50	15					490
	Potamogeton	0	25	25	5	5	5	5	5							25
Old Channel	*Ludwigia*	7	425	418	75	75	75	75	50	50	20					420
	Cabomba	0	180	180	50	30	30	25	15	15	15					180
	Sagittaria	0	450	450	150	75	75	50	50	25	25					450
New Channel	*Ludwigia*	31	100	69		15	15	15	15	5	5					70
	Cabomba	2,397	2,500	103		20	20	20	20	15	10					105
	Sagittaria	0	0	0												0
Upper Spring Run	*Ludwigia*	1	25	24		5	5	5	5	5						25
	Cabomba	2	25	23		5	5	5	5	5						25
	Sagittaria	825	850	25		5	5	5	5	5						25
Restoration Reaches																
Landa Upper	*Ludwigia*	0	25	25			25									25
	Cabomba	150	250	100			25	35	20	10	10					100
	Sagittaria	50	250	200			50	50	50	25	25					200
Landa Lake Lower	*Ludwigia*	5	50	45			15	10	10	5	5					45
	Cabomba	100	125	25			10	10	5							25
	Sagittaria	7	100	93			25	25	25	10	10					95
	Vallisneria	24,500	22,500	0												0
Old Channel ERPA	*Ludwigia*	618	850	232	100	75			30	15	15					235
	Cabomba	119	200	81	25	25			25	10	5					90
	Sagittaria	591	750	159	75	25			35	15	10					160
	Vallisneria	715	750	0												0
	Potamogeton	73	100	27	10	10			5	5						30

*** Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the goals and management objective over time. It is estimated that approximately 1/2 of the HCP annual budget for this mitigation measure would be needed each year to maintain these conditions from 2024 through 2027.**

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc.

2) Anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth.

3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.

4) Non-native vegetation removal (and replacement with natives) will occur in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) outside of the LTBG and Restoration reaches in order to assure that non-native plants don't reestablish.

5) Riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

6) No significant interuptions due to HCP Provision M.

7) Mapping to compare against goals will be conducted annually each Fall.

3.1.2 San Marcos System

3.1.2.1 Existing HCP Aquatic Vegetation Goals

An evaluation of Table 27 reveals that to accomplish the existing San Marcos HCP long-term biological goals, approximately 6,150 m^2 of an additional aquatic vegetation needs to be established. Of this amount, it needs to be highlighted that 725 m^2 is made up of non-native aquatic vegetation (*Hygrophila*, *Hydrilla*, and *Vallisneria*). This is the same non-native vegetation that has been actively removed since the implementation of the HCP to improve overall habitat conditions in the San Marcos system. As such, no active planting of these non-natives is proposed to meet the goal. Rather, the restoration team would simply stop gardening activities in certain discrete areas to allow these non-native plants to re-grow in these reaches but only until they meet their respective existing long-term biological goals. Ecologically, not only is this difficult to propose, but practically it makes the accomplishment of the native vegetation goals more difficult. This is especially true given how extensive the aerial coverage of non-natives is in the San Marcos River where at the start of the restoration efforts they comprised ~ 75 percent of the total aquatic vegetation. Confining removal of non-natives to the three LTBG reaches as well as maintaining the existing target areal coverage of these non-natives for fountain darters will likely ensure that these non-native species will expand into the LTBG reaches to the detriment of accomplished native aquatic vegetation recovery.

Table 27. Existing (top), HCP Goals (middle), and Difference (bottom) in aerial coverage of aquatic vegetation in the San Marcos system long-term biological goal (LTBG) reaches.

EXISTING EAHCP vegetation species and aerial coverage (POST FLOOD 2015)

Long-term Biological Goals reaches and Restoration reaches	Vegetation species						
	Hygrophila	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring Lake Dam - LTBG reach	38	0	0	9	0	7	0
City Park - LTBG reach	297	1	0	228	54	92	0
I35 - LTBG reach	0	0	0	0	0	0	0

EAHCP existing goals for vegetation species and aerial coverage in support of fountain darter habitat.

Long-term Biological Goals reaches and Restoration reaches	Vegetation species						
	Hygrophila	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring Lake Dam - LTBG reach	50	200	25	100	1000	100	125
City Park - LTBG reach	200	1000	50	500	2000	300	50
I35 - LTBG reach	50	200	300	100	300	100	25

DIFFERENCE between current EAHCP vegetation aerial coverage and existing HCP vegetation goals by reach.

Long-term Biological Goals reaches and Restoration reaches	Vegetation species						
	Hygrophila	*Ludwigia*	*Cabomba*	*Hydrilla*	*Potamogeton*	*Sagittaria*	*Vallisneria*
Spring Lake Dam - LTBG reach	-12	-200	-25	-91	-1000	-93	-125
City Park - LTBG reach	97	-999	-50	-272	-1946	-208	-50
I35 - LTBG reach	-50	-200	-300	-100	-300	-100	-25

As discussed for the Comal system, in developing a schedule several factors were also considered for the San Marcos system such as propagation rates of each species, the amount of area still needing to be obtained for each species, the amount of non-native aquatic vegetation needing to be removed in each reach before native plantings, and which areas have currently been worked in since 2013. The San Marcos restoration team assessed their success in the previous years to create a schedule of restoration activities to complete the goals. However, since expansion rates are highly variable between years, it needs to be understood that the timeline is still only an estimate with several built in assumptions. The San Marcos River timeline and schedule assumptions include 1) anthropogenic influences such as recreational disturbance and urban runoff are managed and do not change in disturbance rate or area, 2) no major setbacks from full system resets occur due to flooding events, etc. 3) no significant interruptions in work due to Provision M, 4) propagation rates remain sufficient to replace denuded areas of nonnative aquatic vegetation, and 5) non-native aquatic vegetation removal will occur in certain areas outside of LTBG reaches in order to mitigate reestablishment of non-natives. Monitoring of river based recreation however, strongly suggests that with the observed population increases in San Marcos, including the new records of student numbers at Texas State University, that the assumption of constant recreational disturbance rates may not be realistic.

Table 28 (Appendix B, Table B4) outlines the proposed restoration timeline for the accomplishment of the rooted aquatic vegetation for ***existing*** HCP goals in the San Marcos system. As evident in Table 28, it is not possible to meet all the existing HCP long-term biological goals for vegetation coverage in all reaches prior to 2027 using the existing HCP budget. The main roadblocks are relative to *Ludwigia* and *Potamogeton* in the Spring Lake Dam reach; *Ludwigia*, *Potamogeton* and *Sagittaria* in the City Park reach; and *Ludwigia* and *Cabomba* in the I35 reach. In fact, based on the challenges noted in the following section regarding competition between previously unseen Texas wild rice levels (as goals) and native aquatic vegetation historically encountered, recreation in the upper reaches and river channel adjustments of equilibrium below Rio Vista dam, it may not be possible to ever meet the original HCP goals for aquatic vegetation in the San Marcos River into the future.

It also needs to be understood that although the Table 28 schedule only addresses work in the LTBG reaches, it does not mean that aquatic gardening and maintenance does not need to occur in other parts of the system. Under this option, work is mandatory in the remainder of the system for two primary reasons. The first is that to sustain the aquatic plant coverage within the LTBG reaches, non-native vegetation removal (and replacement with natives) will be required in many upstream key areas in order to assure that non-native plants don’t reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG reaches (beyond their defined aerial targets). Secondly, work towards achieving the undefined management objective of proportional expansion is required per the HCP. It is anticipated that the combination of these two factors will require the complete use of the annual HCP budget for this mitigation measure through 2027.

Table 28. Proposed restoration timeline designed to meet the **existing HCP** aquatic vegetation goals over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2)			HCP Term Timeline*												Total
		Current (Dec 2015)	Goal	Needed	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																	
Spring Lake Dam	*Ludwigia*	0	200	200	10	10	10	10	10	10	10	10	10	10	10	10	120
	Cabomba	0	25	25	5	5	5	5	5								25
	Potamogeton	0	1000	1000	50	50	50	50	50	50	50	50	50	50	50	50	600
	Sagittaria	7	100	93	15	15	15	15	15	15	5						95
	Hygrophila	38	50	12	1	1	1	1	1	1	1	1	1	1	1	1	12
	Hydrilla	9	100	91	1	5	5	5	5	10	10	10	10	10	10	10	91
	Vallisneria	0	125	125	10	10	10	10	10	10	10	10	10	10	10	15	125
City Park	*Ludwigia*	1	1000	999	50	50	50	50	50	50	50	50	50	50	50	50	600
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	54	2000	1946	50	50	50	50	50	50	50	50	50	50	50	50	600
	Sagittaria	92	300	208	15	15	15	15	15	15	15	15	15	15	15	15	180
	Hygrophila	297	200	0													0
	Hydrilla	228	500	272	12	15	20	25	25	25	25	25	25	25	25	25	272
	Vallisneria	0	50	50	1	1	3	5	5	5	5	5	5	5	5	5	50
I35	*Ludwigia*	0	200	200	10	10	10	10	10	10	10	10	10	10	10	10	120
	Cabomba	0	300	300	15	15	15	15	15	15	15	15	15	15	15	15	180
	Potamogeton	0	300	300	25	25	25	25	25	25	25	25	25	25	25	25	300
	Sagittaria	0	100	100	10	10	10	10	10	10	10	10	5	5	5	5	100
	Hygrophila	0	50	50	1	1	3	5	5	5	5	5	5	5	5	5	50
	Hydrilla	0	100	100	5	5	5	5	10	10	10	10	10	10	10	10	100
	Vallisneria	0	25	25	1	1	1	1	1	1	1	1	2	5	5	5	25

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**

Red shaded boxes represent non-native vegetation which will not be planted. It will simply be allowed to reestablish in isolated areas to meet the existing HCP goals.

Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

3.1.2.2 Proposed revisions to Native Aquatic Vegetation

Based on three years of successful non-native vegetation species removal and subsequent establishment of native vegetation, the elimination of all non-native vegetation species from the long-term biological goals is recommended. As described above, the long-term biological goals for the fountain darter are for the protection of the fountain darter, not specific aquatic vegetation types. Maintaining a diverse community of native aquatic vegetation not only benefits the fountain darter but the entire aquatic ecosystem. Upon assessment by the San Marcos restoration team, the following issues were identified per species:

- *Hygrophila* and *Hydrilla* have been successfully removed and are below the existing HCP goals in all but one of the LTBG reaches. Because removal of non-natives has been successful, we recommend removing all three non-native species entirely from the HCP goals. However, this poses a conflict in the HCP long-term biological goals table in that 1,200 m^2 of fountain darter habitat is being removed from the system (based on tabular targets by species). This would therefore require replacement of a similar amount of the same quality of native habitat, or possibly a lesser amount of higher quality fountain darter habitat. In other words, as long as the resulting total number of fountain darters remains similar, the specific target aquatic vegetation species is irrelevant;
- Significant progress with Texas wild rice has been made throughout the San Marcos River including within the LTBG reaches. Additionally, fountain darter use of Texas wild rice was quantified by Texas State University in 2015;
- Although not on as large of a spatial scale, successful restoration of *Heteranthera* and *Sagittaria* has been accomplished in the San Marcos River with resulting documentation of fountain darter use within *Heteranthera*;
- Only limited success has been documented for *Ludwigia* and *Potamogeton* thus far, primarily due to focus on Texas wild rice versus other native species. However, a wealth of information has been gained on planting techniques, gardening techniques, and general growth patterns relative to competition with other native and non-native species. This includes success in the Comal for these species and supports their use to further evaluate these native species to fulfill the long-term biological goals for fountain darters.

The most notable revision is the proposed removal of all non-natives (*Hygrophila, Hydrilla,* and *Vallisneria*) from the fountain darter long-term biological goals. To compensate for the loss in coverage of habitat, two new native species (*Heteranthera* and *Zizania texana* [i.e. Texas wild rice]) are proposed for addition as they both have been confirmed as suitable habitat for the fountain darter. In September 2015, TSU conducted fountain darter counts by visual observation (i.e., scuba) in both Texas wild rice and *Heteranthera*. Divers started at the downstream end of vegetation patches and swam upstream counting any fountain darter observed. Results from the assessment estimated approximately 5 fountain darters per m^2 in *Heteranthera* and Texas wild rice. It is noted that these fountain darter numbers reflect visual observation counts and may be lower estimates as well as not necessarily reflecting the same number of fountain darters potentially obtained from actual drop net sampling of these two vegetation types. However, there is currently no drop net data collected for these species to test that comparison and the San Marcos restoration team considers these densities to be conservative estimates (i.e. likely under estimated density).

An issue not fully vetted during the development of the existing HCP long-term biological goals was the potential conflict of HCP specific goals imposed by Texas wild rice targets. Achieving Texas wild rice specific goals poses a competing issue for other native aquatic vegetation targets within the LTBG reaches. As discussed, the long-term biological goals were established based on the largest historical amount of a given vegetation type regardless of year, with corrections for overall stream area. However, over the time period evaluated for the HCP goals development, Texas wild rice has never been observed at levels requested by the HCP. To meet the Texas wild rice HCP goals, other native species goals are forced to be reduced as there is simply not enough suitable habitat present in these reaches to accommodate targets for all plants. As such, certain native species such as *Ludwigia* and *Potamogeton* require reductions in coverage to accommodate Texas wild rice. As all three of these native vegetation species are suitable fountain darter habitat, making these adjustments minimizes any potential negative impacts from proposed vegetation adjustments.

The rest of the proposed revisions are adjustments in coverage per reach based on the San Marcos restoration team's experience of what might be potentially feasible to achieve over time in the San Marcos system based on HCP concurrent activities (both passive and active restoration measures). As shown in Table 14 and Table 29, the proposed revisions result in a slight reduction (575 m^2) of overall aquatic vegetation in the LTBG reaches. It should be remembered that the original vegetation goals were set based on the highest coverage of specific species in a given LTBG reach recorded since 2000, regardless of year, with subsequent adjustments for overall surface area within each LTBG reach. Based on three years of intensive restoration work in the system, the competing goals for Texas wild rice, and system-specific circumstances described below it is the conclusion of the project team that the original HCP goals are not achievable.

Table 29. Proposed Revised long-term biological goals for the fountain darter in the San Marcos System.

PROPOSED REVISED HCP GOALS FOR ESTABLISHED LTBG REACHES

Fountain darter habitat (aquatic vegetation) in meters squared (m^2)							
Study reach	*Ludwigia*	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*	*TOTAL*
Spring lake Dam	100	50	200	200	100	700	1,350
City Park	150	50	1,450	300	100	1,750	3,800
IH-35	50	50	150	150	50	600	1,050
Total	300	150	1,800	650	250	3,050	6,200
Fountain darter median density (number/m^2)							
	Ludwigia 7	*Cabomba* 7	*Potamogeton* 5	*Sagittaria* 1	*Heteranthera* 5	*Zizania* 5	*TOTAL*
# darters * veg total	2,100	1,050	9,000	650	1,250	15,250	29,300

Unlike the Comal system, proposed adjustments to the San Marcos River goals needed to incorporate several unique factors that have evolved since the implementation of the HCP. The first is relative to the Spring Lake Dam and City Park LTBG reaches and involves the HCP decision to designate these areas for spatially restricted recreation access. By design, recreation in the San Marcos River is now being directed into specific highly recreated zones in order to remove contact recreation pressure in other key areas of the San Marcos River to minimize recreation based aquatic vegetation disturbance (Figure 22). This HCP decision automatically results in a reduction in potential restoration habitat area in the Spring Lake Dam and City Park LTBG reaches as it is not cost efficient or sustainable to plant native vegetation in areas that will be denuded by recreationalists each summer. This decision was not factored into to the development of the original HCP long-term biological goals.

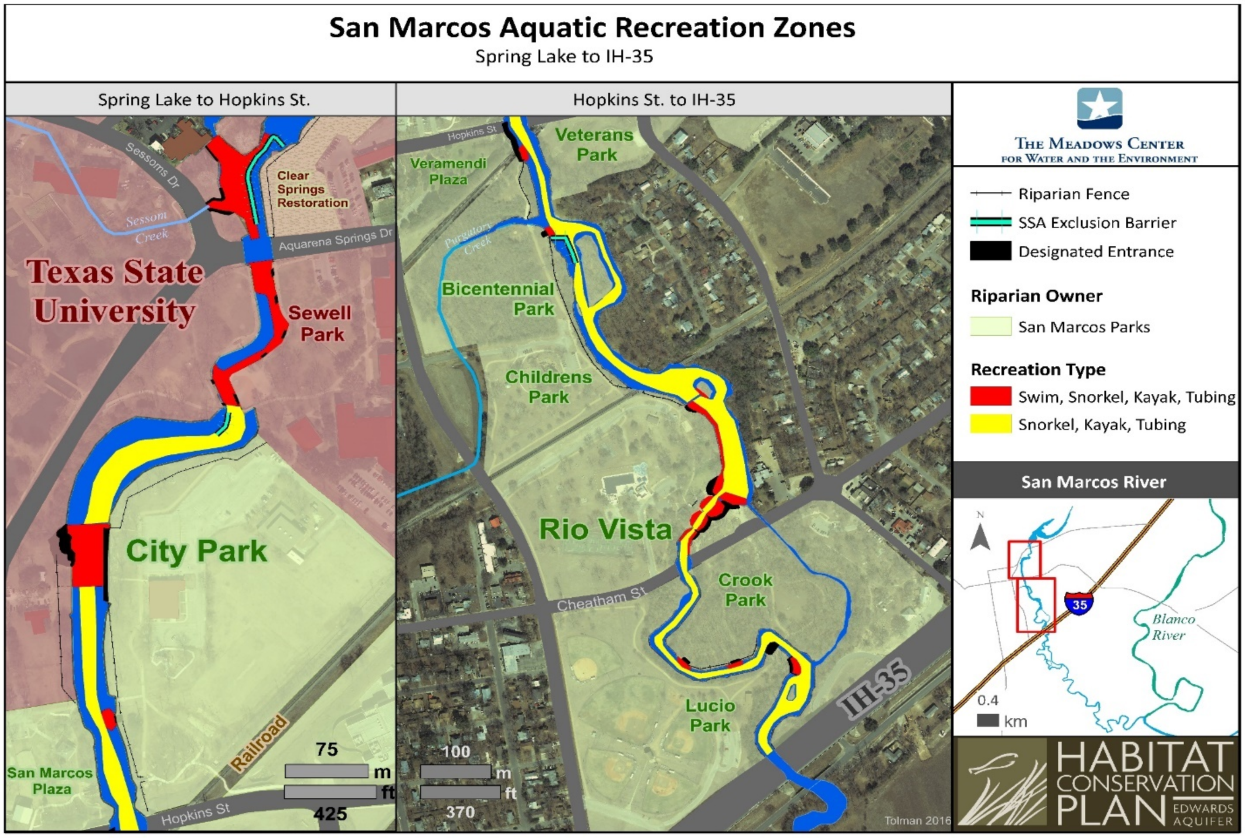

Figure 22. Concentrated HCP recreational access points (red).

The unique situation in the I35 LTBG reach revolves around the changing river hydraulics that has followed the reconstruction of Rio Vista Dam. Since that event, aquatic vegetation in the I35 LTBG reach has dramatically declined (Figure 23) ultimately requiring the HCP long-term biological monitoring program to extend the sampling reach down to the I35 highway bridge to provide enough aquatic vegetation for adequate sampling (BIO-WEST 2014b). Thus, until the river reaches its new equilibrium below Rio Vista dam, the project team does not feel that the existing HCP goals for native aquatic vegetation are achievable in the I35 LTBG reach. With this shift in vegetation in the LTBG reaches, a slight decrease (15%) occurs relative to the total number of darters protected (34,325 [original – Table 14] versus 29,300 [proposed - Table 29]). This slight reduction emphasizes the importance of the HCP management objective of proportional expansion of aquatic vegetation in the San Marcos River discussed further in Section 3.1.2.3.

Figure 23. San Marcos River downstream of Rio Vista Dam just downstream of Cheatham street bridge– swift channel with limited to no submerged aquatic vegetation (2016).

An evaluation of Table 30 reveals that to accomplish the proposed revised San Marcos long-term biological goals, approximately 4,150 m^2 of an additional aquatic vegetation needs to be established. Table 31 (Appendix B, Table B5) outlines the proposed restoration timeline for the accomplishment of the proposed revised aquatic vegetation goals in the San Marcos system. For successful implementation of this schedule, it is critical that concurrent aquatic plant propagation, gardening, and maintenance occur throughout the HCP timeline. As evident in Table 31, under this scenario it is possible to meet the proposed revised HCP long-term biological goals for vegetation coverage in all LTBG reaches by the conclusion of 2025. With that said, upon accomplishment of target aquatic vegetation goals per reach, plant propagation (at a reduced level compared to full production) as well as gardening will still be necessary to maintain vegetation stands to sustain the target areal coverage over time.

It also needs to be clear that although the Table 31 schedule only addresses work in the LTBG reaches, it does not mean that non-native aquatic vegetation removal, aquatic gardening and maintenance does not need to occur in other parts of the system. Under this option, work is mandatory in the remainder of the system for two primary reasons. The first is that to sustain the aquatic plant coverage within the LTBG reaches, non-native vegetation removal (and replacement with natives) will be mandatory in many areas in order to assure that non-native plants don't reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG reaches. Secondly, work towards achieving the undefined management objective of proportional expansion is required per the HCP. It is anticipated that the combination of these two factors will require the complete use of the annual HCP budget for this mitigation measure through 2027.

Table 30. Existing (top), Proposed (middle), and Difference (bottom) in aerial coverage of native aquatic vegetation in the San Marcos system long-term biological goal (LTBG) reaches.

EXISTING EAHCP vegetation species and aerial coverage (POST FLOOD 2015)

Long-term Biological Goals reaches and Restoration reaches	Vegetation species					
	Ludwigia	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*
Spring Lake Dam - LTBG reach	0	0	0	7	0	598
City Park - LTBG reach	1	0	54	92	7	1,261
I35 - LTBG reach	0	0	0	0	0	28

PROPOSED EAHCP goals for vegetation species and aerial coverage in support of fountain darter habitat.

Long-term Biological Goals reaches and Restoration reaches	Vegetation species					
	Ludwigia	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*
Spring Lake Dam - LTBG reach	100	50	200	200	100	700
City Park - LTBG reach	150	50	1450	300	100	1,750
I35 - LTBG reach	50	50	150	150	50	600

DIFFERENCE between current EAHCP vegetation aerial coverage and proposed vegetation aerial coverage by reach.

Long-term Biological Goals reaches and Restoration reaches	Vegetation species					
	Ludwigia	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*
Spring Lake Dam - LTBG reach	-100	-50	-200	-193	-100	-102
City Park - LTBG reach	-149	-50	-1396	-208	-93	-489
I35 - LTBG reach	-50	-50	-150	-150	-50	-572

Table 31. Proposed restoration timeline designed to meet the **proposed HCP** native aquatic vegetation goals over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2)			HCP Term Timeline*												Total
		Current (Dec 2015)	Goal	Needed	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																	
Spring Lake Dam	*Ludwigia*	0	100	100	10	10	10	10	10	10	10	10	10	10			100
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	200	200	25	25	25	25	25	15	15	15	15	15			200
	Sagittaria	7	200	193	25	20	20	20	20	20	20	20	20	10			195
	Heteranthera	0	100	100	10	10	10	10	10	10	10	10	10	10			100
	Zizania	598	700	102	25	25	15	15	15	10							105
City Park	*Ludwigia*	1	150	149	25	25	20	20	10	10	10	10	10	10			150
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	54	1450	1396	125	115	130	125	125	150	150	150	155	175			1400
	Sagittaria	92	300	208	15	15	15	15	25	25	25	25	25	25			210
	Heteranthera	7	100	93	10	10	10	10	10	10	10	10	10	5			95
	Zizania	1,261	1,750	489	40	75	75	75	75	50	50	50					490
I35	*Ludwigia*	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	150	150	15	15	15	15	15	15	15	15	15	15			150
	Sagittaria	0	150	150	30	10	10	10	10	10	10	10	25	25			150
	Heteranthera	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Zizania	28	600	572	75	75	75	75	75	75	75	50					575

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**
Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

3.1.2.3 Proposed Proportional Expansion definition using Restoration Reaches

As introduced in Section 2.1, the fountain darter long-term biological goals for the San Marcos system also have a management objective that identifies extending aquatic vegetation restoration work beyond the three established reaches in equal proportion to the efforts expended in LTBG reaches. This objective is not formally defined in the HCP and thus, based on three years of restoration experience in the San Marcos system, we suggest the following clarification to proportional expansion. Although the main HCP goal is for the survival and recovery of the fountain darter in the wild, this is not the focus of the long-term biological goals. These goals are striving for conditions should they ever be achieved and maintained that would warrant the down listing or delisting of the species. As such, we recommend the following as a definition of the "proportional expansion" of this work in the San Marcos system. A formal definition would greatly assist in the development of a schedule for application of HCP funds for this mitigation measure. A formal definition would also likely aid in the efficiency of utilization of HCP financial resources for this mitigation activity.

To meet this management objective, we recommend establishing known "Restoration reaches" in addition to the LTBG reaches. The proposed five Restoration reaches in the San Marcos system are shown in Figure 24 and represent reaches both upstream and downstream of the City Park LTBG reach, as well as the entire stretch of the river from downstream of the I35 LTBG reach to the I35 highway bridge. This expansion includes the majority of key fountain darter habitat areas between Spring Lake Dam and Rio Vista Dam, as well as nearly the entirety of the river from Rio Vista Dam to I35. We do not propose native aquatic vegetation restoration activities specific to fountain darters downstream of I35 although we want to be clear that successful propagation of native aquatic vegetation as a consequence of upstream restoration efforts are likely and beneficial to fountain darters and other native taxa in this reach of the San Marcos River. Although fountain darters are found downstream of this area, we do not feel that the costs associated with repeated restoration in a reach so prone to flooding destruction is a practical use of HCP funding. However, per the established Texas wild rice HCP goals, restoration for Texas wild rice will continue downstream of I35 as described in the following section.

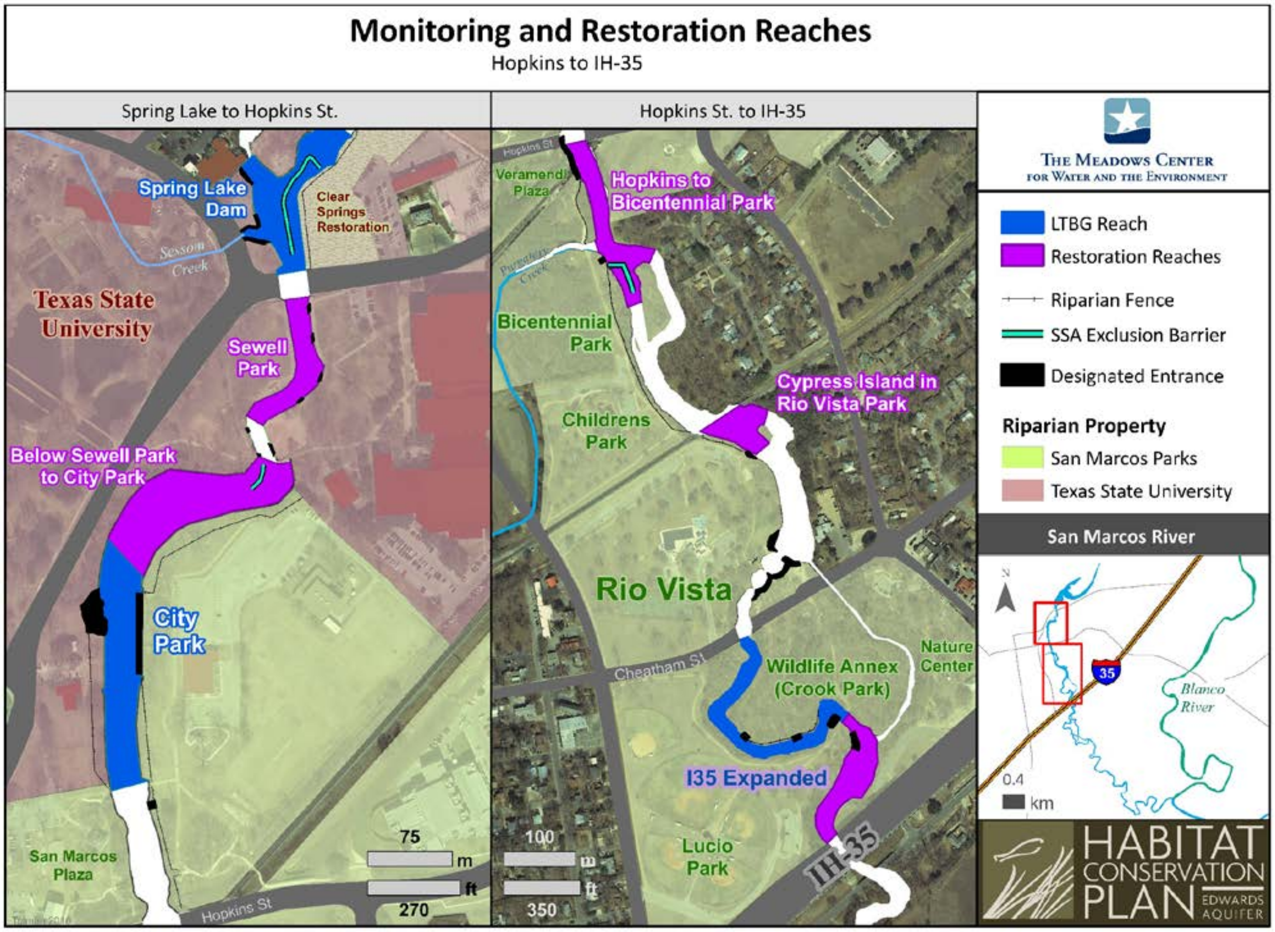

Figure 24. Long-term biological goal (LTBG) reaches and proposed “restoration reaches” for the San Marcos system.

The most recent aquatic vegetation coverage, incorporating Texas State University and HCP biological monitoring vegetation map data, was used to develop proposed HCP goals for native aquatic vegetation among proposed Restoration reaches. Table 32 presents the proposed native aquatic vegetation goals and resulting fountain darter totals using established fountain darter densities by vegetation type. In order to develop aquatic vegetation goals for the Restoration reaches, the current area coverage of non-native aquatic vegetation was estimated and summed for each restoration reach. Eighty percent of the total coverage of non-native aquatic vegetation was used to estimate the amount of area available for native vegetation establishment. (This assumes 100 percent of the non-natives are removed from target restoration areas and native plantings are introduced with a successful establishment rate of 80 percent). We used 80 percent for native aquatic vegetation areal coverage instead of 100 percent since we have found replacement of non-native aquatic vegetation to native aquatic vegetation is not a 1:1 ratio. The total potential estimate for native establishment in a reach was distributed among native aquatic vegetation species based on habitat preferences of each native species and available habitat found within each reach. These estimates were then added to the current area coverage for each native species in a reach to develop proposed HCP goals for each restoration reach. The goals for the expanded portion of the IH35 reach were developed slightly different since little non-native aquatic vegetation currently exists. Total river area was calculated in the portion of the reach estimated to be suitable habitat for native vegetation establishment based on our experience and reach characteristics. Fifty percent of the total area coverage was used to determine area estimates for successful native vegetation establishment. We used only 50% of the total area since the Rio Vista to IH35 reach is still undergoing channel adjustments from Rio Vista Dam, has greater riparian canopy cover and limited planting within the reach provides less information to set our estimated success rate any higher pending more extensive work in this reach.

Table 32. Proposed restoration reaches to define "proportional expansion" in the San Marcos System.

PROPOSED RESTORATION REACHES TO DEFINE "PROPORTIONAL" APPLICATION

Fountain darter habitat (aquatic vegetation) in meters squared (m^2)							
Study reach	*Ludwigia*	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*	*TOTAL*
Sewell Park	25	25	150	25	25	1,100	1,350
Below Sewell to City Park[A]	50	50	500	700	50	2,300	3,650
Hopkins Street - Snake Island	50	50	475	750	50	950	2,325
Cypress Island - Rio Vista	50	50	150	50	100	350	750
IH-35 Expanded[B]	50	100	250	450	50	450	1,350
Total	225	275	1,525	500	275	5,150	9,425
Fountain darter median density (number/m^2)							
	Ludwigia 7	*Cabomba* 7	*Potamogeton* 5	*Sagittaria* 1	*Heteranthera* 5	*Zizania* 4.5	*TOTAL*
# darters * veg total	1,575	1,925	7,625	500	1,375	23,175	36,175

[A] Sewell Park to the upstream boundary of the City Park LTBG reach

[B] Immediately downstream of the established I35 LTBG reach to I35

As evident in Table 32, adding these "Restoration reaches" adds over 9,000 m^2 of native aquatic vegetation and approximately 36,000 fountain daters. These both more than offset the reductions in aquatic vegetation and fountain darters described for the proposed LTBG reaches. In addition to defining this HCP management objective for future comparison, this step was necessary to meet the scope of this project which involves the development of a restoration schedule that strives to accomplish and maintain the long-term biological goals and objectives.

An evaluation of Table 33 reveals that to accomplish the proposed proportional expansion management objective, approximately 2,700 m^2 of an additional aquatic vegetation needs to be established in the Restoration reaches. Table 34 outlines the proposed restoration timeline for accomplishing the goals proposed for the LTBG reaches, Restoration reaches, and additional Texas wild rice target segments in the San Marcos River. Reaches considered of highest priority include the LTBG reaches, two restoration reaches, Cypress Island – Rio Vista Dam and I35 expanded, and the Texas wild rice reaches in Spring Lake and below I35. If this schedule was implemented, the San Marcos restoration team proposes to focus removal and planting efforts in these reaches to the extent annual budgets allow. Upon successful implementation in these priority areas, the next step would be to shift efforts to restoration reaches between the LTBG reaches and continue to expand Texas wild rice in target reaches. As evident in Table 34, under this scenario it is possible to meet the proposed revised HCP long-term biological goals for vegetation coverage in all LTBG reaches and Restoration reaches by the conclusion of 2027.

Table 33. Existing (top), Proposed (middle), and Difference (bottom) in aerial coverage of native aquatic vegetation in the proposed restoration reaches.

EXISTING EAHCP vegetation species and aerial coverage (POST FLOOD 2015)

Long-term Biological Goals reaches and Restoration reaches	**Vegetation species**					
	Ludwigia	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*
Sewell Park	0	14	116	2	0	1,169
Below Sewell - City Park[A]	0	0	172	727	6	2,247
Hopkins St - Snake Island	0	0	269	620	0	693
Cypress Island - Rio Vista Dam	0	0	0	5	63	122
IH35 Expanded[B]	8	33	0	355	0	57

PROPOSED EAHCP goals for vegetation species and aerial coverage in support of fountain darter habitat.

Long-term Biological Goals reaches and Restoration reaches	**Vegetation species**					
	Ludwigia	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*
Sewell Park	25	25	150	25	25	1,100
Below Sewell - City Park[A]	50	50	500	700	50	2,300
Hopkins St - Snake Island	50	50	475	750	50	950
Cypress Island - Rio Vista Dam	50	50	150	50	100	350
IH35 Expanded[B]	50	100	250	450	50	450

DIFFERENCE between current EAHCP vegetation aerial coverage and proposed vegetation aerial coverage by reach.

Long-term Biological Goals reaches and Restoration reaches	**Vegetation species**					
	Ludwigia	*Cabomba*	*Potamogeton*	*Sagittaria*	*Heteranthera*	*Zizania*
Sewell Park	-25	-11	-34	-23	-25	69
Below Sewell - City Park[A]	-50	-50	-328	27	-44	-53
Hopkins St - Snake Island	-50	-50	-206	-130	-50	-257
Cypress Island - Rio Vista Dam	-50	-50	-150	-45	-37	-228
IH35 Expanded[B]	-42	-67	-250	-95	-50	-393

[A] Sewell Park to the upstream boundary of the City Park Long-term biological goals reach

[B] Immediately downstream of I35 long-term biological goal reach to I35

Upon accomplishment of coverage goals per reach, plant propagation (at a reduced level compared to full production) and gardening will still be necessary to maintain vegetation stands to sustain this coverage over time. It also needs to be understood that although the schedule only addresses work in the LTBG and Restoration reaches, it does not mean that non-native aquatic species removal, native aquatic planting, gardening and maintenance does not need to occur outside of those areas. To sustain the aquatic plant coverage within the LTBG and Restoration reaches, non-native vegetation removal (and replacement with natives) will be mandatory in certain key areas in order to assure that non-native plants don’t reestablish in these areas and start producing propagules and fragments that when broken off float through and potentially establish in the LTBG and designated Restoration reaches.

Table 34. Proposed restoration timeline designed to meet the **Combined proposed HCP** aquatic vegetation goals (***including Texas wild rice***) over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2)			HCP Term Timeline*												Total
		Current (Dec 2015)	Goal	Needed	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																	
Spring Lake Dam	*Ludwigia*	0	100	100	10	10	10	10	10	10	10	10	10	5	5		100
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	200	200	25	25	25	25	25	15	15	15	15	10	5		200
	Sagittaria	7	200	193	25	20	20	20	20	20	20	20	20	5	5		195
	Heteranthera	0	100	100	10	10	10	10	10	10	10	10	10	5	5		100
	Zizania	598	700	102	25	25	15	15	15	10							105
City Park	*Ludwigia*	1	150	149	25	25	20	20	10	10	10	10	10	5	5		150
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	54	1450	1396	150	100	100	100	100	100	100	125	125	125	125	150	1400
	Sagittaria	92	300	208	15	15	15	15	25	25	25	25	25	15	10		210
	Heteranthera	7	100	93	10	10	10	10	10	10	10	10	10	5			95
	Zizania	1,261	1,750	489	40	75	75	75	75	50	50	50					490
I35	*Ludwigia*	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	150	150	15	15	15	15	15	15	15	15	15	10	5		150
	Sagittaria	0	150	150	30	10	10	10	10	10	10	10	25	15	10		150
	Heteranthera	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Zizania	28	600	572	75	75	75	75	75	75	75	50					575

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**

Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

Table 34 continued. Proposed restoration timeline designed to meet the **Combined proposed HCP** aquatic vegetation goals (***including Texas wild rice***) over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2) Current (Dec 2015)	Goal	Needed	HCP Term Timeline* 2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Total
Restoration Reaches																	
Sewell Park	*Ludwigia*	0	25	25												25	25
	Cabomba	14	25	11												15	15
	Potamogeton	116	150	34	40												40
	Sagittaria	2	25	23						10	15						25
	Heteranthera	0	25	25						10	15						25
	Zizania	1,169	1,100	0													0
Below Sewell to City Park	*Ludwigia*	0	50	50								15	15	15	5		50
	Cabomba	0	50	50								15	15	15	5		50
	Potamogeton	172	500	328								50	75	75	75	55	330
	Sagittaria	727	700	0													0
	Heteranthera	6	50	44								15	10	10	10		45
	Zizania	2,247	2,300	53								25		15	15		55
Hopkins St - Snake Island	*Ludwigia*	0	50	50									10	10	15	15	50
	Cabomba	0	50	50									10	10	15	15	50
	Potamogeton	269	475	206	50								20	20	55	65	210
	Sagittaria	620	750	130	50								20	20	20	20	130
	Heteranthera	0	50	50									10	10	15	15	50
	Zizania	693	950	257	35						50	35	35	35	35	35	260
Cypress Island - Rio Vista Dam	*Ludwigia*	0	50	50	10	10	10	10	10								50
	Cabomba	0	50	50	10	5	5	5	5	5	5	5	5				50
	Potamogeton	0	150	150	15	10	10	25	10	20	20			25	15		150
	Sagittaria	5	50	45	15	5	5	5	5	5	5						45
	Heteranthera	63	100	37	10	5	5	5	5	5	5						40
	Zizania	122	350	228	50	50	50	25	25	25	5						230
I35 expanded	*Ludwigia*	8	50	42		10	10	10	12								42
	Cabomba	33	100	67		25	25	10	10								70
	Potamogeton	0	250	250		30	25	25	25	50	20			25	25	25	250
	Sagittaria	355	450	95		25	25	10	10	10	15						95
	Heteranthera	0	50	50		10	10	5	10	10	5						50
	Zizania	57	450	393		50	50	50	50	50	50	50	45				395
Additional Texas wild-rice Reaches																	
Spring Lake	Zizania	31	1,000	969	50	100	100	100	100	100	100	100	100	100	20		970
Below I35	Zizania	0	280	280		20	20	30	30	30	30	30	30	30	30		280

*** Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the goals over time.**

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

3.1.2 Texas wild rice

The project team presently supports the ranges of Texas wild rice goals specified in the HCP with the following notes. We note as discussed previously, vegetation targets supporting fountain darter numbers may in some instances be in conflict with other target aquatic vegetation species since the respective estimates were derived independently and therefore it may be difficult to exceed the lower boundaries of the ranges for Texas wild rice goals per segment. The work with Texas wild rice over the past three years served as the basis for our assumptions on effort to achieve Texas wild rice goals and management objectives within the allocated budget in Table 7.1 of the HCP. It should also be noted that the Below I35 section of the river encompasses Cape's Dam which may be removed in the future. Modeling of river bed evolution over time and subsequent channel hydraulic properties indicate that removal of Cape's Dam will be beneficial in creating additional Texas wild rice and other native aquatic vegetation habitat with the associated increase in the quality of fountain darter suitable habitat in this reach. Removal of the dam will also benefit fountain darter and other native aquatic species by elimination of an upstream passage barrier.

Impacts of Floods/Scour Events

Areas of the San Marcos River were scoured during the October 30, 2015 flood event that resulted in loss of Texas wild rice coverage among restoration reaches. Figures 25 and 26 illustrate the loss of Texas wild rice aerial coverage at Sewell Park and City Park directly following the October 30, 2015 flood event. It is important to note that the remapping after the October 2013 flood showed that less than 10 percent of the Texas wild rice restoration plants were lost. The Memorial Day flooding in 2015 also had a differential effect on aquatic vegetation restoration in that the large backwater affect from the Blanco River resulted in large amounts of fine sediment smothering some native plants rather than loss due to scour events coming down the San Marcos watershed area(s).

Figure 25. Imagery illustrating Texas wild rice coverage prior to and after the October 30, 2015 flood event at Sewell Park in the San Marcos River.

Figure 26. City Park at Lion's Club, prior to (top) and after (bottom) the October 30, 2015 flood event. Loss of Texas wild rice is highlighted in red.

The San Marcos restoration team has assessed regrowth of aquatic vegetation following the October 30, 2015 flood event. Images captured with the Texas State quadcopter suggest Texas wild rice and other native species are expanding in aerial coverage since the flood event. For example, Figure 27 illustrates expansion of *Potamogeton* and Texas wild rice within Sewell Park three months following the October 2015 flood event. Observance in the expansion of Texas wild rice suggests the leaves of Texas wild rice were removed during the flood event, but the basal root structure remained.

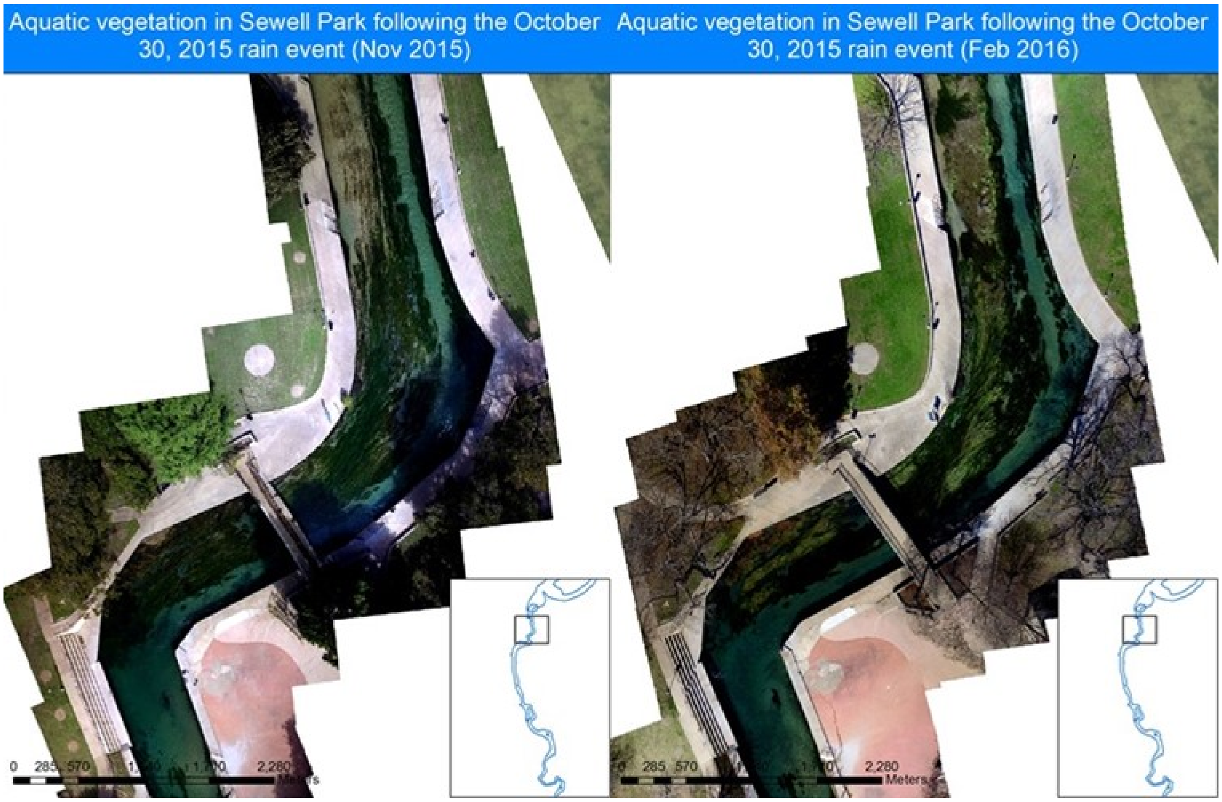

Figure 27. Mosaicked and georeferenced imagery capture by Texas State quadcopter immediately following and three months after the October 30, 2015 flood event in Sewell Park in the San Marcos River.

Table 34 in the previous section outlines the Texas wild rice restoration schedule within the LTBG reaches, proposed Restoration reaches, and additional Texas wild rice segments of Spring Lake and below I35. Texas wild rice goals are currently being met in the Spring Lake Dam LTBG reach and Sewell Park restoration reaches, respectively. Predicted accomplishment of the proposed Texas wild rice HCP goals in all LTBG reaches, proposed Restoration reaches and additional Texas wild rice areas (Spring Lake and below I35) with existing HCP funding is 2026 assuming no system resets like floods.

3.2 Old Channel Flow Split Recommendations

As described in Section 2.3, based on the knowledge gained on upper end scour at 70 to 80 cfs, and the exposure of Comal Springs riffle beetle habitat below the 150 cfs flow-split distribution, the following adjustments to the current HCP flow-split values are recommended in Table 35.

Table 35. HCP flow-split management recommendations for the Old and New Channels of the Comal River.

PROPOSED
FLOW-SPLIT MANAGEMENT FOR OLD AND NEW CHANNELS

Total Comal	Old Channel (cfs)		New Channel (cfs)	
Springflow (cfs)	Fall, Winter	Spring, Summer	Fall, Winter	Spring, Summer
350+	65	60	285+	290+
300	65	60	235	240
250	60	55	190	195
200	60	55	140	145
150	55		95	
100	50		50	
80	45		35	
70	40		30	
60	35		25	
50	35		15	
40	30		10	
30	20		10	

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APPENDIX A

LESSSONS LEARNED – AQUATIC VEGETATION RESTORATION

Comal System - Lessons learned and challenges

Hygrophila Removal

The task of *Hygrophila* removal posed the first major challenge. With *Hygrophila* monoculture infesting almost all of the Old Channel and some of Landa Lake this task seemed overwhelming at the start. Not only did the weed cover such large amounts of area, removal and control was limited to mechanical removal means introducing multiple unknowns into the task. Unlike many other aquatic weeds, little information has been collected regarding the management of *Hygrophila* in waterways and little information is available regarding its biology as well.

The initial restoration plan called for removal of *Hygrophila* in approximately 15 x 15-foot (ft) cells. When restoration efforts began in 2013 removal of *Hygrophila* was carried out by placing a 15-ft wide seine at the downstream edge of the area to be cleared, in order to catch removed *Hygrophila* fragments and roots (Figure A1-A). Using garden rakes, a majority of the top growth of the *Hygrophila* was removed, allowing it to float into the net. This provided a chance for any organisms present in the *Hygrophila* growth to swim or fall out. Plant parts were removed regularly from the net and placed into tubs, removed from the water and loaded onto a trailer to be hauled offsite to be composted. Once a majority of the top growth was removed, the area was raked over to further disturb and loosen remaining *Hygrophila* roots from the sediment. The roots were allowed to float to the surface and then drift into the net, where they were collected and removed. Once the area was thoroughly raked, any remaining *Hygrophila* parts were removed by hand, using snorkel or SCUBA techniques, depending on the depth of the water in the restoration plot.

Some initial problems with this method included dealing with the large volume of plant material that was removed from each restoration plot. Removal and disturbance of large amounts of *Hygrophila* as well as associated bryophytes and organic material quickly overwhelmed the net causing it to sink and the plant material to escape if not properly attended. Additionally, this drift net system had to be supported with stakes and T-posts on each end, which was difficult to install in areas with gravel or rocky substrate and in fast moving water. To make the method of removal more efficient, a 20-ft long floating boom net system was devised to allow for the removal of *Hygrophila* within a larger swathe of area (Figure A1-B, Figure A2). This floating system was also self-supporting and could handle a much larger amount of plant material without becoming overwhelmed. Later as work moved downstream below Elizabeth Street in 2015 *Hygrophila* biomass increased significantly as well as river depth and width. To accommodate for this, a 70 ft long floating net was used to clear *Hygrophila* from stream bank to stream bank (Figure A1-C). Bank to bank clearing proved more efficient and progressed faster than clearing multiple small sections which required tearing down and resetting equipment and nets each time. The team continues to allow a period of two to three weeks post removal for any leftover *Hygrophila* fragments to sprout making identification and further removal by hand easier. After this time the team makes a second pass along the stream bottom to remove these pieces. Depending on the amount of regrowth a third pass was often warranted especially if the substrate is gravel or cobble making root removal more tedious. Usually though the area is ready to receive native plants after the second pass.

Figure A1. Nets used to collect removed *Hygrophila* evolved from a simple 15-foot-long fish seine (A) to custom made floating nets better suited to handle large volumes of biomass (B) and cover larger sections of the river (C).

Figure A2. Comal restoration team removing *Hygrophila* in the Old Channel. Raking by hand removes the initial biomass which is allowed to float downstream into the boom net where it is collected and removed. In areas with difficult access *Hygrophila* material is loaded onto a floating barge which when full can then be floated to the stream bank and off loaded onto a trailer.

