Appendix H | **2021 City of New Braunfels Reports**

H1 | **Native Aquatic Vegetation Restoration in the Comal River System**

2021 Native Aquatic Vegetation Restoration and Maintenance in the Comal River

PREPARED FOR:

City of New Braunfels
550 Landa Street
New Braunfels, Texas 78130

PREPARED BY:

BIO-WEST, Inc.
1812 Central Commerce Court
Round Rock, Texas 78664

November 10, 2021

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

As part of the Edwards Aquifer Recovery Implementation Program (EARIP) Habitat Conservation Plan (HCP), scientists at BIO-WEST, Inc. (BIO-WEST) have conducted native aquatic plant restoration activities to improve habitat for the federally listed, endangered Fountain Darter (*Etheostoma fonticola*) and native aquatic fauna. This year marked the ninth consecutive year for restoration and maintenance activities. The continued intent of this HCP measure is to increase the cover and distribution of target native aquatic plant species, subsequently benefiting the Fountain Darter by increasing available native habitat and improving the quality of existing habitat. This 2021 Native Aquatic Vegetation Restoration and Maintenance report summarizes the activities and restoration results within the project areas.

1.1 Project Areas Overview

The project area generally covers the upper two kilometers of the Comal River but is divided into multiple Restoration and Long-term Biological Goal (LTBG) reaches (**Figure 1**). LTBG reaches are the sampling sites in which routine biological monitoring is conducted. Fountain Darter sampling, water quality, discharge and various other data are collected specifically in the LTBG reaches to support the HCP long-term monitoring program. The restoration reaches are included to expand restoration and habitat improvement to the system. This project area encompasses Bleiders Creek through a spring run channel, referred to as Upper Spring Run, into Landa Lake and extending into the Mill Race, effectively ending at the first low-head dam. The project area also extends into the Old Channel and downstream approximately 1,100 meters. The Upper New Channel Long-Term Biological Goal (LTBG) Reach is disjunct from the rest of the project area. Each project reach has its own restoration timeline and goals as directed by annual work plans provided by the City of New Braunfels.

In 2021, significant effort was focused in the Landa Lake LTBG Reach. This included maintaining previously restored areas and creating new areas for plantings of *Ludwigia repens* and *Cabomba caroliniana*. Restoration activities in the Old Channel were focused almost entirely in the restoration reach. Although the Old Channel Restoration Reach was not originally a

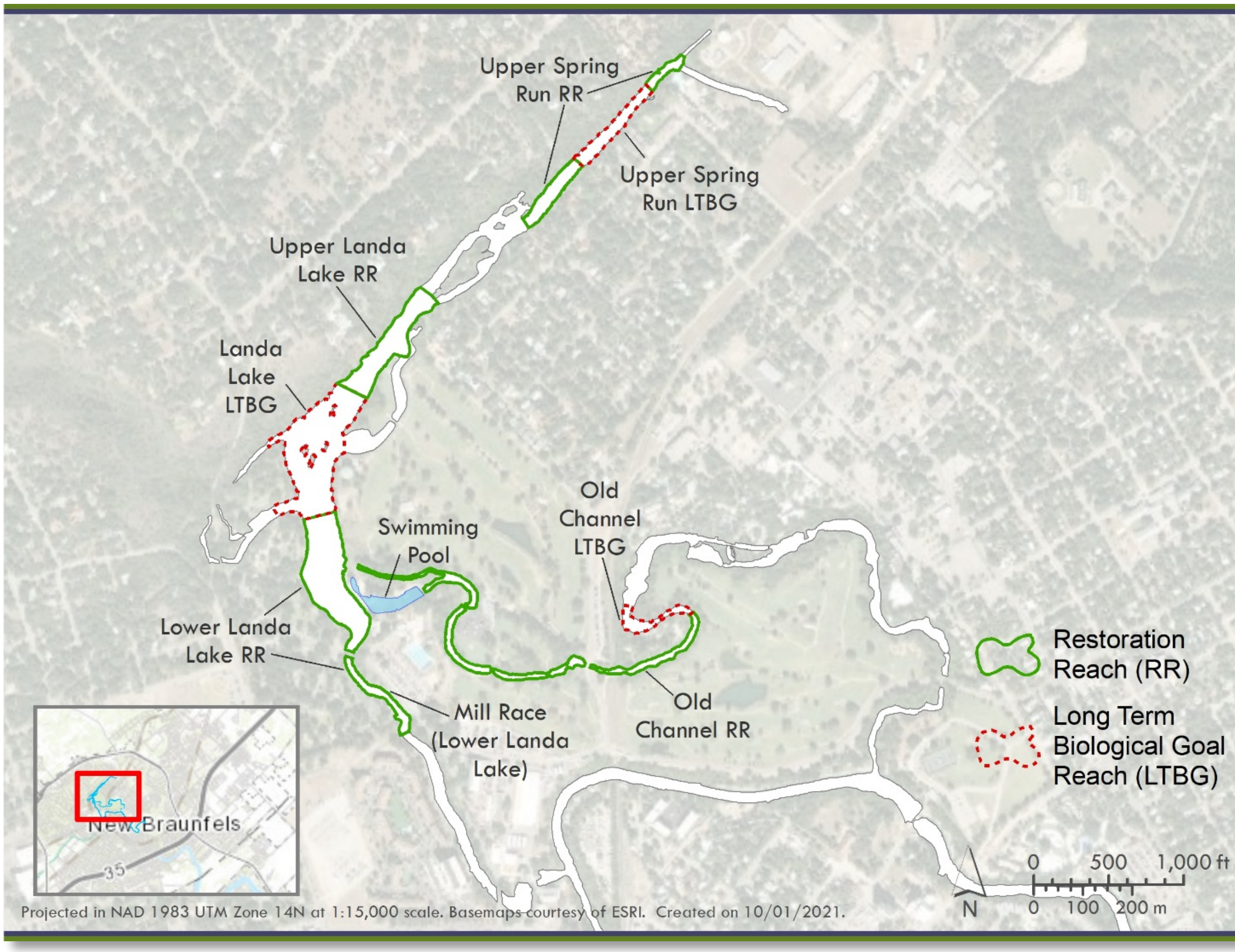


Figure 1 Location of the Landa Lake, Upper Spring Run and Old Channel Long Term Biological Goal (LTBG) Reaches (outlined in red). Green outlines the restoration areas.

target for restoration plantings this year, plans were modified to include reestablishment of *Ludwigia repens* and *Cabomba caroliniana*, as the cover of both species had declined significantly over the last two years due to competition from other native aquatic plant species. The Upper and Lower Landa Lake continue to maintain their minimal vegetation goals. The Upper New Channel LTBG and the Upper Spring Run reaches continue to be significantly impacted by recreation and disruptive flow-pulses from heavy rainfall events. As such, less effort was given to these locations. As is common each year, general maintenance such as vegetation mat removal, tree trimming and clearing of debris was conducted as needed across the project area to enhance habitat quality for native aquatic vegetation.

2 Spring / River Conditions in 2021

The aquatic vegetation community benefited from both the lack of scouring flood events and relatively stable flows through 2021 (**Figure 2**). During the first half of the year, discharge was noticeably below the historical daily median and continued to decline into April. However late spring and early summer precipitation provided a considerable boost to the Edwards Aquifer and resulted in spring discharge nearing the daily median for the remainder of the year. The summer months experienced a buildup of floating vegetation mats along with epiphytic algae despite average total system discharge conditions. Over the past nine years, these vegetation mats continue to be a common occurrence in the summer regardless of the flow conditions. September remained unusually dry with no considerable precipitation contributing to spring or surface flow. In October, a significant pulse flow event affected the entire system with runoff from Bleiders Creek, Panther Canyon and Dry Comal Creek providing elevated discharge and creating turbid conditions for several days. However, total system discharge has returned to median conditions as of this report.