Despite its density *Hygrophila* has shown to be relatively easy to remove. The plant has a very shallow fibrous root system produced from nodal rooting of buried stems. We have found the root system to usually be within the top 4 inches of sediment but can be deeper and more densely developed if the plant is growing in gravel and faster flowing water. *Hygrophila* produces no other subterranean propagules or anchoring structures so hand pulling is quite easy and sufficiently removes the plant. While *Hygrophila* is not a well rooted plant the very brittle stems attribute to its very effective dispersal. When restoration activities started in Landa Lake and the Old Channel ample amounts of *Hygrophila* patches were present upstream of both locales. Although we were quite effective at replacing *Hygrophila* with established natives within restored locations *Hygrophila* fragments from upstream patches, outside of restoration locales, continually settled in our restored areas. Fragments from *Hygrophila* in the Upper Spring Run moved into and collected around the restored areas in Landa Lake, near the three islands area. Many times these fragments would accrue into floating mats which would settle onto or around the restored native plant beds and begin rooting. Regular gardening and removal of these mats prevented any re-establishment but no doubt *Hygrophila* would have a chance of re-establishing if regular maintenance was not conducted.

The spring fed swimming pool also provided large amounts of *Hygrophila* to the downstream Old Channel restored area especially during active swimming seasons when swimmers would fragment *Hygrophila* growing in the pool and fragments would discharge into the Old Channel with effluent water. As more progress was made in restoring the Old Channel it became clear that *Hygrophila* had to be removed from the spring fed swimming pool. Doing so has drastically decreased the amount of fragments supplied into the Old Channel and little regrowth of *Hygrophila* within the pool or in the Old Channel has occurred.

In some instances, *Hygrophila* has been difficult to remove due to mixing with other native plants or in instances when it grows in cobble substrate. In the first instance effectively removing the root mass is difficult since *Hygrophila* roots readily intertwine with those of native plants. Here the only choice is to completely remove both species by thoroughly digging out the surrounding sediment instead of tilling with hand tools. In cobble substrate where tilling is also difficult we have placed 6 millimeter (mm) thick rubber pond liner over the *Hygrophila* patches weighted with sandbags. After leaving this for several weeks the *Hygrophila* is effectively killed.

After removal of *Hygrophila* considerable changes in the stream bed have been noted. In most areas where *Hygrophila* has been removed the substrate has changed from very fine slit to clay, sand or gravel substrate (Figure A3). In many instances this substrate change favors re-introduction of native aquatic plants, but in some instances thick layers of silt have washed away after *Hygrophila* removal to reveal solid bedrock. In this case nothing can be planted and the site must be left bare for bryophytes to settle in.

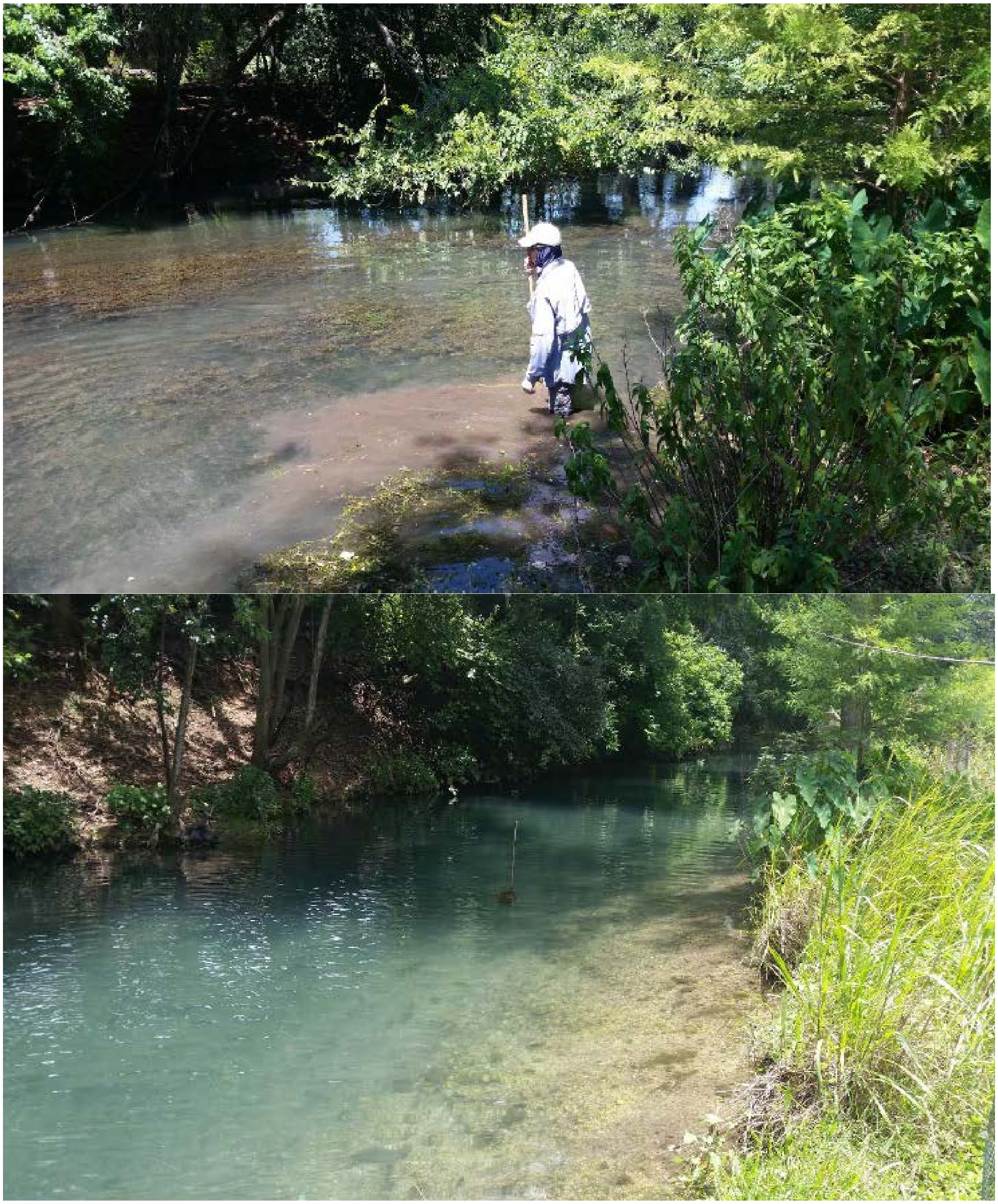


Figure A3. Old Channel below Elizabeth Street. Before removal of *Hygrophila* ample amounts of silt are usually present (Top) after removal the substrate typically turns to gravel or sand (Bottom).

Propagating and Planting Native Aquatic Vegetation

The Comal restoration team quickly recognized that supplying the types and quantities of native aquatic plants proposed for the project would be difficult. Commercial availability of submersed aquatic plants is mostly limited to the aquarium trade. *Ludwigia* and *Cabomba* are commonly sold as aquarium plants but it did not seem appropriate to buy these species from a supplier in Florida or California when they already existed in the Comal system. Additionally, the chance of introducing another aquatic invasive with externally supplied native plants is possible. It seemed most appropriate to utilize what was available. Thankfully *Cabomba* and *Sagittaria* are quite abundant in certain locales of the Comal River while *Ludwigia*, although less abundant, still occurred in a few dense patches. The next challenge was how and where to propagate species in sufficient quantities to meet restoration needs. In a trial and error test we first tried two options. In one option we placed potted plants sprigged from propagules collected from the Comal system in aquaculture ponds at the USFWS San Marcos Aquatic Resources Center (SMARC) (Figure A4, top) for grow out and in the second option we grew plants within the system or transplanted them from one location of abundance to restored locations. In the long-term the second option proved much more feasible and successful then the first and has been the option utilized throughout the project with some modifications. It turned out that while plants grown in the aquaculture ponds did well at first eventually algae became an issue growing on all species and producing poor, spindly plants. Also transporting plant propagules to the ponds and established plants from the ponds back to the Comal River multiple times proved expensive, inefficient and stressed the plants.

For *in situ* propagation the team devised a method utilizing metal trays to hold quart nursery pots and nursery trays filled with soil and plants underwater. These Mobile Underwater Propagation Trays, or MUPPTs for short, could be transported easily, set in place in a suitable growing location in the river or lake and stocked with plants. The trays could be moved to sites where they were needed for restoration, although MUPPTs usually proved too heavy when loaded with soil and plants so the team usually transported the planted pots in tubs to the restoration location. The BIO-WEST team collected native soil from silty areas in Landa Lake to use as a planting medium and sprigged apical stem fragments of *Ludwigia*, *Cabomba* and rosettes of *Sagittaria* into the MUPPTs (Figure A4, bottom). An *in situ* growing location was selected in Landa Lake where no vegetation existed, the water was shallow (2 to 3' deep) with moderate flow and full day exposure to sun light. Over our trial runs in early 2013 *Ludwigia* clearly grew the best compared to the other two species becoming root bound within a few weeks with top growth doubling in size. *Cabomba* never grew well in the pots. Its top growth remained spindly and thin very rarely adding additional side shoots and never became root bound and after several trials *Sagittaria* seemed to regularly become a victim of herbivory from unknown aquatic animals which appeared to leave the *Ludwigia* and *Cabomba* alone.

With *Ludwigia*'s stellar performance in the MUPPTs and *Cabomba* and *Sagittaria* lacking we chose to utilize only *Ludwigia* in MUPPT propagation. *Cabomba* and *Sagittaria* are quite abundant in certain locations of the Comal so transplanting these species from one location to another seemed more appropriate and cost effective. Thus, propagation and planting is species-specific in the Comal system (Figure A5). Planting of individual plants in a couple of different patterns has been proven to be effective, yet dependent on location. One pattern consists of planting individuals approximately every foot off center creating a staggered pattern. This pattern is used in silty, easily plantable substrate when a large amount of area needs to be revegetated. Another planting pattern consists of clumping multiple individuals close together to produce a stand of plants. This pattern has shown to be more effective in faster flowing water and in substrate that is more difficult to dig in. Typically, heavy duty forestry dibbles are used to plant individual plants by creating a divot in the substrate in which a plant can be inserted. In some areas with soft silty substrate plants are easily pushed deep into the soil by hand and require no extra effort.

Figure A4. Two methods of plant propagation were tested. First, plants were grown in a closed system aquaculture pond (top). Secondly, plants were grown in an in situ nursery using MUPPTs (bottom). The in situ method was found to work best with *Ludwigia* and provide over 1,000 high quality healthy plants every three weeks during peak growing

Figure A5. Mature root bound *Ludwigia* ready for planting (upper left) *Ludwigia* growing in a MUPPT (upper right) *Cabomba* sprigs collected from the New Channel (lower left) *Sagittaria* transplants collected from Landa Lake (lower right).

Plant Suitability for Restoration Activities

Ludwigia by far has shown to be the gold star plant of choice for the restoration process in the Comal River. It is easy to grow from apical stem cuttings which typically already have nodal roots. It grows well in plant containers where it forms dense root bound plants within three weeks, during peak growing season, and it spreads relatively rapidly after planting at the restored site. Initially *Ludwigia* was in short supply in the Comal River. While some small stands existed in Landa Lake and the Old Channel these did not provide enough material to start the propagation process. One large stand of *Ludwigia* was present in the New Channel and this area provided all of the propagative material for 2013. After 2013 sites where *Ludwigia* had been restored into Landa Lake and the Old Channel were established and expanded enough so that propagative material could be harvested from these locations. The propagation and production of *Ludwigia* has had few challenges even from the beginning. However, we have found that considerations such as time of propagation, quality of stem cuttings, number of stem cuttings planted per pot and type of sediment collected to grow out plants all have big effects on the robustness of the matured *Ludwigia*.

Ludwigia planted in nursery pots early in the year (February to March) take 5 to 6 weeks to produce a nice root bound pot. While *Ludwigia* planted from April to October typically become root bound in three weeks. During peak season more than 1,000 *Ludwigia* plants can be provided every three weeks which provides sufficient quantities of plants to meet restoration needs. Occasionally freshly cut *Ludwigia* stems are sprigged into place to provide additional plants, but this method is only effective in areas where water current is moderate, otherwise these unrooted sprigs are pulled out by the water current and float away. Where *Ludwigia* sprigs do take root they tend to grow slower at first as they develop a root system but have been shown to establish well over the long-term.

While *Ludwigia* is indeed our keystone species for restoration efforts its reintroduction into certain restoration areas has had challenges. First, cover of *Hygrophila*, which has physical characteristics very similar to *Ludwigia*, was usually very dense and consistent especially in the Old Channel where the plant covered areas bank to bank. *Ludwigia* growth however has shown to be patchier with smaller individual patches covering an area rather than one large continuous patch as was the case with *Hygrophila*. *Ludwigia* growth and expansion has also tended to be variable across sites. In some locations *Ludwigia* growth expands rapidly to become very dense only to separate into multiple individual patches. In other locations *Ludwigia* stands remain large (Figure A6) while in a few areas *Ludwigia* did very well forming dense growth at the onset only to shrink significantly or disappear a few months later. While *Ludwigia* has grown successfully in a majority of restored locales these observations have shown that *Ludwigia* growth is quite consistent during the propagation phase but its growth and expansion can be variable once it is planted into the ecosystem.

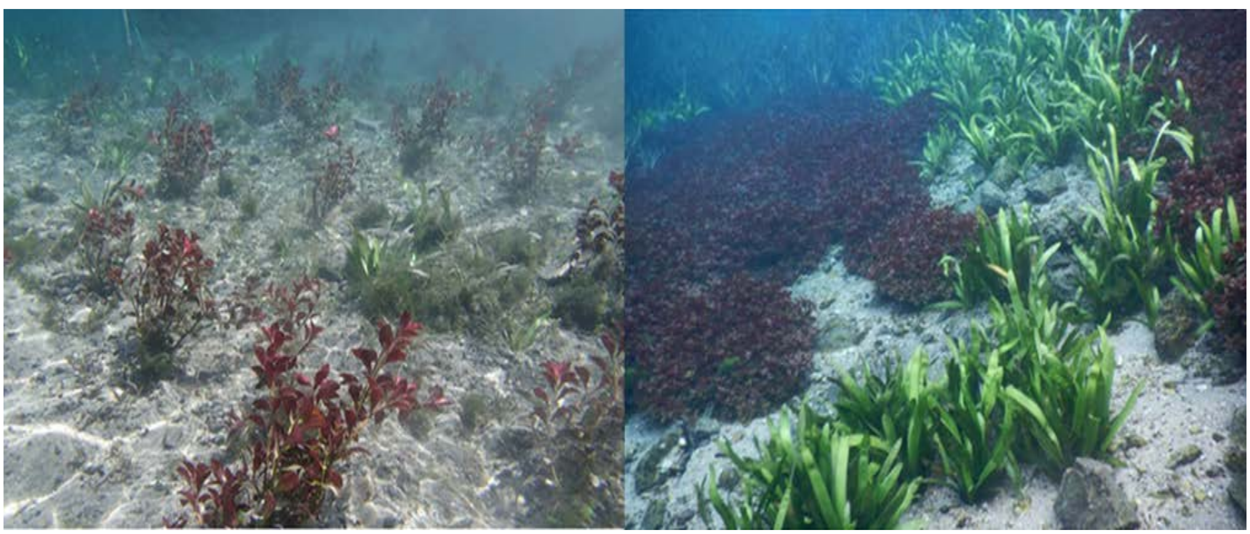


Figure A6. Mature root bound *Ludwigia* and *Sagittaria* newly planted in Landa Lake (left) and after 3 months of growth (right)

The challenges for *Cabomba* have been much greater than that for *Ludwigia*. Propagation of *Cabomba* in the MUPPTs was not as successful as the plants grew top growth but never produced a robust root mass most likely because the clay soil used in MUPPT pots is too dense for strong *Cabomba* root production. When transporting and planting, *Cabomba* was brittle and plants typically fell apart during the planting process due to lack of root mass. All in all, *Cabomba* propagation was not effective. However, *Cabomba* is plentiful in the New Channel of the Comal River so the restoration team decided to rely on sprigged *Cabomba* from apical stem cuttings. Current methods of planting *Cabomba* consist of collecting sprigs from the New Channel by grapple hook which are then bundled into fist sized bundles wrapped with rubber bands to keep bundles together. Since *Cabomba* stems grow relatively long in the New Channel bundles are typically 12 to 32 inches in length. Bundles are then planted at a depth of 2/3 their length if possible in soft silty sediment. This planting depth prevents *Cabomba* from loosening and floating away as well as provides multiple buried nodes for production of good root structure. *Cabomba* has shown to be fickle when it comes to light availability and soil type so planting of *Cabomba* is only limited to areas with full sun and soft silty substrate which in turn greatly limits the number of locations where *Cabomba* can be planted for restoration purposes. The establishment of *Cabomba* has no doubt been the greatest challenge with this plant. Where the plant has established, most notably in the upper section of the Old Channel, it has done exceedingly well. In other locations such as the eastern shoreline of Landa Lake it has struggled to persist. In some locations *Cabomba* did very well immediately after planting but declined steadily months later. This was most notable along a planted section in Spring Run One. Here turbidity from the public wading pool and poor water quality most likely play a factor. Some issues with *Cabomba* restoration could potentially be alleviated by reducing riparian shade while others such as turbidity, and soil type cannot be amended. However, where *Cabomba* can establish it has shown to grow in dense monospecific stands with dense root systems and expands rapidly.

Sagittaria also did not grow well under MUPPT cultivation. However, with this species being quite prolific in Landa Lake it was decided to transplant *Sagittaria* from Landa Lake to the Old Channel where a greater cover was needed. Initially we transplanted whole plants harvested from Landa Lake but it was quickly determined whole plants were too buoyant to remain in place after planting especially in areas with water current. After harvesting *Sagittaria* from Landa Lake the leaves of the plant are trimmed to decrease buoyancy. This simple action has allowed for a large percentage of planted *Sagittaria* to remain in place after planting. *Sagittaria* establishes well and expands rapidly after a relatively short time. A few plants can form a dense colony within months. *Sagittaria* has also shown to be slightly tolerant of lower light levels allowing it to be planted in deeper water and in shady locations.

Although not targeted species for restoration, a few other native plants have been incorporated into the restoration plan. *Potamogeton illinoensis* and submerged *Justicia americana* have both shown to provide very good velocity buffers in fast flowing locations of the Old Channel and protect plantings of target native species downstream of these velocity buffers. Neither species has been investigated as darter habitat using drop nets in the Comal River. However, *Potamogeton* has been sampled with drop nets in the San Marcos River and is documented as providing suitable fountain darter habitat. Both vegetation species have been documented to support fountain darters in the Comal system via dip net sampling. Both vegetation species occur in small quantities out-side of monitoring reaches however, these species are currently not being planted in large quantities as darter habitat and have been intended only to support the persistence of our target native species. *Vallisneria* has been incorporated into some restoration areas as velocity buffers but has failed to do as well in the Old Channel as these two species.

A great case study for the use of velocity shelters was afforded the restoration team during the removal of the large sediment island located at the upstream portion of the Old Channel restoration reach. The sediment island was located approximately meters downstream of the Landa Lake dam (Figure A7). The island comprised approximately 200 m^2, much of which was overgrown with the invasive cane *Arundo donax* (Figure A7 top left). The cane was first cut and hauled off-site to a sanitary landfill. Following removal of the cane, siltation fencing was installed completely encircling the sediment island, and heavy equipment was mobilized and then utilized during the sediment removal process. To limit turbidity in the surrounding waters, the interior of the island was removed first followed by the downstream edge. Material was removed down to a depth of 12 to 16 inches below the surrounding water surface. At this depth, a layer of natural small gravel was reached, providing a suitable planting bed for *Ludwigia*.

Native vegetation restoration at the site included planting *Ludwigia*, *Sagittaria*, and *Cabomba* in designated habitat areas. Habitat areas were selected based on experience with native vegetation preferences in the Comal system. Within the Sediment Island restoration site, *Ludwigia* was planted in areas with faster velocities, *Sagittaria* was planted in areas with slower velocities and silt and sand substrate, and *Cabomba* was planted in the deepest areas with silt substrates and the slowest velocities. The area was planted with *Ludwigia* grown in the nursery pond and MUPPTs. *Ludwigia* root balls were planted 8 to 12 inches deep ensuring they were well anchored into the substrate. A deep planting depth also places axillary roots usually present along the stems of *Ludwigia* in contact with the substrate allowing the plant stems to quickly spread. Plants were spaced approximately 1 foot apart, on-center in a grid pattern (Figure A7, bottom left). *Sagittaria* and *Cabomba* transplants were collected from a large colony nearby and transplanted as a grouped planting.

Over the course of the first two years the Sediment Island site was monitored to see how each species fared. *Sagittaria* grew well becoming denser and expanded upstream. Over the first few months *Cabomba* faded entirely most likely due to the swift currents as well as the dense riparian shade located along the bank. *Ludwigia* fared well but was also noticeably impacted by the velocity coming down the Old Channel from the Landa Lake culverts. As *Ludwigia* growth progressed and became denser, resistance from the high water velocity would rip out large patches. This repeated until *Ludwigia* growth, initially thick and uniform became patchy and sometimes quite sparse with an increasing amount of bare area persisting for an extended period of time (Figure A8). Several supplemental plantings of *Ludwigia* were provided to help thicken bare areas but these were removed over time as well. At this point it was obvious that a velocity buffer needed to be introduced to protect *Ludwigia* from scour, and allow it to expand naturally to fill in more of the area. After two years of observing this repeated cycle in early 2015 *Justicia*, *Vallisneria*, and *Potamogeton* were planted at the upstream end and edge of the former Sediment Island. *Justicia* and *Potamogeton* grew fast expanding into their respective niche and have stabilized (Figure A8). *Vallisneria* has persisted but has not expanded.

Figure A7: Photographs of the sediment island pre- and post-removal (Top left – Fall 2012; Top Right – April 2013; Bottom Left – April 2013; Bottom right – August 2013).

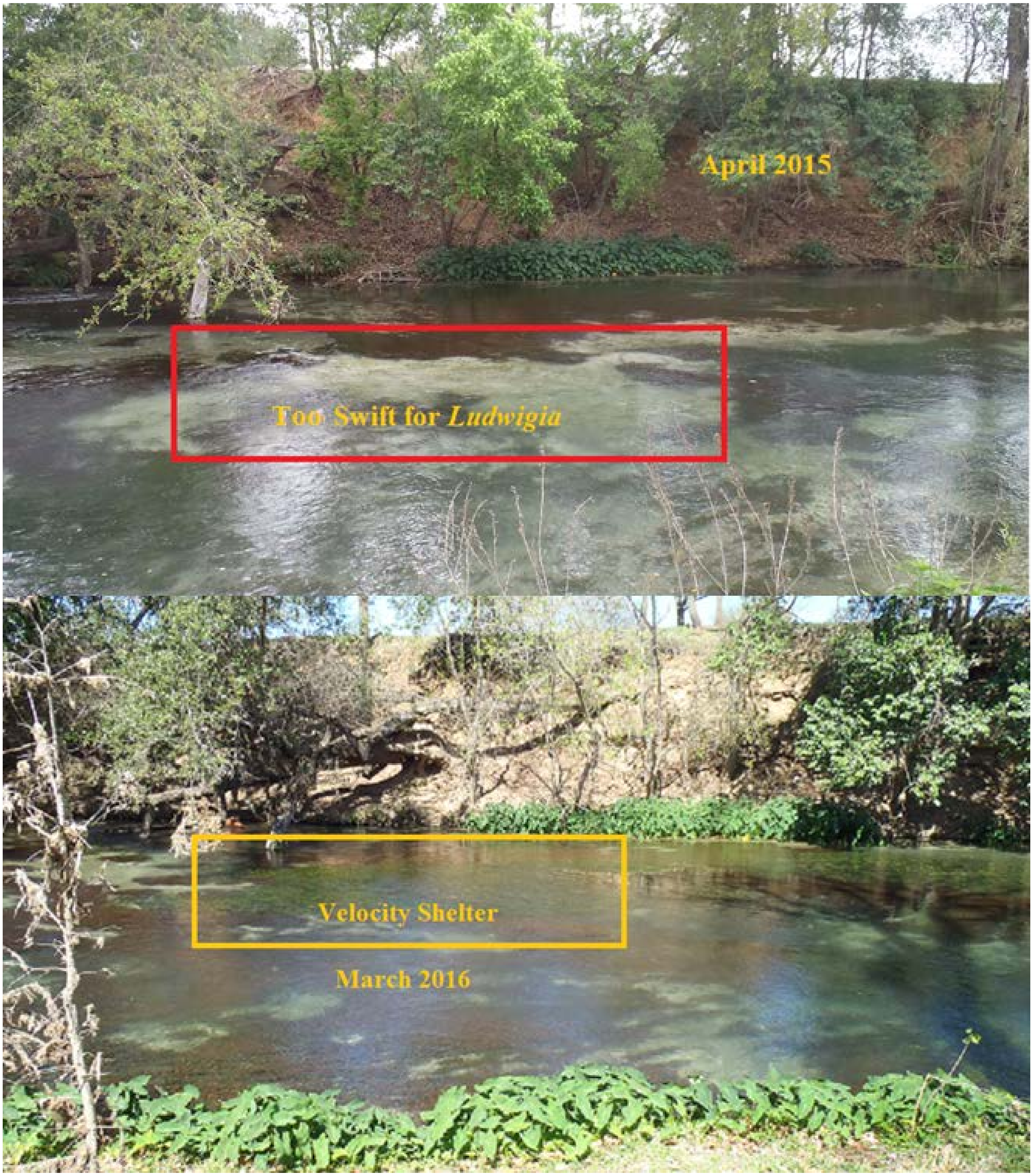


Figure A828. Native aquatic vegetation restoration coverage in the former Sediment Island footprint in April 2015 (top) and March 2016 (bottom).

Although bryophytes are routinely lumped into the aquatic vegetation classification these plants are entirely different from the other target species. First, bryophytes are a nonvascular plant and do not produce roots, flowers or stem propagules. Instead some species, (there are five species in the Comal System), loosely attach to substrate, submerged trees and rocks or float at the water's surface. Other species of bryophytes securely attach to solid substrate via a holdfast. Either way bryophytes are not considered a "permanent" plant and can move, float or the substrate they grow on can be dislodged by changes in water current. Initially the team believed there was no way to propagate or plant bryophytes into restored areas such as can be done with rooted plant species. Additionally, over the course of the last three years there has seemingly been no shortage of bryophyte cover in Landa Lake or the Old Channel. One observation made is that removal of dense *Hygrophila* in the Old Channel has opened up more bare substrate in which bryophytes floating downstream can settle expanding bryophyte cover. This has posed a problem as this increase in bryophyte biomass began to cover planted *Ludwigia* and *Sagittaria*. Banks of bryophytes were noted to form sometimes waste deep over planted *Ludwigia* and *Sagittaria* and this in turn did, in some instances, smother these species despite efforts by the crew to dislodge bryophyte biomass and send it downstream. Bryophytes are extremely sensitive to changes in water velocity and strong pulses such as those from urban runoff or floods can cause large quantities of bryophytes to drift leaving areas previously thick with bryophyte cover completely bare and pile bryophytes into new areas. This happened on a large scale after the October 2015 flood when bryophyte cover in the Old Channel went from nearly 1,000 m^2 before the flood to just 16 m^2 after the flood. Since this is the first time during the restoration program that bryophytes have been severely lacking it provides some thought on what to do to stabilize bryophyte colonies during floods or promote their resurgence after a flood.

One simple solution to promote bryophytes is the planting of *Sagittaria*. Due to its open growth form *Sagittaria* collects and holds bryophytes very well, sometimes maybe too well to the detriment of the *Sagittaria*. In 2014 we field tested and deployed several coconut coir mats placed onto the stream bottom to provide structure for bryophytes to attach (Figure A9). These worked well but at that time bryophytes were abundant and this method was deemed unnecessary. Another future solution is the inclusion of strategically placed woody debris along the channel to help collect bryophytes and provide them a sturdier structure on which to grow. Providing some back water habitat that is protected from all but the largest of floods would be yet another solution. All in all, we have shown that although highly transitory and ephemeral some management activities can be conducted to promote, maintain and protect bryophyte cover, to some degree, from floods. However, challenges do exist in protecting other restored species such as *Ludwigia*, *Cabomba*, and *Sagittaria* from damage by an overabundance of bryophytes.

Figure A9. Bryophytes attached to coconut coir mat (left). Coir mat laid on stream bed bottom provides structure for bryophyte attachment (right).

Aquatic Gardening and Maintenance

After *Hygrophila* removal and native plant re-introduction, regular and continued aquatic gardening and maintenance is conducted to ensure *Hygrophila* regrowth is prevented and encourage native plant expansion (Figure A10). Although it depends on the location, we have noticed that the gardening of *Hygrophila* tends to decrease as time progresses and *Hygrophila* propagules make their way out of the system. This has been incredibly enhanced by removing all upstream sources of *Hygrophila* including within Upper Spring Run and the spring fed swimming pool. In general, after an area has been restored, an aquatic gardening schedule of once per month during the growing season (April to September) seems appropriate for identifying and removing *Hygrophila* sprigs. In some cases, such as in the Landa Lake restoration area, no *Hygrophila* sprigs have been observed after removal was completed, while in other areas, such as the Old Channel, *Hygrophila* persists after restoration activities and a gardening regime is continuous. In September 2015, a total system gardening event took place to remove any *Hygrophila* sprigs which remained from summer removal activities occurring in the Upper Spring Run.

Aquatic gardening entails more than just removal of *Hygrophila* sprigs but also consists of maintenance of the aquatic habitat areas. When moving into the Old Channel below Elizabeth Street, the restoration team removed large swaths of *Arundo donax*, log jams, and low-hanging limbs along the edges of the stream bank in order to prevent floating litter buildup. These litter mats capture debris including *Hygrophila* fragments and can allow *Hygrophila* fragments to root and grow providing more propagule material to the system. In some instances, these debris mats also block light from reaching planted native plants. Other aquatic gardening activities carried out include supplemental planting of native plants, removing dense bryophyte growth in newly-planted areas, and trimming *Ludwigia* patches with hedge clippers to prevent topped-out growth and encourage spreading. In Landa Lake native *Vallisneria* and *Sagittaria* have recently begun to invade *Ludwigia* and *Cabomba* restoration plots so removal and gardening of these plants have been warranted to protect our target species and promote the desired native plant community. While labor intensive, these tasks greatly improve the establishment and growth potential of re-introduced native plants as well as provide a chance for us to observe first hand any difference in plant growth between locations as well as the overall health of plants on a monthly basis and any locations which become problematic, either with *Hygrophila* re-growth or another issue, are quickly tended to.

Figure A10. Patches of *Hygrophila* regrowth after initial removal (left) and are removed by gardening activities via SCUBA or snorkeling over the course of several weeks (right).

Mapping and Monitoring

One important lesson learned is that active data collection, applied research and monitoring of restored areas provides an opportunity to track the maturation of re-introduced native plants, collect data on the biological integrity of the restored locations and address any issues which may impact the long-term success of restoration efforts. Initially our monitoring program consisted of two episodes of vegetation mapping, Spring and Fall, along with monthly quadrate monitoring to determine plant expansion. After 2013 it became evident we needed a more thorough mapping schedule as well as an ability to compare restoration sites before work had begun and afterwards on an annual basis. Seasonal mapping events are conducted in order to evaluate the restoration project as plant cover expands and retracts multiple times a year and restoration activities add additional plants and planted area. Typically, a baseline mapping event is conducted in January before any restoration work has begun for the year. Subsequently mapping in 2015 occurred in January, April, August, October (Figure A11, top) and a special post flood evaluation was carried out in November. This expanded data set helps us track the cover of each plant species across a year, determine success of planted plots and where to focus continued restoration activities. Additionally, specific quadrat monitoring (Figure A12) is conducted each year to evaluation restoration success in various hydraulic habitat and substrate types. More recently aerial photographs have been collected to get a sense of how much of the restoration area is under riparian canopy cover (Figure A11, bottom). Dense low hanging canopy cover blocks sunlight and continues to be a challenge for native aquatic vegetation expansion.

Hygrophila was seemingly more tolerant of canopy shade however native aquatic plants have shown not to tolerate dense riparian shade well.

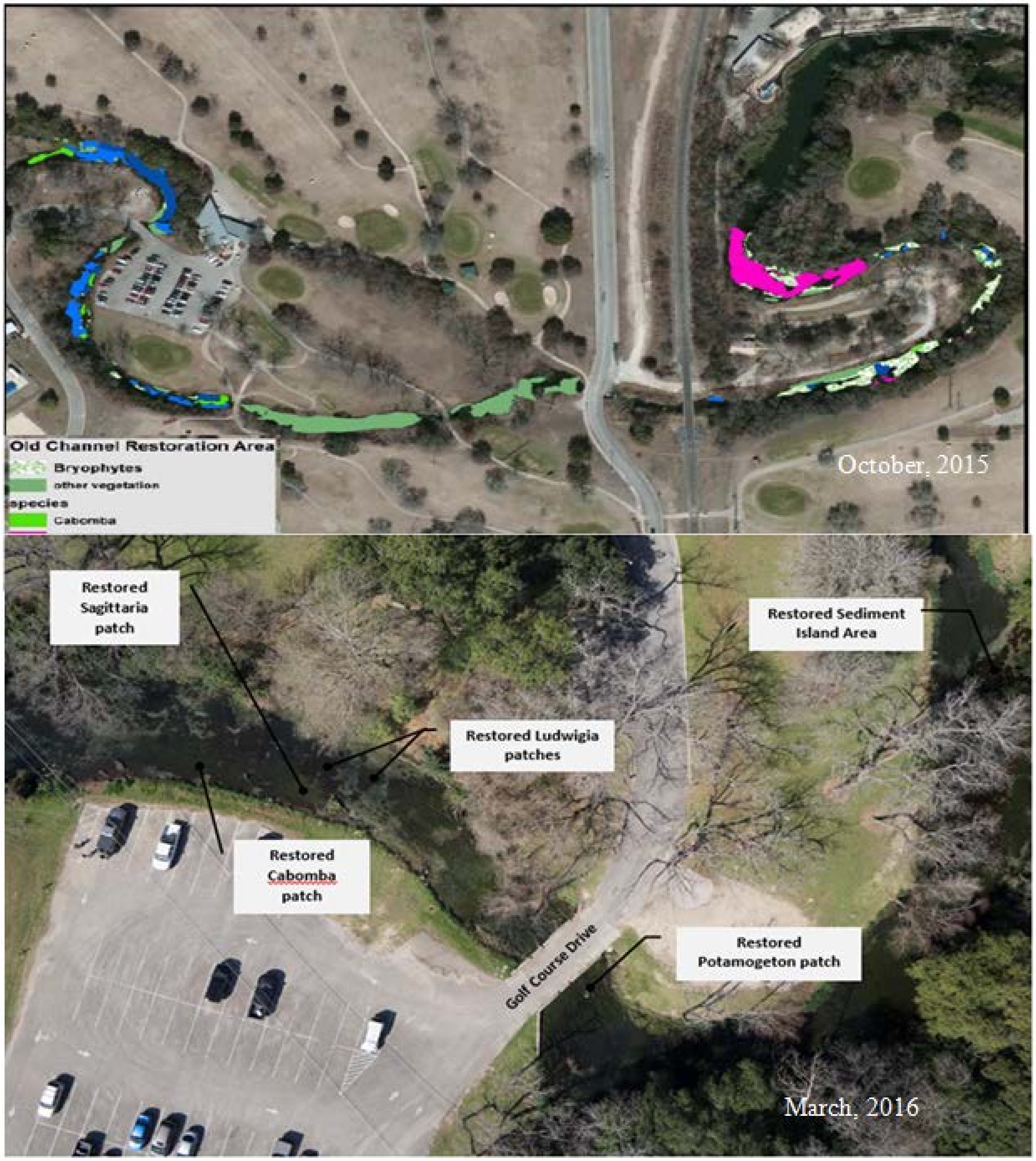


Figure A1129. Seasonal mapping with gps (top) along with aerial pictures from a UAV (bottom) provide monitoring capabilities to track success of native aquatic plant restoration.

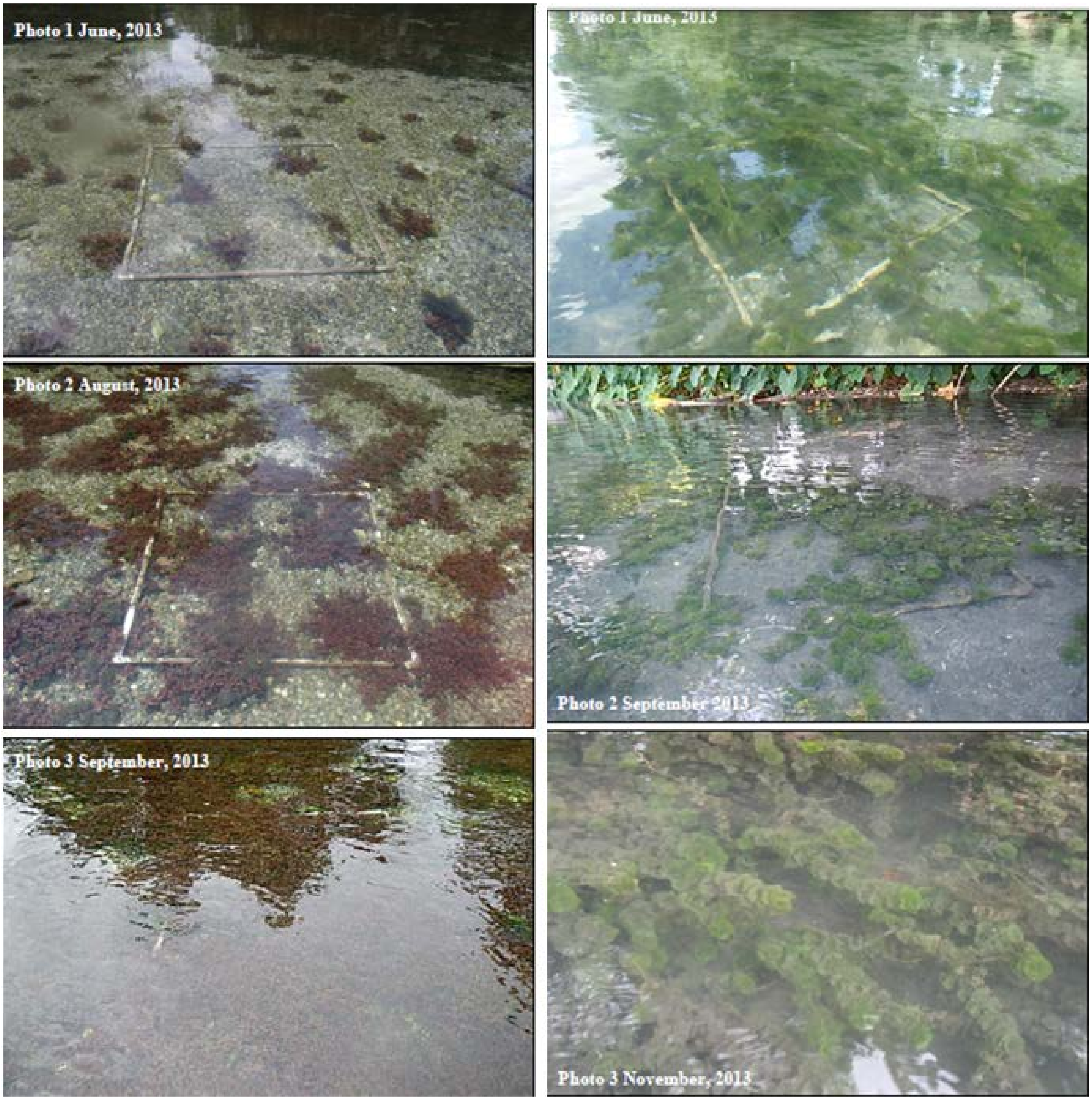


Figure A12. Quadrat monitoring provides data on how fast planted plants expand. Although there is a big locality effect restored plants can reach a high degree of cover within 3 to 4 months.

San Marcos River - Lessons learned and challenges

Non-Native Vegetation Removal

Since 2013, Texas State University removal efforts have focused on *Hydrilla verticillata, Hygrophila polysperma,* and *Nasturtium officinale*, as these species are the most actively invasive and compose approximately 75% of the submerged aquatic vegetation community in the San Marcos River. Prior to non-native aquatic vegetation removal, an area is fanned to minimize incidental take of fountain darters and other native species. Any removed non-native aquatic vegetation is sorted to recover aquatic species and transported for disposal at the City of San Marcos or Spring Lake composting facility. Initial methods for collecting non-native aquatic vegetation was accomplished by placing removed vegetation into mesh bags, which could then be transported for sorting prior to disposal (Figure A12). However, the method of using bags, although minimizing disturbance of aquatic fauna, was tedious and inefficient when pulling large stands of dense vegetation. Since *Hydrilla* can often grow the length of the water column (up to 6-8 ft., Figure A13), TSU explored alternative methods to effectively collect and transport large densities of non-native aquatic vegetation.

Therefore, since 2014, TSU has transitioned into using large bag seines to collect and transport non-native aquatic vegetation. By using bag seines, TSU has been able to remove large, dense stands of non-native aquatic vegetation in areas outside of direct river access locations. Large bag seines are secured with t-posts downstream of the area targeted for non-native aquatic vegetation removal (Figure A14). While divers are actively removing non-native aquatic vegetation, observers are at the bag seine locations to ensure removed vegetation is collected into the seines. Since using the bag seines, TSU has learned that by placing bag seines in a velocity funnel downstream of a worked area, a larger area can be worked since pulled vegetation is funneled into the seines (Figure A14). Once a seine is full, it can be transported to a river access point using a rope or buoy to help keep the bag afloat and ensure fragments are kept in the bag during transport (Figure A15-A). Since the bag seine is efficient in capturing a large amount of aquatic vegetation, TSU needed a method to transport the vegetation from the river to the truck or trailer (Figure A15-B).

Figure A1230. TSU removing non-native vegetation with mesh bags at Sewell Park in 2013.

Figure A13. *Hydrilla verticillata* in the San Marcos River.

Figure A14. TSU using large seines to remove non-native vegetation from the San Marcos River.

Texas State built a litter composed of a tarp fastened to a wooden/PVC support structure to assist in transporting large volumes of non-native aquatic vegetation (Figure A15-C) to a dump trailer. The removed vegetation is then sorted and checked to ensure there are no fauna mixed within the vegetation. Figure A15-D illustrates the large volumes of *Hydrilla* able to be removed and sorted using bag seines and a dump trailer.

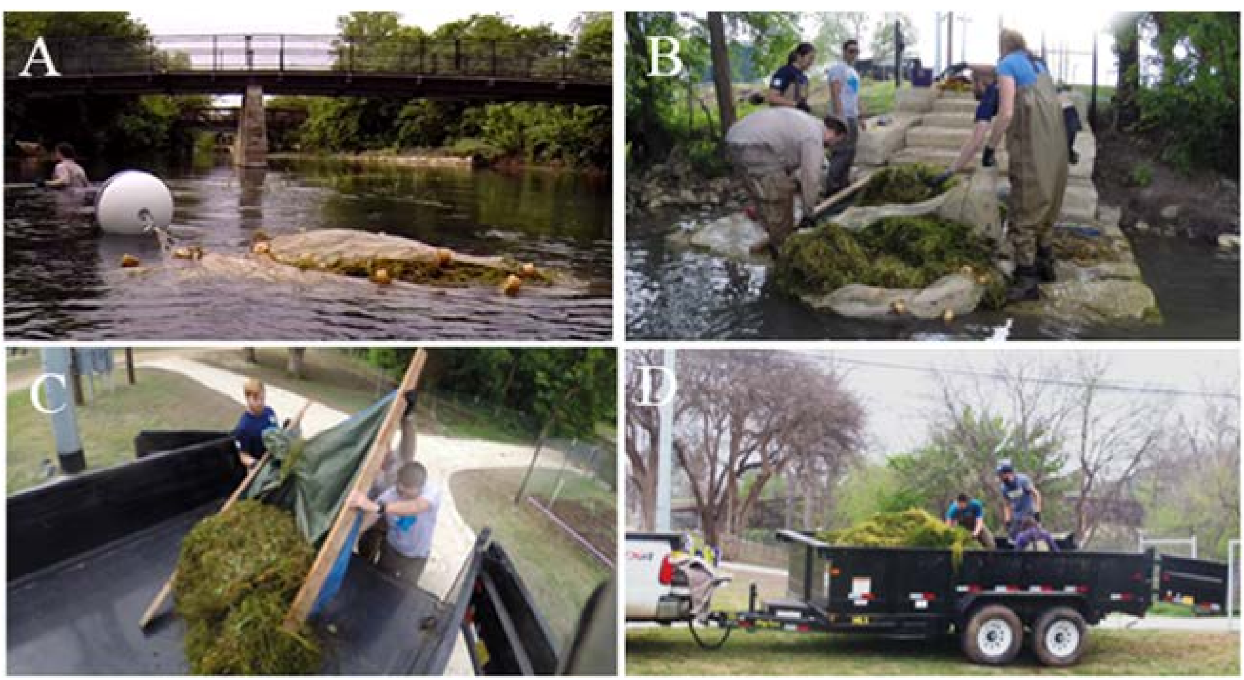
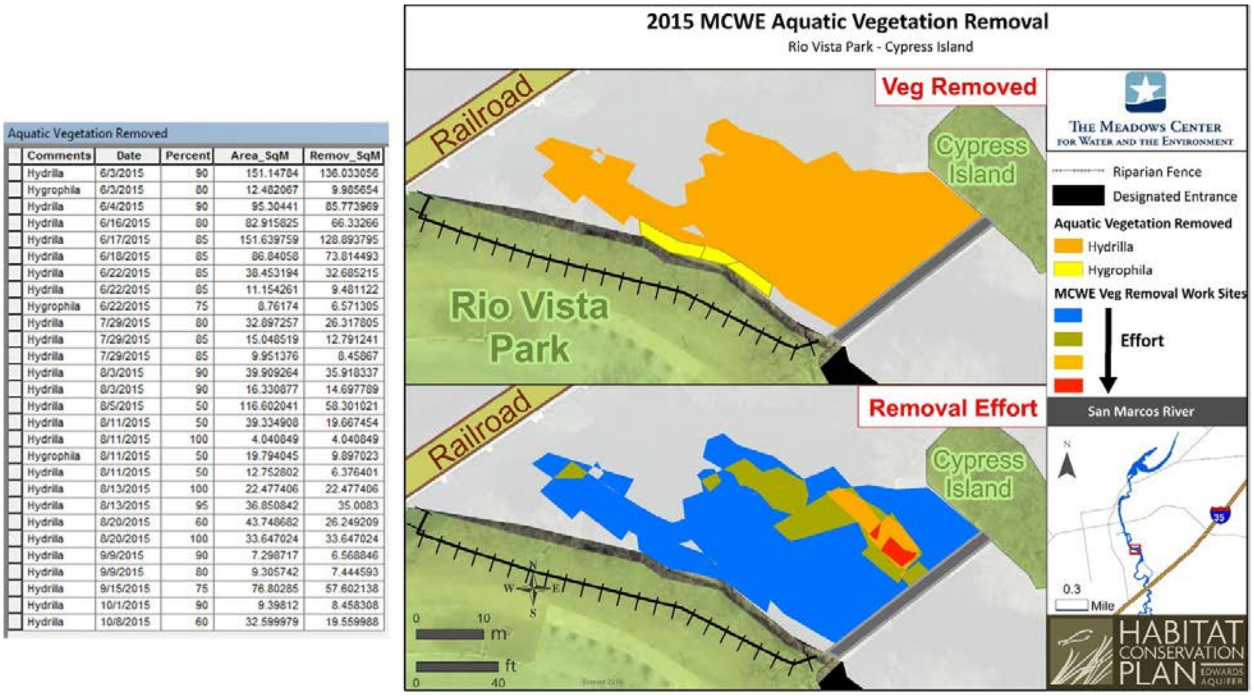


Figure A15. A) TSU staff pulling a seine bag across the river in City Park. B) TSU pulling a seine bag out of the river at a river access point in City Park. C) TSU loading non-native aquatic vegetation off of a litter into the dump trailer. D) TSU sorts through non-native aquatic vegetation that has been removed from City Park.

Texas State tracks efforts for non-native aquatic vegetation removal and maintenance with polygons created in ArcGIS. Each removal site is denoted with a georeferenced polygon that contains the date, species removed, estimated area (m^2), and percent removed. As a result, the layer helps TSU keep track of areas worked as well as capturing the degree of overlap between work sites to identify areas that require repeated removal efforts (Figure A16).



Aquatic Vegetation Removed

Comments	Date	Percent	Area_SqM	Remov_SqM
Hydrilla	6/3/2015	90	151.14784	136.033056
Hygrophila	6/3/2015	80	12.482067	9.985654
Hydrilla	6/4/2015	90	95.30441	85.773969
Hydrilla	6/16/2015	80	82.915825	66.33266
Hydrilla	6/17/2015	85	151.639759	128.893795
Hydrilla	6/18/2015	85	86.84058	73.814493
Hydrilla	6/22/2015	85	38.453194	32.685215
Hydrilla	6/22/2015	85	11.154261	9.481122
Hygrophila	6/22/2015	75	8.76174	6.571305
Hydrilla	7/29/2015	80	32.897257	26.317805
Hydrilla	7/29/2015	85	15.048519	12.791241
Hydrilla	7/29/2015	85	9.951376	8.45867
Hydrilla	8/3/2015	90	39.909264	35.918337
Hydrilla	8/3/2015	90	16.330877	14.697789
Hydrilla	8/5/2015	50	116.602041	58.301021
Hydrilla	8/11/2015	50	39.334908	19.667454
Hydrilla	8/11/2015	100	4.040849	4.040849
Hygrophila	8/11/2015	50	19.794045	9.897023
Hydrilla	8/11/2015	50	12.752802	6.376401
Hydrilla	8/13/2015	100	22.477406	22.477406
Hydrilla	8/13/2015	95	36.850842	35.0083
Hydrilla	8/20/2015	60	43.748682	26.249209
Hydrilla	8/20/2015	100	33.647024	33.647024
Hydrilla	9/9/2015	90	7.298717	6.568846
Hydrilla	9/9/2015	80	9.305742	7.444593
Hydrilla	9/15/2015	75	76.80285	57.602138
Hydrilla	10/1/2015	90	9.39812	8.458308
Hydrilla	10/8/2015	60	32.599979	19.559988

Figure A16. Maps depicting the degree of effort put forth in non-native vegetation removal at Cypress Island in 2015 and an example of the layers attribute table with information for each polygon.

Special Cases of Vegetation Removal

Under rare circumstances, TSU has removed aquatic vegetation considered native but located in areas out of natural habitats. For example, a large patch of cutgrass, *Zizaniopsis*, was spreading in a section of Sewell Park. Cutgrass is characterized as a littoral zone species and does not typically occupy the main river channel. The cutgrass patch was causing downstream effects including reduced velocities and accumulated areas of fine sediment (Figure A17), resulting in suboptimum habitat for Texas wild rice and other native species. Among the months of June and July 2013, TSU removed the cutgrass islands in the San Marcos River at Sewell Park. Shovels and pick axes were needed to dislodge the extensive root system of the cutgrass (Figure A18). Removal of the cutgrass was completed during low flow conditions so much of the cutgrass was out of water. However, all cutgrass removed was inspected for all fountain darters life stages prior to being placed into the truck or trailer for disposal. Approximately 155 m^2 of cutgrass was removed from the San Marcos River at Sewell Park. Total estimated volume was 31.7 m^3 (1,118 ft^3). Figure A19 illustrates changes in the river after the removal of the cutgrass island. Since the removal of the cutgrass, Texas wild rice and other native species have expanded in the area

(Figure A20). Texas State Univerisity continues to monitor the river for new stands of cutgrass and these are removed if found.