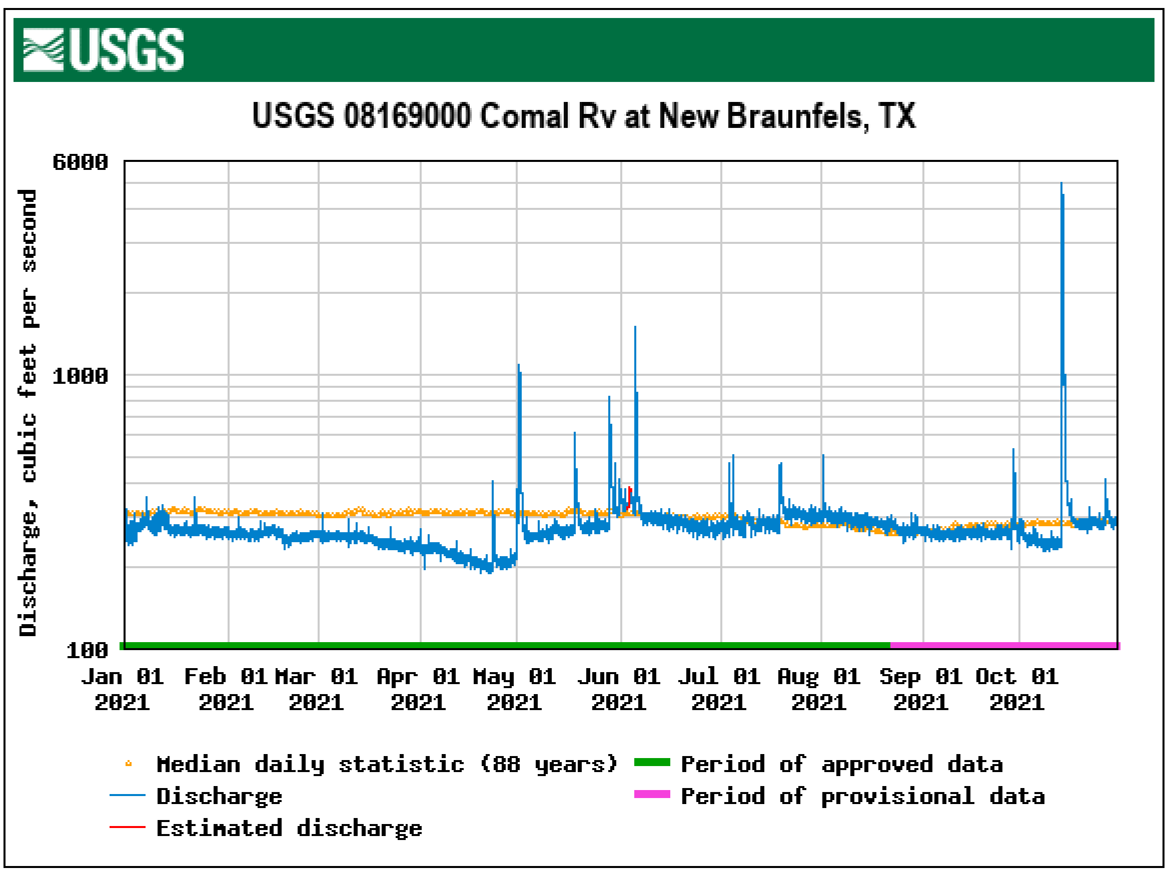


Figure 2 Discharge in the Comal River from January through October 2021 (USGS 2021).

3 Plant Propagation Methods

The native aquatic plant species targeted for this project include: *Ludwigia repens* (Ludwigia), *Cabomba caroliniana* (Cabomba), *Sagittaria platyphylla* (Sagittaria), *Potamogeton illinoensis* (Potamogeton) and *Vallisneria neotropicalis* (Vallisneria). In 2021, only Ludwigia and Cabomba were planted as all other species have either met the target goals in their respective reach or are deemed not appropriate for that specific area. The methods for aquatic plant propagation in 2021 remained comparable to methodologies employed in previous years. Mobile underwater plant propagation trays (MUPPTs) were utilized to propagate the majority of the Ludwigia necessary for the project. This procedure was supplemented with sprigging from trimmed stem fragments, as the past several years have demonstrated this to be a reliable way to supplement Ludwigia colonies, and the Ludwigia colonies also benefit from the occasional trimming. As in previous years, Cabomba was sprigged into the planting site from mother colonies located within other locations of the Comal River. As in years past, plant production in the MUPPTs began in February. Over the course of 2021, the MUPPTs were harvested as needed and restocked accordingly. Detailed background information regarding plant propagation methods can be found in previous reports (BIO-WEST 2013b, 2014, 2015, 2016).

4 Aquatic Vegetation Restoration Program

Aquatic habitat restoration field efforts in the project areas consist of three main activities: 1) removal of invasive *Hygrophila polysperma* (Hygrophila); 2) planting of native aquatic plants; and 3) monitoring, mapping and gardening of restored areas. Each activity is covered in detail in sections 4.1 – 4.3.

4.1 Hygrophila Removal

From 2013 to 2018, significant effort was put into removing and eliminating Hygrophila from Bleiders Creek, Upper Spring Run, Landa Lake and the first kilometer of the Old Channel restoration reach. Since 2019, the presence of Hygrophila has been greatly reduced and is now found in only a few locations in the project area. Typical occurrences of Hygrophila are now limited to sprigs or small clumps, less than a meter in diameter, and usually along the stream edges (**Figure 3**).

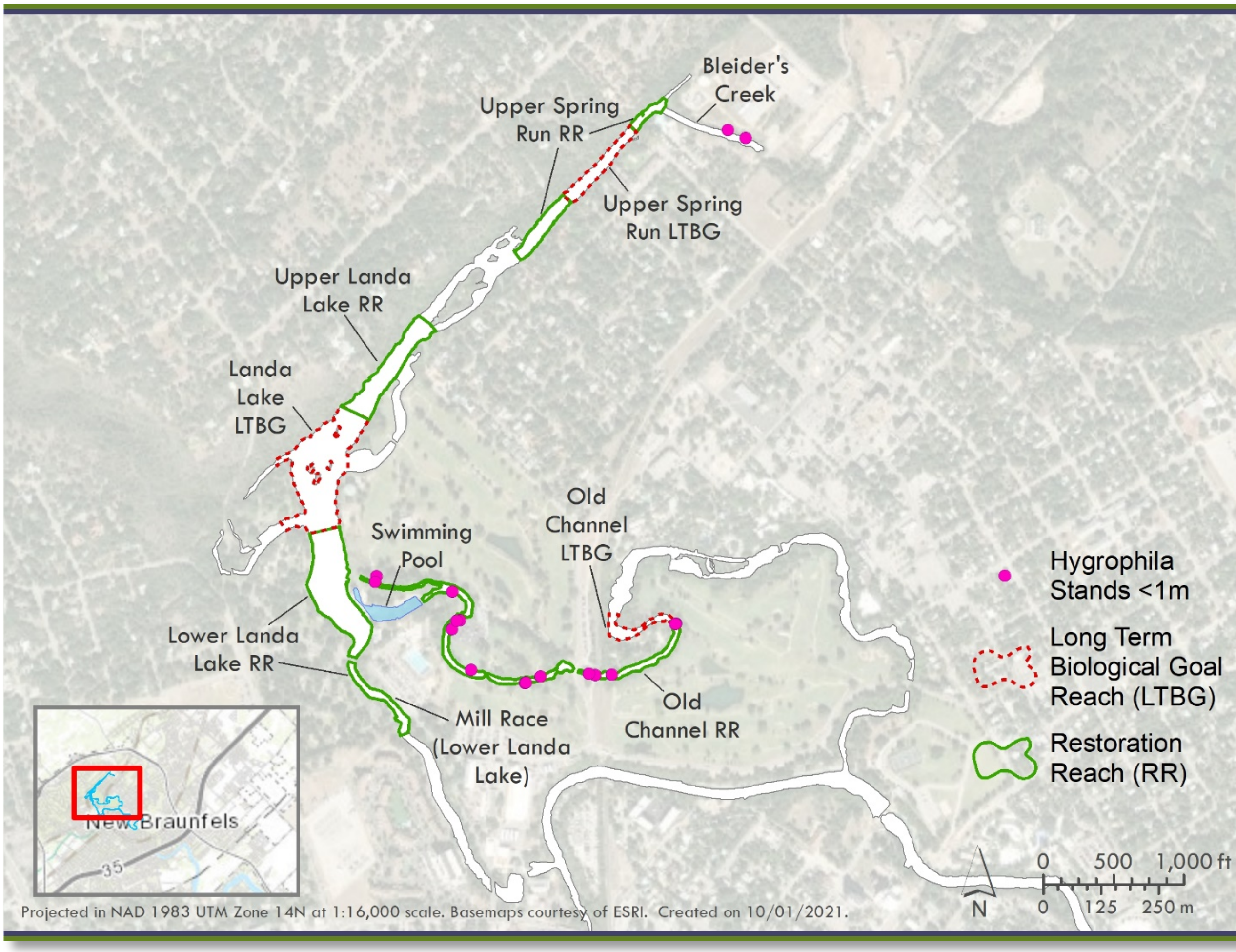


Figure 3 February 2021 baseline distribution of Hygrophila in the study area. Map does not represent locations where Hygrophila appeared later in the year.