Figure A17. *Zizaniopsis* in Sewell Park, 2013.

Figure A18. Example of methods used to remove cutgrass at Sewell Park.

Figure A19. Before (left) and after (right) the removal of the cutgrass islands in the San Marcos River at Sewell Park.

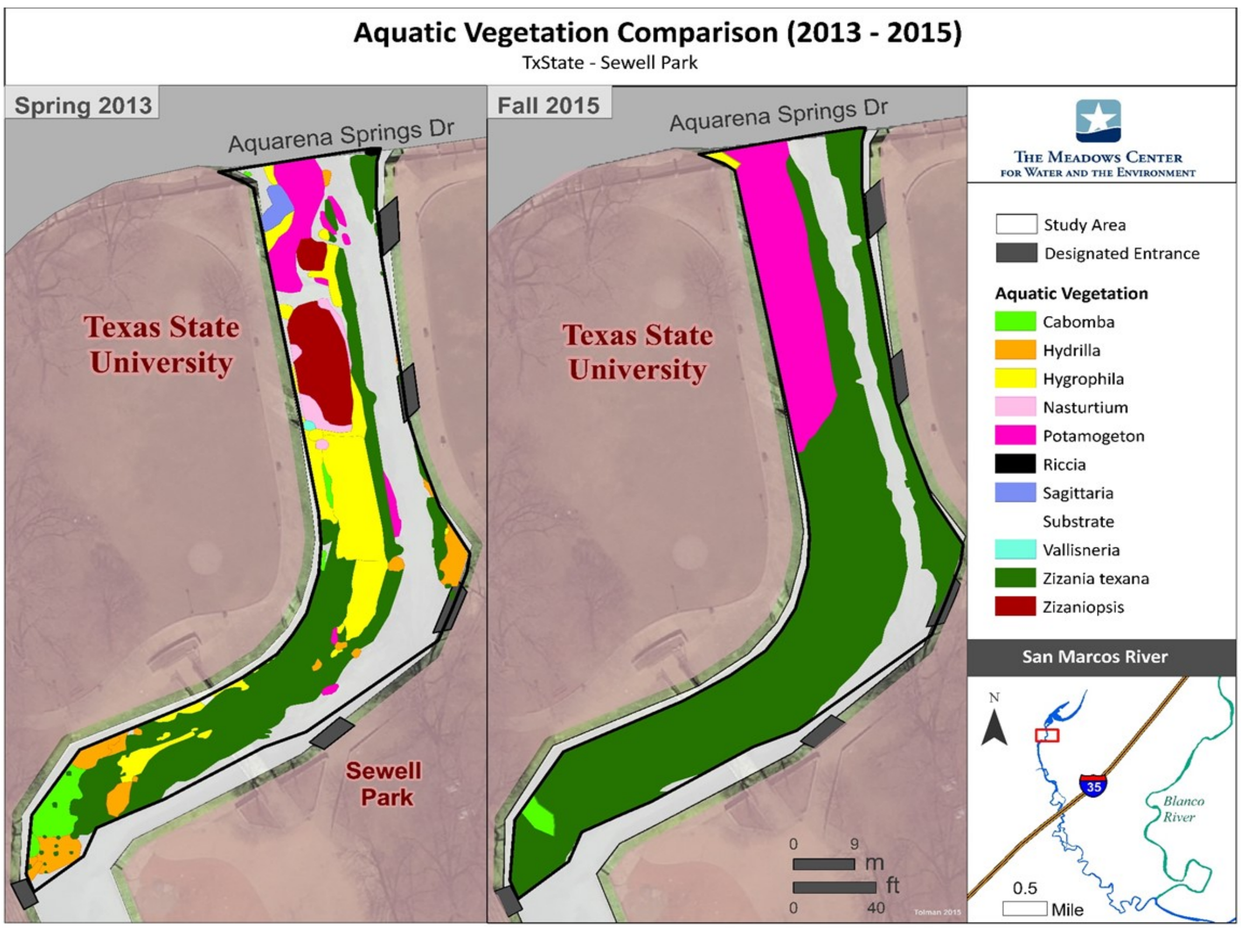


Figure A20. Aquatic vegetation comparison map, 2013-2015.

Vegetation Mats

Vegetation mats form from a combination of vegetation fragments dispersed from Spring Lake and floating aquatic vegetation occur in the San Marcos River. Vegetation mats accumulate in areas of emergent aquatic vegetation, channel margins, or in velocity funnels (Figure A21). During periods of low flow, vegetation mats can expand rapidly, covering large areas of native aquatic vegetation while blocking sunlight for the underlying species. Texas State University became aware of the abundance and adverse effects of vegetation mats when work was suspended during the period of low flow restrictions in 2014. Below is a case example of the effects vegetation mats can have if not removed. Fortunately, the ability to remove vegetation mats and perform maintenance during periods of low flow has been modified in Provision M. Since 2014, TSU has learned to monitor and remove vegetation mats to prevent loss of native aquatic vegetation species. Approximately 1,361 m^2 of floating vegetation/vegetation mat has been removed as of 2014.

Figure A21. Example of a vegetation mat accumulated in the San Marcos River.

Approximately 334 m^2 of vegetation mat was removed in an area just downstream of Sewell Park after low flow restrictions were lifted in October 2014. Most vegetation removed was watercress and took four days of effort to remove (Figure A22). Figures A23 and A24 illustrate the expansion of watercress and *Hydrilla* within the patch of Texas wild rice. After non-native removal in the area, replanting was necessary since a loss of plants was observed (Figure A16). A total of 1,564 plants were planted, mostly Texas wild rice, and required four days of effort.

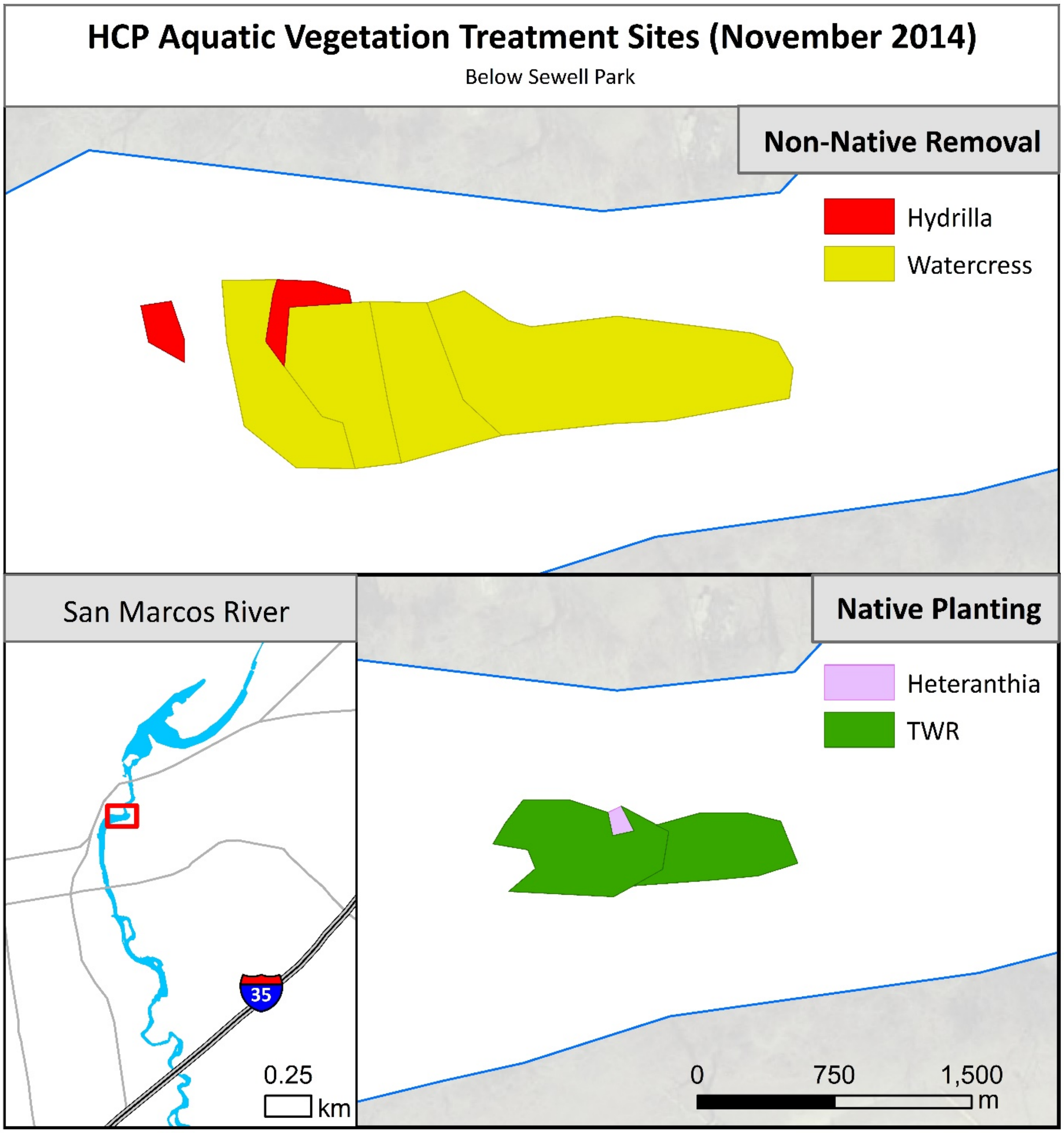


Figure A22. Area of vegetation mat removed after low restrictions lifted in 2014 (top) and subsequent planting with native aquatic vegetation (bottom).

Figure A23. The area outlined in the red polygon illustrates the expansion of watercress within a large patch of Texas wild rice just downstream of Sewell Park during the period of low flow restrictions (Aug 7, 2014 – Oct 2014).

Figure A24. The area outlined in the yellow polygon illustrates the expansion of *Hydrilla* within a large patch of Texas wild rice just downstream of Sewell Park during the period of low flow restrictions (August 7, 2014 – October 2014).

Propagating and Planting Native Aquatic Vegetation
Once an area is denuded of non-native aquatic vegetation, the area is targeted for planting Texas wild rice and/or selected native aquatic vegetation species. Initial efforts for restoration of Texas wild rice or other native vegetation species was targeted for planting approximately 20 percent of the denuded surface area. The U.S. Fish and Wildlife Service (USFWS) San Marcos Aquatic Resource Center (SMARC) is contracted to propagate native aquatic vegetation species for TSU replanting efforts.

In order to produce the necessary plants needed to cover denuded areas, TSU needed an additional location to propagate native aquatic vegetation. Texas State began propagating native aquatic vegetation species at the Freeman Aquatic Building (FAB) raceways located at TSU (Figure A25). Growth and mortality of native aquatic vegetation in the raceways was assessed to determine if it was a feasible location (description below). After the assessment was completed, TSU determined the raceways were satisfactory for propagating native aquatic vegetation species. Since June 2013, approximately 50% of native aquatic vegetation replanted into the San Marcos River is propagated in the raceways. On occasion, plants received from SMARC are brought to the FAB raceways for an additional growth period before planting into the river.

Figure A2531. Native aquatic vegetation propagated in raceways located on Texas State University campus. TSU staff monitors the growth and health of propagated plants.

Approximately 4,000 Texas wild rice and other native species' fragments were collected from the San Marcos River beginning 10/29/2012 – 12/31/2013. Fragments were planted according to USFWS guidelines within two, 120 ft. raceways. The raceways are composed of concrete although one has a gravel floor. A total of 7 pumps have been used in various configurations to maximize flow in areas of the greatest need. Texas State planted an average of six fragments per pot and has a total of 630 pots at present. Table A1 summaries the number of fragments and pots planted for each species as well as survivability we observed during this period. Over a two-week period, 120 Texas wild rice individual plants grew an average of 6.8centimeters (cm). Various manual (non-chemical) methods were used to clean algae from the plants.

Table A136. Species, number of fragments, number of pots, and survivability for native vegetation propagated at Texas State Aquatic Station (10/29/2012-12/31/2013).

Species	# of fragments	# of pots	% survivability
Zizania texana	4,050	630	90
Sagittaria	85	25	100
Ludwigia repens	26	26	100
Potamogeton	12	2	100

Since the initiation of the restoration effort, TSU has occasionally encountered issues with propagating native aquatic vegetation in the raceways and modified their methods accordingly. A die off of potted *Ludwigia* has occasionally occurred and TSU discovered it was a result of predation from an aquatic moth (pers. comm., Jeff Hutchinson, USFWS). To reduce the risk of moth predation, TSU learned to raise the water levels in the raceways to prevent *Ludwigia* from becoming emergent since that appeared to correspond with the moth invasion. Algal growth on propagated plants was another issue TSU observed in the raceways. Mass amounts of algal growth would accumulate on newly planted fragments that reduced the growth and health of the plants. Texas State found installing sunlight barriers reduced the amount of algal growth and in turn, increased survivability of the plantings.

Texas State University has found the following two methods to be successful in planting native aquatic species including:

1) Relocation of native aquatic vegetation individuals from one area of the river to a newly denuded area.
2) Planting potted plants propagated at SMARC or FAB raceways.

For method 1, native aquatic vegetation individuals are removed by hand in one area and immediately replanted in an area denuded of non-native aquatic vegetation. Texas State found this method extremely successful with the native species, *Sagittaria*. Approximately 600 individual plants of *Sagittaria* were relocated to the dock area below Sewell Park. Since 2013 the coverage has expanded in this area an estimated 180 m^2 (Figure A26).

Figure A26. *Sagittaria* has expanded in Sewell Park since 2013.

For method 2, holes for native plants are made with a trowel shovel or simply by hand depending on substrate type (Figure A27). Potted plants are removed from their pots, placed in the hole, and soil is pressed down by hand to ensure the plant is sufficiently secured in the hole (Figure A28). Texas State planting efforts are tracked with polygons containing the date, number of individuals, estimated area (m^2), and estimated density planted (individuals/m^2). Therefore, a map illustrating planting locations and densities can be generated using weekly polygons (Figure A29).

Figure A27. Example of TSU staff using a hand shovel to dig a hole while planting Texas wild rice.

Figure A28. Example of TSU staff pressing soil around a newly planted Texas wild rice stand to secure the plant.

Planted_2015

Comments	Date	Number	area_sqm	density	AreaSqM
Heteranthia	6/23/2015	450	8.90206	50.550099	8.90206
Heteranthia	6/23/2015	450	3.171439	141.891435	3.171439
Heteranthia	6/25/2015	45	2.388962	18.836635	2.388962
Heteranthia	6/25/2015	45	1.58889	28.321658	1.58889
Heteranthia	7/20/2015	198	5.248957	37.721779	5.248957
Heteranthia	7/20/2015	100	0.811063	123.294938	0.811063
Heteranthia	7/20/2015	30	0.884256	33.926836	0.884256
Heteranthia	7/20/2015	30	1.126307	26.635727	1.126307
Heteranthia	7/20/2015	116	2.991359	38.778357	2.991359
Heteranthia	7/22/2015	24	0.953863	25.160847	0.953863
Heteranthia	8/12/2015	25	10.845219	2.305163	10.845219
Heteranthia	8/12/2015	25	8.119865	3.078869	8.119865
Heteranthia	8/12/2015	25	6.686445	3.738908	6.686445
Heteranthia	8/26/2015	75	5.659955	13.25099	5.659955
Heteranthia	8/26/2015	135	4.505665	29.962283	4.505665
Heteranthia	9/9/2015	204	2.96154	68.883084	2.96154
Heteranthia	9/9/2015	102	3.539926	28.814162	3.539926
Ludwigia	6/23/2015	9	0.076231	118.062168	0.076231
Ludwigia	8/4/2015	400	13.839884	28.901977	13.839884
Ludwigia	8/4/2015	209	7.397247	28.253754	7.397247
Sagitaria	7/28/2015	230	16.597286	13.857687	16.597286
Sagitaria	8/12/2015	75	2.623808	28.584404	2.623808
TWR	6/23/2015	388	12.06495	32.15927	12.06495
TWR	6/23/2015	776	19.217575	40.379704	19.217575
TWR	6/25/2015	162	4.187085	38.690397	4.187085
TWR	6/25/2015	162	2.318359	69.87701	2.318359
TWR	7/20/2015	105	4.706791	22.308193	4.706791
TWR	7/20/2015	392	5.778006	67.843469	5.778006
TWR	7/20/2015	150	6.427294	23.337971	6.427294
TWR	7/20/2015	100	3.446079	29.018487	3.446079
TWR	7/20/2015	200	6.591344	30.342825	6.591344
TWR	7/22/2015	350	9.495344	36.860171	9.495344
TWR	7/22/2015	250	7.541923	33.148043	7.541923
TWR	7/22/2015	155	3.859525	40.160381	3.859525
TWR	7/22/2015	155	3.4731	44.628713	3.4731
TWR	8/4/2015	320	13.200783	24.240986	13.200783
TWR	8/4/2015	283	30.608238	9.245877	30.608238
TWR	8/10/2015	750	73.874639	10.152334	73.874639
TWR	8/12/2015	510	17.520232	29.109204	17.520232
TWR	8/19/2015	200	5.097501	39.234914	5.097501
TWR	8/19/2015	200	11.115809	17.992393	11.115809
TWR	8/19/2015	200	10.892296	18.361602	10.892296
TWR	8/26/2015	330	14.253726	23.15184	14.253726
TWR	9/9/2015	76	3.157782	24.067528	3.157782
TWR	9/9/2015	152	5.799809	26.207758	5.799809
TWR	9/16/2015	828	36.101616	22.935262	36.101616
TWR	10/21/2015	408	18.388903	22.187294	18.388903

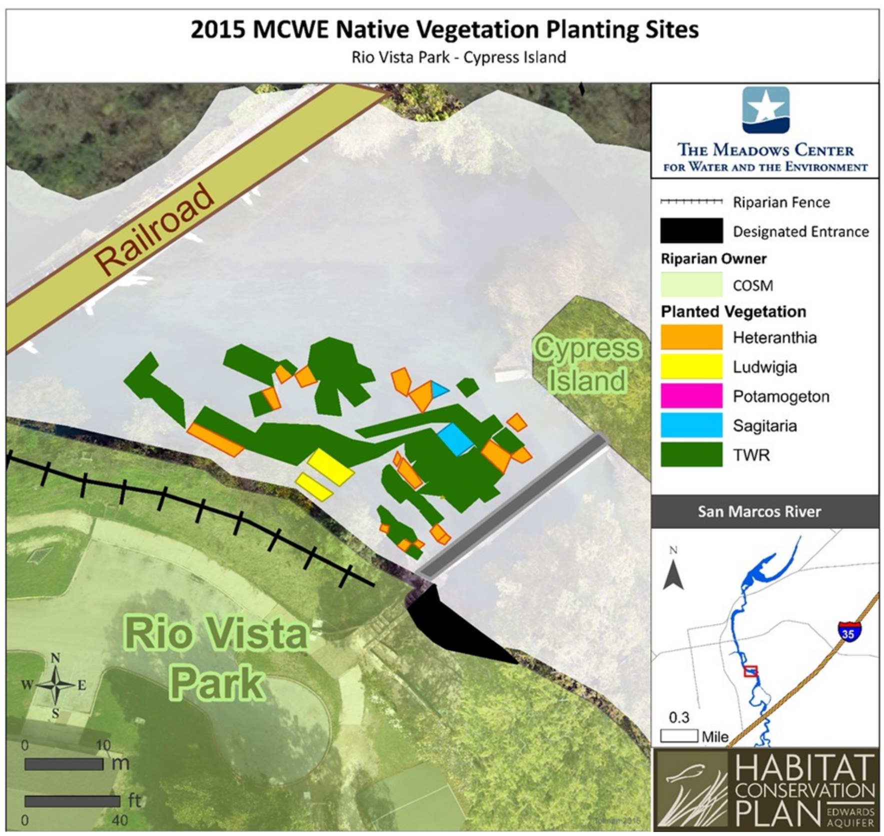


Figure A29. Native vegetation planting sites map, 2015.

Texas wild rice Expansion

Texas State University used a 0.25m^2 grid to monitor Texas wild rice expansion after removal of non-native aquatic vegetation adjacent to Texas wild rice patches. Texas State University established known locations and used pieces of rebar embedded into the substrate to relocate grid positions. At each location, grids were used to quantify the area of expansion (i.e., growth) of the Texas wild rice on a monthly basis. At each grid, habitat characteristics (e.g., water depth, canopy cover, current velocity) were recorded each time we assessed vegetation growth. A total of 48 grids were placed in the San Marcos River to monitor the expansion of Texas wild rice patches following the removal of *Hydrilla verticillata* and *Hygrophila polysperma.* (Figure A30). Grids were located within a range of depths (0.22 m – 0.68 m), current velocities (0.02 m/s – 0.41 m/s), and substrates (i.e., silt, sand, clay, gravel, and cobble). Texas State observed tiller growth and plant expansion in 95% of the grids with growth observed in as little as a month (Figure A31). Texas wild rice expansion was generally observed laterally of an existing patch or on the downstream portion of the patch among all ranges of depths and current velocities measured. No growth was observed at the start of a Texas wild rice patch.

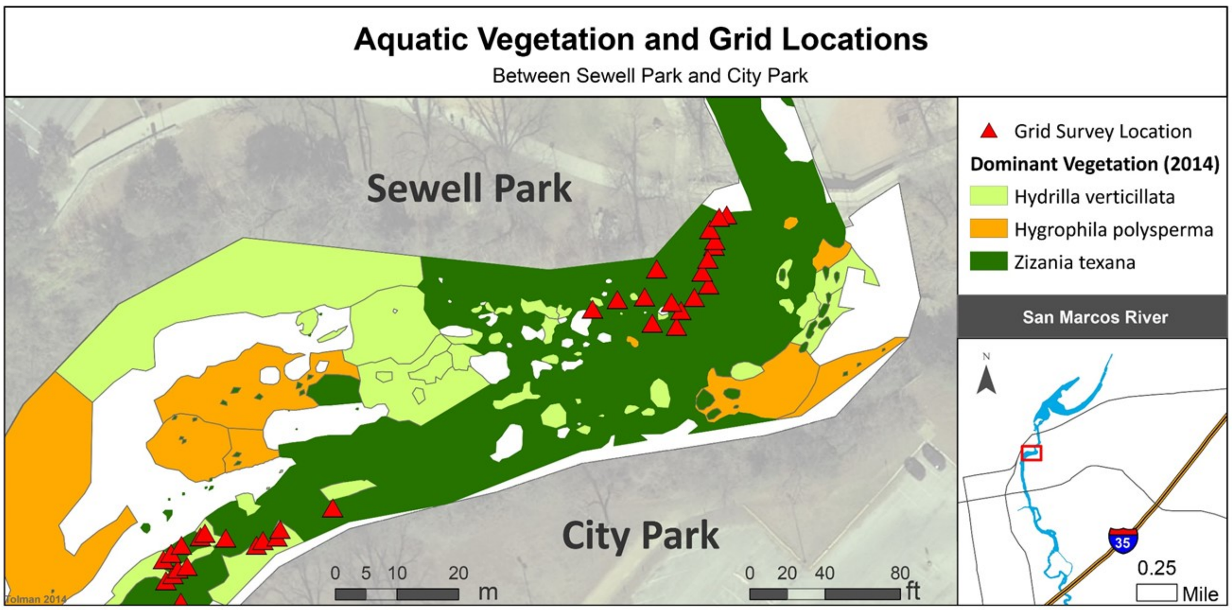


Figure A30. Aquatic vegetation and grid locations map, 2014.

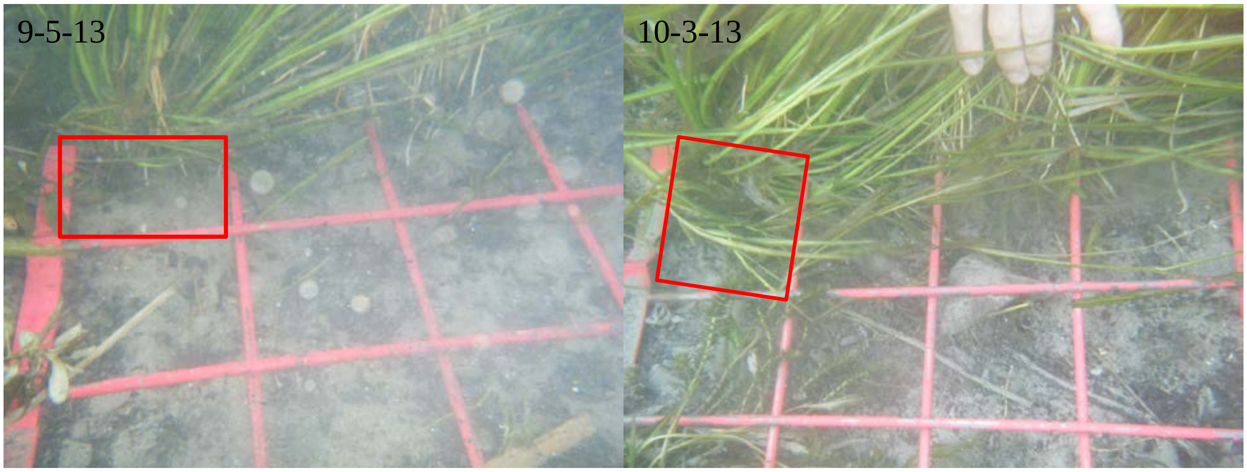


Figure A31. Example of Texas wild rice growth (red polygons) observed in one month after non-native aquatic vegetation removal.

Ludwigia repens

Little knowledge is currently known for optimum habitat characteristics for the native aquatic vegetation species, *Ludwigia repens* in the San Marcos River. Therefore, TSU planted *Ludwigia* in a wide variety of habitat types ranging from areas with shallow depths, high velocities over coarse substrates to areas with more slackwater habitats over silt substrate to determine which habitat results in greatest rates of expansion and persistence. Approximately 12,279 *Ludwigia* individuals were planted since 2013 constituting an estimated 550 m^2. In 2015, < 1% of the total area treated in TSU sites was occupied by *Ludwigia*. Texas State University observed that once planted, *Ludwigia* quickly spreads but then patches typically reduce in size and eventually disappear completely or become invaded by other aquatic vegetation species (Figure A32, Figure A33). Even after constant maintenance and supplemental plantings, TSU has yet to discern an optimum habitat type to maintain persistent stands of *Ludwigia*.

Figure A32. *Ludwigia repens* patch at Sewell Park reduced in size between 2014-2016.

Figure A33. *Ludwigia repens* was planted in area of Sewell Park in the San Marcos River. Expansion was initially observed after planting; however, the image from Feb 2016 illustrates the lack of persistence observed with *Ludwigia* patches

Native aquatic vegetation method adjustments

Since 2013, TSU has adjusted planting locations of Texas wild rice and other native species based on observed successful or unsuccessful establishment. Since Texas wild rice expansion was observed lateral and downstream of Texas wild rice stands, TSU shifted supplemental Texas wild rice plantings to lateral and downstream areas of existing Texas wild rice patches. During low flow conditions in 2014, some of TSU plantings became emergent due to shallow depths. Therefore, TSU shifted planting locations to areas of greater depth to prevent the stands from becoming emergent with any further decrease in flow. With the variabilty observed in the expansion and persistence of *Ludwigia repens*, TSU assessed the use of other native aquatic vegetation species for replacing non-native aquatic vegetation and expanding fountain darter habitat. Texas State University assessed the presence of fountain darters in two native aquatic vegetation species, *Heteranthera dubia* and *Zizania texana* since no fountain darter density information exists for the two species.

Beginning in 2015, TSU captured work efforts using a quadacopter. Images are taken of an area prior to non-native aquatic vegetation removal, after non-native aquatic vegetation removal, and subsequent replanting with native aquatic vegetation (Figure A34). Images captured using the quadacopter have assisted TSU in documenting work efforts and helped with mapping changes in aquatic vegetation among work sites through time. The images captured are used to make mosaics which are georeferenced. In conjunction with vegetation data collected with Trimble GPS units, the georeferenced mosaics help assess changes in the aquatic vegetation community within TSU work sites. Texas State also found the quadcopter useful in tracking changes in aquatic vegetation after large, high flow pulse events, such as the flood event that occurred on October 30, 2015 in the San Marcos River. TSU has found the quadcopter an effective tool for completing rapid assessments in areas without dense canopy cover (Figure A35).

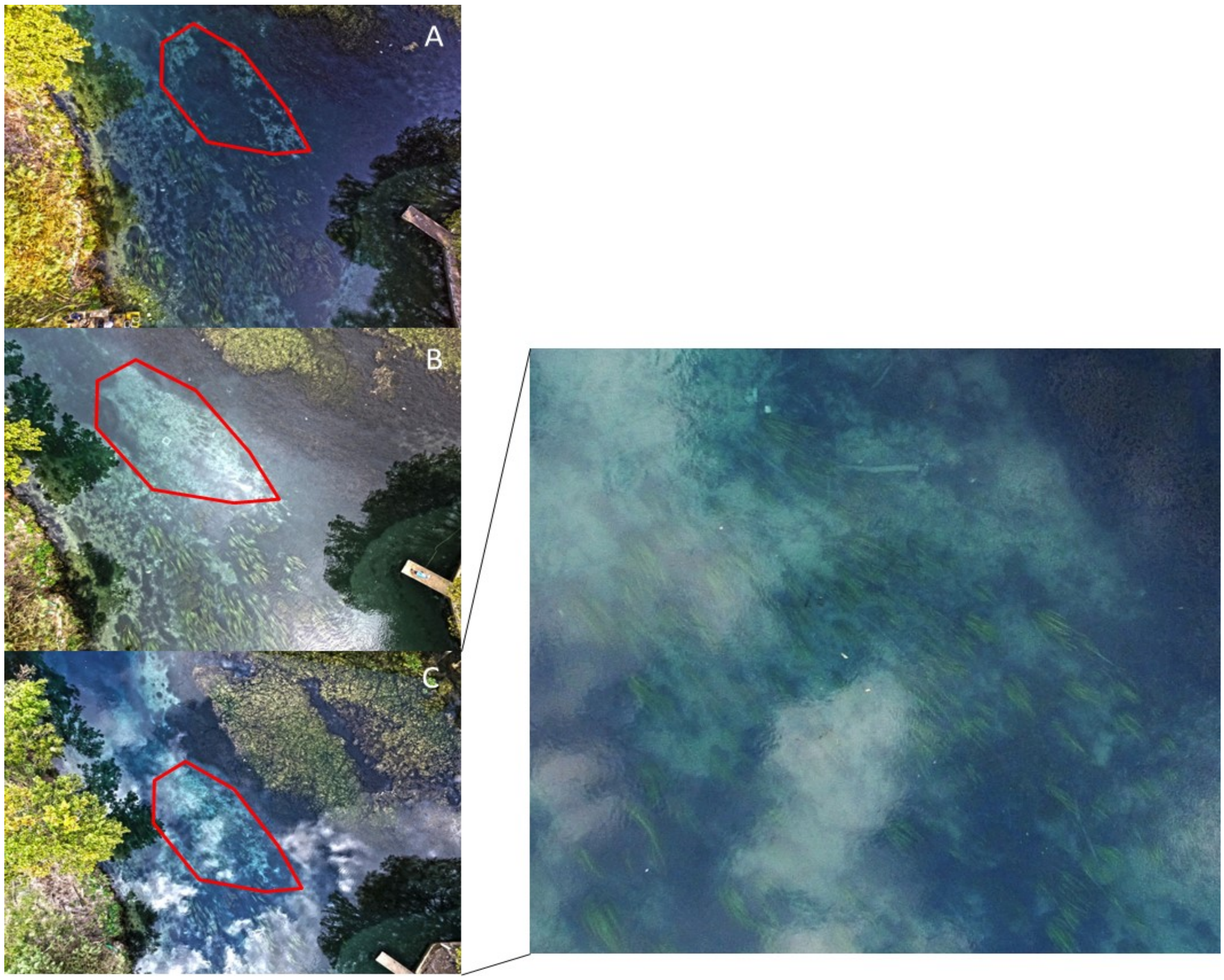


Figure A34. Images captured by TSU quadcopter of an area prior to non-native aquatic vegetation removal (A), after non-native aquatic vegetation removal (B), and replanting the denuded area with native aquatic vegetation (C).

Figure A35. Mosaicked and georeferenced imagery capture by TSU quadcopter prior to, immediately after, and three months following the October 30, 2015 high flow event in Sewell Park in the San Marcos River.

APPENDIX B
RESTORATION SCHEDULES PER SYSTEM

TABLE B1. COMAL AQUATIC VEGETATION RESTORATION SCHEDULE *(Last revised May 2016)*

Proposed restoration timeline designed to meet the **EXISTING HCP** rooted aquatic vegetation goals over time in the Comal system.

REACHES	SPECIES	Meters squared of aquatic vegetation (m^2)			HCP TERM TIMELINE *											TOTAL
		Current (2016)	Goal	Needed	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																
Landa Lake	*Ludwigia*	474	900	426	125	60	60	90	95							430
	Cabomba	240	500	260	60	50	40	50	60							260
	Sagittaria	2,759	1,250	0												0
	Vallisneria	12,012	13,500	1,488	160	150	150	150	150	130	120	120	120	120	120	1490
	Hygrophila	0	250	250	10	15	25	25	25	25	25	25	25	25	25	250
Old Channel	*Ludwigia*	7	1,500	1,493	150	150	150	125	125	100	75	75	75	75	75	1175
	Filamentous algae	0	200	200	25	20	20	20	20	20	15	15	15	15	15	200
	Hygrophila	450	200	0												0
New Channel	*Cabomba*	2,397	350	0												0
	Hygrophila	796	1,350	554	50	50	50	50	50	50	50	50	50	50	55	555
Upper Spring Run	*Ludwigia*	1	150	149	25	25	15	15	15	15	15	15	10			150
	Hygrophila	2	650	648	50	50	50	50	50	50	50	50	50	100	100	650
	Sagittaria	825	600	0												0

*** Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**

Red shaded boxes represent non-native vegetation which will not be planted. It will simply be allowed to reestablish in isolated areas to meet the existing HCP goals.

Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc.

2) Anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth.

3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.

4) Non-native vegetation removal (and replacement with natives) will occur in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) outside of the LTBG and Restoration reaches in order to assure that non-native plants don't reestablish.

5) Riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

6) No significant interuptions due to HCP Provision M.

7) Mapping to compare against goals will be conducted annually each Fall.

TABLE B2. COMAL AQUATIC VEGETATION RESTORATION SCHEDULE *(Last revised May 2016)*

Proposed restoration timeline designed to meet the **PROPOSED HCP** rooted aquatic vegetation goals over time in the Comal system.

REACHES	SPECIES	Meters squared of aquatic vegetation (m^2)			HCP TERM TIMELINE *											TOTAL
		Current (2016)	Goal	Needed	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																
Landa Lake	*Ludwigia*	474	900	426	100	100	100	105	25							430
	Cabomba	240	500	260	60	60	60	40	40							260
	Sagittaria	2,759	2,250	0												0
	Vallisneria	12,012	12,500	488	100	100	100	100	90							490
	Potamogeton	0	25	25	5	5	5	5	5							25
Old Channel	*Ludwigia*	7	425	418	100	100	100	100	20							420
	Cabomba	0	180	180	75	30	30	25	20							180
	Sagittaria	0	450	450	150	75	75	75	75							450
New Channel	*Ludwigia*	31	100	69		25	25	20								70
	Cabomba	2,397	2,500	103		35	35	35								105
	Sagittaria	0	0	0												0
Upper Spring Run	*Ludwigia*	1	25	24		10	10	5								25
	Cabomba	2	25	23		10	10	5								25
	Sagittaria	825	850	25		10	10	5								25

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the proposed revised LTBG reach goals.**
Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc.

2) Anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth.

3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.

4) Non-native vegetation removal (and replacement with natives) will occur in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) outside of the LTBG and Restoration reaches in order to assure that non-native plants don't reestablish.

5) Riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

6) No significant interuptions due to HCP Provision M.

7) Mapping to compare against goals will be conducted annually each Fall.

TABLE B3. COMAL AQUATIC VEGETATION RESTORATION SCHEDULE *(Last revised May 2016)*

Proposed restoration timeline designed to meet the **PROPOSED COMBINED HCP** rooted aquatic vegetation goals and defined management objective via Restoration Reaches over time in the Comal system.

REACHES	SPECIES	Meters squared of aquatic vegetation (m^2)			HCP TERM TIMELINE *											TOTAL
		Current (2016)	Goal	Needed	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																
Landa Lake	*Ludwigia*	474	900	426	75	75	75	105	35	35	30					430
	Cabomba	240	500	260	50	50	50	30	30	25	25					260
	Sagittaria	2,759	2,250	0												0
	Vallisneria	12,012	12,500	488	100	100	75	75	75	50	15					490
	Potamogeton	0	25	25	5	5	5	5	5							25
Old Channel	*Ludwigia*	7	425	418	75	75	75	75	50	50	20					420
	Cabomba	0	180	180	50	30	30	25	15	15	15					180
	Sagittaria	0	450	450	150	75	75	50	50	25	25					450
New Channel	*Ludwigia*	31	100	69		15	15	15	15	5	5					70
	Cabomba	2,397	2,500	103		20	20	20	20	15	10					105
	Sagittaria	0	0	0												0
Upper Spring Run	*Ludwigia*	1	25	24		5	5	5	5	5						25
	Cabomba	2	25	23		5	5	5	5	5						25
	Sagittaria	825	850	25		5	5	5	5	5						25
Restoration Reaches																
Landa Upper	*Ludwigia*	0	25	25			25									25
	Cabomba	150	250	100			25	35	20	10	10					100
	Sagittaria	50	250	200			50	50	50	25	25					200
Landa Lake Lower	*Ludwigia*	5	50	45			15	10	10	5	5					45
	Cabomba	100	125	25			10	10	5							25
	Sagittaria	7	100	93			25	25	25	10	10					95
	Vallisneria	24,500	22,500	0												0
Old Channel ERPA	*Ludwigia*	618	850	232	100	75			30	15	15					235
	Cabomba	119	200	81	25	25			25	10	5					90
	Sagittaria	591	750	159	75	25			35	15	10					160
	Vallisneria	715	750	0												0
	Potamogeton	73	100	27	10	10			5	5						30

*** Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the goals and management objective over time. It is estimated that approximately 1/2 of the HCP annual budget for this mitigation measure would be needed each year to maintain these conditions from 2024 through 2027.**

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, culvert repairs, etc.

2) Anthropogenic factors such as recreational disturbances (swimming, wading and paddle boats), turbidity from swimming pools and urban runoff can be managed to provide the suitable water quality for aquatic plant growth.

3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.

4) Non-native vegetation removal (and replacement with natives) will occur in certain areas (i.e. spring fed swimming pool, confluence with Blieder's creek, etc.) outside of the LTBG and Restoration reaches in order to assure that non-native plants don't reestablish.

5) Riparian restoration in the Old Channel is mandatory to accomplish the proposed goals.

6) No significant interuptions due to HCP Provision M.

7) Mapping to compare against goals will be conducted annually each Fall.

TABLE B4. SAN MARCOS AQUATIC VEGETATION RESTORATION SCHEDULE *(Last revised May 2016)*

Proposed restoration timeline designed to meet the **EXISTING HCP** aquatic vegetation goals over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2)			HCP Term Timeline*												Total
		Current (Dec 2015)	Goal	Needed	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																	
Spring Lake Dam	*Ludwigia*	0	200	200	10	10	10	10	10	10	10	10	10	10	10	10	120
	Cabomba	0	25	25	5	5	5	5	5								25
	Potamogeton	0	1000	1000	50	50	50	50	50	50	50	50	50	50	50	50	600
	Sagittaria	7	100	93	15	15	15	15	15	15	5						95
	Hygrophila	38	50	12	1	1	1	1	1	1	1	1	1	1	1	1	12
	Hydrilla	9	100	91	1	5	5	5	5	10	10	10	10	10	10	10	91
	Vallisneria	0	125	125	10	10	10	10	10	10	10	10	10	10	10	15	125
City Park	*Ludwigia*	1	1000	999	50	50	50	50	50	50	50	50	50	50	50	50	600
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	54	2000	1946	50	50	50	50	50	50	50	50	50	50	50	50	600
	Sagittaria	92	300	208	15	15	15	15	15	15	15	15	15	15	15	15	180
	Hygrophila	297	200	0													0
	Hydrilla	228	500	272	12	15	20	25	25	25	25	25	25	25	25	25	272
	Vallisneria	0	50	50	1	1	3	5	5	5	5	5	5	5	5	5	50
I35	*Ludwigia*	0	200	200	10	10	10	10	10	10	10	10	10	10	10	10	120
	Cabomba	0	300	300	15	15	15	15	15	15	15	15	15	15	15	15	180
	Potamogeton	0	300	300	25	25	25	25	25	25	25	25	25	25	25	25	300
	Sagittaria	0	100	100	10	10	10	10	10	10	10	10	5	5	5	5	100
	Hygrophila	0	50	50	1	1	3	5	5	5	5	5	5	5	5	5	50
	Hydrilla	0	100	100	5	5	5	5	10	10	10	10	10	10	10	10	100
	Vallisneria	0	25	25	1	1	1	1	1	1	1	1	2	5	5	5	25

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**

Red shaded boxes represent non-native vegetation which will not be planted. It will simply be allowed to reestablish in isolated areas to meet the existing HCP goals.

Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

TABLE B5. SAN MARCOS AQUATIC VEGETATION RESTORATION SCHEDULE (*Last revised May 2016)*

Proposed restoration timeline designed to meet the **PROPOSED HCP** aquatic vegetation goals over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2)			HCP Term Timeline*												Total
		Current (Dec 2015)	Goal	Needed	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																	
Spring Lake Dam	*Ludwigia*	0	100	100	10	10	10	10	10	10	10	10	10	10			100
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	200	200	25	25	25	25	25	15	15	15	15	15			200
	Sagittaria	7	200	193	25	20	20	20	20	20	20	20	20	10			195
	Heteranthera	0	100	100	10	10	10	10	10	10	10	10	10	10			100
	Zizania	598	700	102	25	25	15	15	15	10							105
City Park	*Ludwigia*	1	150	149	25	25	20	20	10	10	10	10	10	10			150
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	54	1450	1396	125	115	130	125	125	150	150	150	155	175			1400
	Sagittaria	92	300	208	15	15	15	15	25	25	25	25	25	25			210
	Heteranthera	7	100	93	10	10	10	10	10	10	10	10	10	5			95
	Zizania	1,261	1,750	489	40	75	75	75	75	50	50	50					490
I35	*Ludwigia*	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	150	150	15	15	15	15	15	15	15	15	15	15			150
	Sagittaria	0	150	150	30	10	10	10	10	10	10	10	25	25			150
	Heteranthera	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Zizania	28	600	572	75	75	75	75	75	75	75	50					575

*** Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**
Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

TABLE B6. SAN MARCOS AQUATIC VEGETATION RESTORATION SCHEDULE *(Last revised May 2016)*

Proposed restoration timeline designed to meet the **PROPOSED COMBINED HCP** aquatic vegetation goals (Including Texas wild rice) and defined management objective via Restoration Reaches over time in the San Marcos system.

Reaches	Species	Meters squared of aquatic vegetation (m^2)			HCP Term Timeline*												Total
		Current (Dec 2015)	Goal	Needed	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
LTBG Reaches																	
Spring Lake Dam	*Ludwigia*	0	100	100	10	10	10	10	10	10	10	10	10	5	5		100
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	200	200	25	25	25	25	25	15	15	15	15	10	5		200
	Sagittaria	7	200	193	25	20	20	20	20	20	20	20	20	5	5		195
	Heteranthera	0	100	100	10	10	10	10	10	10	10	10	10	5	5		100
	Zizania	598	700	102	25	25	15	15	15	10							105
City Park	*Ludwigia*	1	150	149	25	25	20	20	10	10	10	10	10	5	5		150
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	54	1450	1396	150	100	100	100	100	100	100	125	125	125	125	150	1400
	Sagittaria	92	300	208	15	15	15	15	25	25	25	25	25	15	10		210
	Heteranthera	7	100	93	10	10	10	10	10	10	10	10	10	5			95
	Zizania	1,261	1,750	489	40	75	75	75	75	50	50	50					490
I35	*Ludwigia*	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Cabomba	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Potamogeton	0	150	150	15	15	15	15	15	15	15	15	15	10	5		150
	Sagittaria	0	150	150	30	10	10	10	10	10	10	10	25	15	10		150
	Heteranthera	0	50	50	5	5	5	5	5	5	5	5	5	5			50
	Zizania	28	600	572	75	75	75	75	75	75	75	50					575

* **Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the LTBG reach goals over time.**

Additionally, the ENTIRE HCP BUDGET for this mitigation measure is anticipated to be use each year to strive towards accomplishing the proportional expansion goal as it is presently undefined.

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

TABLE B6 concluded. SAN MARCOS AQUATIC VEGETATION RESTORATION SCHEDULE (*Last revised May 2016)*

Proposed restoration timeline designed to meet the **PROPOSED COMBINED HCP** aquatic vegetation goals (Including Texas wild rice) and defined management objective via Restoration Reaches over time in the San Marcos system.

Reaches	**Species**	**Meters squared of aquatic vegetation (m^2)**			**HCP Term Timeline***												**Total**
		Current (Dec 2015)	**Goal**	**Needed**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	
Restoration Reaches																	
Sewell Park	*Ludwigia*	0	25	25												25	25
	Cabomba	14	25	11												15	15
	Potamogeton	116	150	34	40												40
	Sagittaria	2	25	23						10	15						25
	Heteranthera	0	25	25						10	15						25
	Zizania	1,169	1,100	0													0
Below Sewell to City Park	*Ludwigia*	0	50	50								15	15	15	5		50
	Cabomba	0	50	50								15	15	15	5		50
	Potamogeton	172	500	328								50	75	75	75	55	330
	Sagittaria	727	700	0													0
	Heteranthera	6	50	44								15	10	10	10		45
	Zizania	2,247	2,300	53								25		15	15		55
Hopkins St - Snake Island	*Ludwigia*	0	50	50									10	10	15	15	50
	Cabomba	0	50	50									10	10	15	15	50
	Potamogeton	269	475	206	50								20	20	55	65	210
	Sagittaria	620	750	130	50								20	20	20	20	130
	Heteranthera	0	50	50									10	10	15	15	50
	Zizania	693	950	257	35						50	35	35	35	35	35	260
Cypress Island - Rio Vista Dam	*Ludwigia*	0	50	50	10	10	10	10	10								50
	Cabomba	0	50	50	10	5	5	5	5	5	5	5	5				50
	Potamogeton	0	150	150	15	10	10	25	10	20	20			25	15		150
	Sagittaria	5	50	45	15	5	5	5	5	5	5						45
	Heteranthera	63	100	37	10	5	5	5	5	5	5						40
	Zizania	122	350	228	50	50	50	25	25	25	5						230
I35 expanded	*Ludwigia*	8	50	42		10	10	10	12								42
	Cabomba	33	100	67		25	25	10	10								70
	Potamogeton	0	250	250		30	25	25	25	50	20			25	25	25	250
	Sagittaria	355	450	95		25	25	10	10	10	15						95
	Heteranthera	0	50	50		10	10	5	10	10	5						50
	Zizania	57	450	393		50	50	50	50	50	50	50	45				395
Additional Texas wild-rice Reaches																	
Spring Lake	Zizania	31	1,000	969	50	100	100	100	100	100	100	100	100	100	20		970
Below I35	Zizania	0	280	280		20	20	30	30	30	30	30	30	30	30		280
*** Light grey shaded boxes with no numbers will still require aquatic gardening, plant propagation and supplemental plantings to support maintaining the goals over time.**																	

ASSUMPTIONS:

1) Restoration efforts will proceed smoothly with no major setbacks or resets such as floods, dam repairs, etc.
2) Anthropogenic factors such as recreational disturbances and urban runoff are managed.
3) Concurrent aquatic plant propagation, gardening, and maintenance will occur throughout the HCP timeline.
4) Non-native vegetation removal (and replacement with natives) will occur in certain areas outside of the LTBG and Restoration reaches in order to mitigate reestablishment on non-natives.
5) No significant interuptions due to HCP Provision M.
6) Propagation rates remain sufficient to replace denuded area of non-native aquatic vegetation
7) Mapping to compare against goals will be conducted annually each Fall.