To continue to combat Hygrophila, the project team routinely conducted visual snorkel surveys from Bleiders Creek to the end of the Old Channel LTBG Reach and any Hygrophila observed was removed. Greater effort was focused on the Old Channel river sections adjacent to the golf course as these areas tend to have recurring Hygrophila population fragments. The amount of Hygrophila removed from the entire project area totaled 10 m^2 for 2021. One patch of three-square meters appeared during the fall monitoring period and will be subsequently removed in 2022. Fall monitoring also revealed a Hygrophila patch of only a single square meter in size within Bleiders Creek and this was covered with a benthic barrier mat. The likelihood of re-infestation into restored areas is possible, but occasional gardening and ongoing maintenance should prevent Hygrophila from re-establishing and dominating the areas where it has been removed. **Table 1** summarizes Hygrophila removal activities for 2021.

Table 1 **Amount of Hygrophila removed in 2021 per work section**

Location/Section	Area Removed (m²)	Period of Work
Landa Lake (outside of LTBG Reach)	0	Gardened as needed
Old Channel Restoration Reach	1	Gardened as needed
Old Channel LTBG Reach	8	Gardened as needed
Swimming Pool	0	Gardened as needed
Upper Spring Run LTBG Reach	0	Gardened as needed
Upper Spring Run Restoration Reach and Bleiders Creek	< 1	Gardened as needed
Landa Lake Spillway	0	Gardened as needed

4.2 Native Aquatic Plant Restoration

Over the course of 2021, the Comal aquatic restoration project planted 5,936 native aquatic plants, with 3,578 Ludwigia and 1,758 Cabomba planted in Landa Lake LTBG and Old Channel restoration sites. To date the project has planted 81,719 aquatic plants, with Ludwigia accounting for 60% of those plants and Cabomba accounting for approximately 20%. Sagittaria was initially included in restoration plantings but is presently expanding sufficiently on its own in most reaches or otherwise not appropriate for others. Potamogeton has also expanded on its own in the Old Channel, although it failed to survive in past years when planted in Landa Lake. Presumably the high competition and limited suitable growing areas within Landa Lake are factors influencing this result. Based on previous results and observations, the project team has prioritized Ludwigia and Cabomba plantings for restoration in most of the current project areas. If conditions change in the aquatic plant community and inclusion of the other target species is necessary, the project team will amend this strategy.

4.3 Aquatic Gardening and Monitoring

As previously discussed, no large-scale removal of Hygrophila was necessary for 2021. Instead, only routine monthly gardening trips were conducted from Bleiders Creek to the end of the Old Channel LTBG Reach to monitor for Hygrophila sprigs or patches. With Hygrophila mostly absent, aquatic gardening focused on other objectives, including regular trimming of emersed Ludwigia stands in Landa Lake. Trimming provides sprigs for supplemental plantings as well as propagative material for MUPPTs, while also promoting persistence of individual patches by reducing the top growth of the Ludwigia plants and in turn lessening buoyancy of the patches (**Figure 4**). Ludwigia stands that have a high degree of top growth, sometimes extending three to four feet into the water column, tend to be uprooted by water currents over time. Therefore, removal of top growth aids in persistence of these patches.

Other gardening activities in Landa Lake included dislodging or displacing vegetation mats that concentrate over restored plots. Gardening in this reach also entailed removal of Vallisneria and Sagittaria around the perimeter of Ludwigia and Cabomba patches to control encroachment.

Figure 4 Collecting Ludwigia trimmings from overgrown colonies for planting elsewhere in Landa Lake.

Vegetation mats are rarely a problem in the Old Channel and emersed Ludwigia growth is also not an issue since water depth is lower and current velocities are greater than in other reaches. These two factors keep Ludwigia stems short and sprawling. Aquatic gardening activities in the Old Channel typically focus on removing fallen trees or tree limbs which block the channel and facilitate the accumulation of debris. Excessive buildup of thick bryophyte beds can be problematic to Old Channel aquatic vegetation, as thick bryophyte beds can smother Cabomba and Ludwigia;

Sagittaria is less impacted. Accordingly, steps are taken to routinely dislodge epiphytic bryophytes on susceptible restored plantings.

Monitoring and mapping of LTBG and restoration reaches is an important measure within restoration strategies, as it provides data useful in gauging the progress of the project and allows the team to reassess and enhance methodologies for future success. Three mapping events were again conducted in 2021 to evaluate the restoration project and assess native plant coverages. The first was a baseline mapping event conducted in February, before 2021 restoration activities commenced. Subsequent mapping occurred in April and September. Vegetation mapping is conducted by encircling the perimeter of plant patches with a kayak while collecting GPS coordinates via a Trimble GPS unit. Once a patch is mapped it is identified to species, and the density of each species within the patch is estimated to produce a final area coverage estimate in square meters (m^2). These methods are used to quantitatively evaluate the spatial expansion of plant species and qualitatively evaluate the density and health of restored and natural stands. The results of these mapping events are discussed in detail in the respective site results sections below.

4.4 2021 Restoration Results

4.4.1 Old Channel Restoration Results

Five new restoration plots were installed in the Old Channel Restoration Reach in 2021 for a total of 181 m^2 of planted area (**Figure 5**).

Plantings occurred in the Old Channel Restoration Reach from 2015 until 2018. Based on the annual workplan, restoration plantings were only scheduled to occur in the Old Channel LTBG Reach this year. However, the recent expansion of Sagittaria and Potamogeton in the upper stretches of the Old Channel Restoration Reach have contributed to reduced Ludwigia cover and entirely excluded Cabomba here. Based on discussions with the City of New Braunfels, the project team resumed plantings to begin re-establishing these two species in areas where they were once prominent.