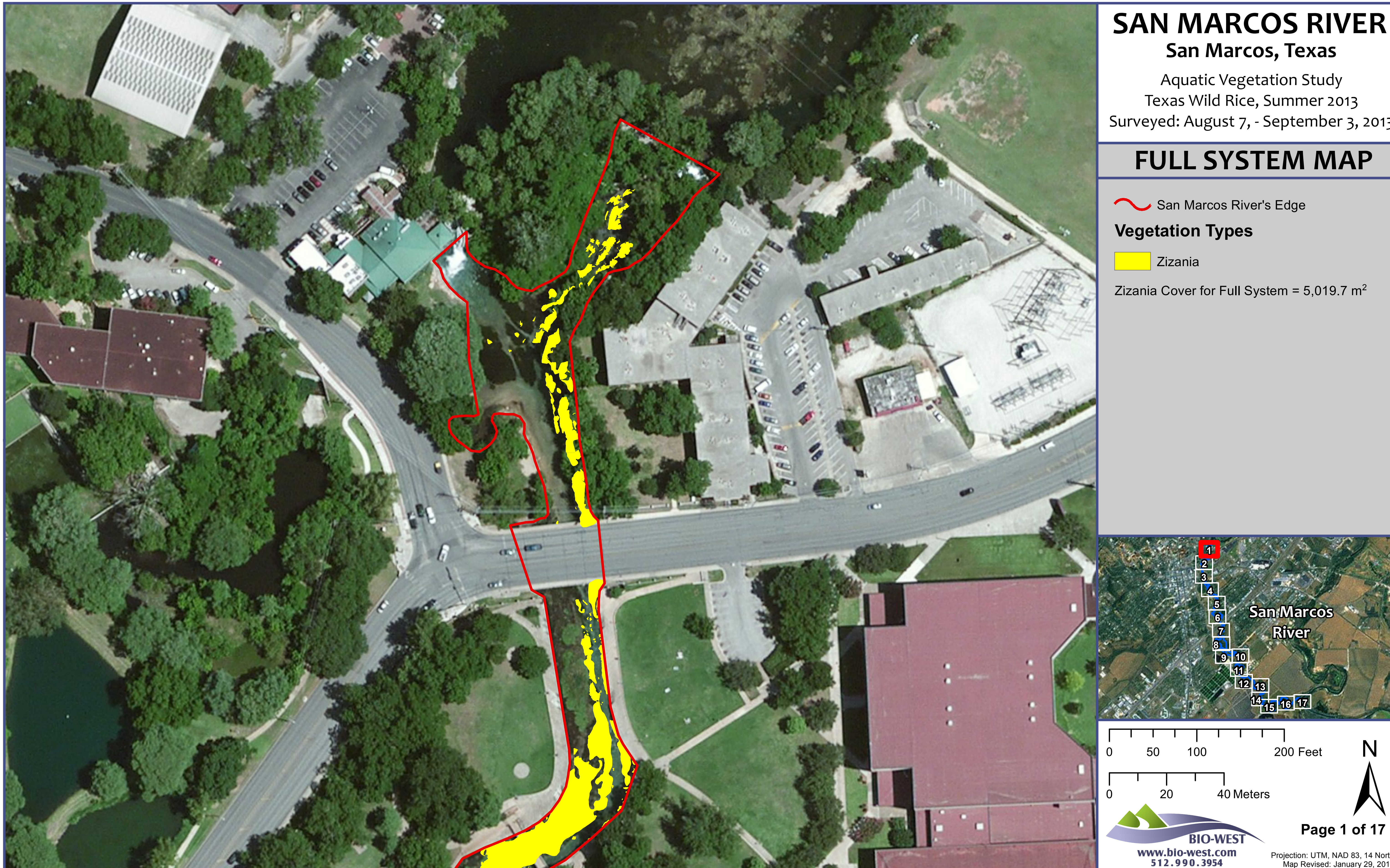
APPENDIX C
TEXAS WILD RICE FULL SYSTEM MAPS (2013 – 2015)

2013

SAN MARCOS RIVER
San Marcos, Texas

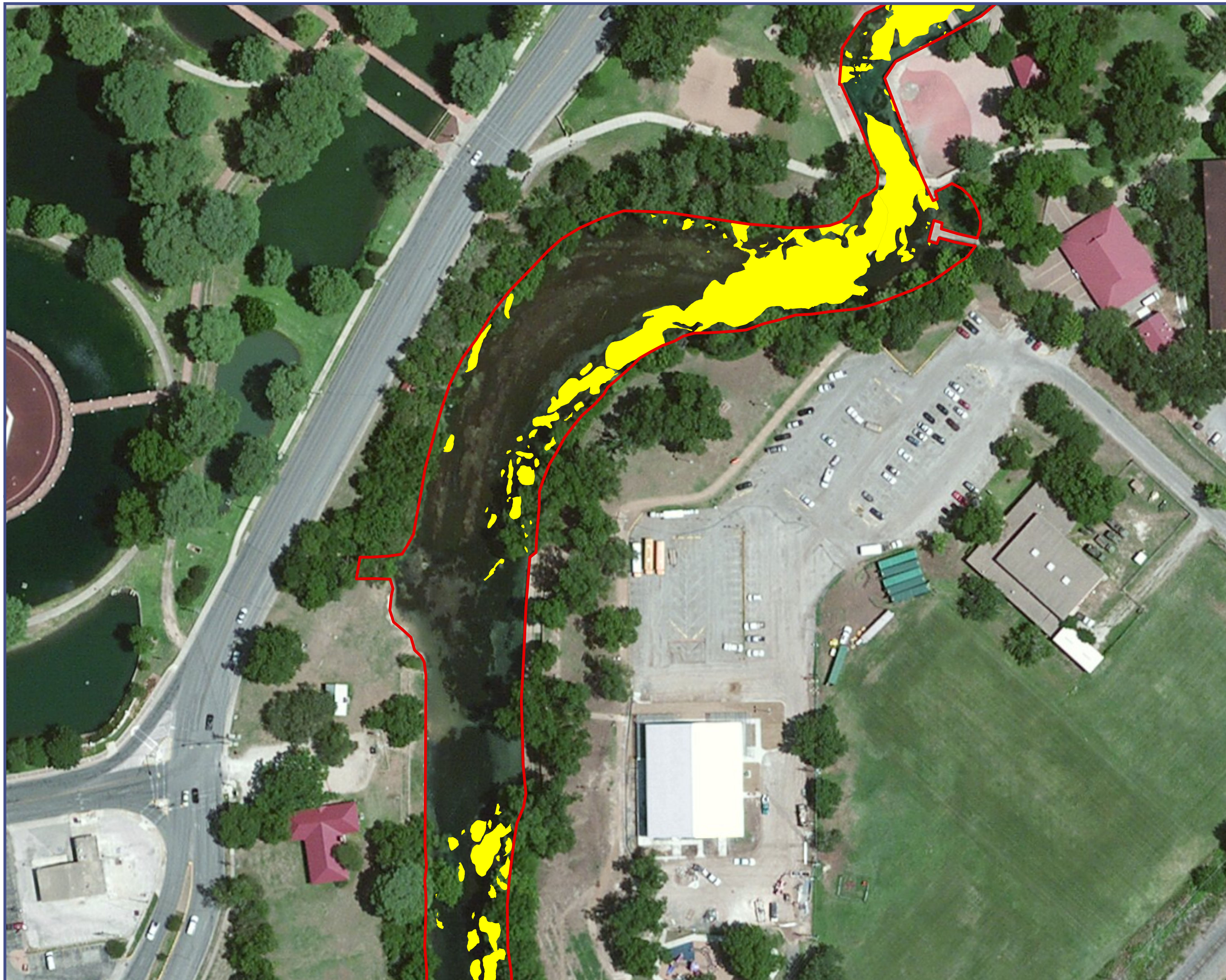
Aquatic Vegetation Study
Texas Wild Rice, Summer 2013
Surveyed: August 7, - September 3, 2013

FULL SYSTEM MAP



BIO-WEST
www.bio-west.com
512.990.3954

Projection: UTM, NAD 83, 14 North
Map Revised: January 29, 2014



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San Marcos, Texas

Aquatic Vegetation Study
Texas Wild Rice, Summer 2013
Surveyed: August 7, - September 3, 2013

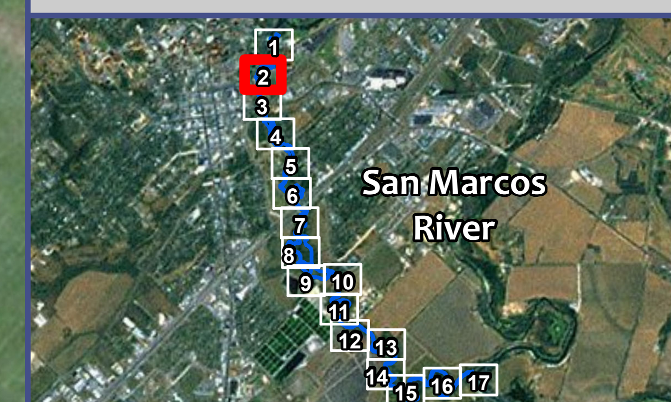
FULL SYSTEM MAP

San Marcos River's Edge

Vegetation Types

Zizania

Zizania Cover for Full System = 5,019.7 m^2



0 50 100 200 Feet

0 20 40 Meters

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BIO-WEST
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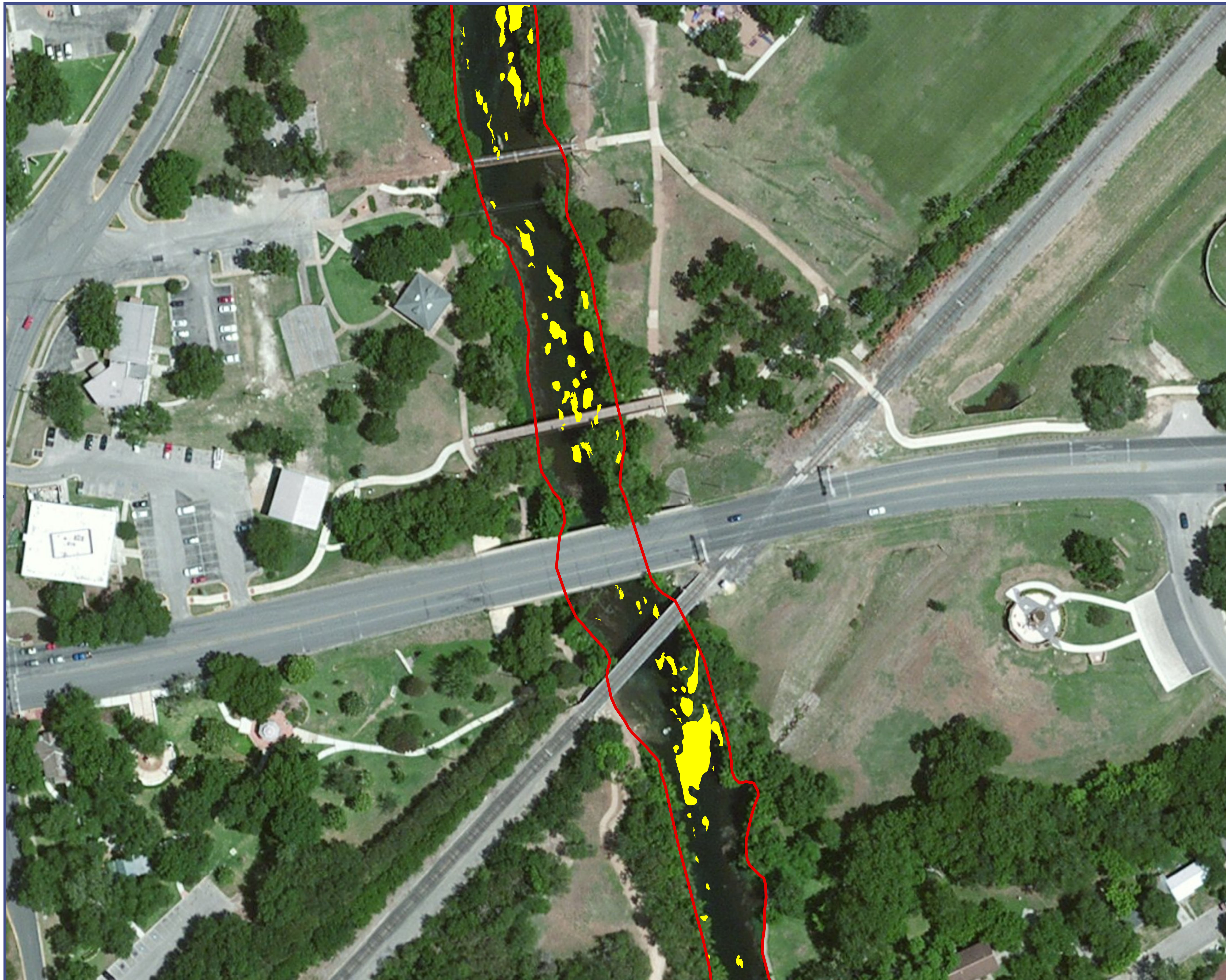
512.990.3954

Projection: UTM, NAD 83, 14 North
Map Revised: January 29, 2014



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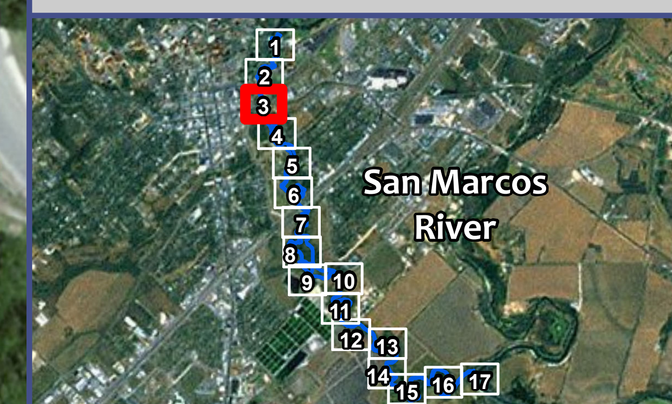

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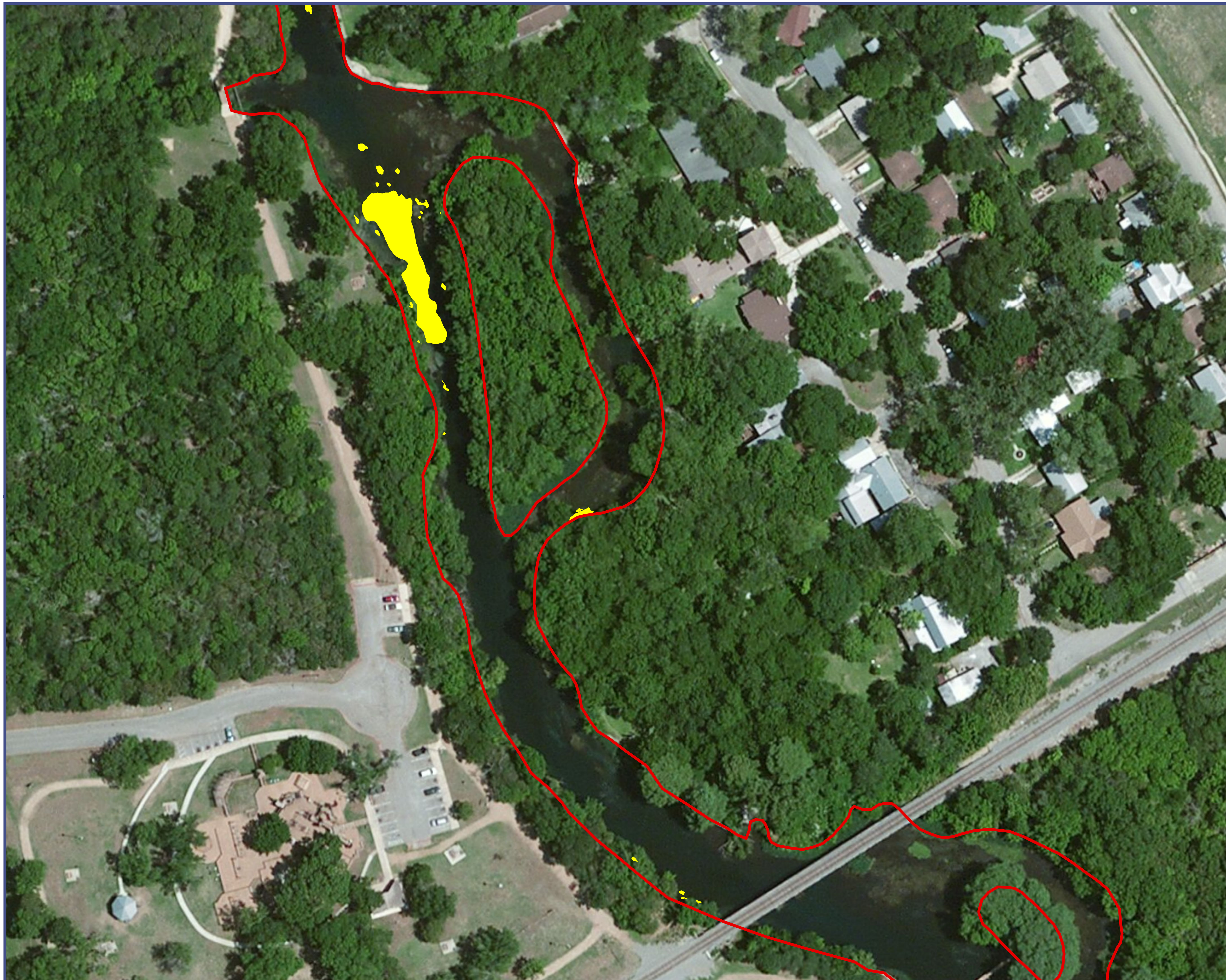

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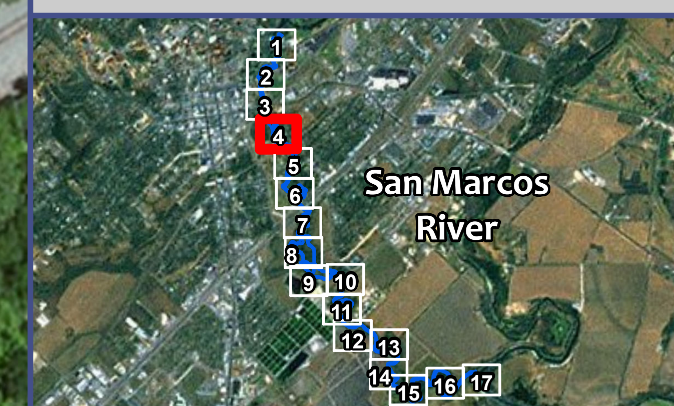

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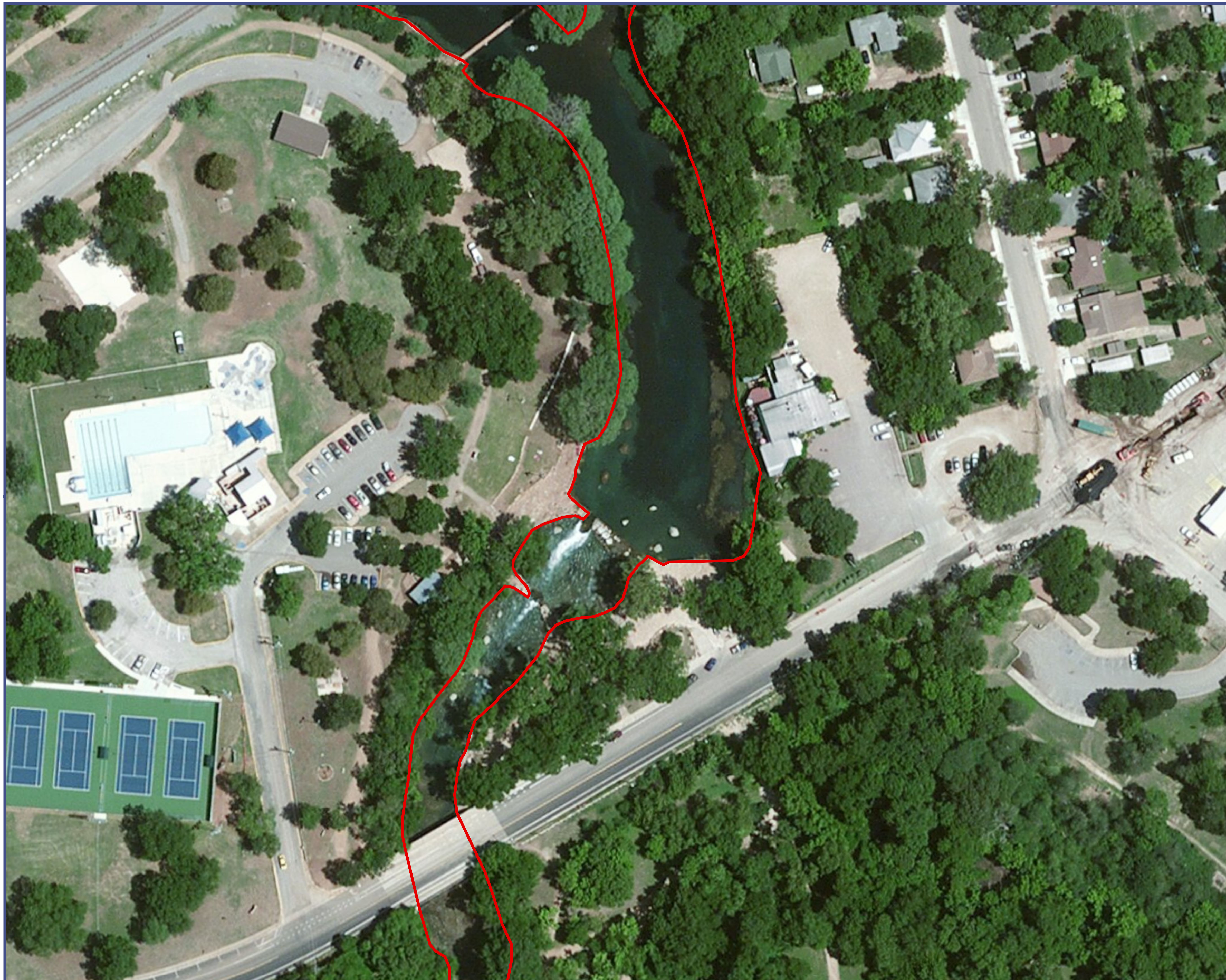

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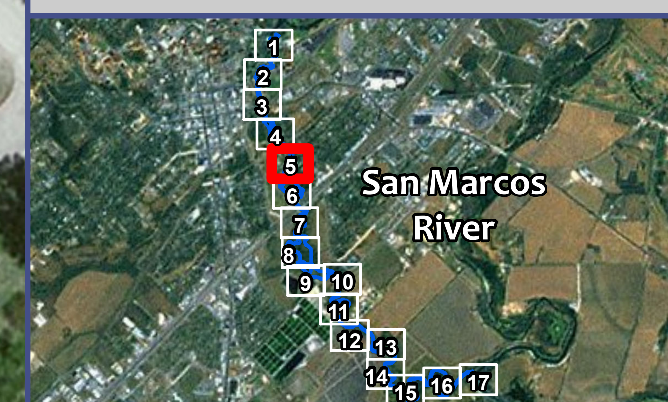

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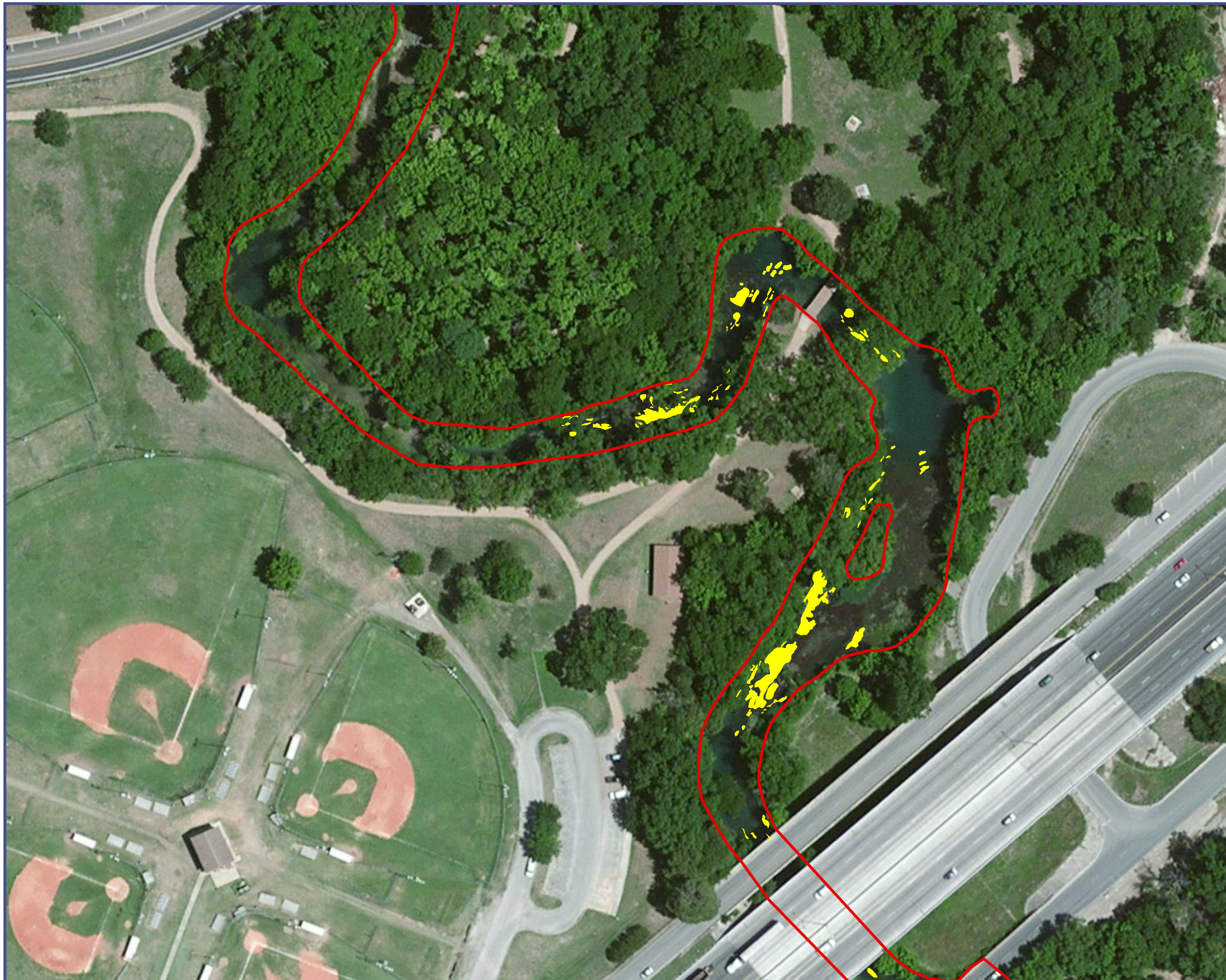

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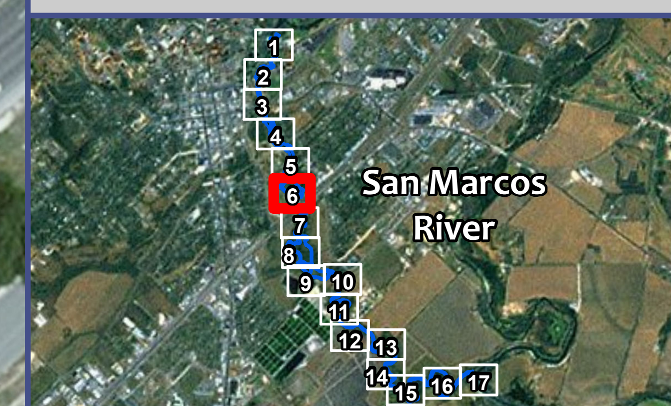

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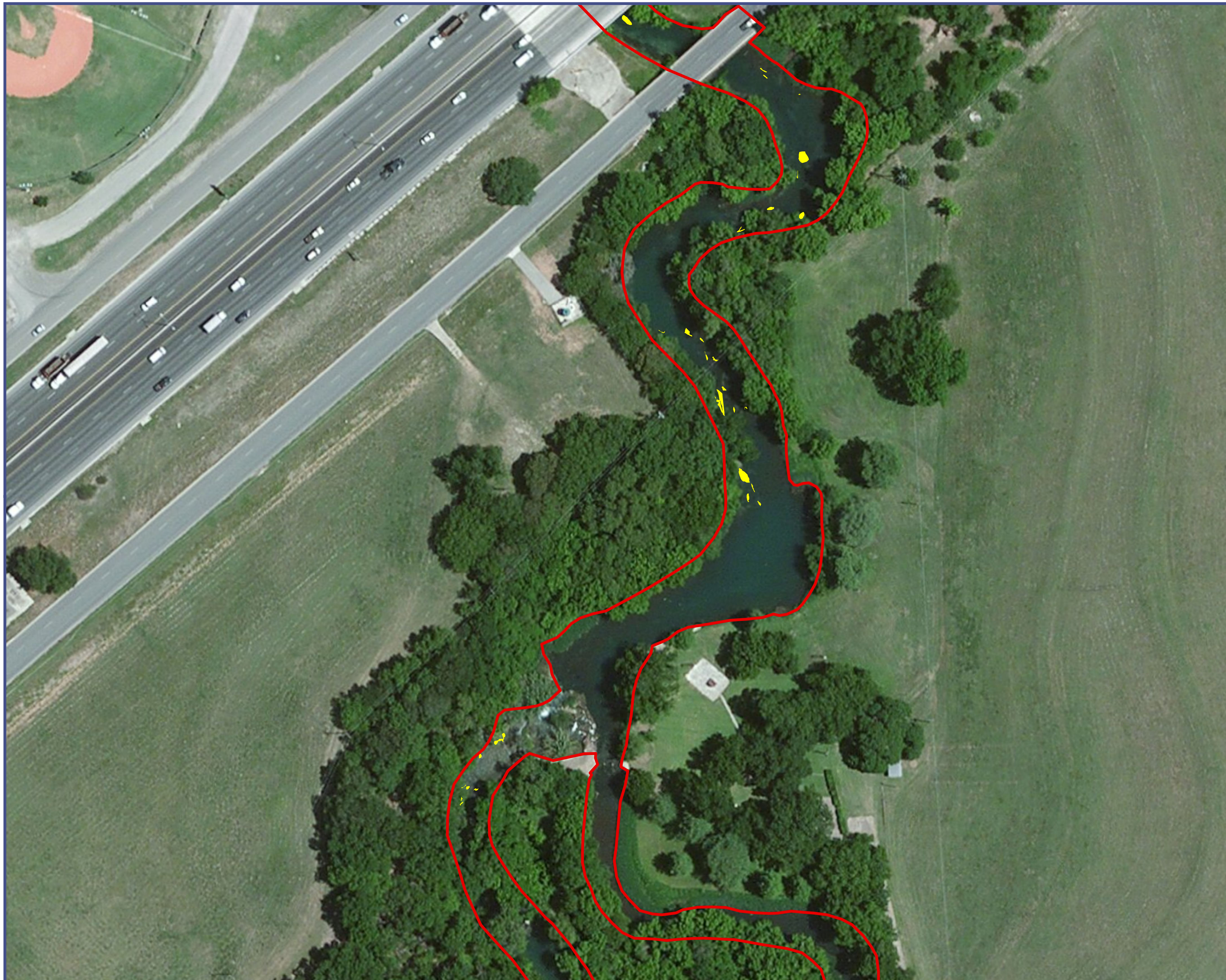

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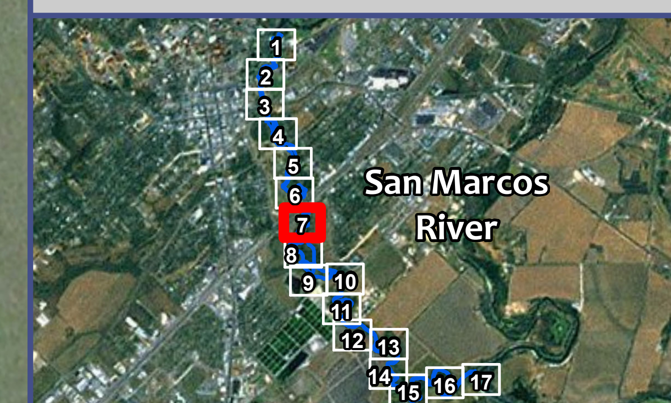

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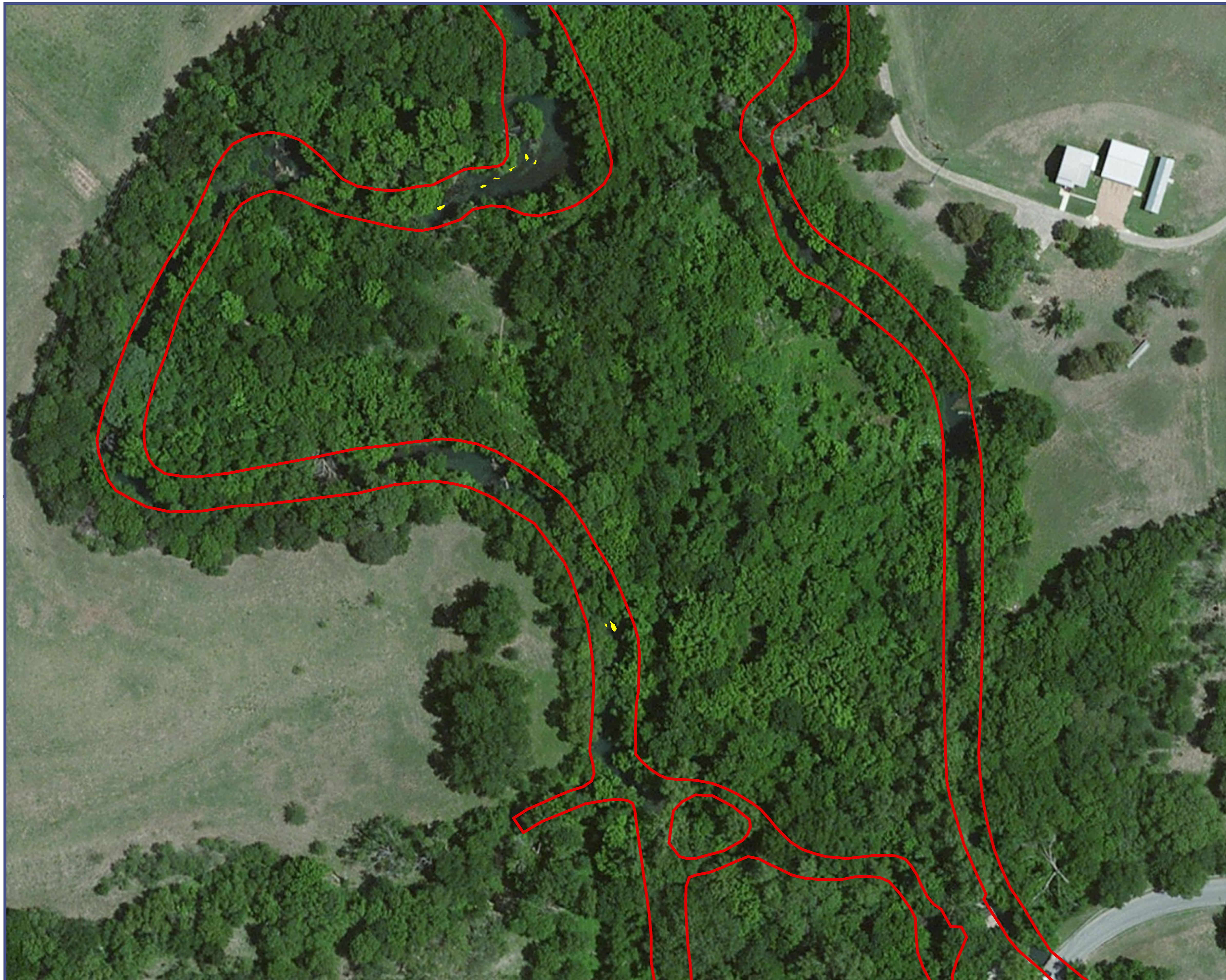

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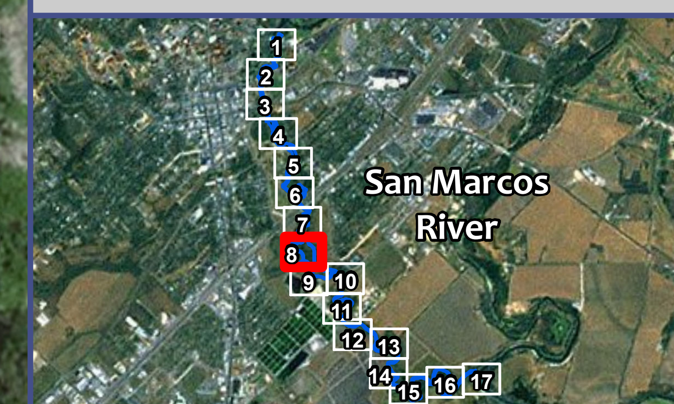

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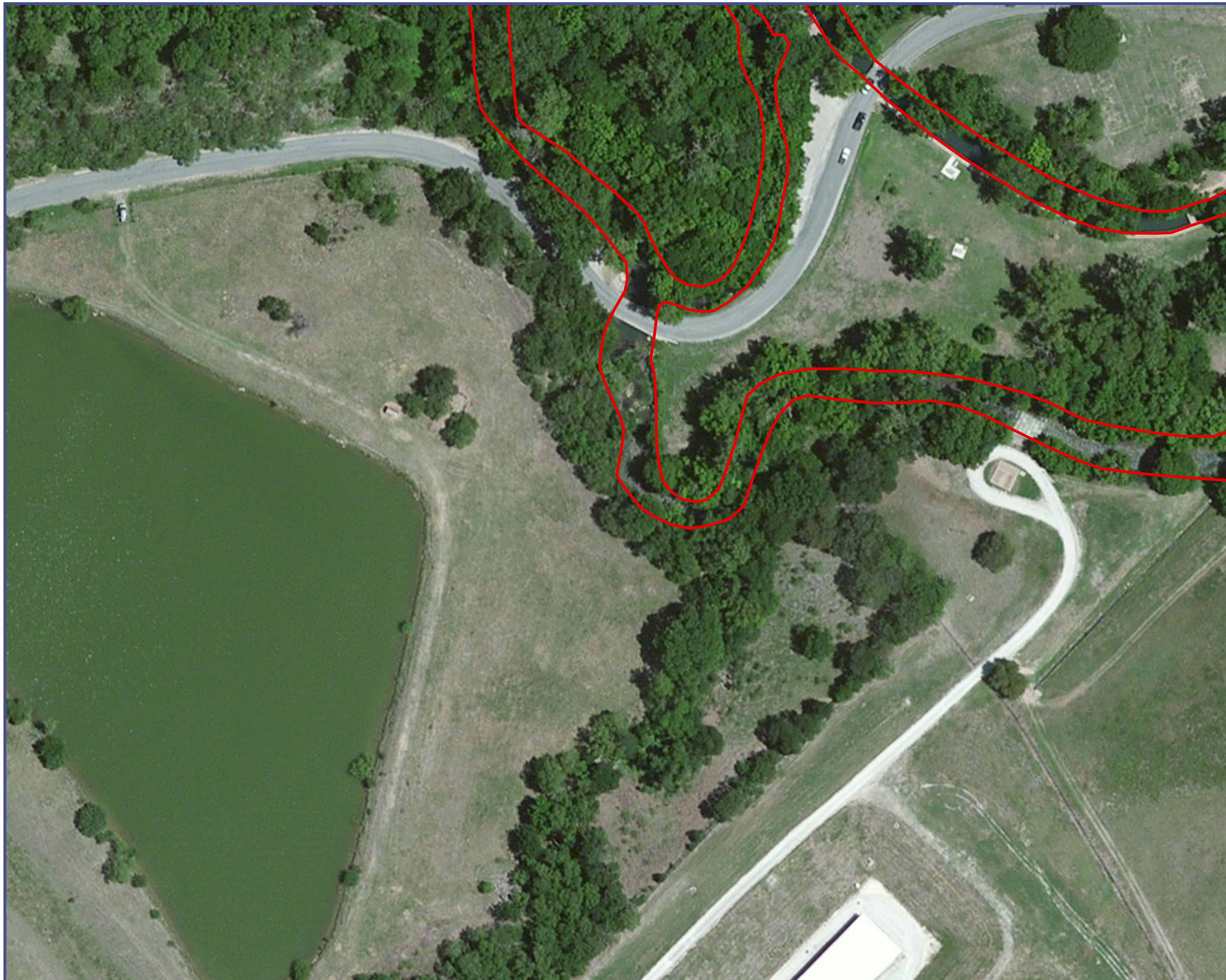

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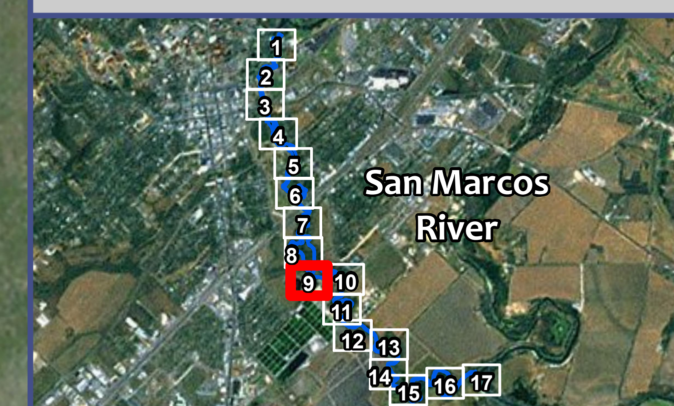

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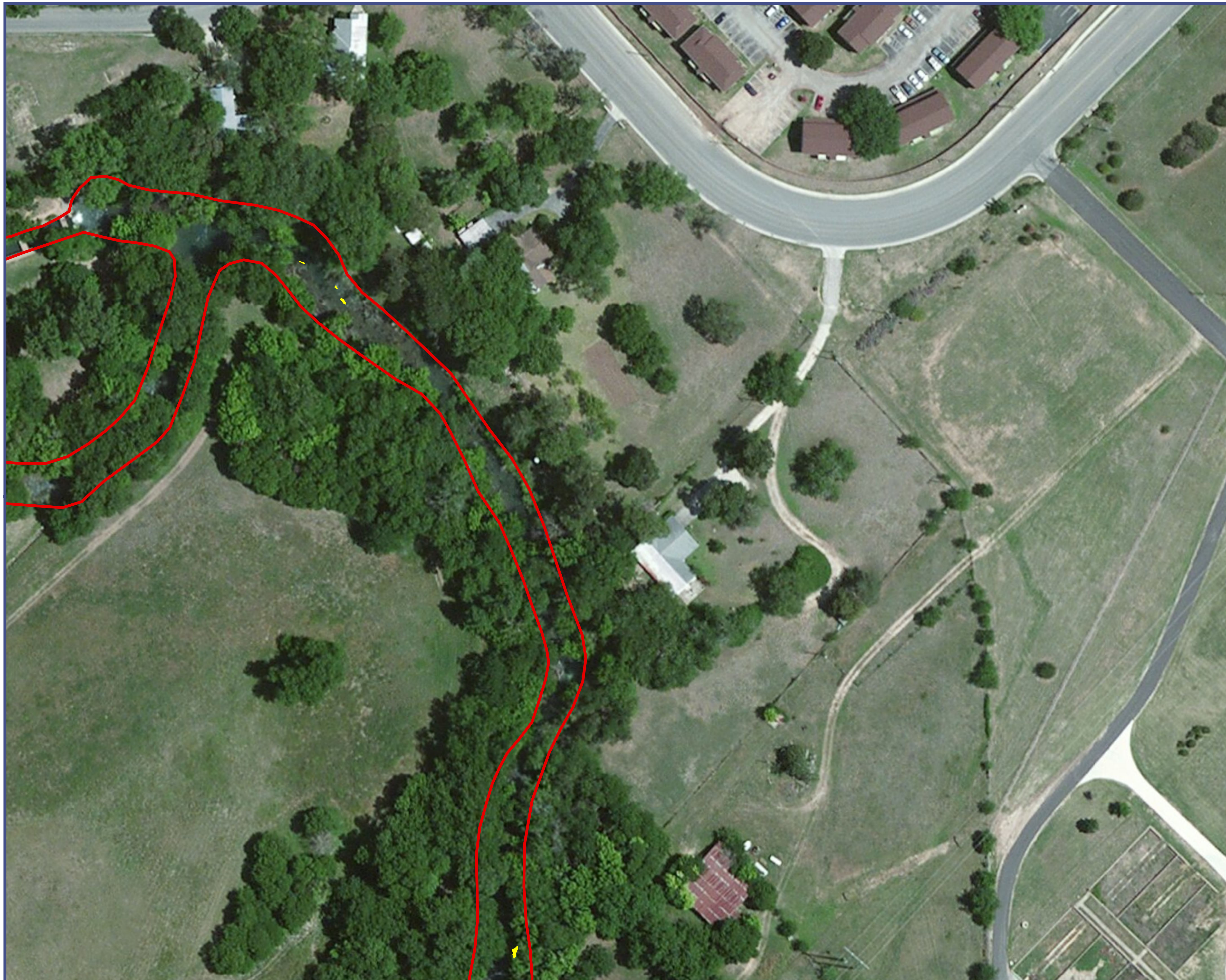

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San Marcos, Texas

Aquatic Vegetation Study
Texas Wild Rice, Summer 2013
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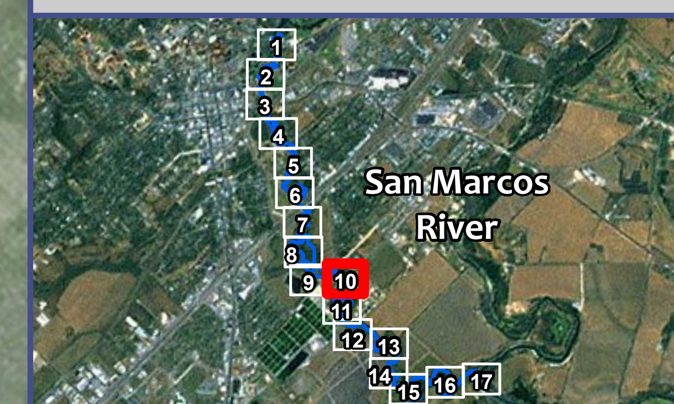

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Aquatic Vegetation Study
Texas Wild Rice, Summer 2013
Surveyed: August 7, - September 3, 2013

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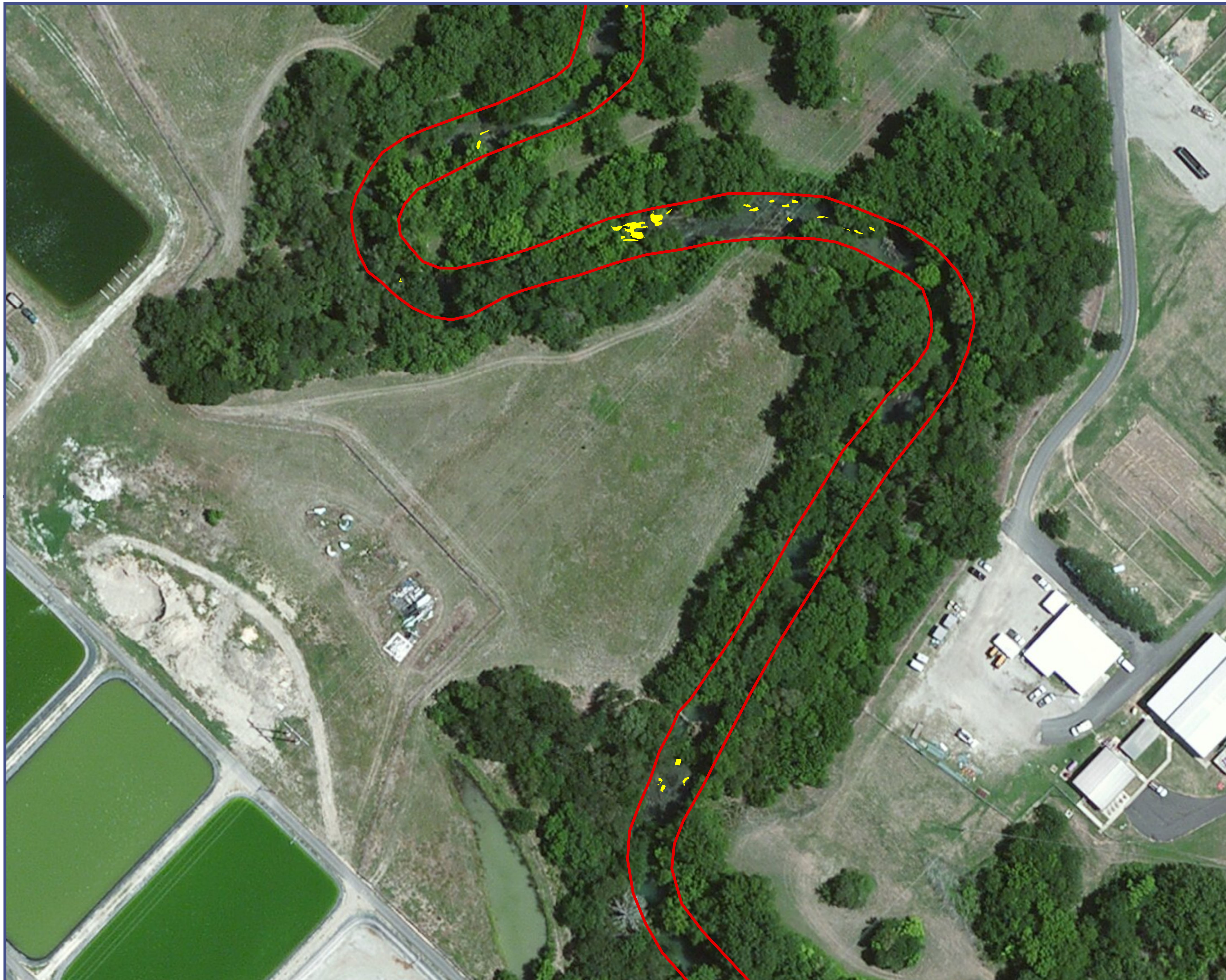

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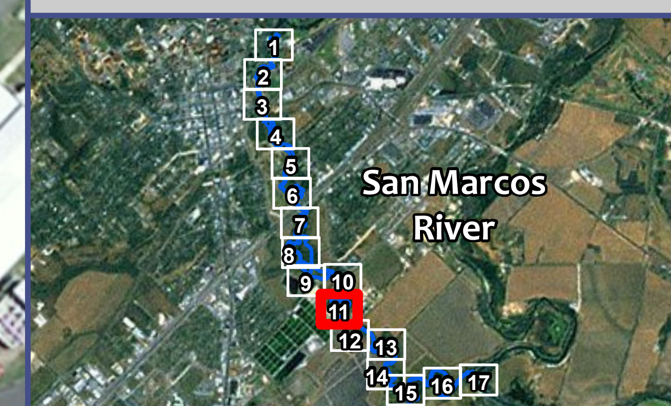

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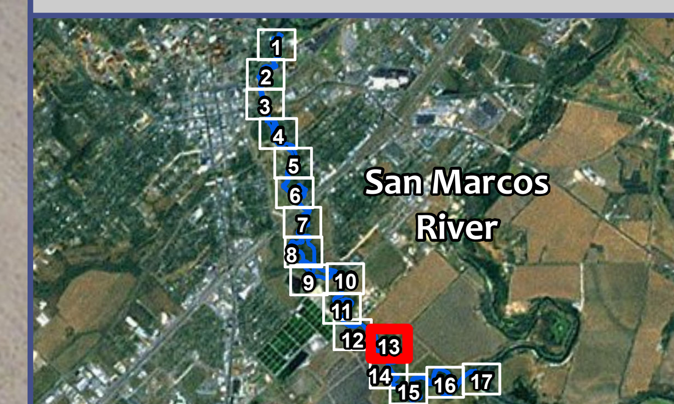

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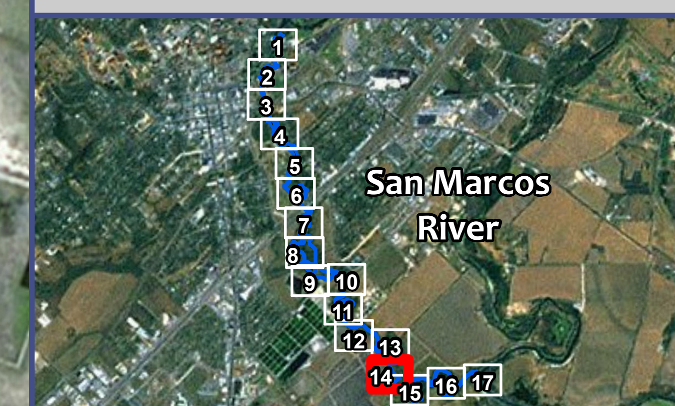

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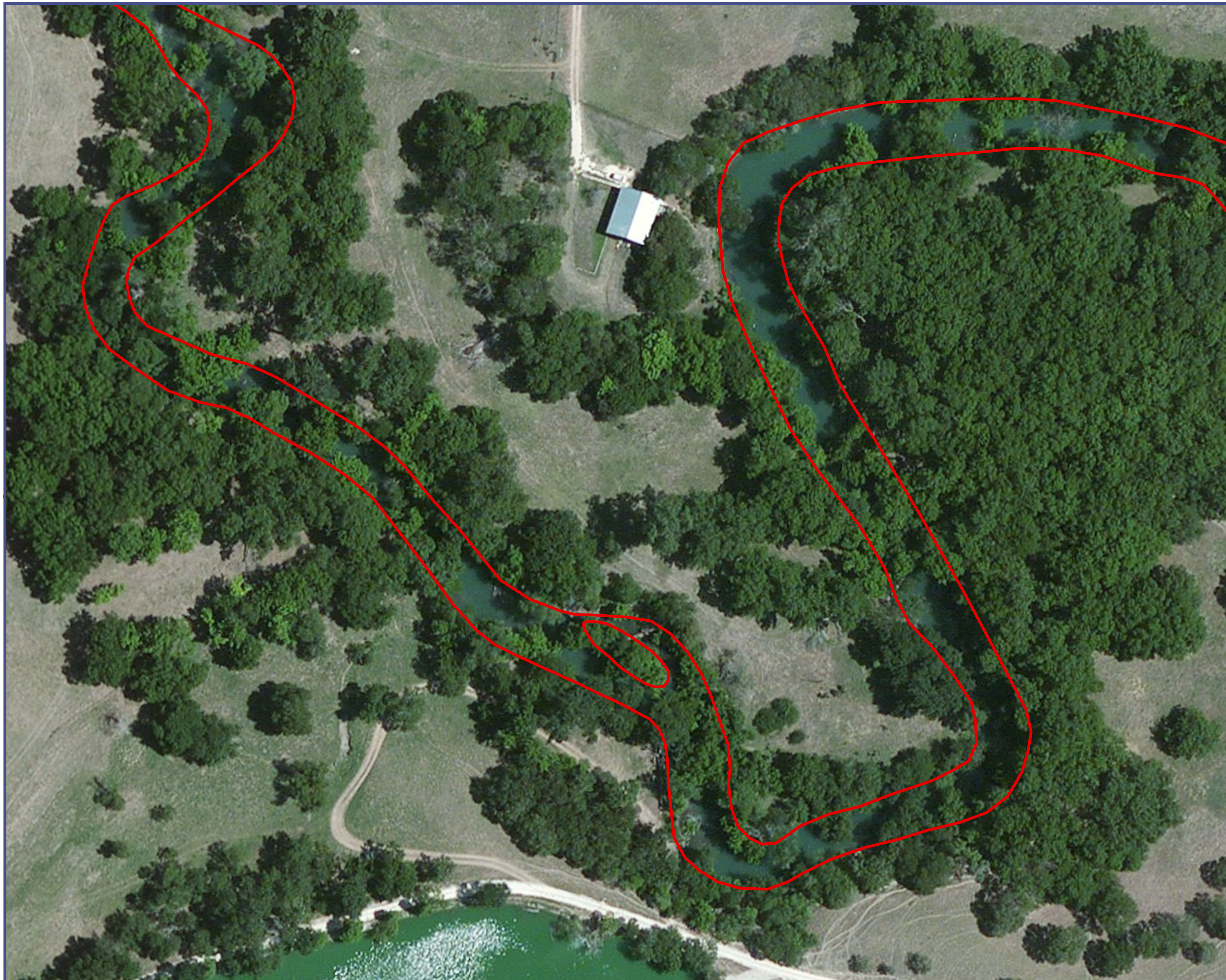

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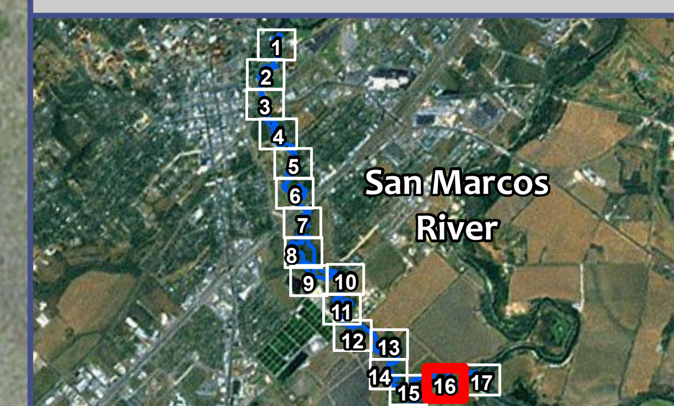

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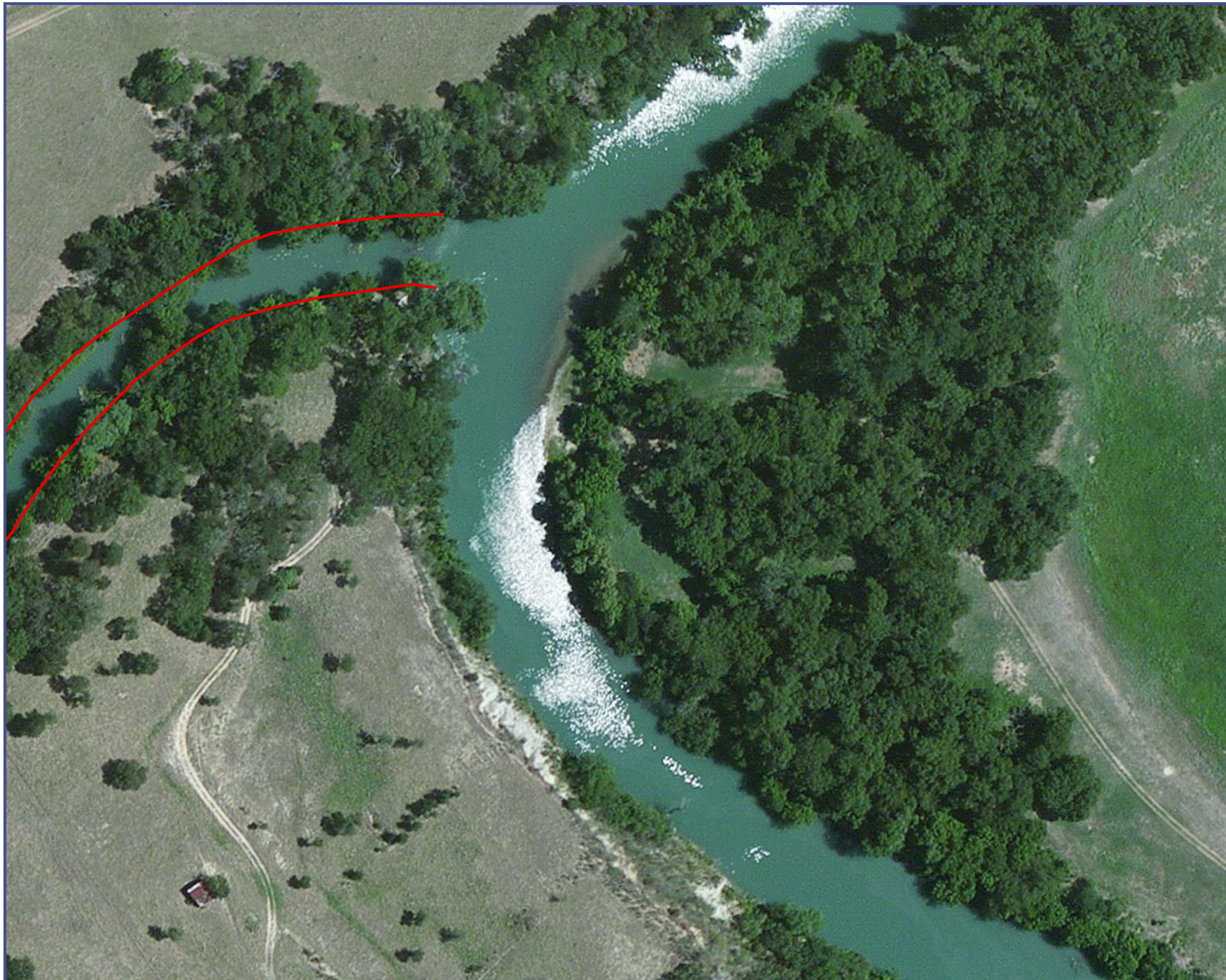

SAN MARCOS RIVER
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FULL SYSTEM MAP

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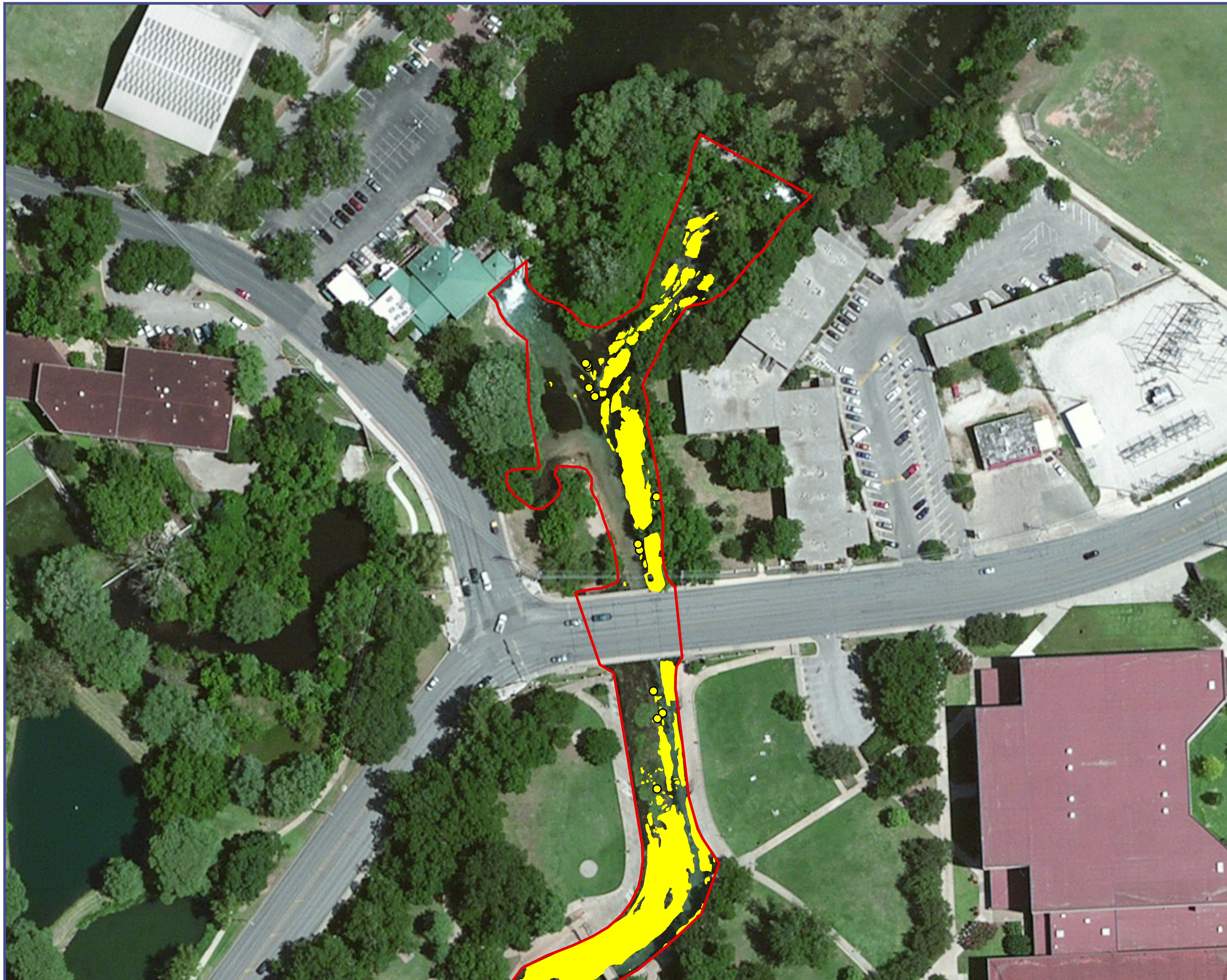

SAN MARCOS RIVER

San Marcos, Texas

Aquatic Vegetation Study
Texas Wild Rice, Summer 2014

FULL SYSTEM MAP

San Marcos River's Edge

Vegetation Types

Zizania

Zizania Cover for Full System = 6,203.2 m^2

0 50 100 200 Feet

0 20 40 Meters

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SAN MARCOS RIVER
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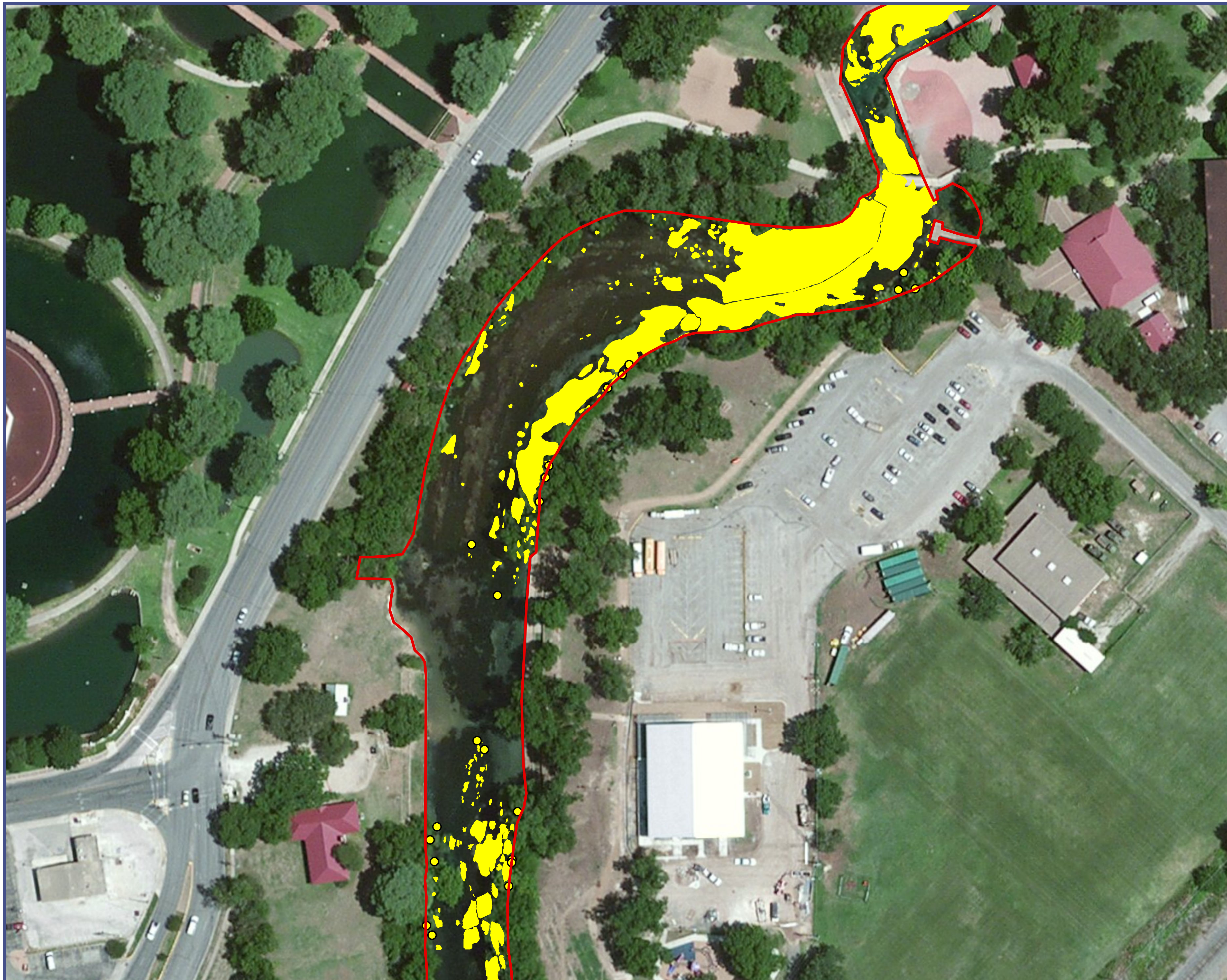

FULL SYSTEM MAP

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Vegetation Types

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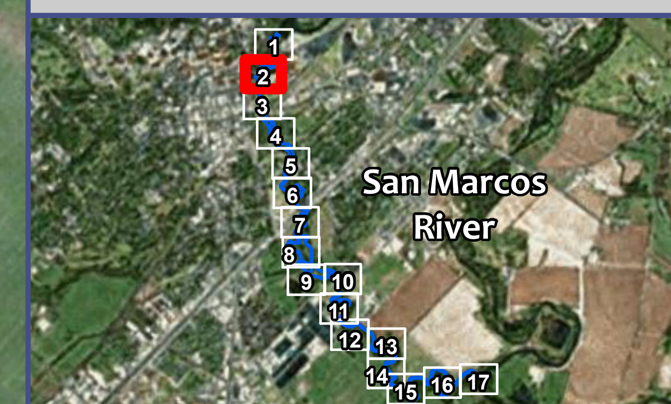

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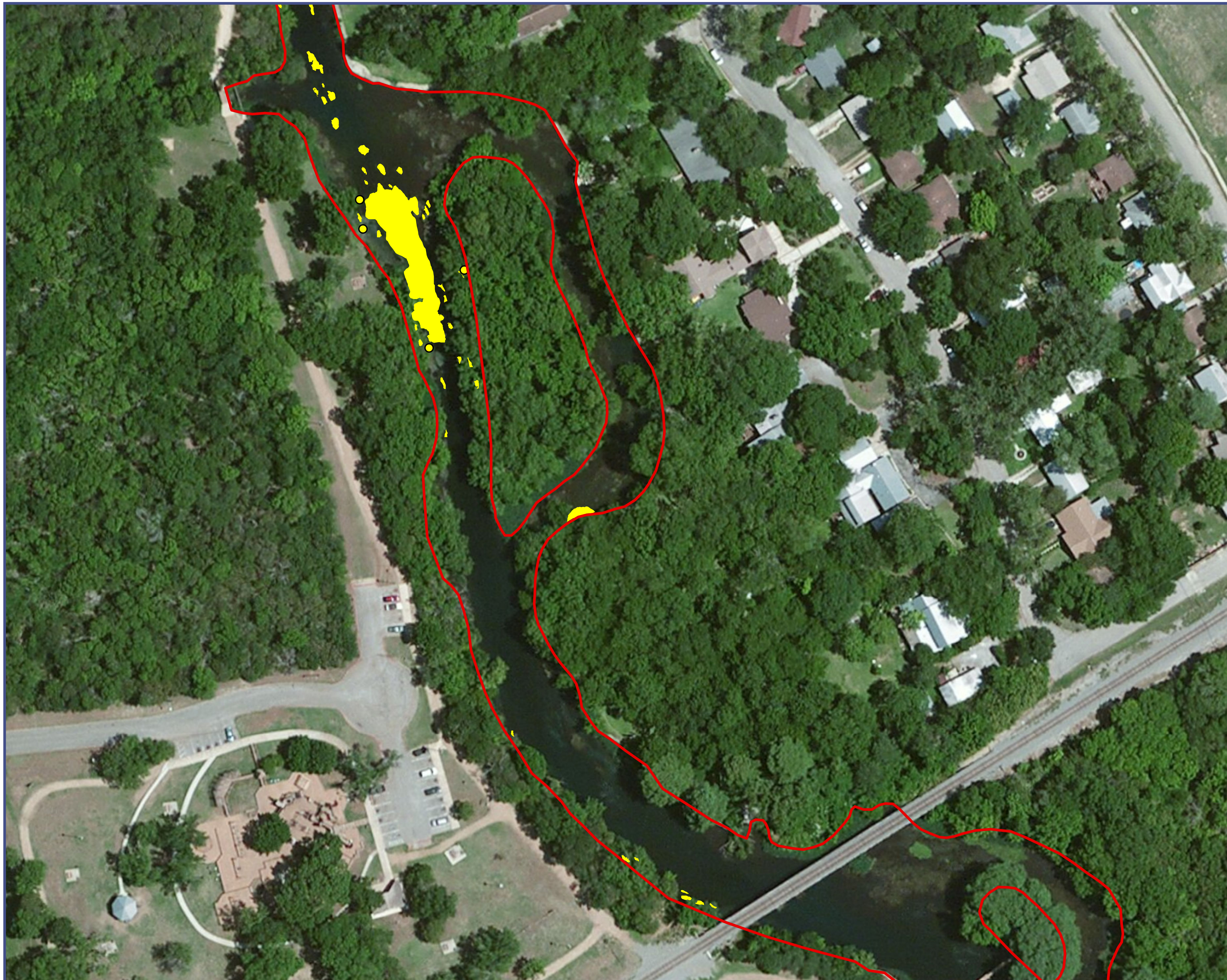

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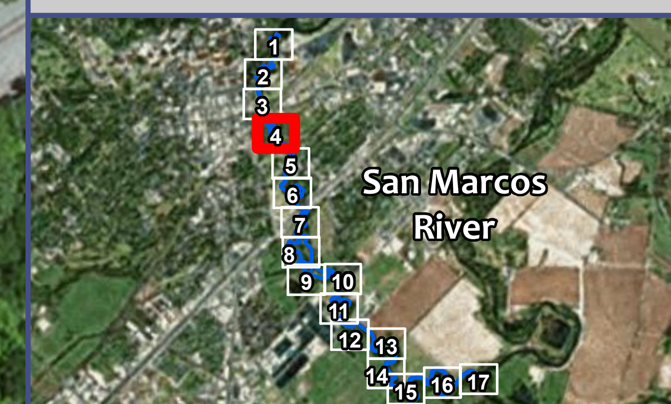

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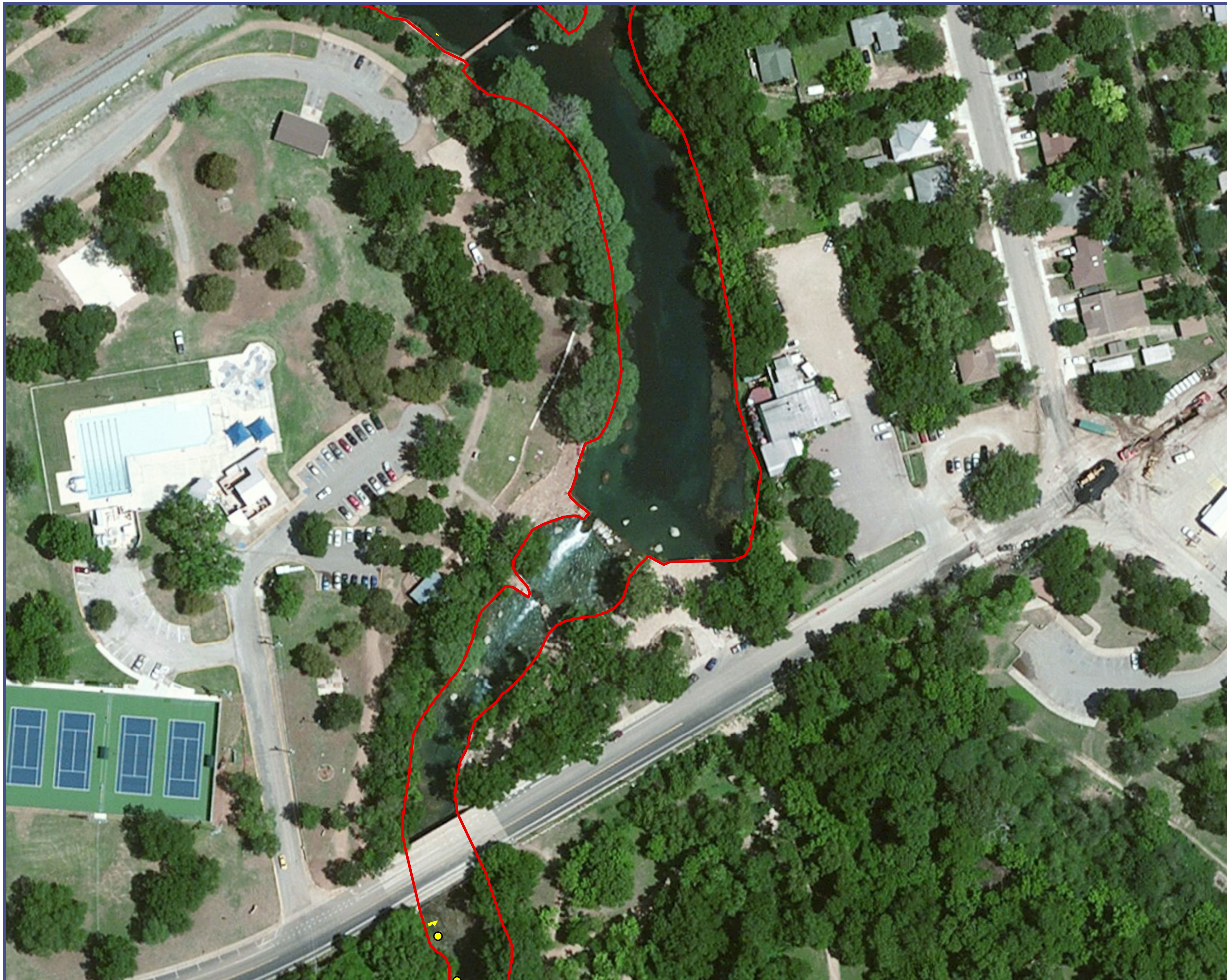

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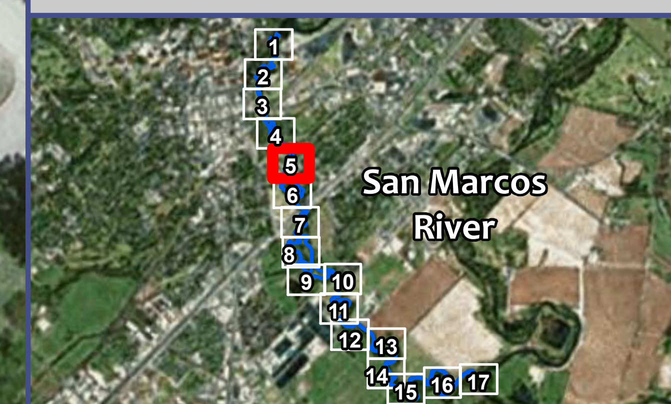

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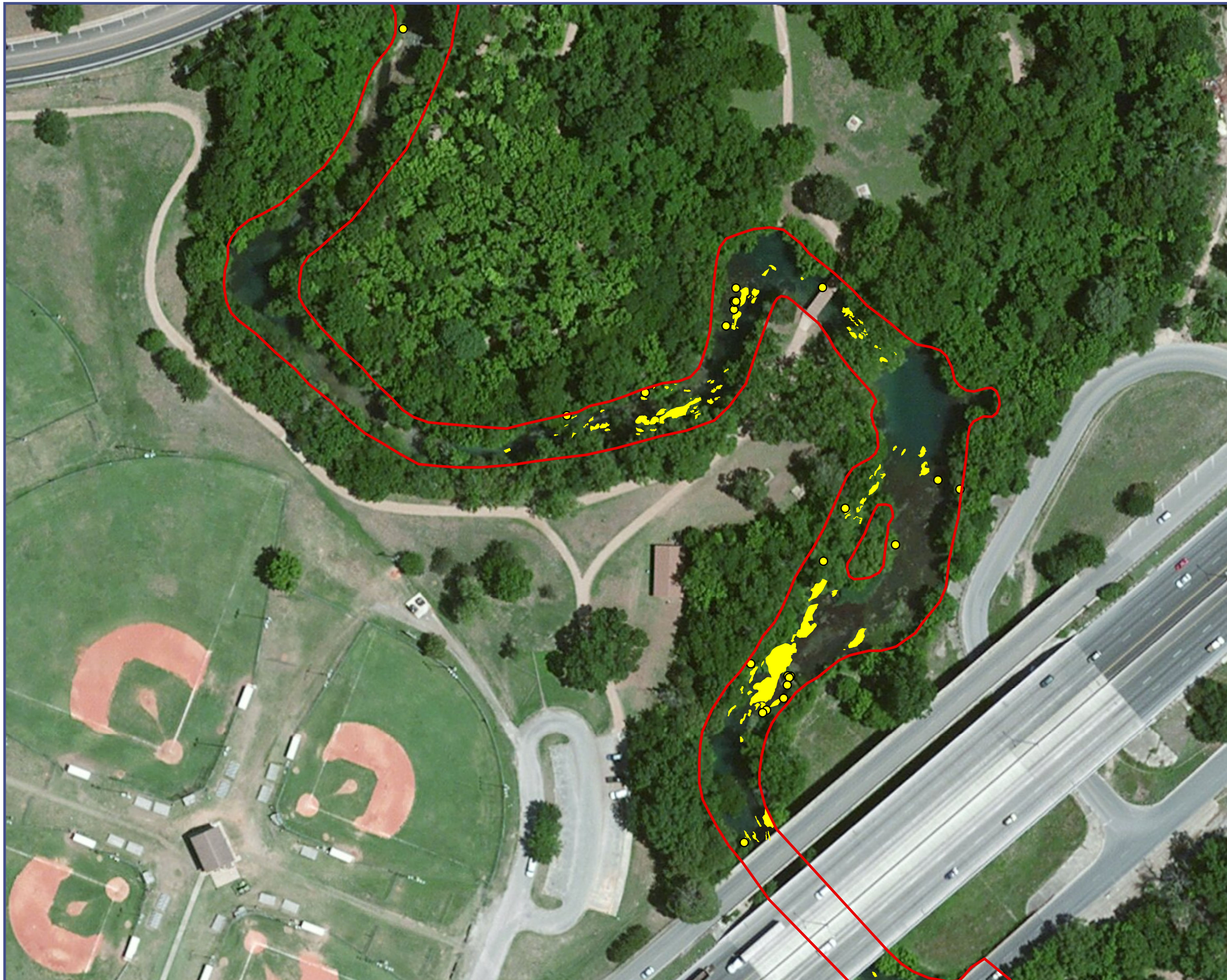

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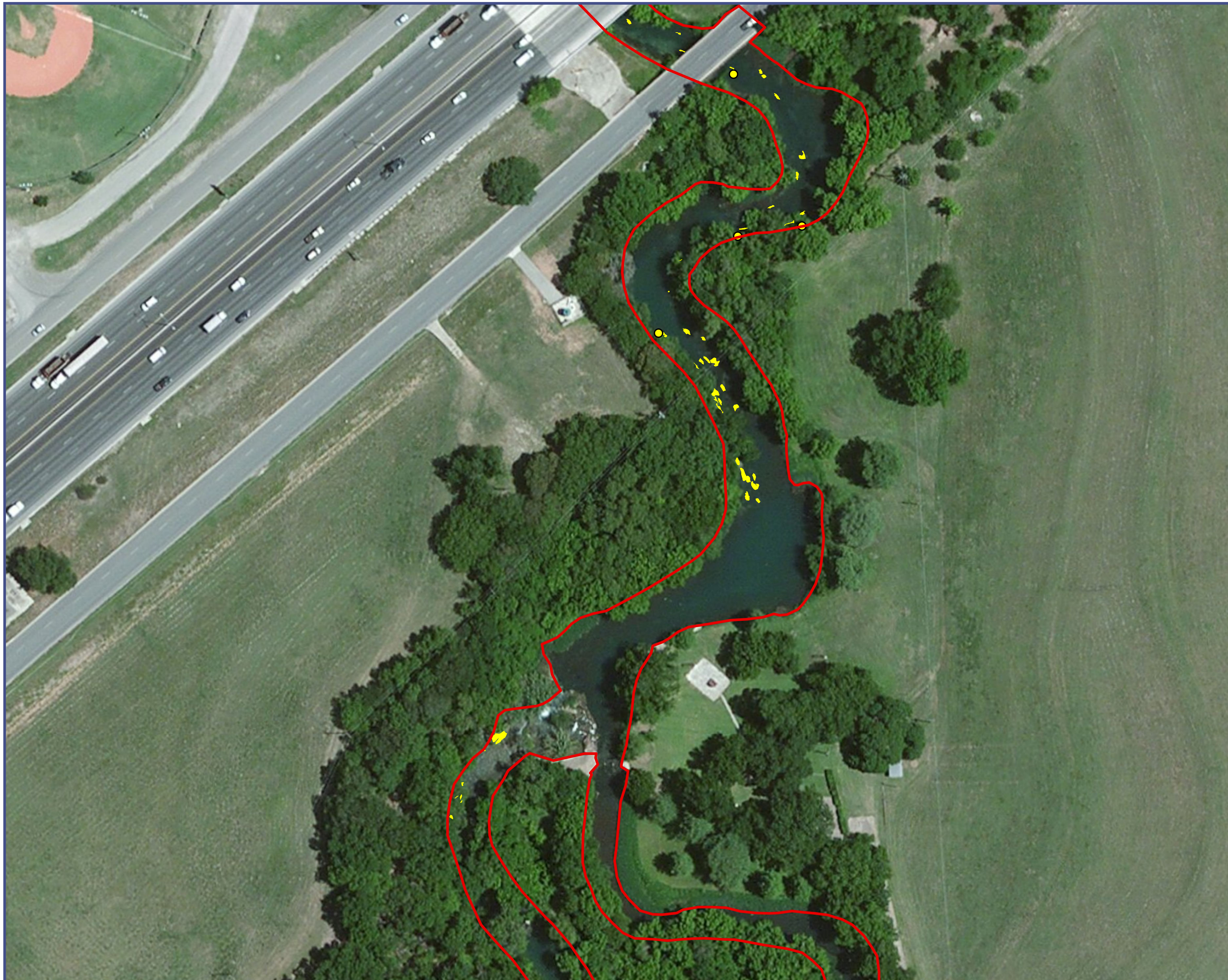

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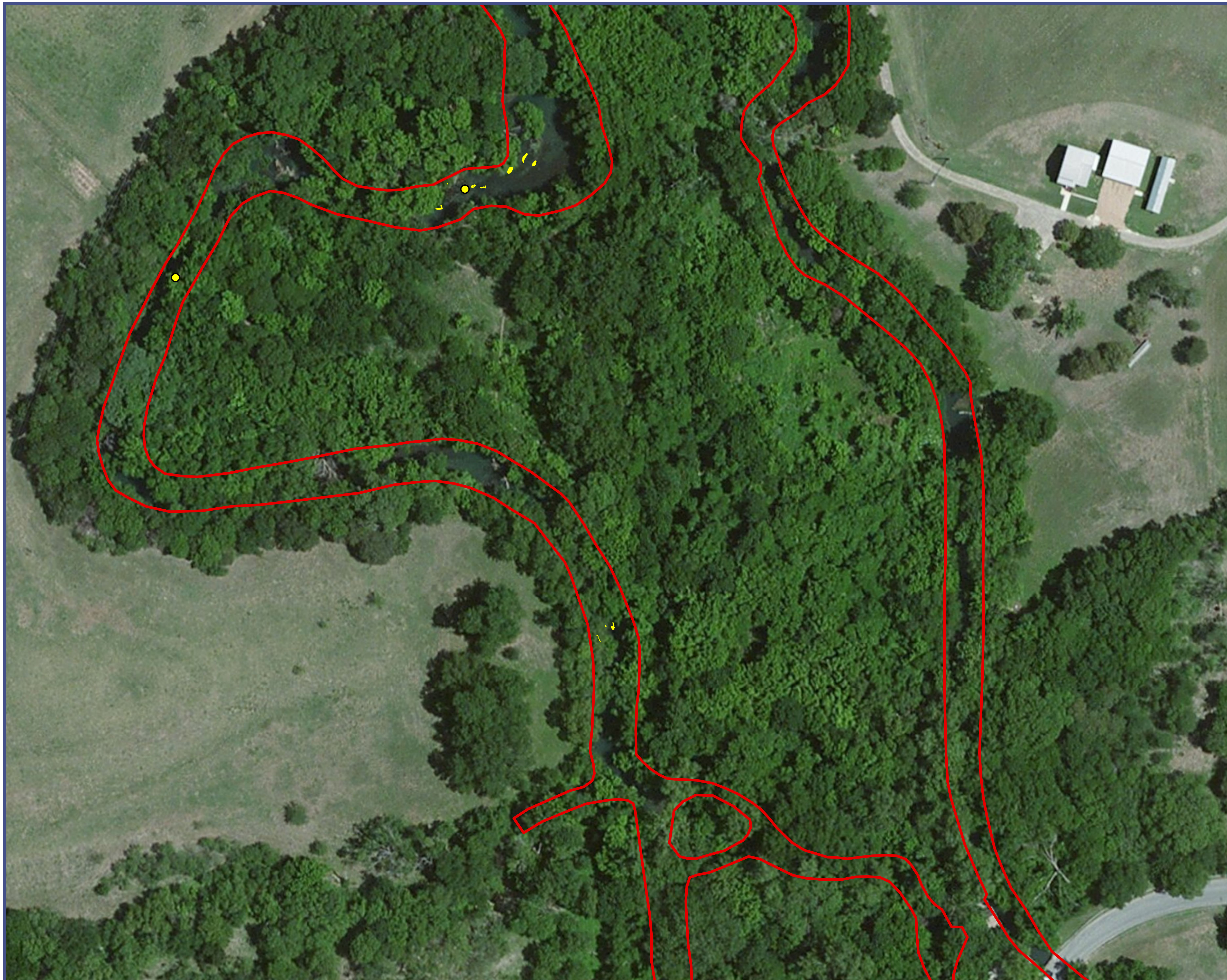

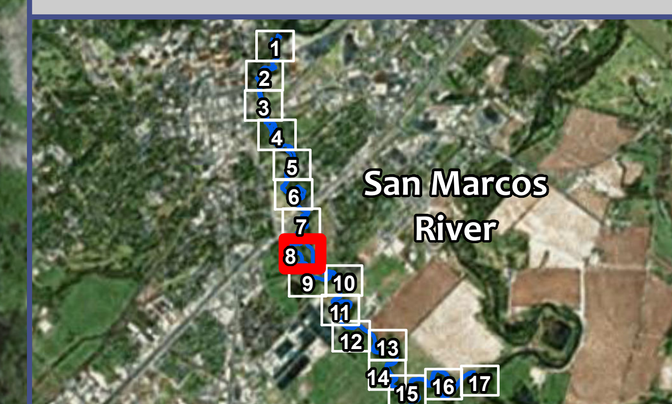

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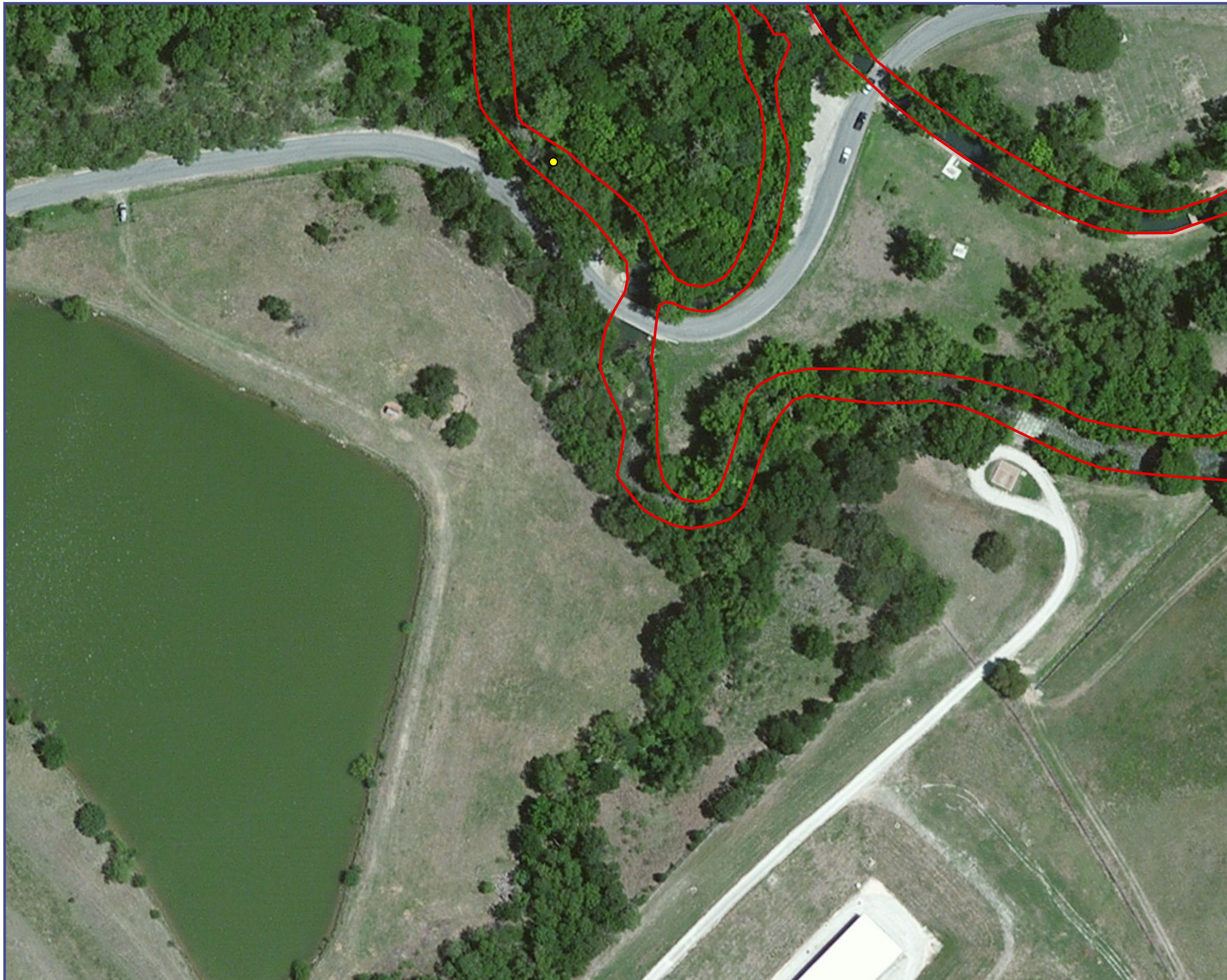

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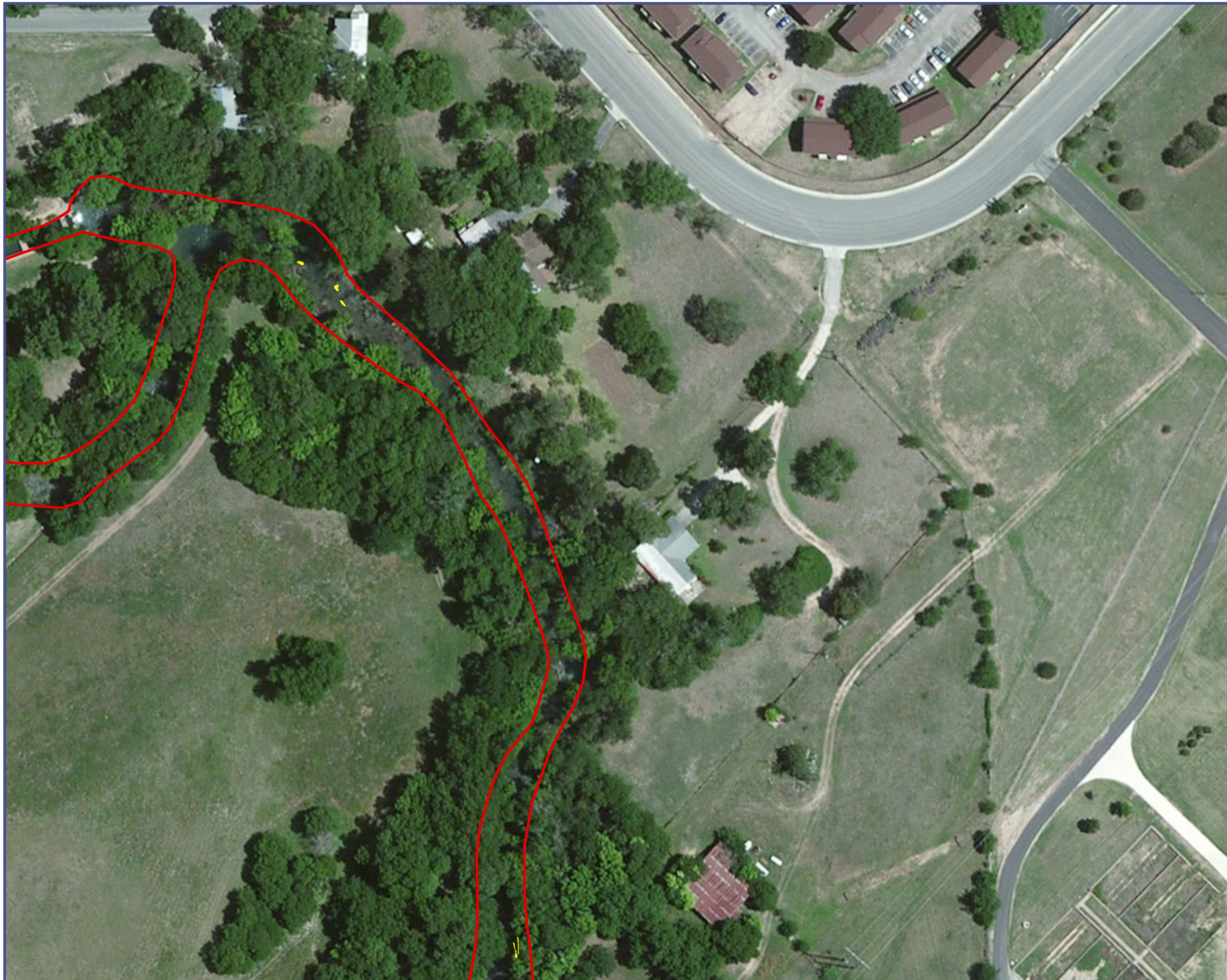

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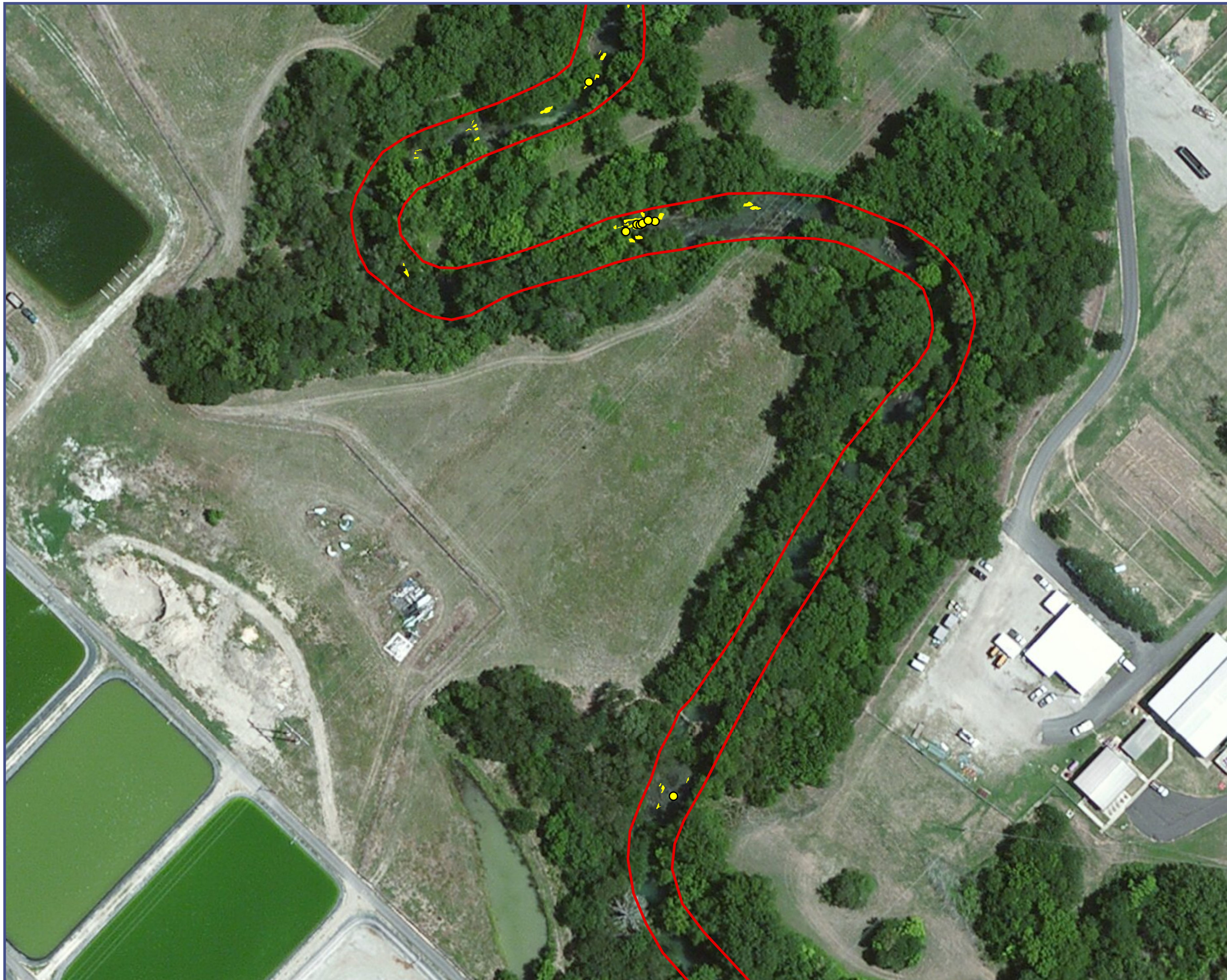

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0 20 40 Meters

N

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Map Revised: December 15, 2014

SAN MARCOS RIVER

San Marcos, Texas

Aquatic Vegetation Study
Texas Wild Rice, Summer 2014

FULL SYSTEM MAP

San Marcos River's Edge

Vegetation Types

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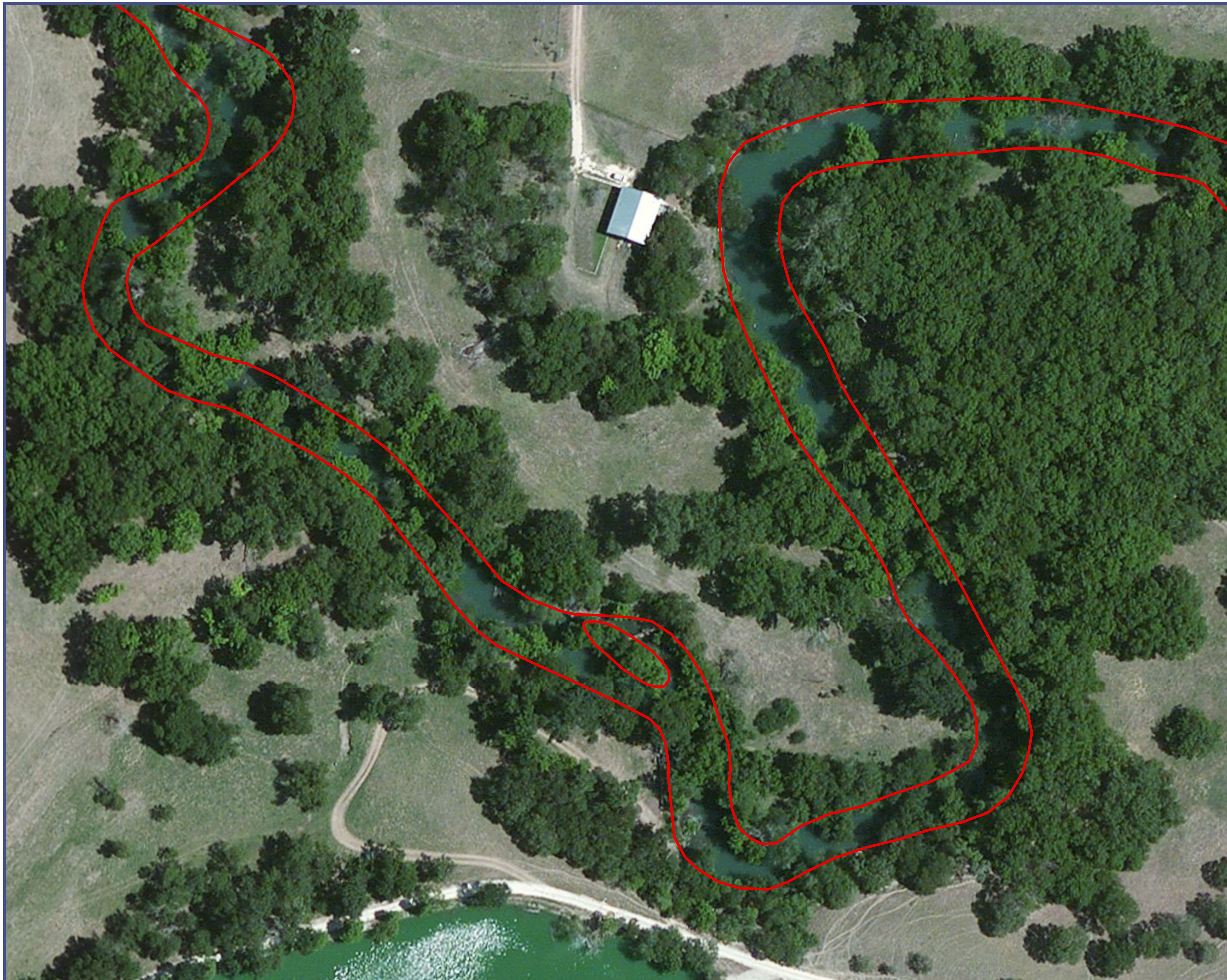