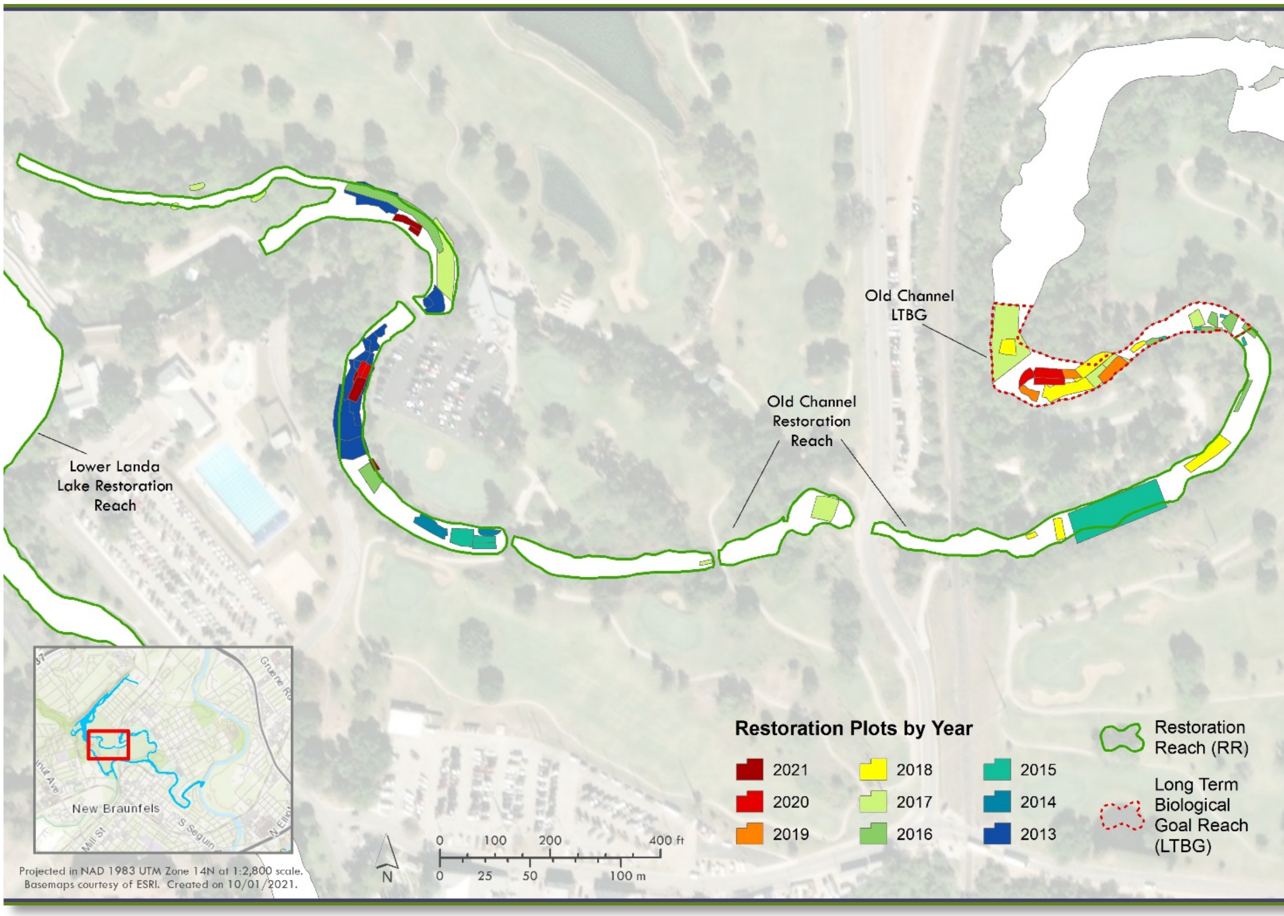


Figure 5 Restoration plots in the Old Channel LTBG and restoration reaches.

In the Old Channel LTBG reach, plantings expanded on their own due to the ample open space and lack of competition from other aquatic plants. The restoration team did not conduct active plantings in this LTBG reach in 2021. Instead, general maintenance and aquatic gardening was carried out to keep the area free of debris and improve natural expansion. The continued challenge to vegetation establishment in this reach is the formation of extensive bryophyte beds and epiphytic growth, which must be cleared occasionally in order for rooted species to thrive.

A total of 1,402 plants covering 181m^2 were planted in the Old Channel Restoration Reach (**Table 2**).

Table 2 **Planting dates and number of target species planted within the Old Channel**

2021 Old Channel Restoration Plantings			
Old Channel Restoration Reach			
Date Planted	Plot	Ludwigia	Cabomba
3/7	21A	300	
5/6	21B	350	
5/10	21C		100
7/9	21D	135	
8/4	21E	517	
Total		1,302	100

Table 3 shows winter, spring and fall coverages (m^2) of the target species and other plants within the Old Channel restoration and LTBG reach. As noted in previous reports, Ludwigia and Cabomba often fluctuate between mapping events across the year, while the coverage of other species such as Vallisneria tends to stay consistent. Inter- and intra-year fluctuations result from both natural losses and expansion in addition to restoration plantings. For both Old Channel reaches, the coverage stayed similar across seasons this year. No floods or other disturbance events caused any scouring effects.

The most noticeable developments in the Old Channel reaches in 2021 were the voluntary expansions of both Ludwigia and Cabomba. In the LTBG reach, these species continued to sprig themselves into bare areas and begin new colonies. Cabomba experienced explosive growth, expanding from 89 m^2 to over 300 m^2 by late summer, despite there being no plantings and only strategic gardening within the LTBG reach. In the restoration reach, Sagittaria was removed and replaced with Ludwigia, giving this species a needed boost for expansion. However, Cabomba expanded well and colonized new areas on its own. These events allude to the fact that the Old Channel reach is morphing into a self-sustaining native aquatic plant community; however, active restoration will still be necessary to adjust the plant community towards the intended goals. For instance, in the Old Channel restoration reach, one benthic barrier was placed within a large monospecific patch of Sagittaria. In 2022, this barrier will be removed, and the area planted with Cabomba to help boost coverage in the future. Now that the project team is aware of the dynamics between mixed stands of Sagittaria/Potamogeton and Ludwigia/Cabomba, efforts can be made to maintain and protect Ludwigia/Cabomba patches from competition in order to preserve desired cover and strive towards meeting HCP goals.

Table 3 **Seasonal cover (m²) of target restoration species in the Old Channel LTBG and Restoration Reaches indicated by GIS mapping from September 2020 to September 2021.**

Species	September 2020	February 2021	April 2021	September 2021
Old Channel LTBG Reach				
Ludwigia	323	251	234	397
Sagittaria	6	0	0	0
Cabomba	190	60	89	340
Hygrophila	0	0	0	0
Bryophyte	687	862	596	211
Old Channel Restoration Reach				
Ludwigia	642	650	733	933
Sagittaria	914	979	898	807
Cabomba	67	15	22	142
Potamogeton	751	623	615	622
Vallisneria	858	940	940	1,081
Hygrophila	0.5	8	0	2
Bryophyte	707	250	104	108

Maps highlighting the species distribution between all three mapping events are provided below (**Figure 6, 7, 8**).