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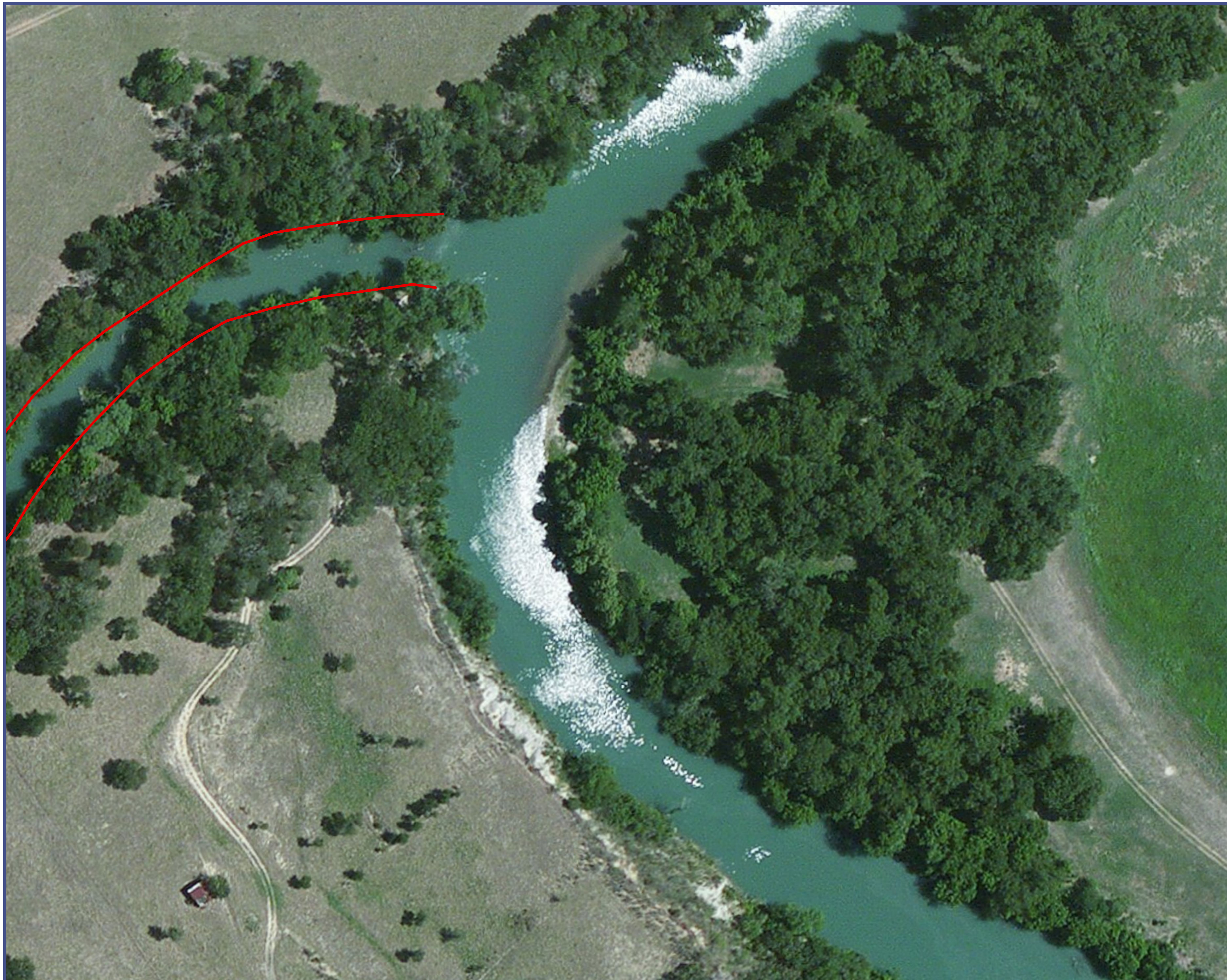

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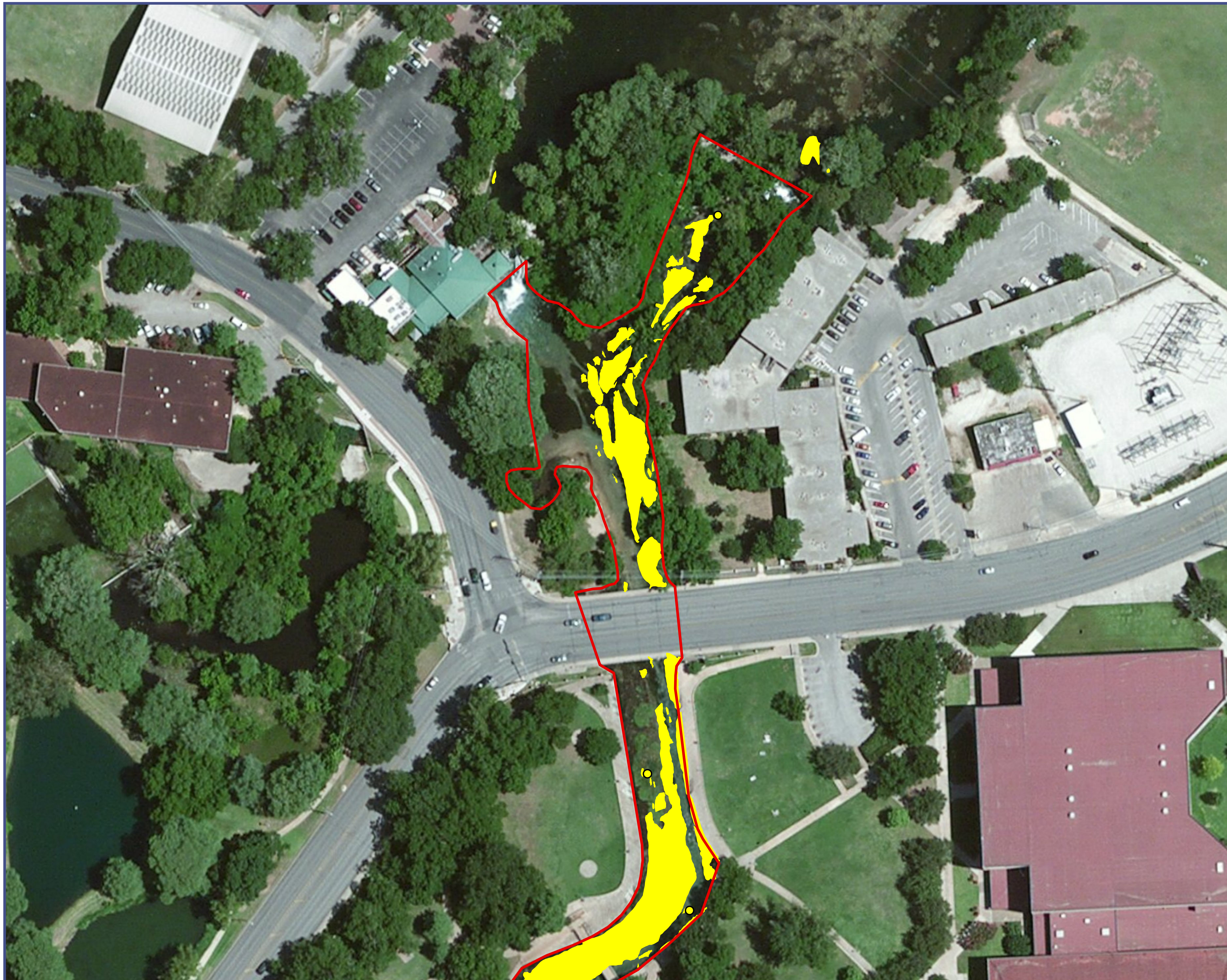
Texas Wild Rice, June 2015



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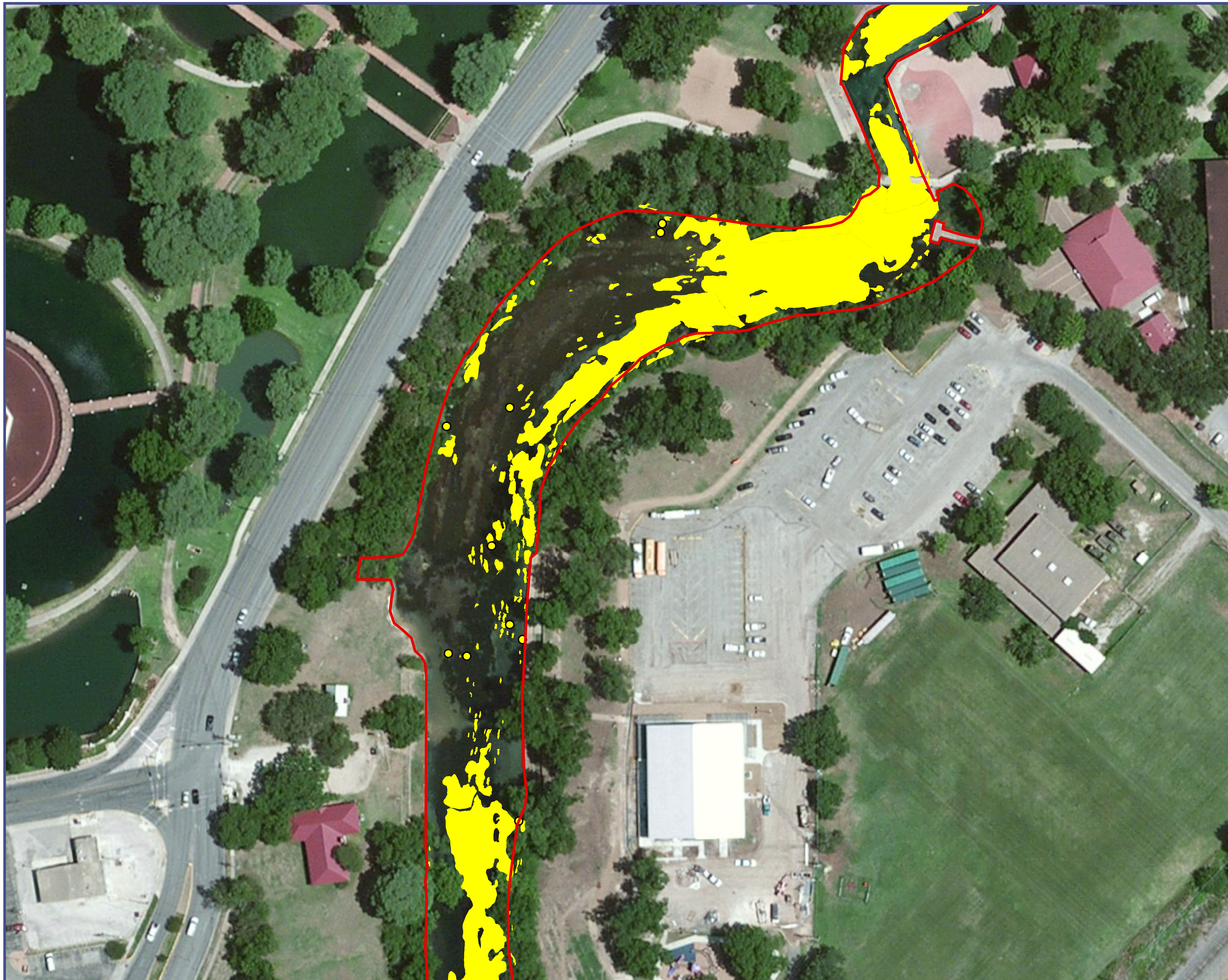

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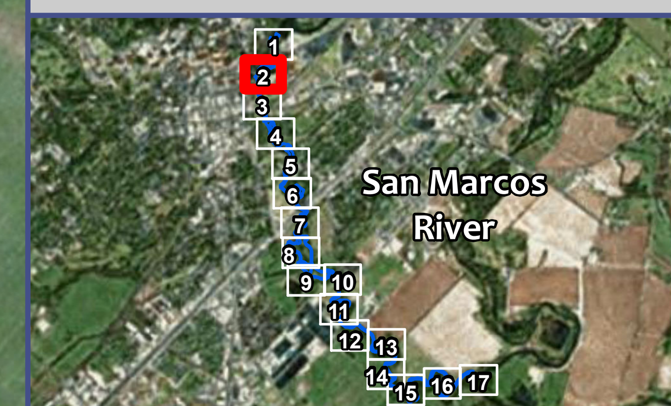

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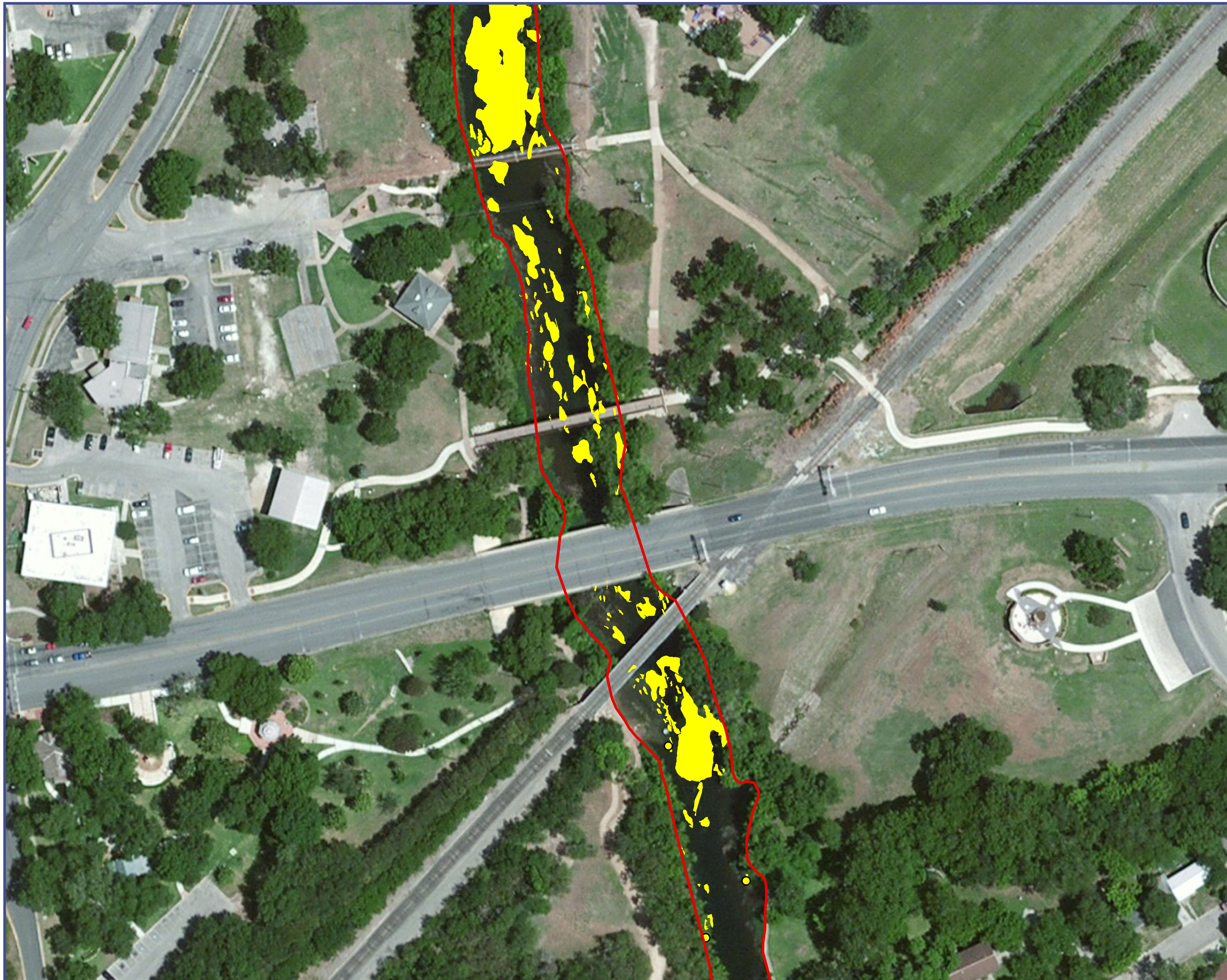

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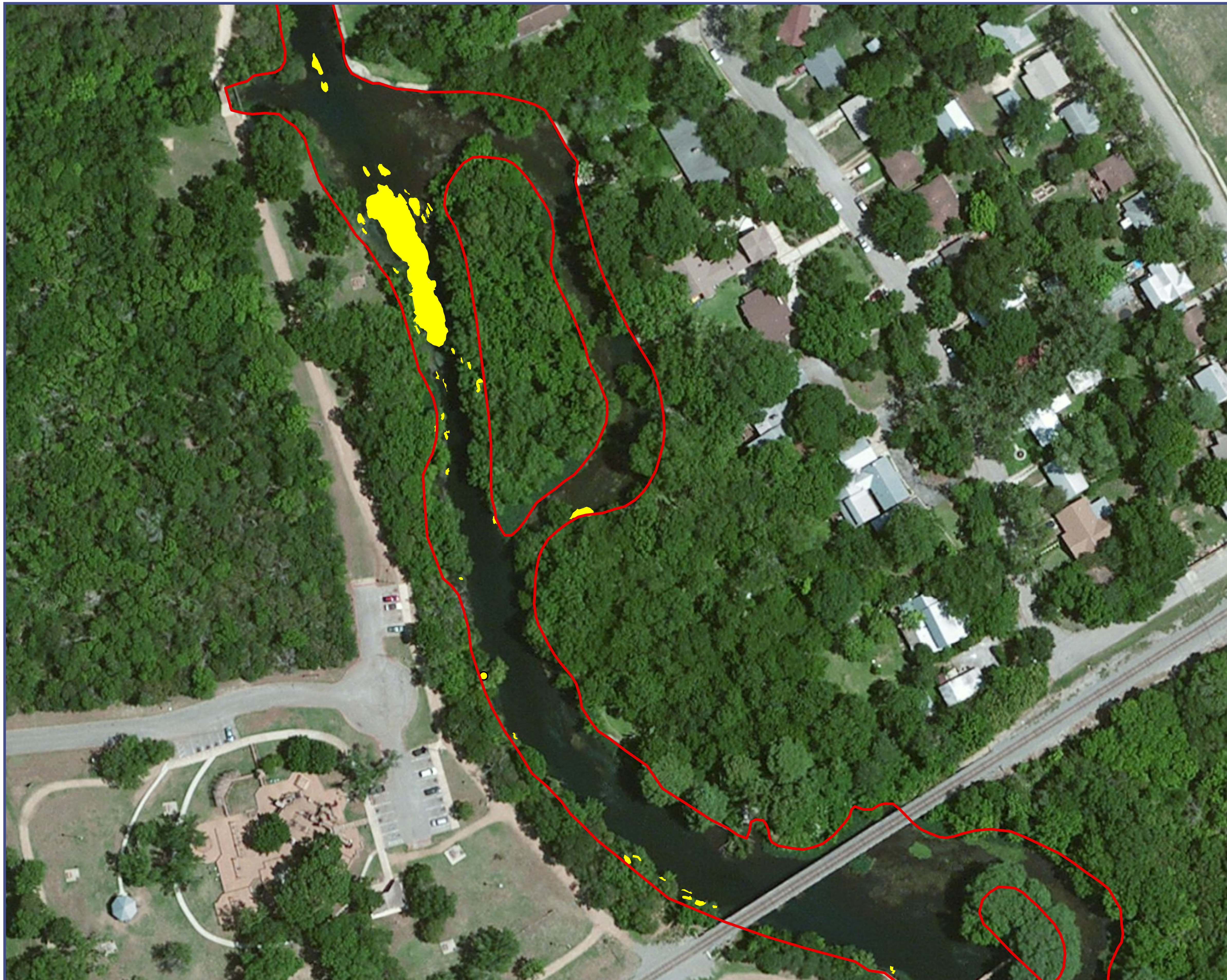

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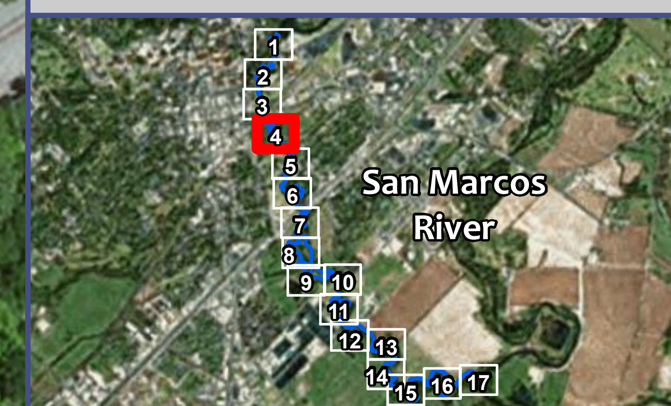

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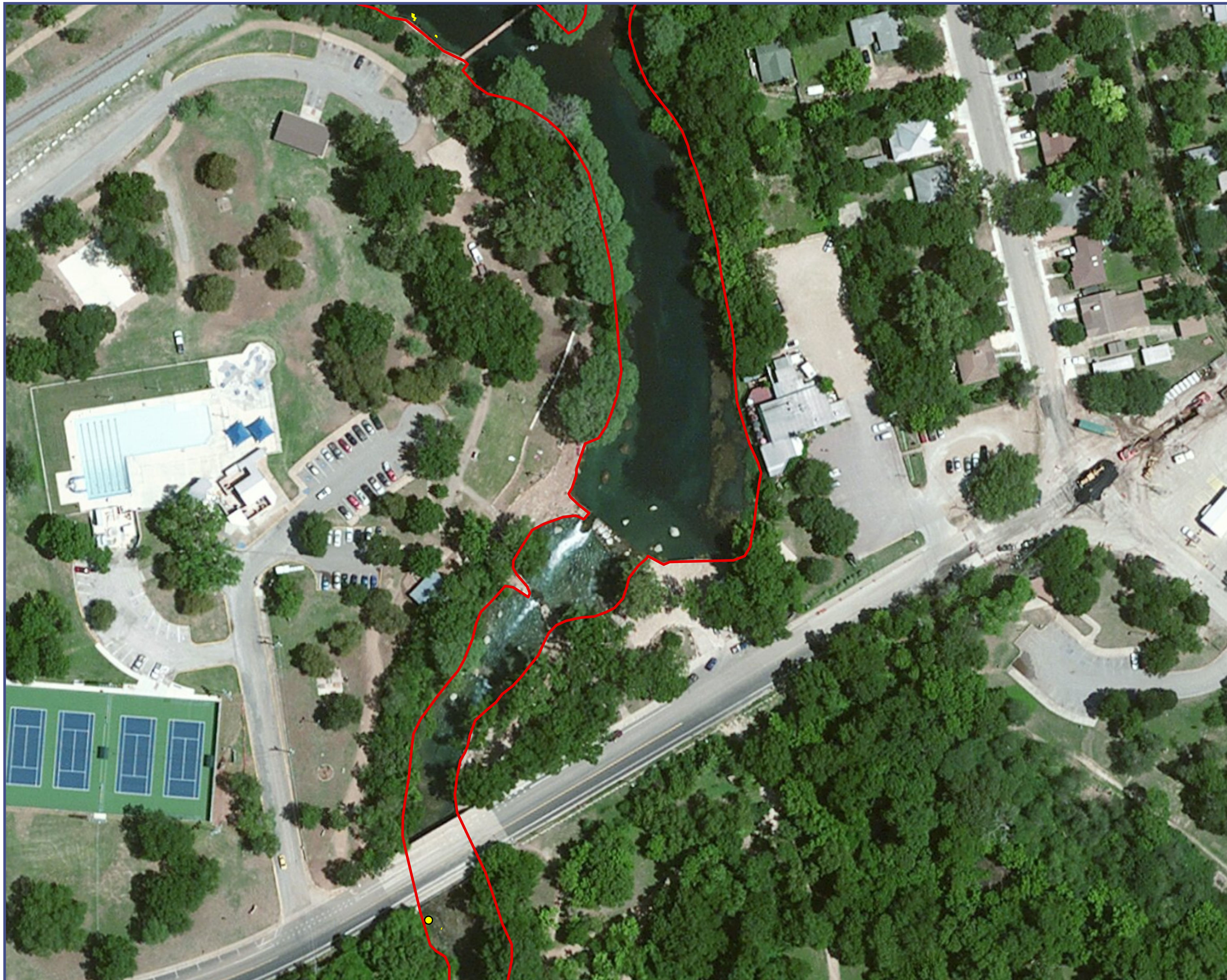

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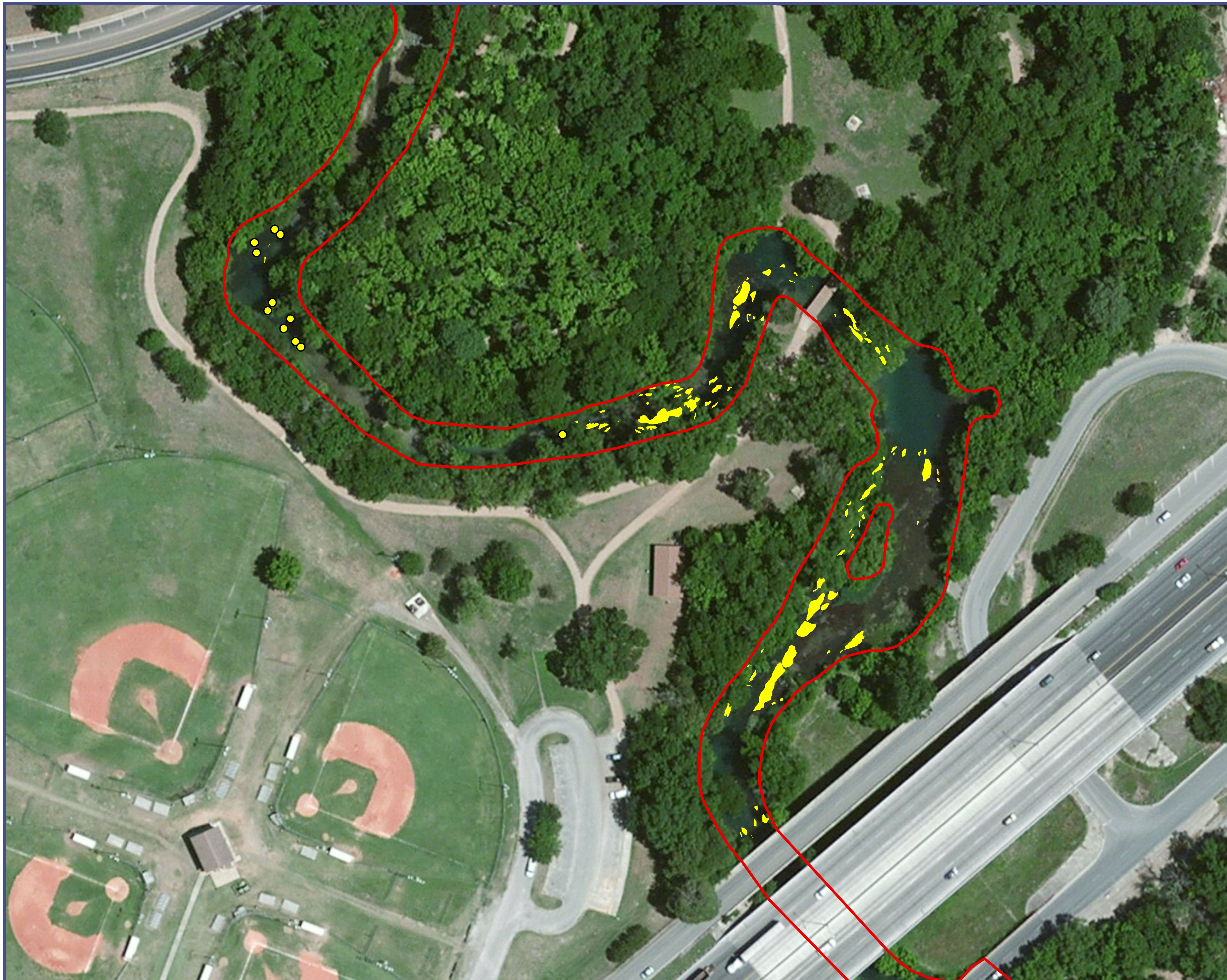

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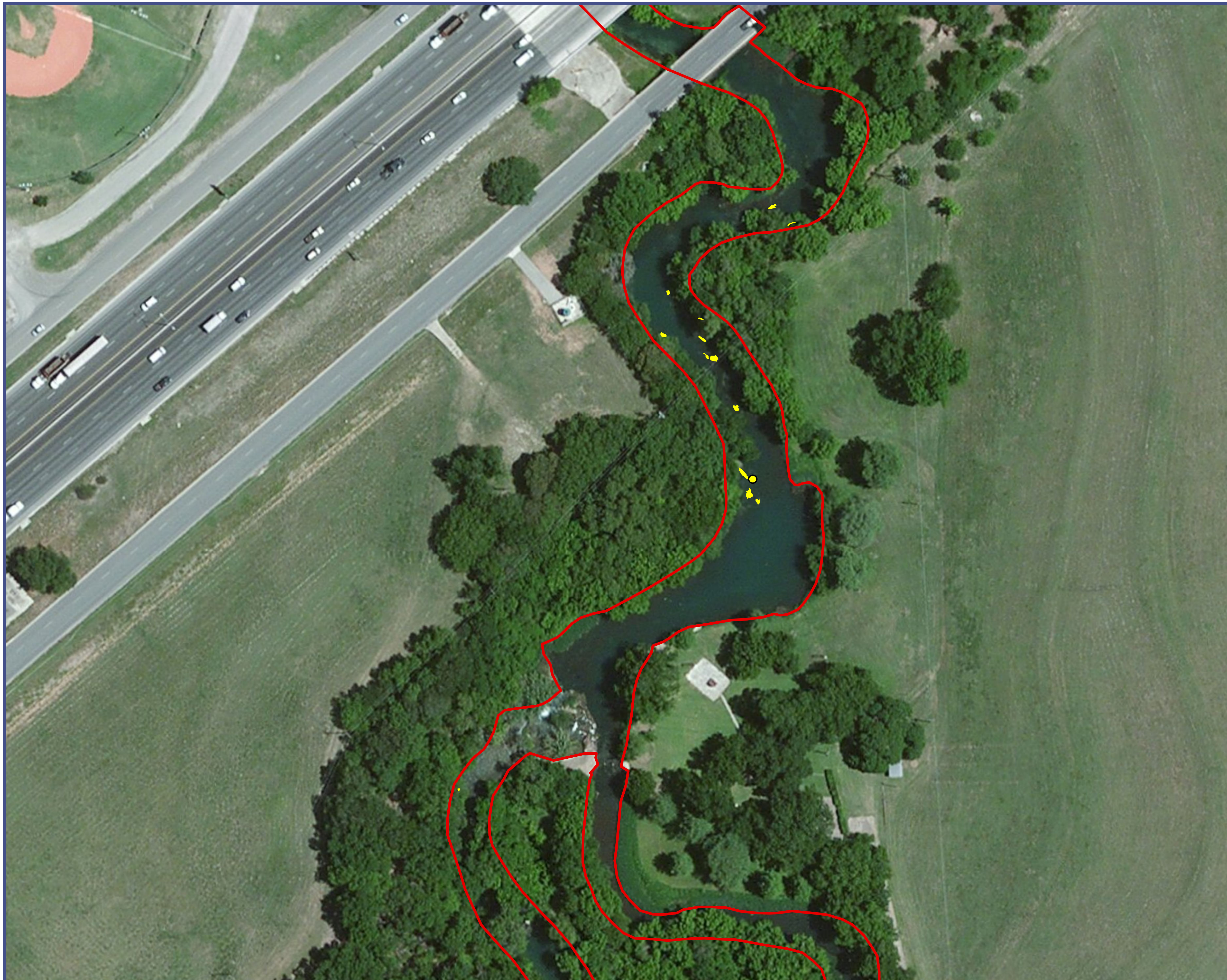

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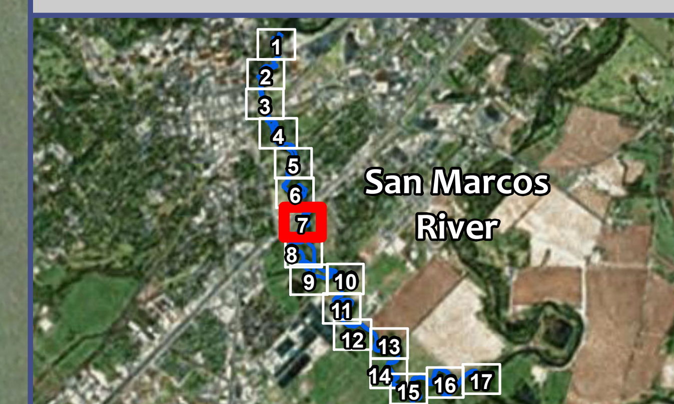

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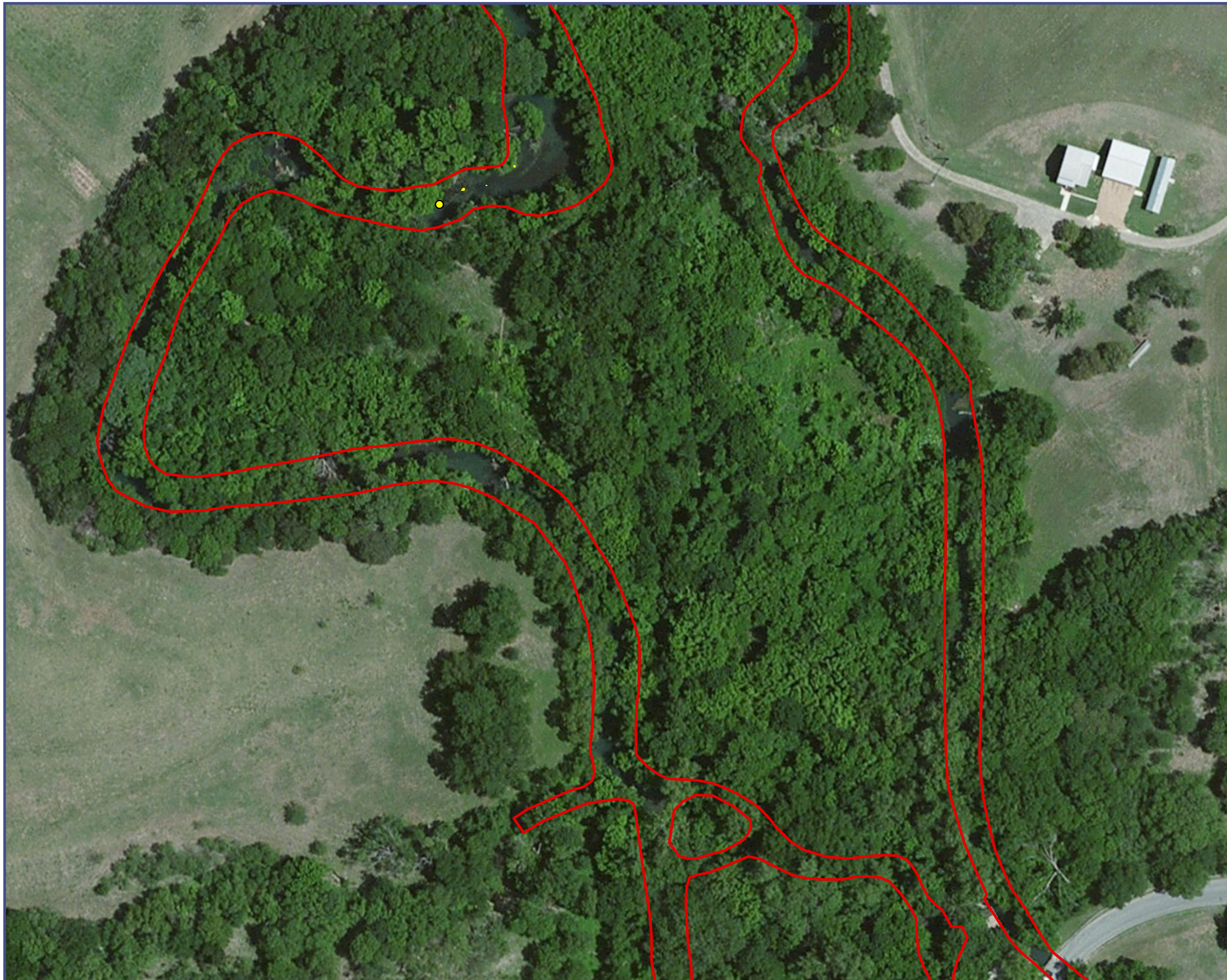

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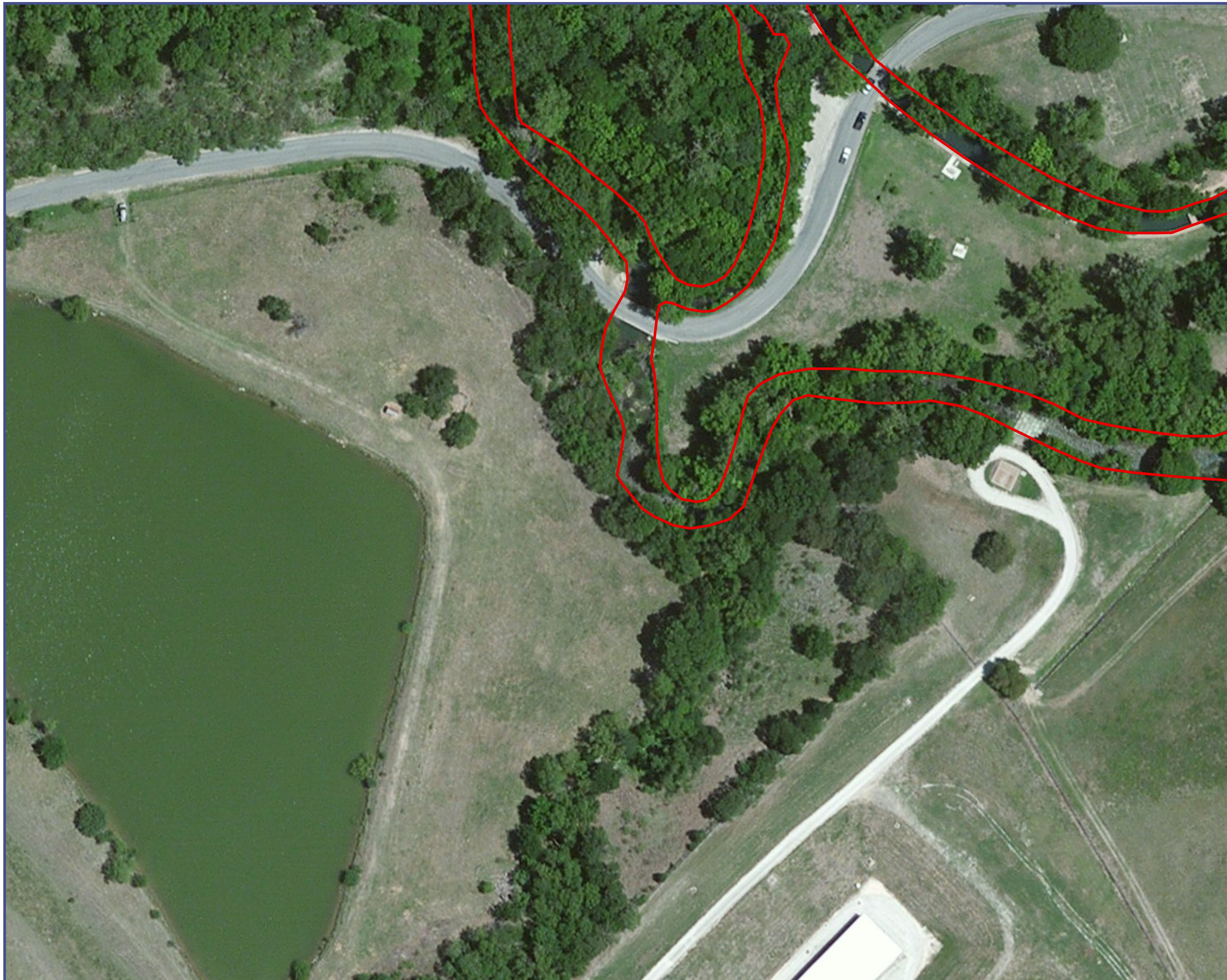

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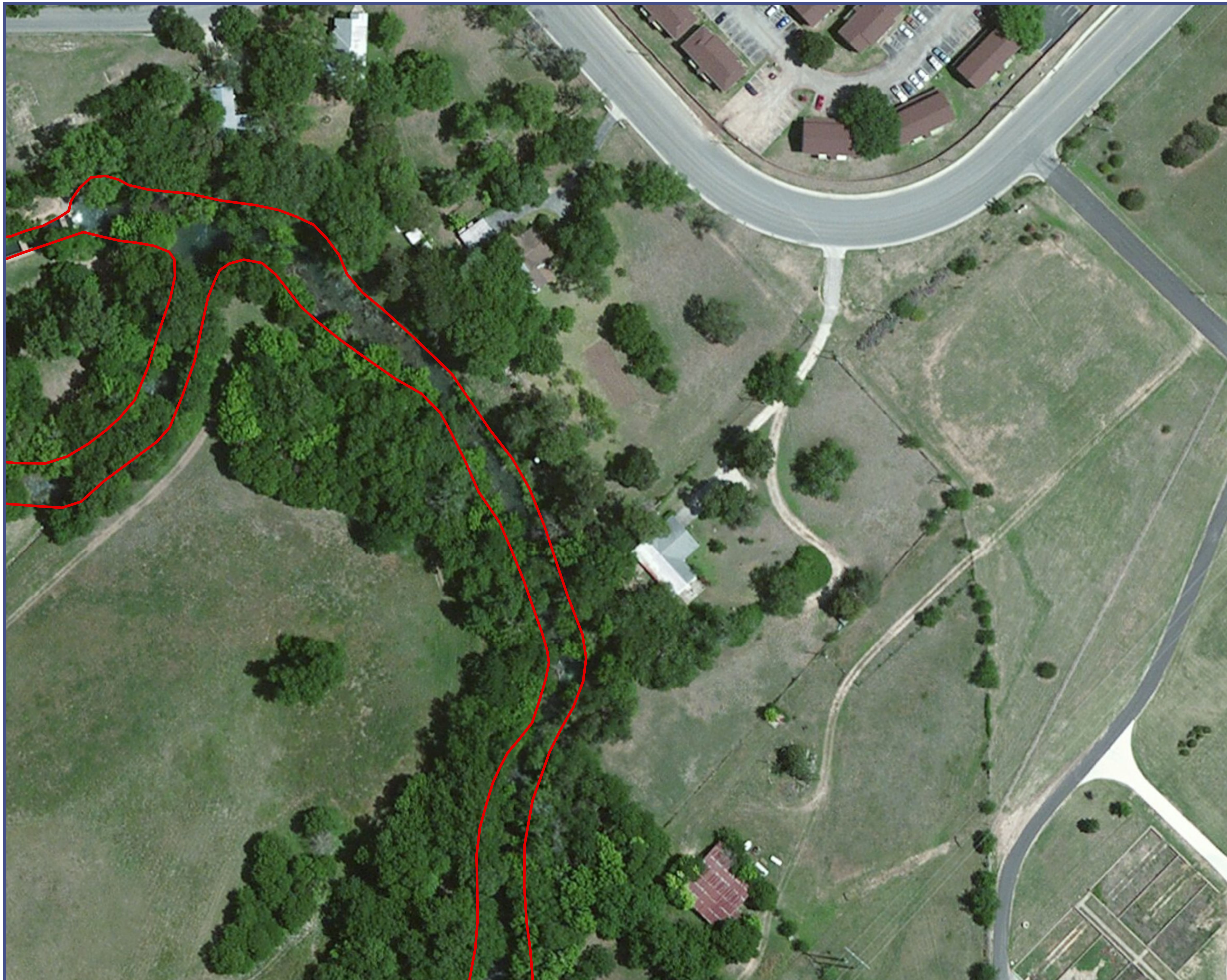

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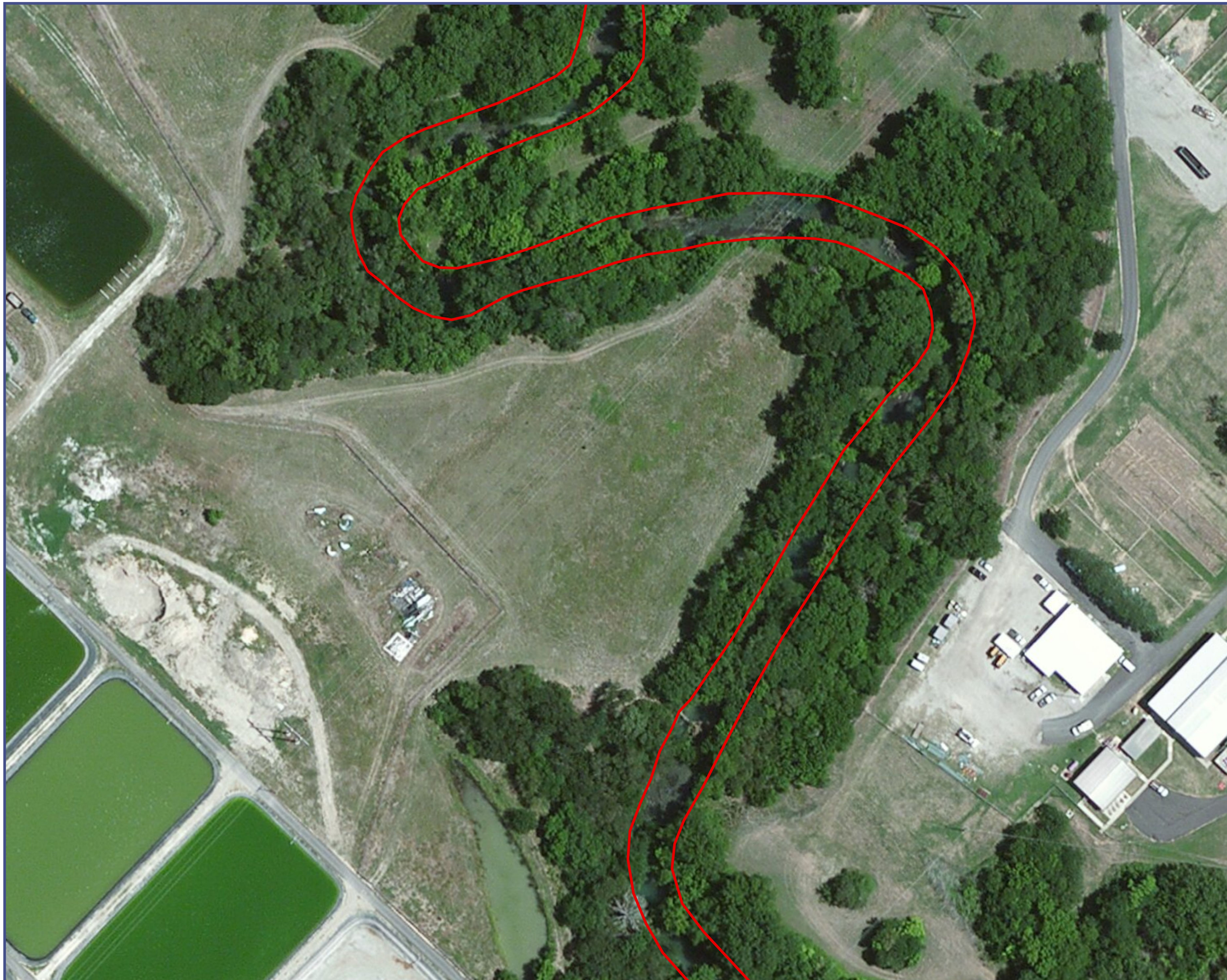

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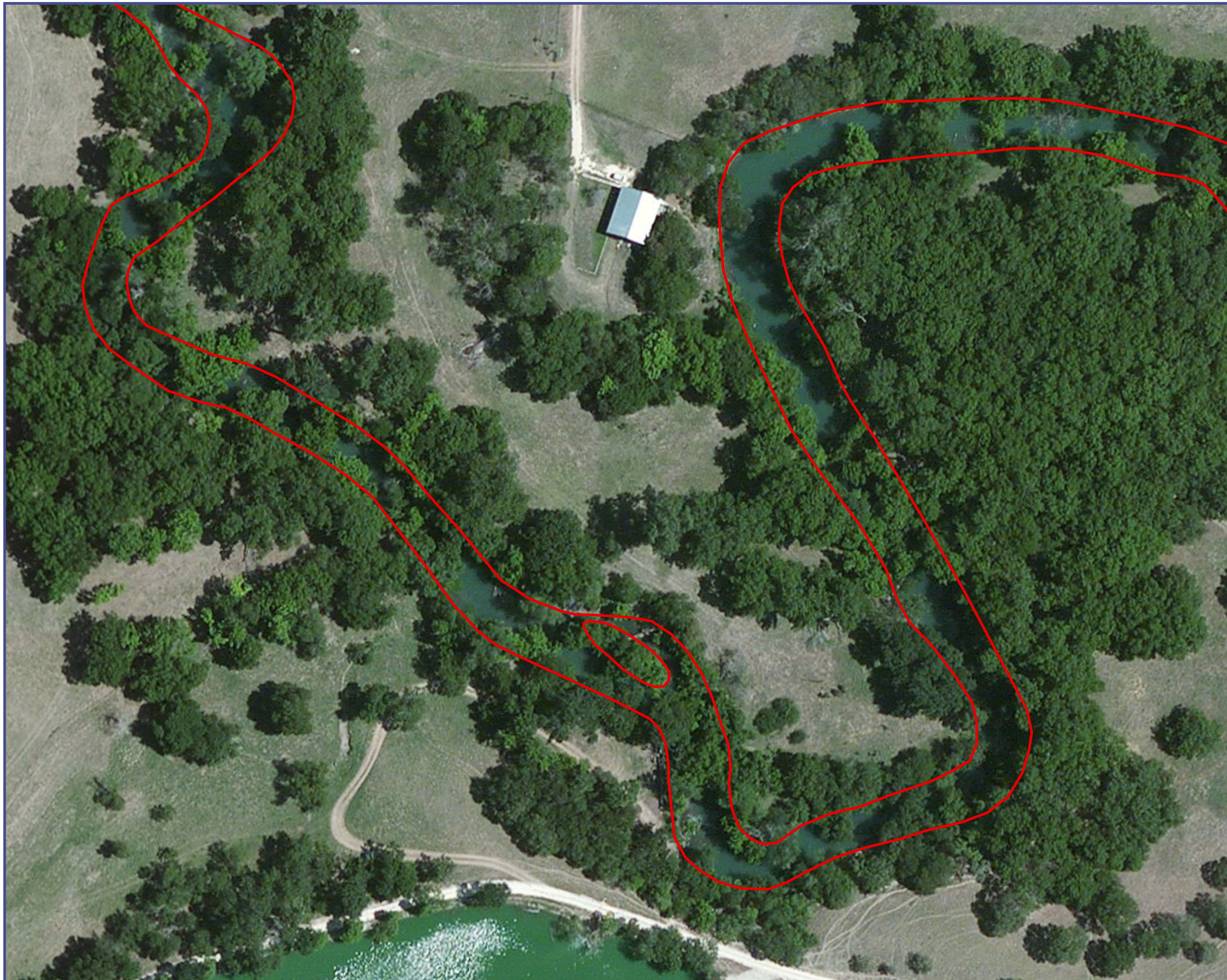

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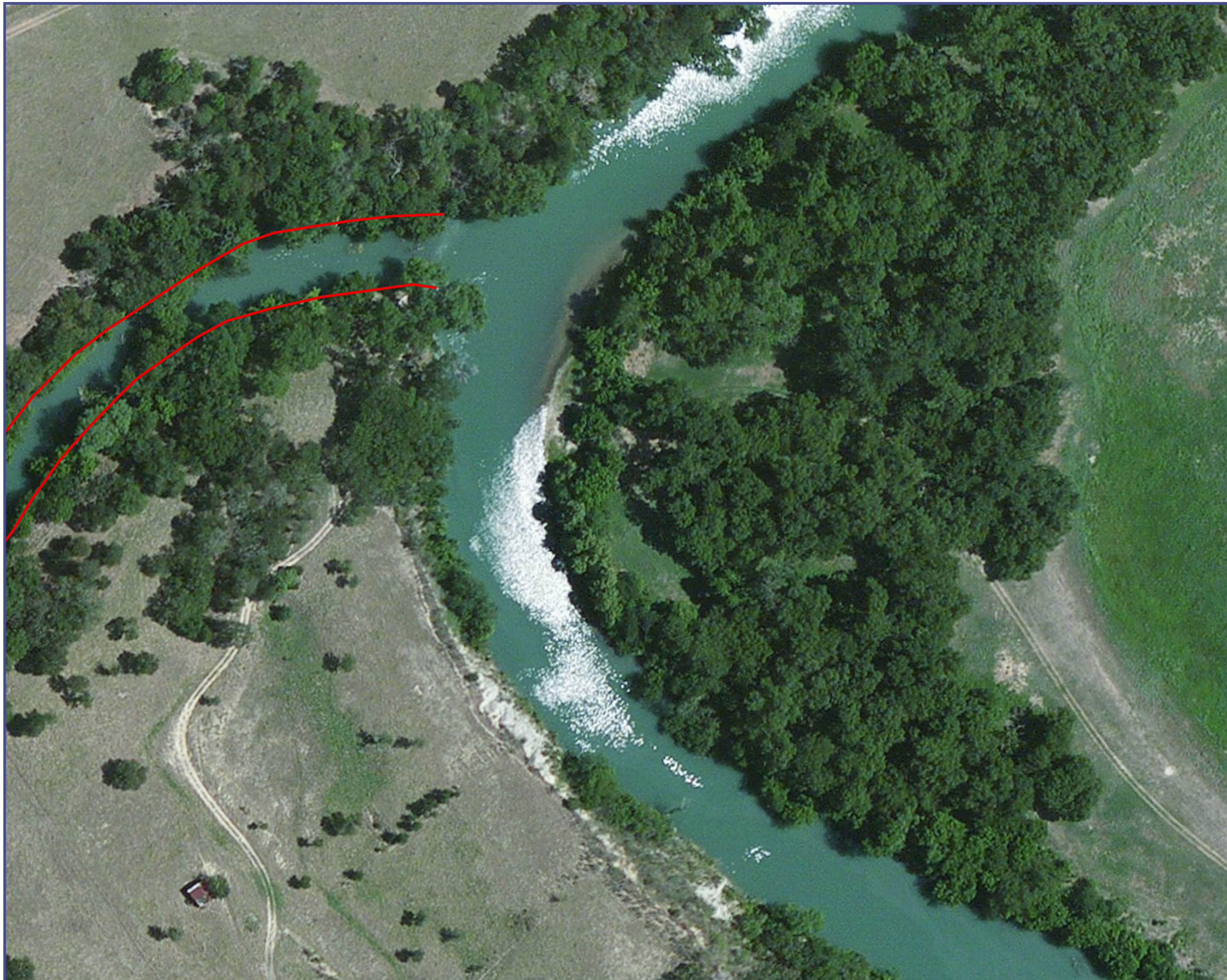

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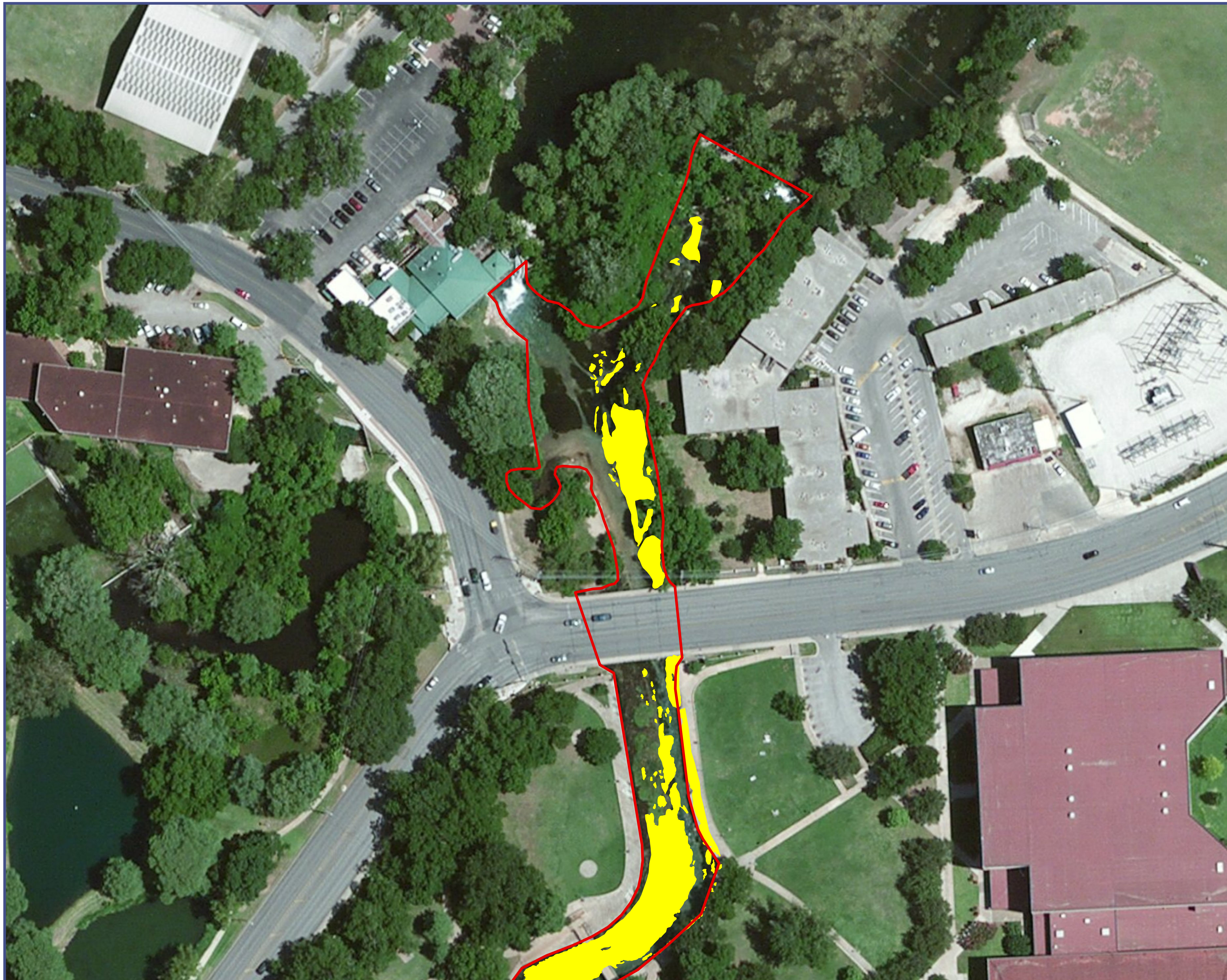

San Marcos River's Edge

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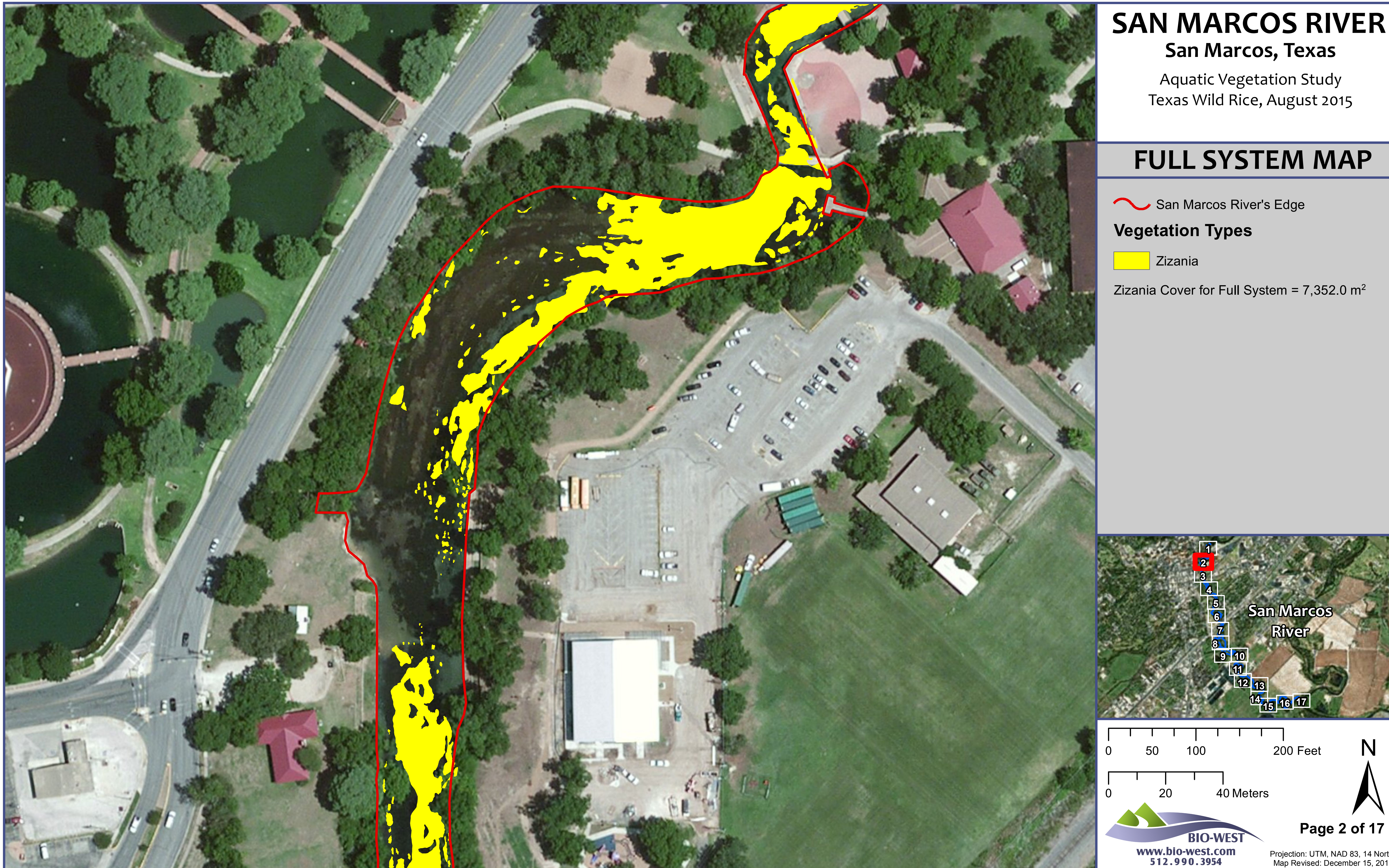

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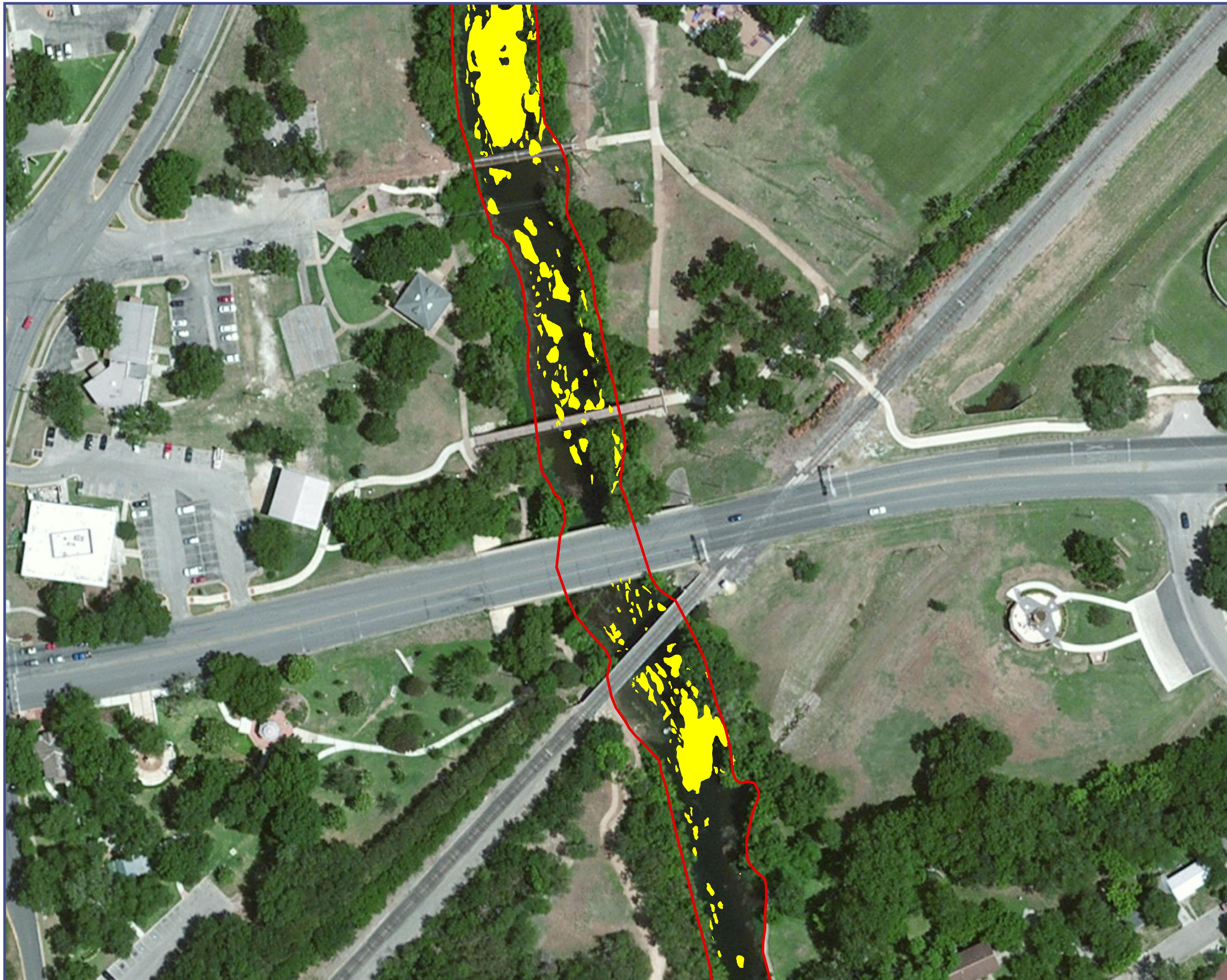

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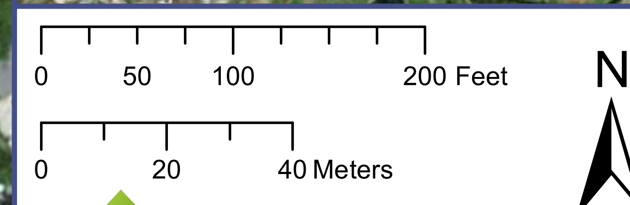

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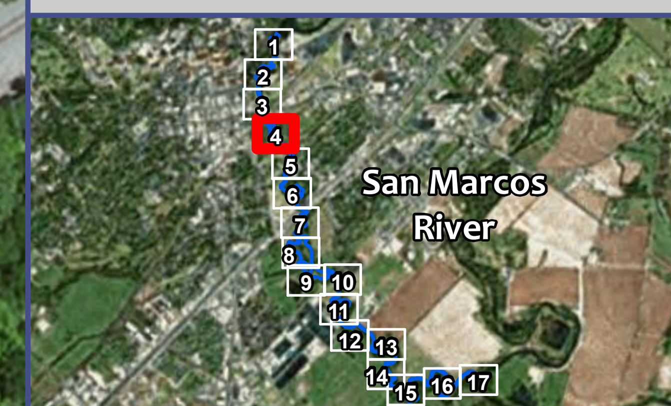

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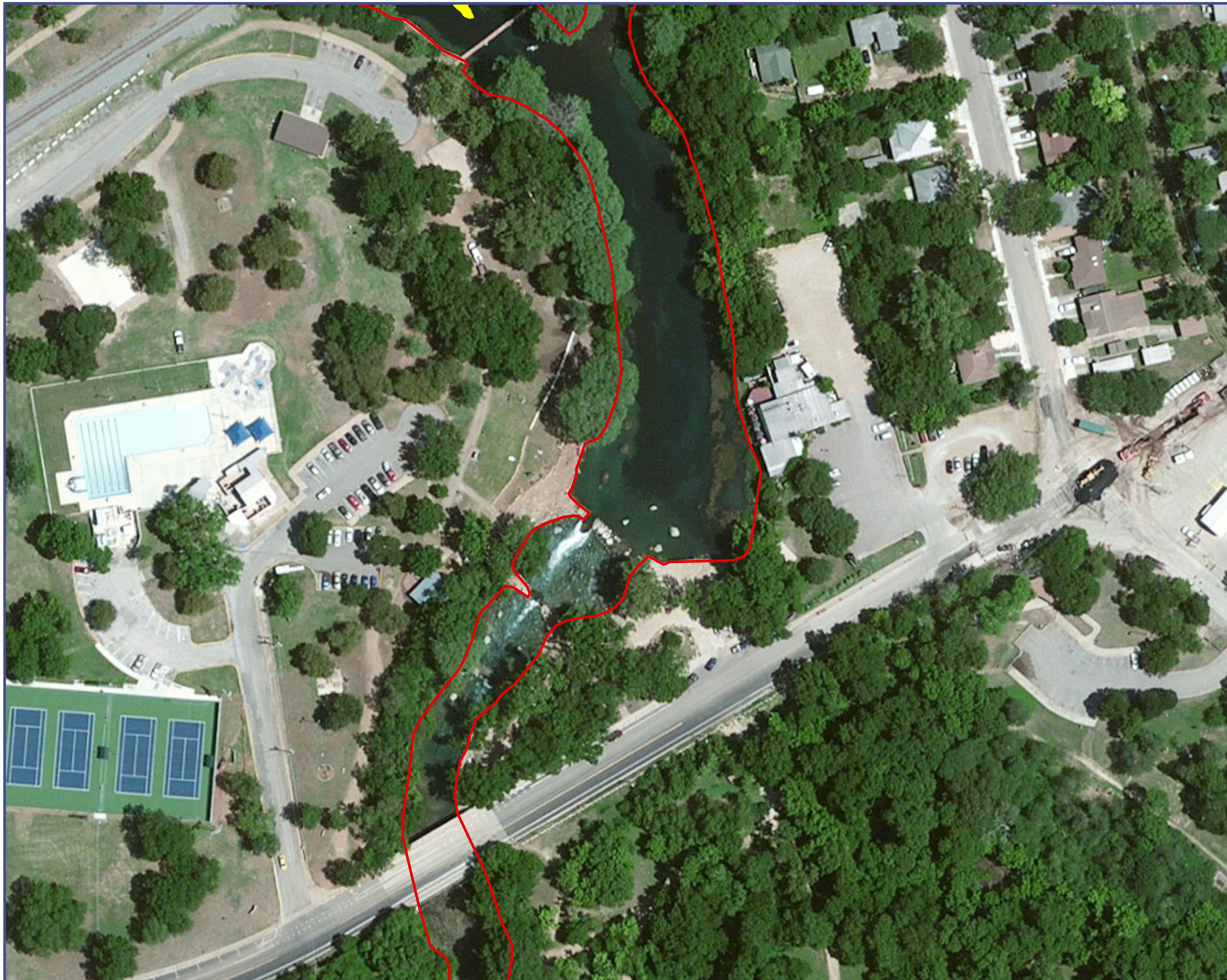

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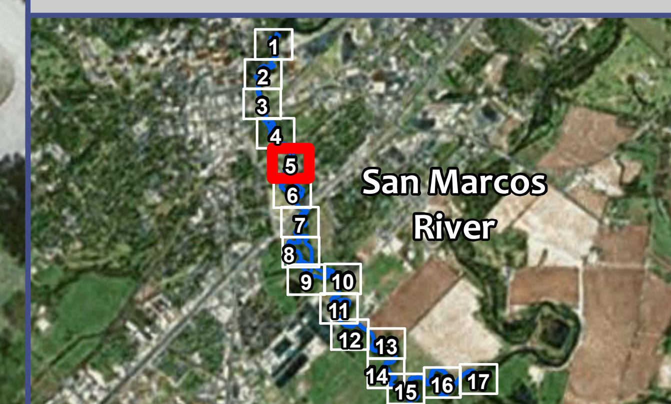

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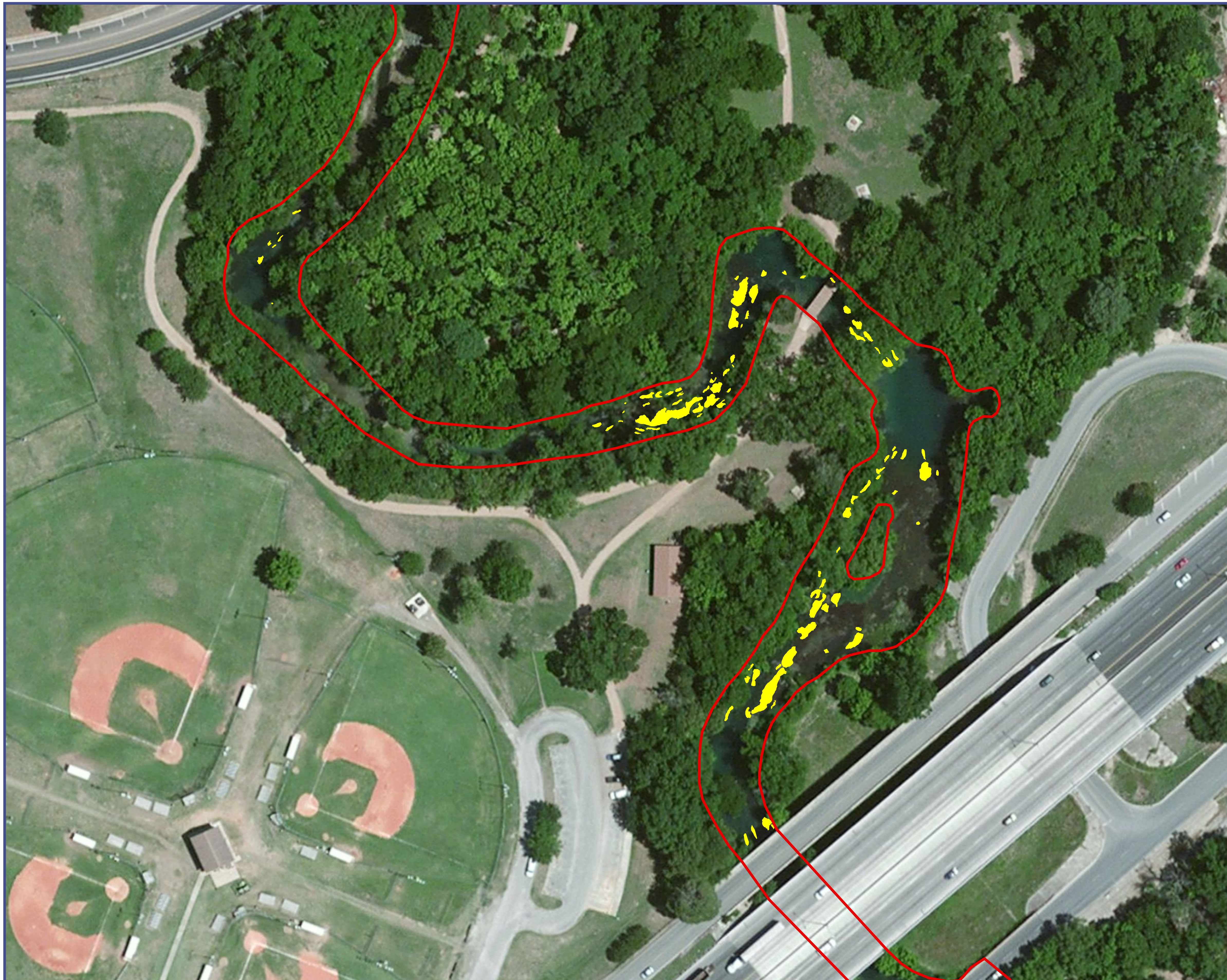

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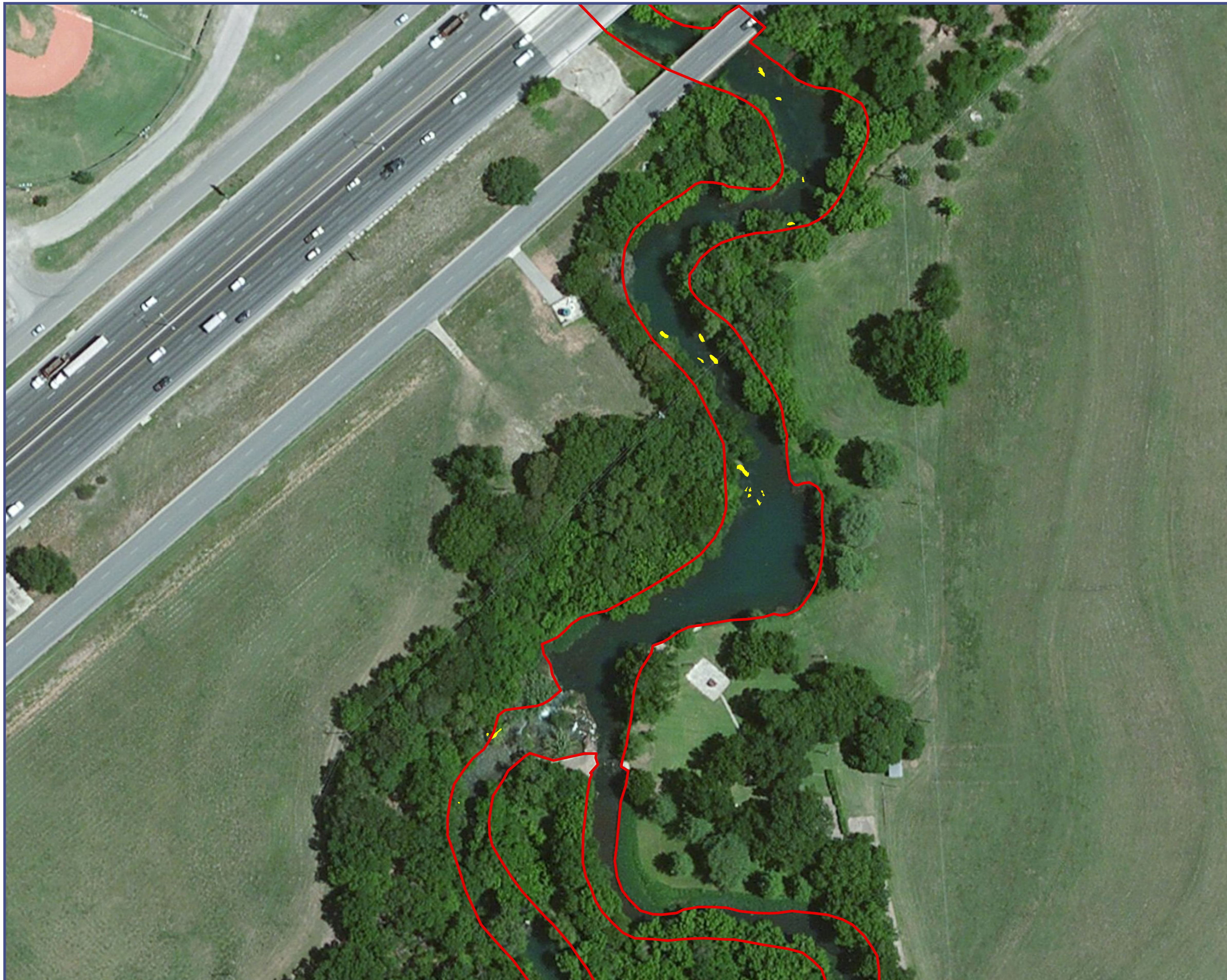

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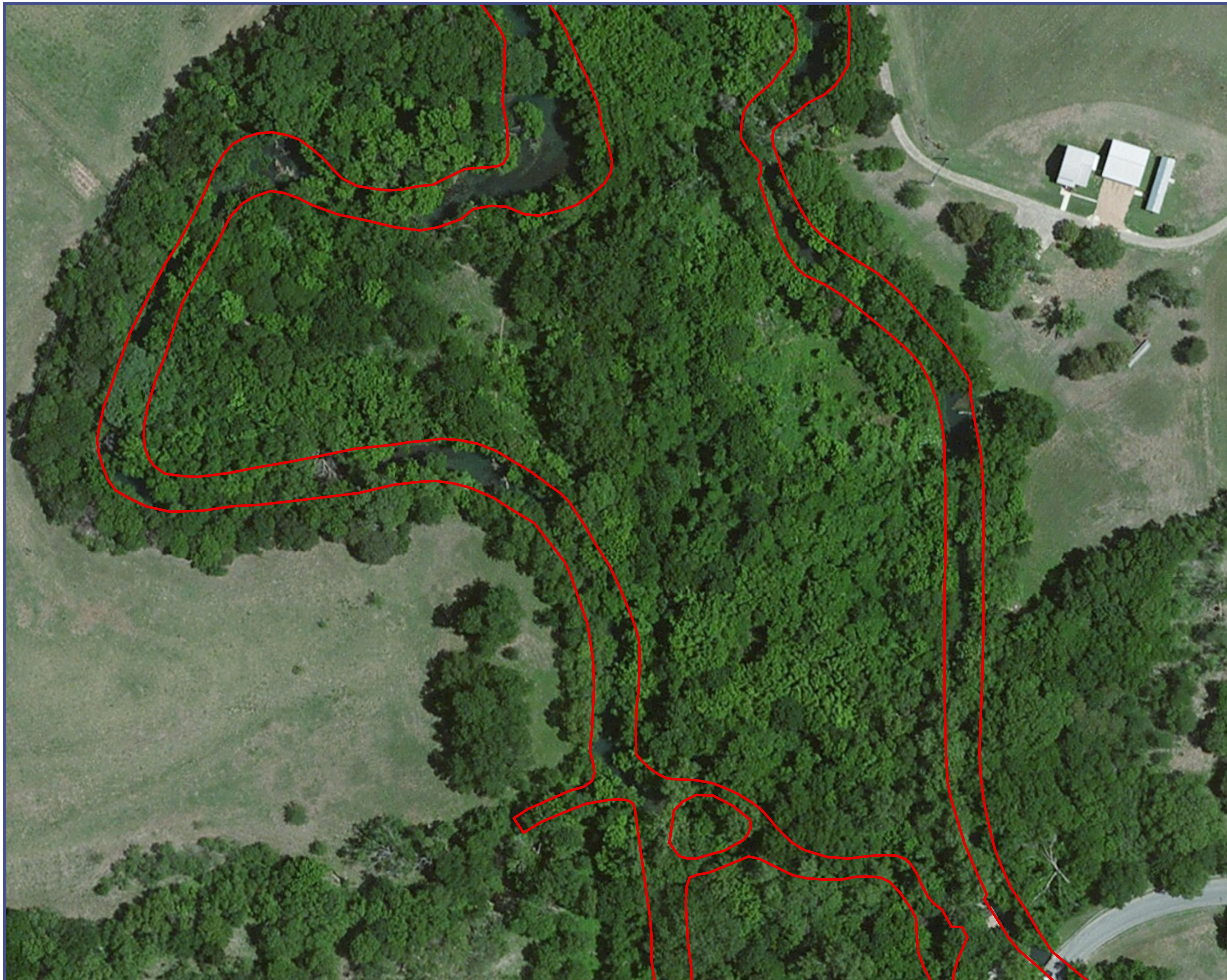

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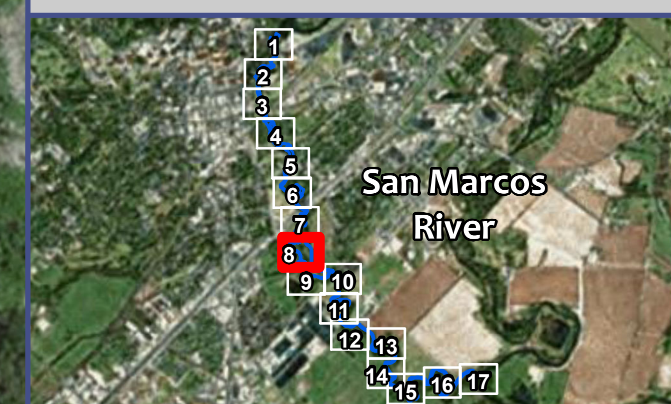

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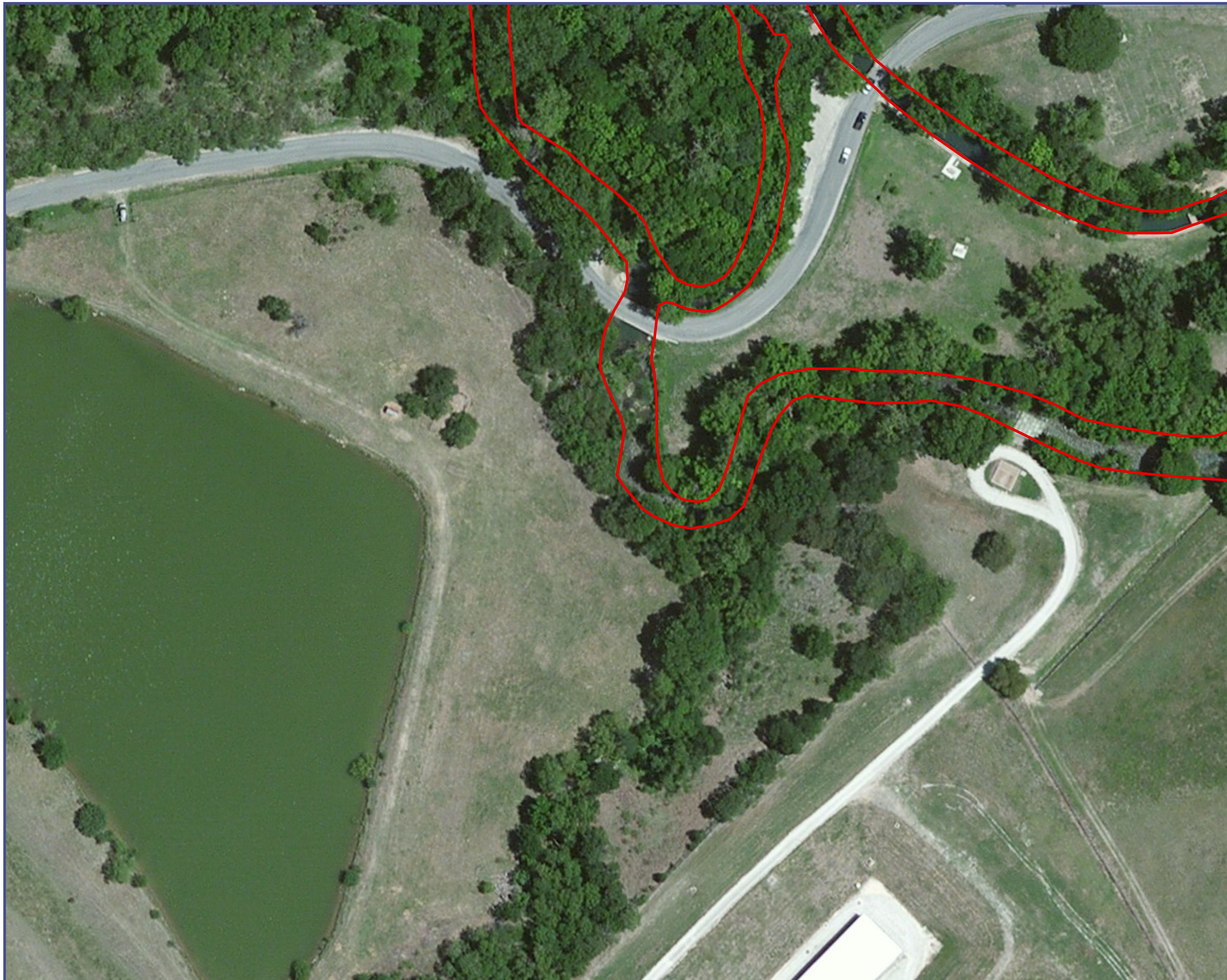

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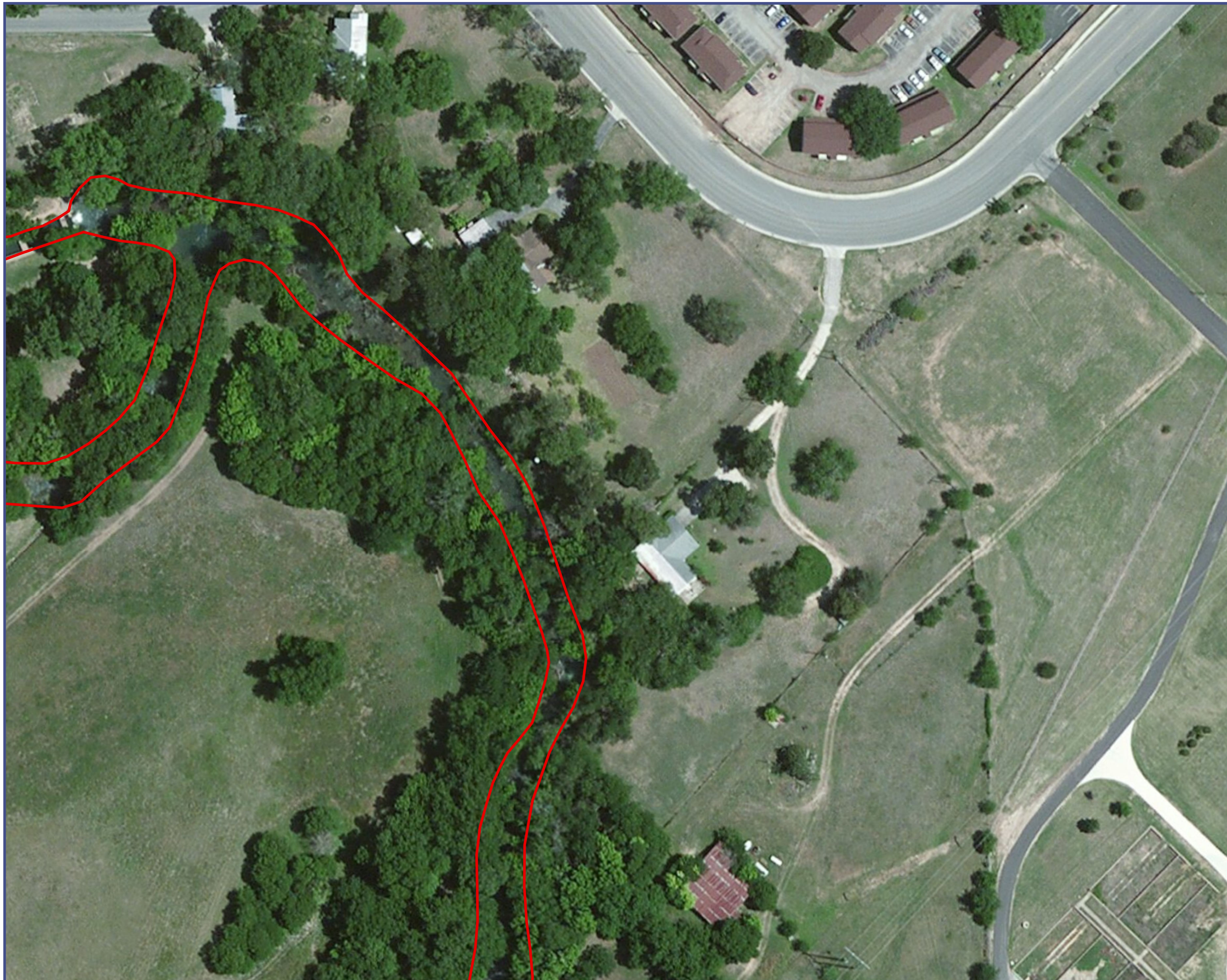

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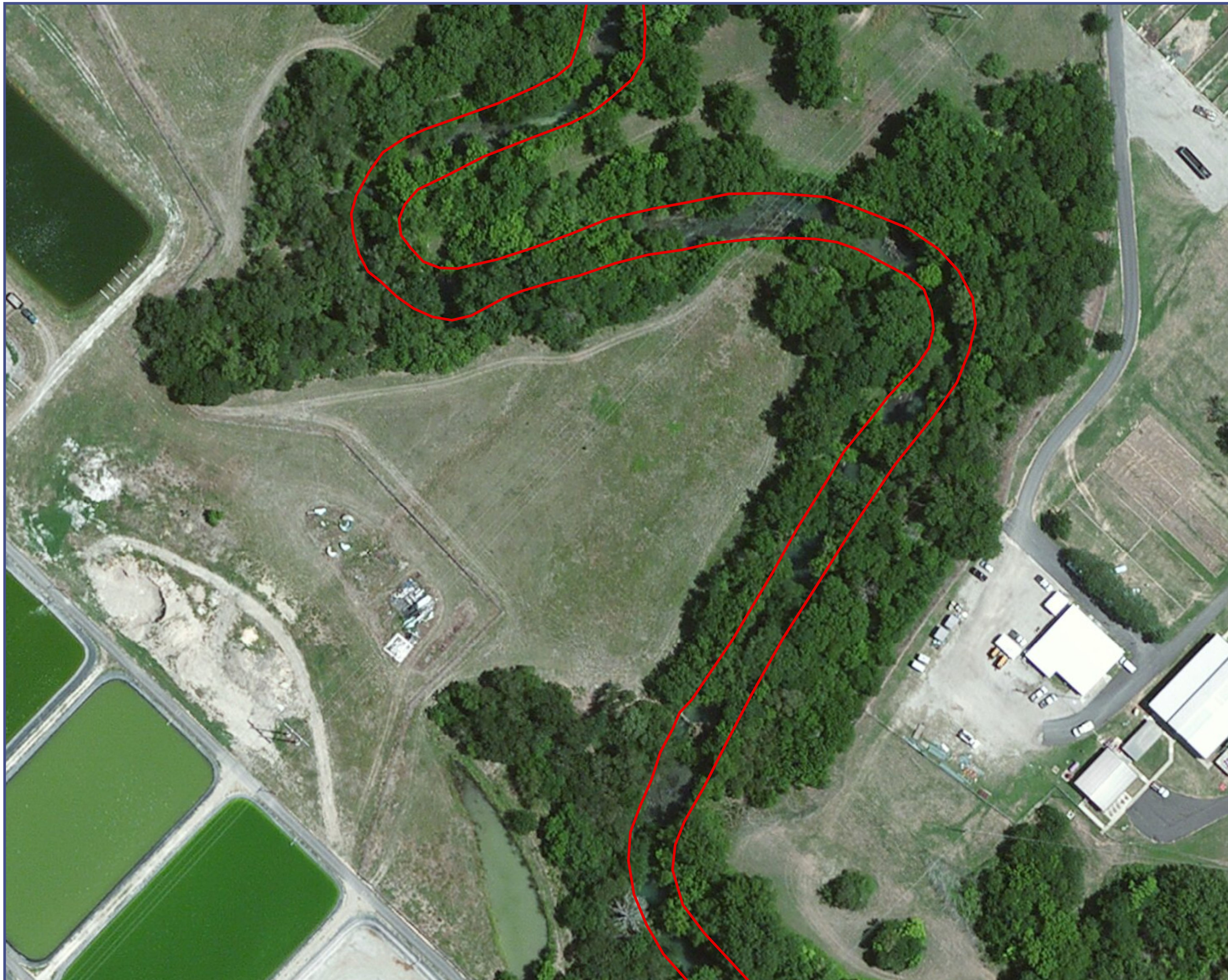

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Map Revised: December 15, 2014

SAN MARCOS RIVER

San Marcos, Texas

Aquatic Vegetation Study
Texas Wild Rice, August 2015

FULL SYSTEM MAP

San Marcos River's Edge

Vegetation Types

Zizania

Zizania Cover for Full System = 7,352.0 m^2

0 50 100 200 Feet

0 20 40 Meters

N

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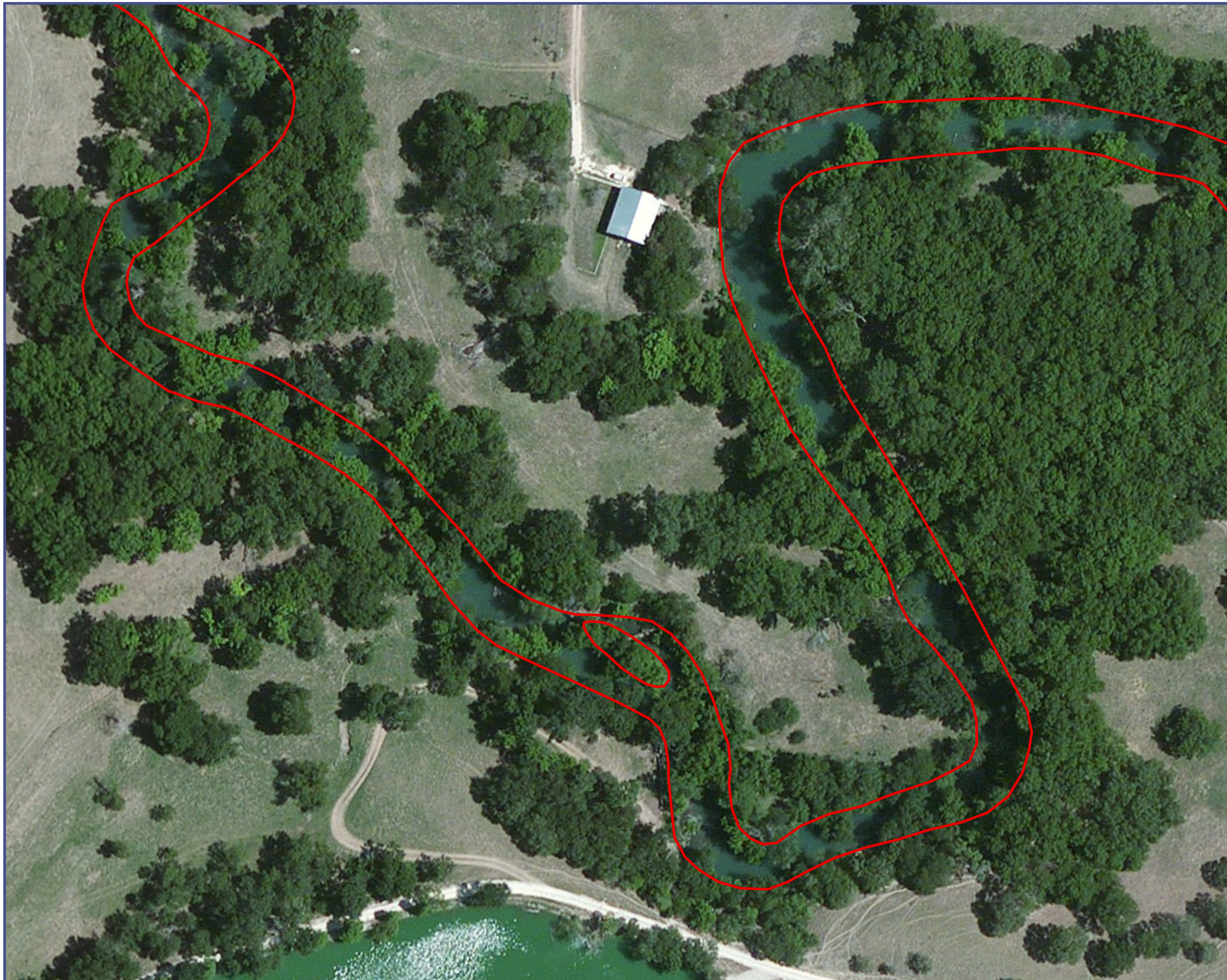

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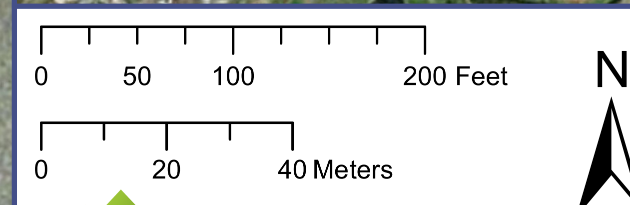

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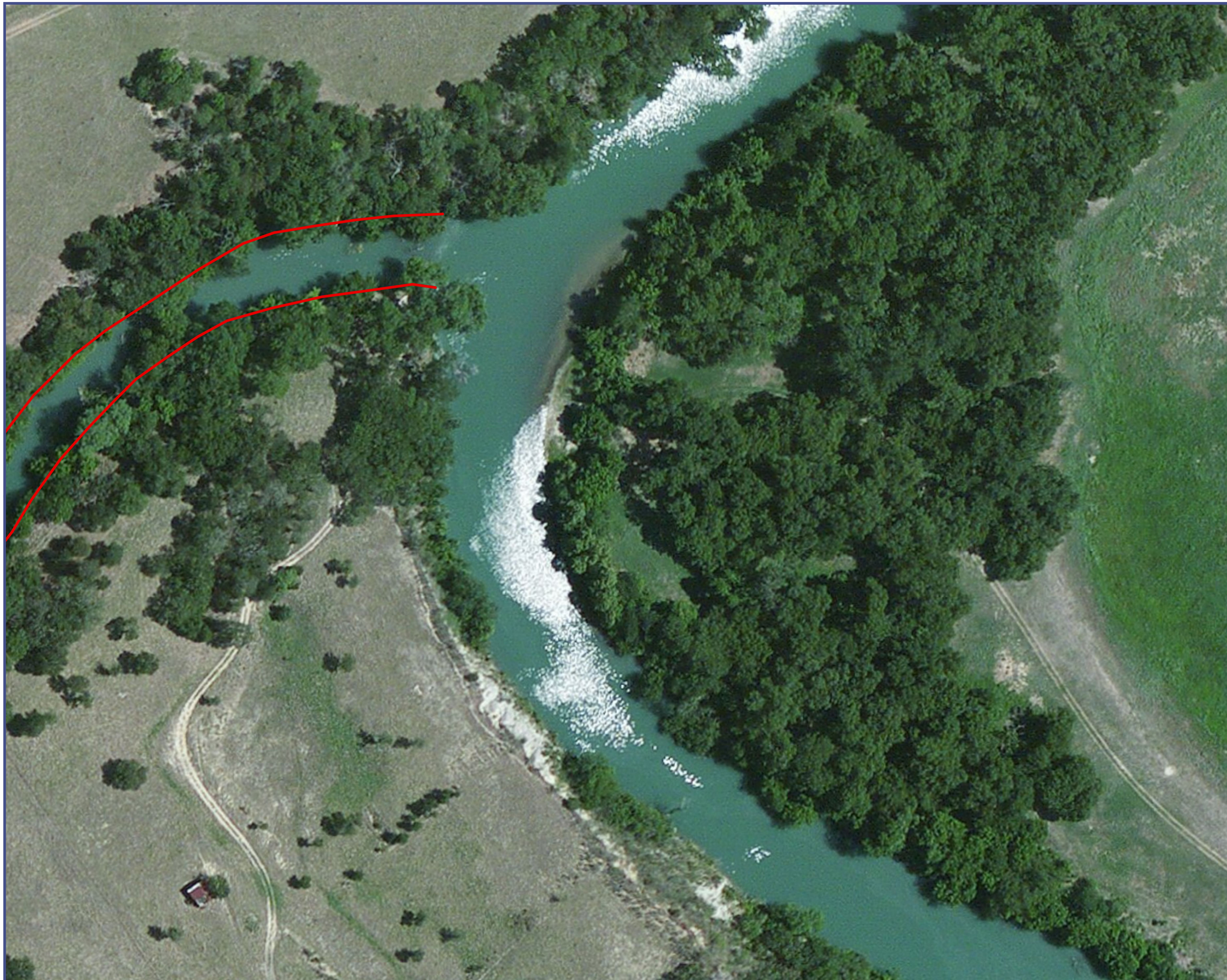

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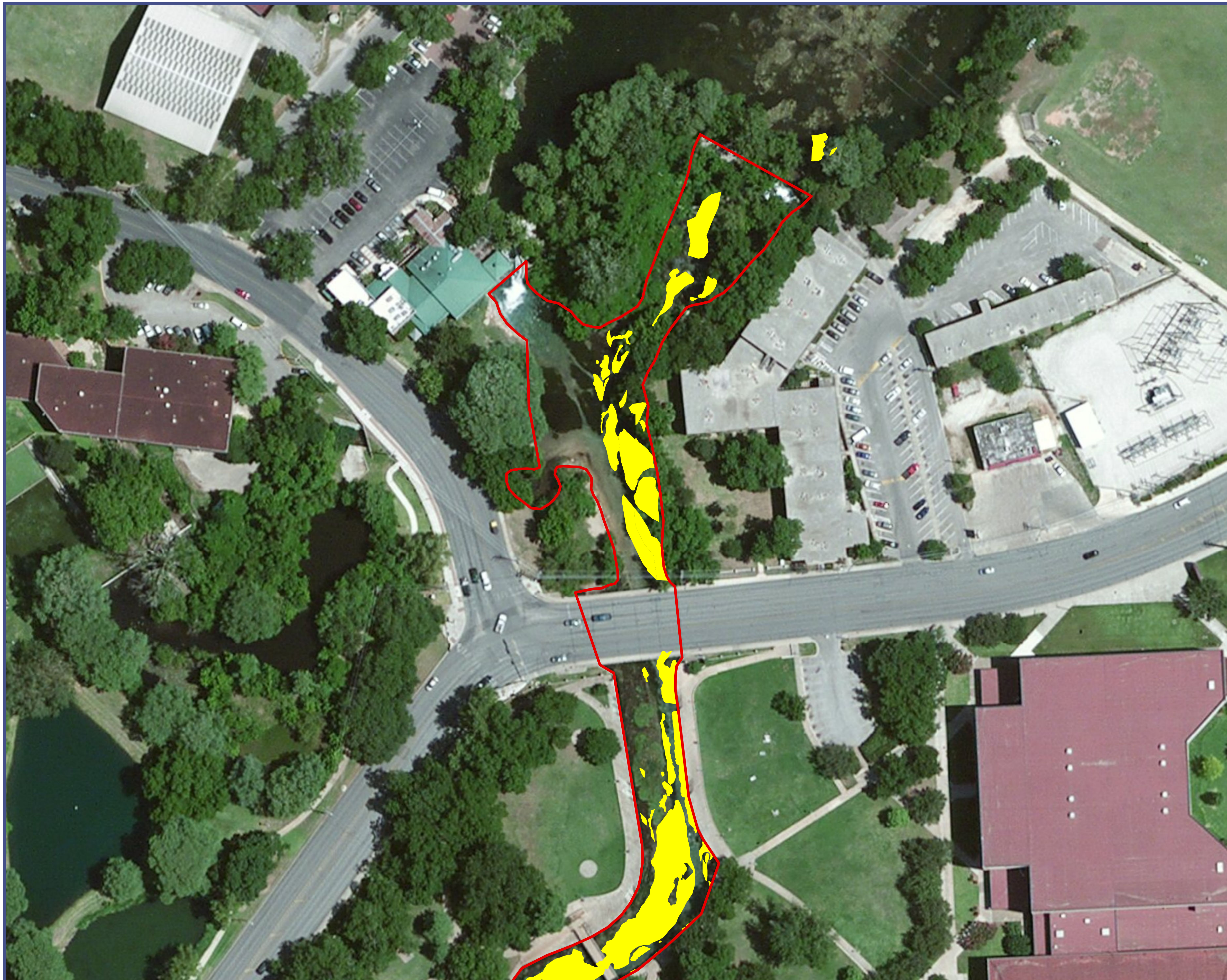

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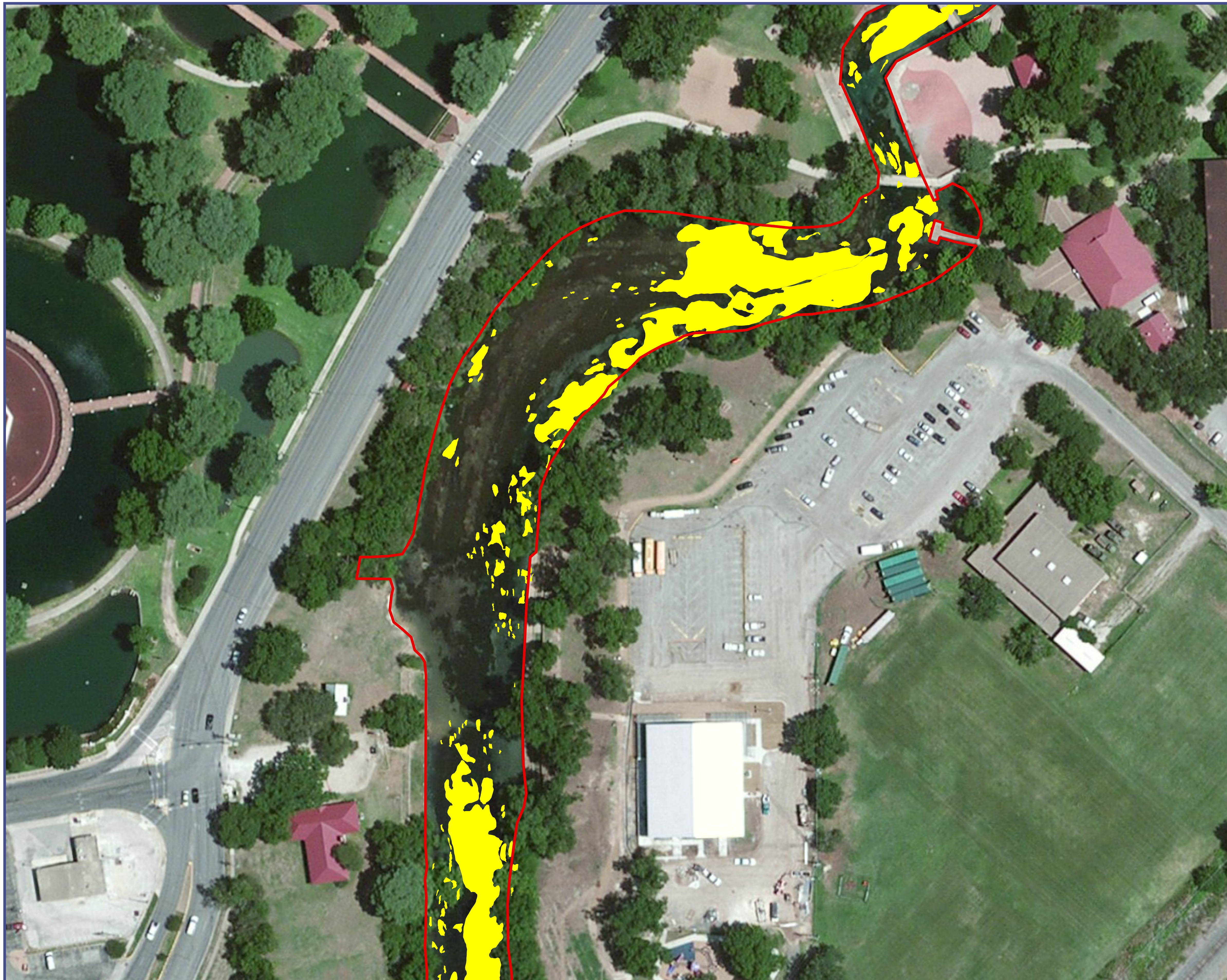

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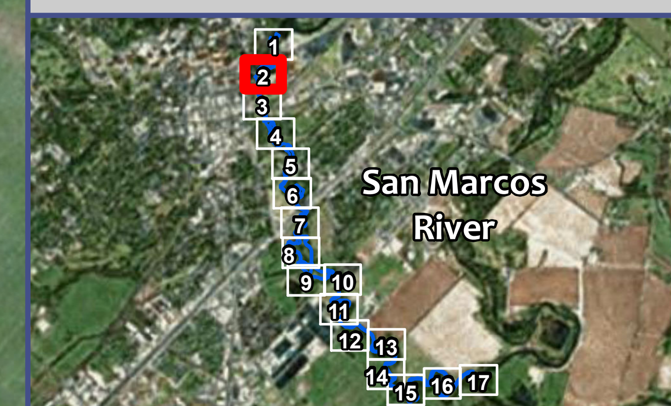

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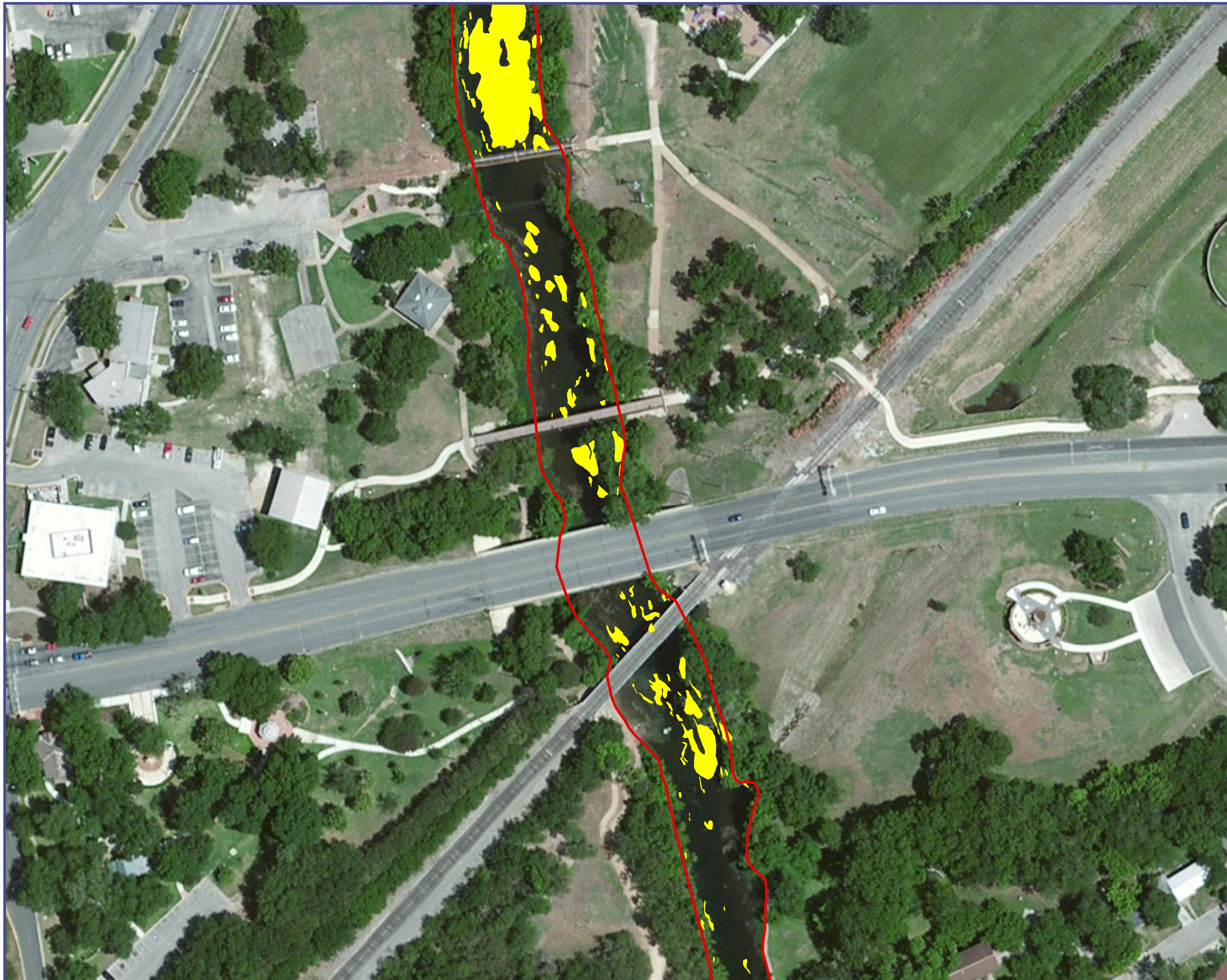

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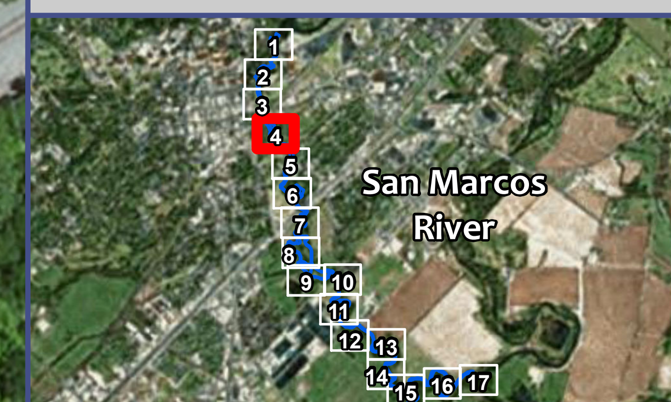

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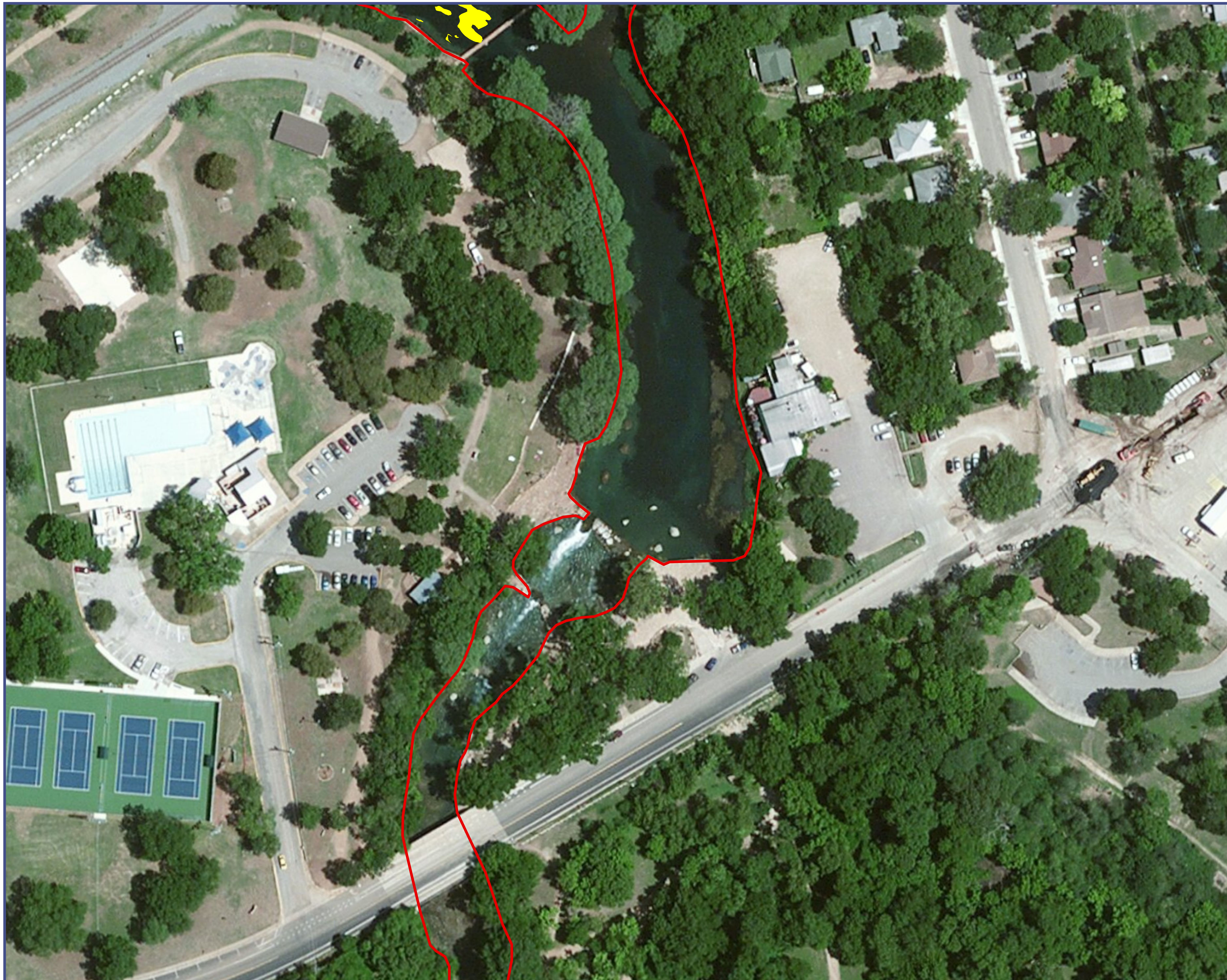

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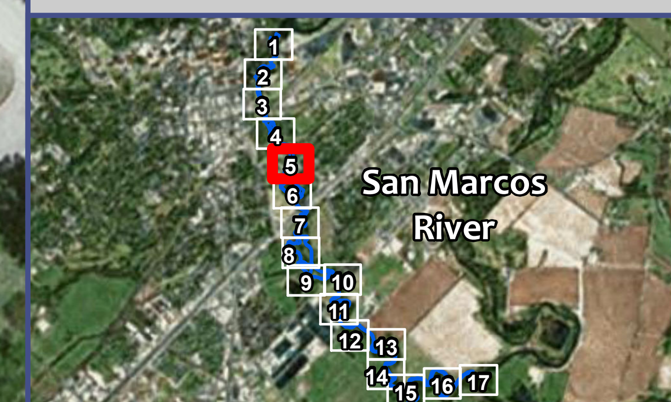

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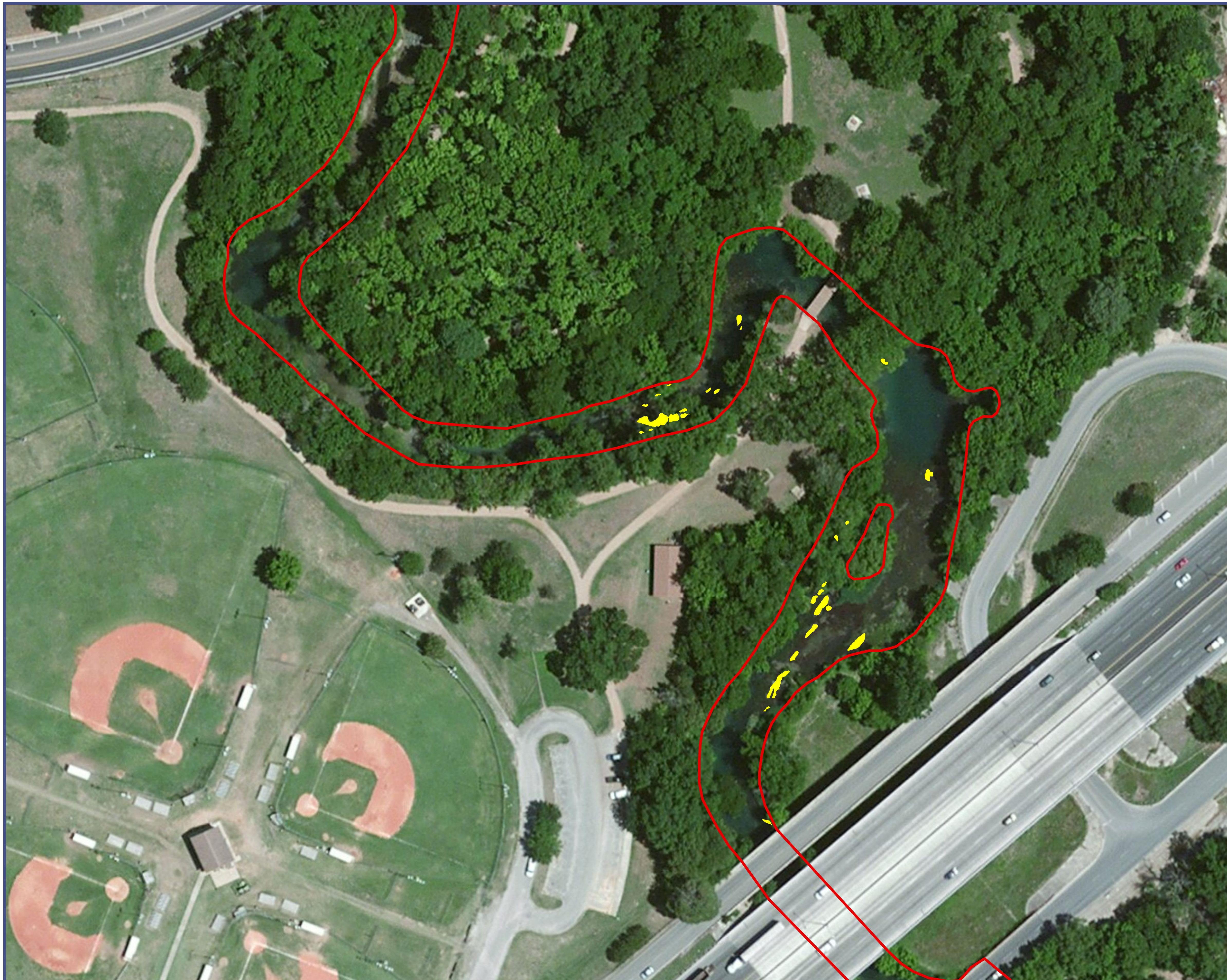

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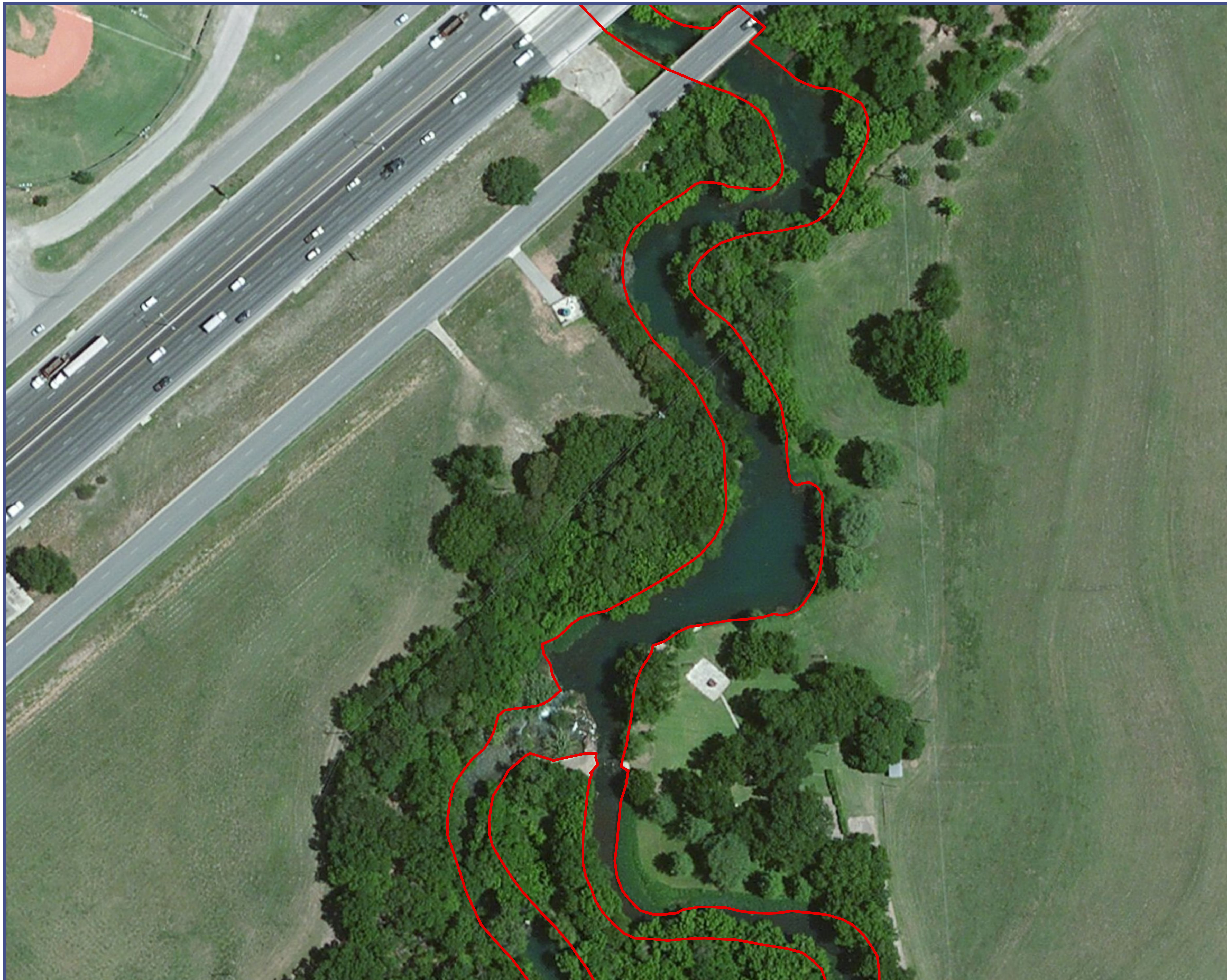

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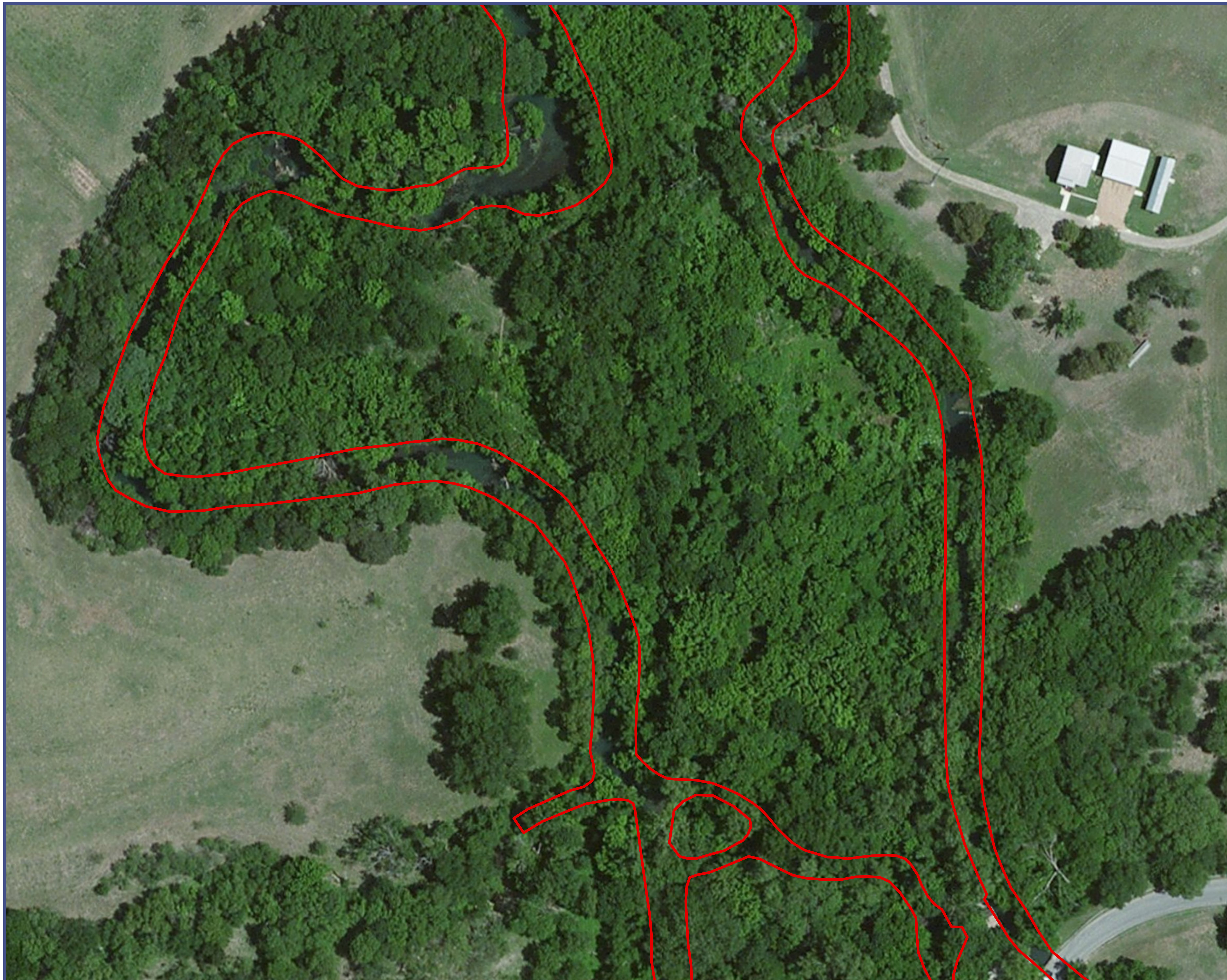

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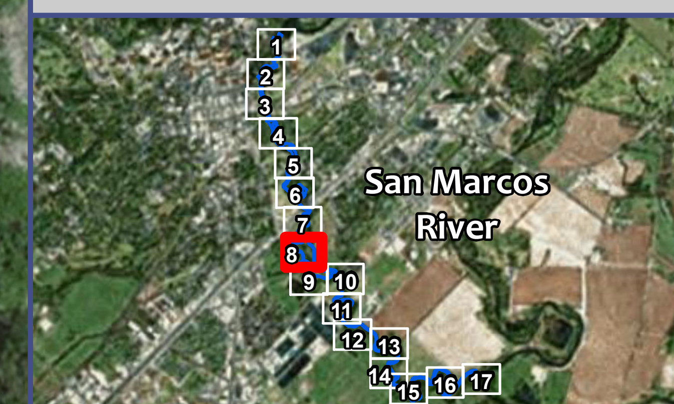

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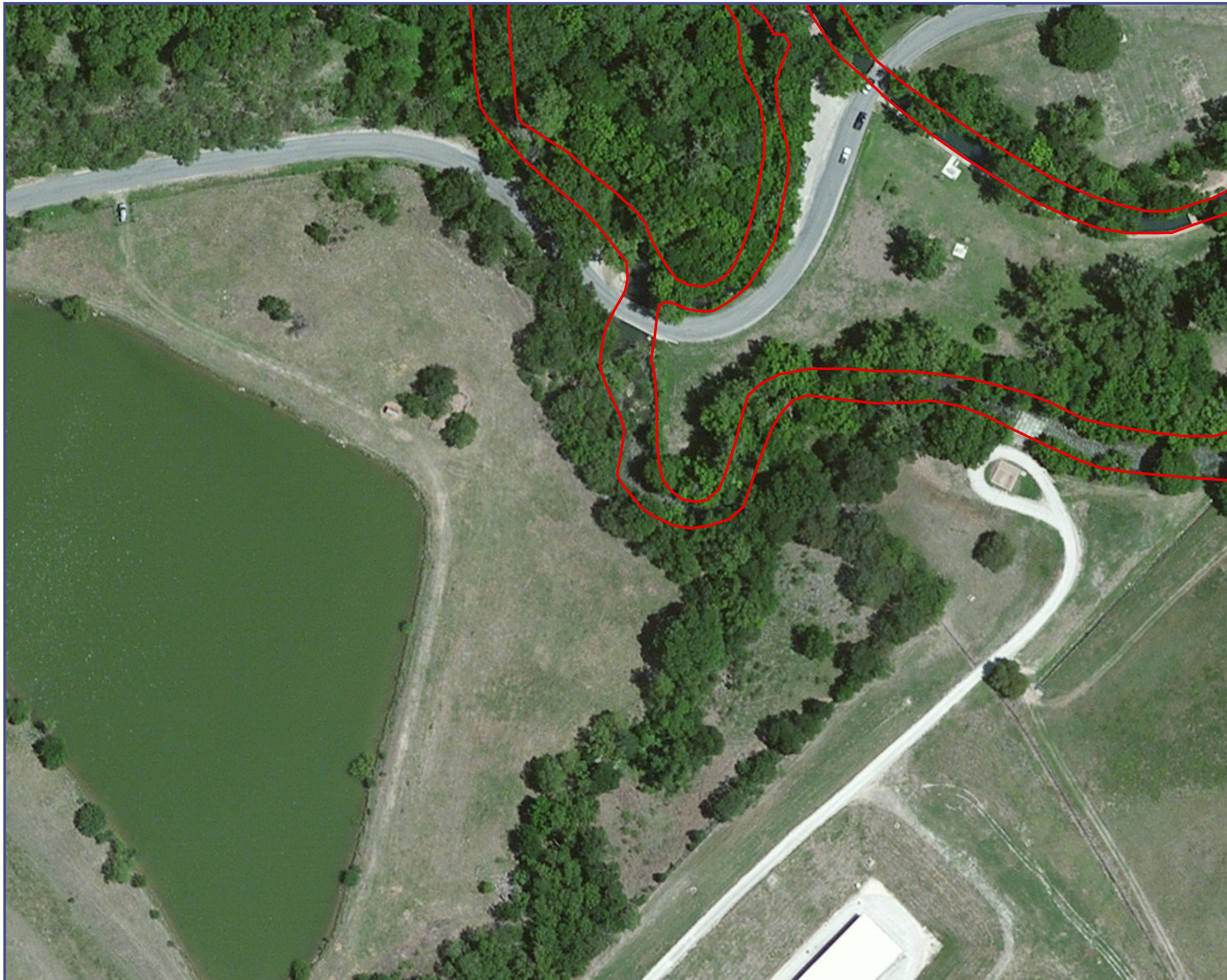

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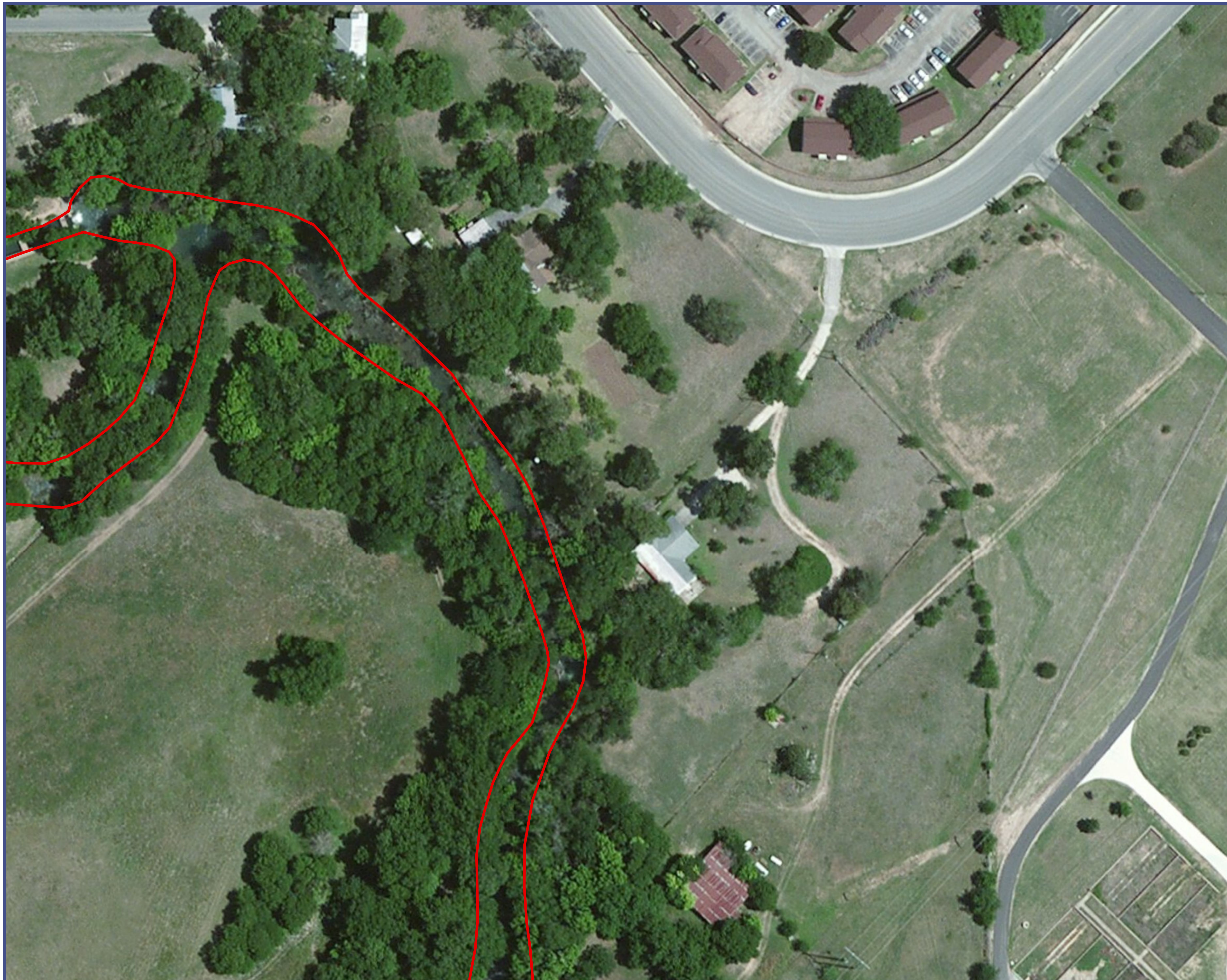

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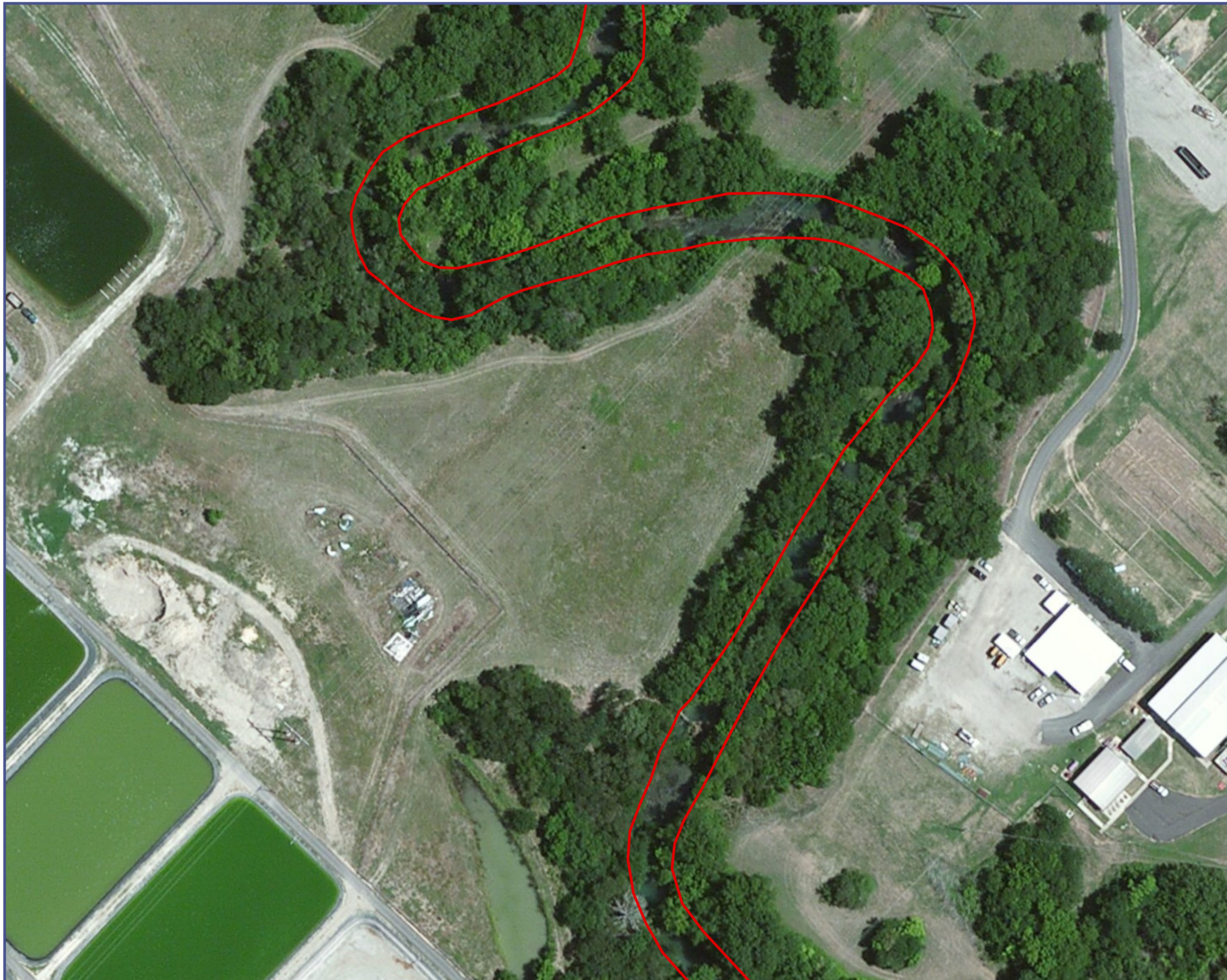

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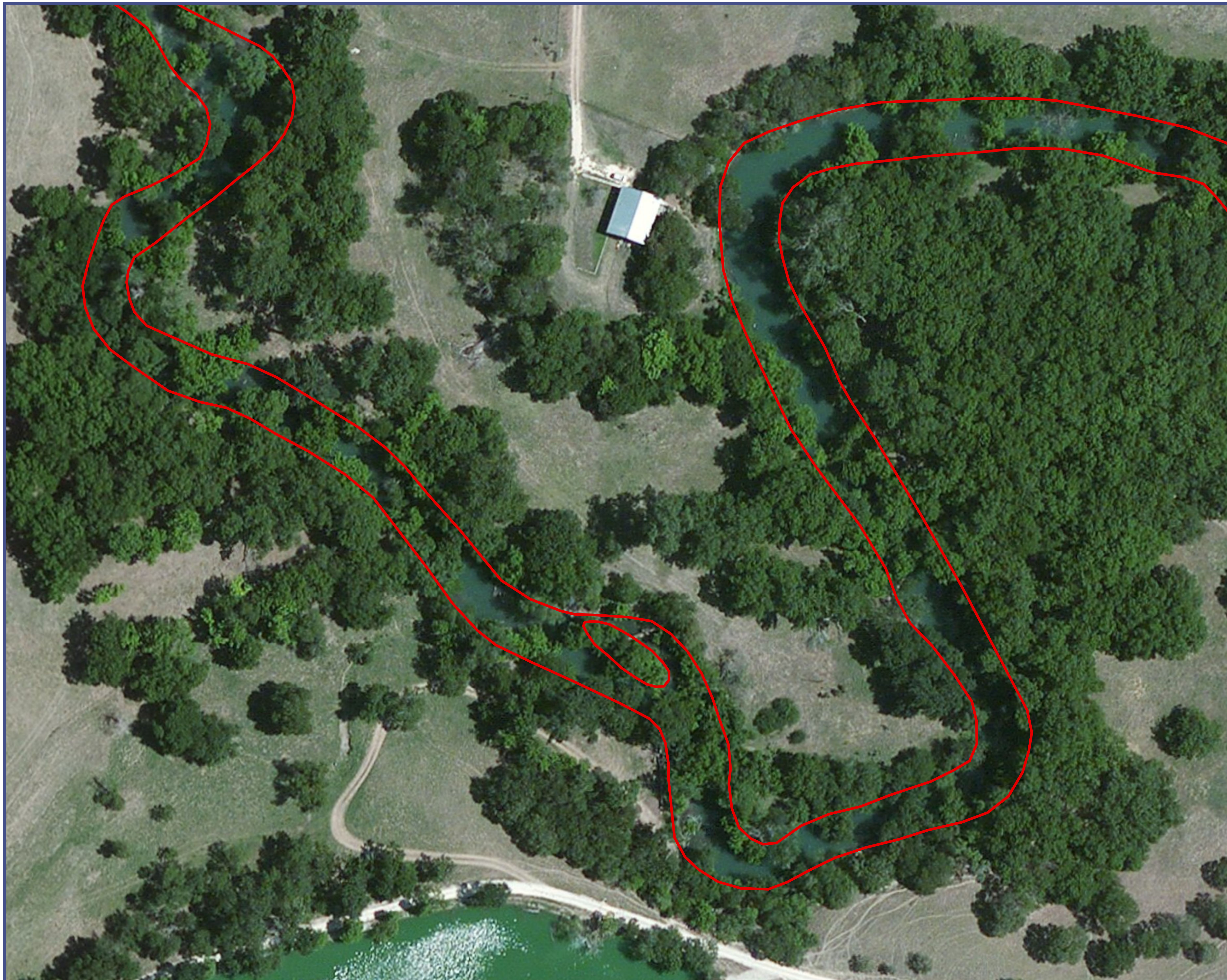

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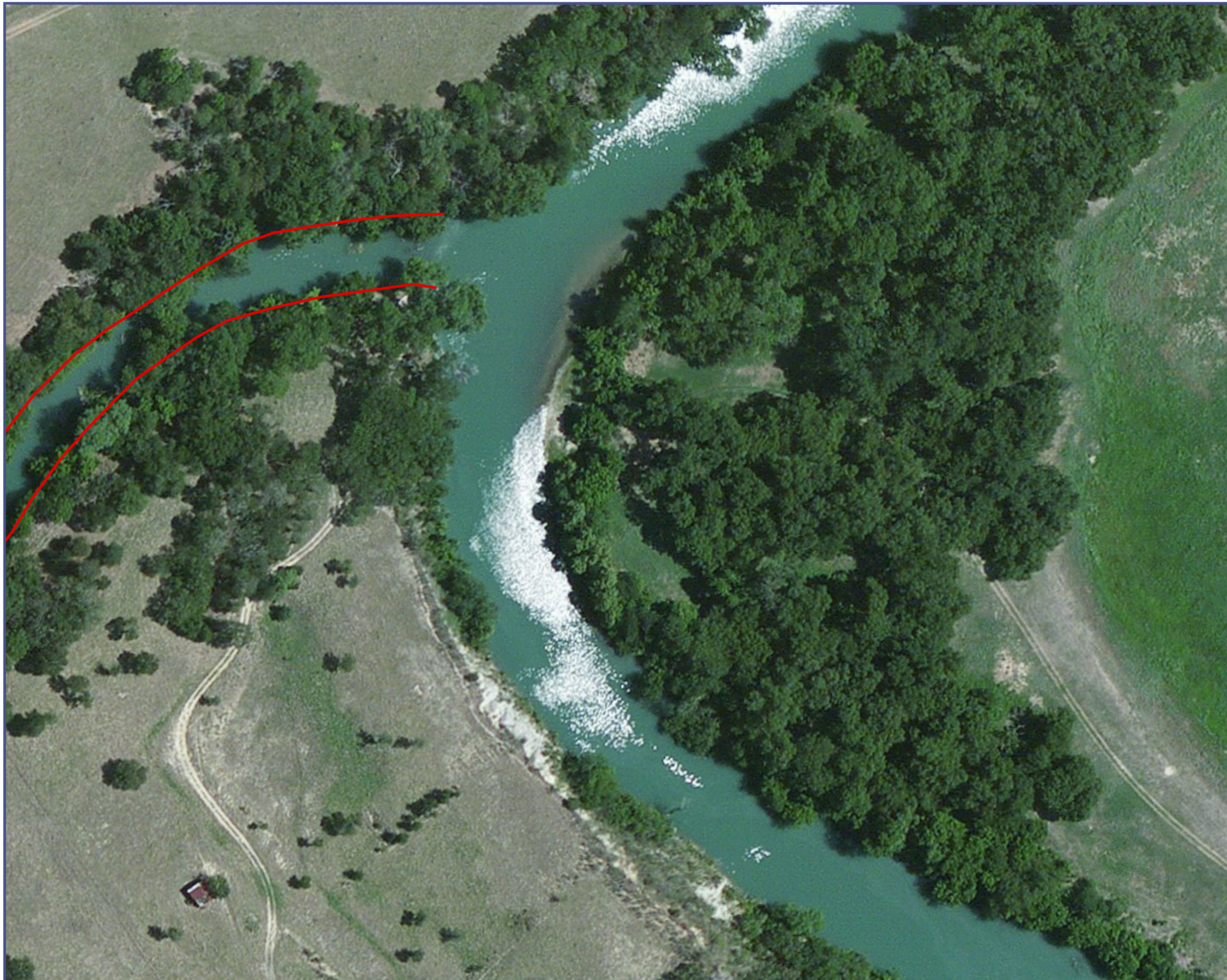

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