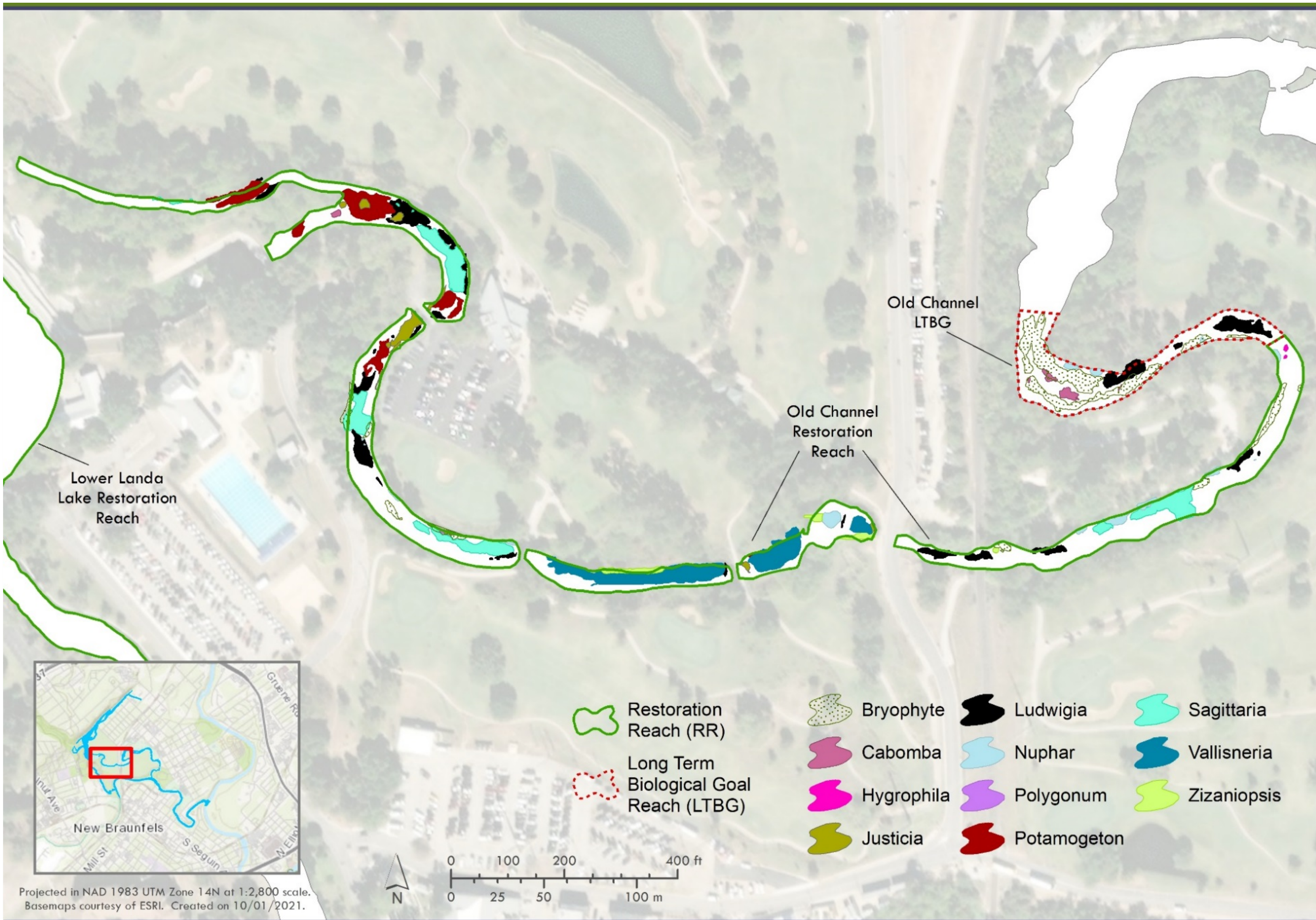


Figure 6 Restored aquatic vegetation in the Old Channel in February 2021.

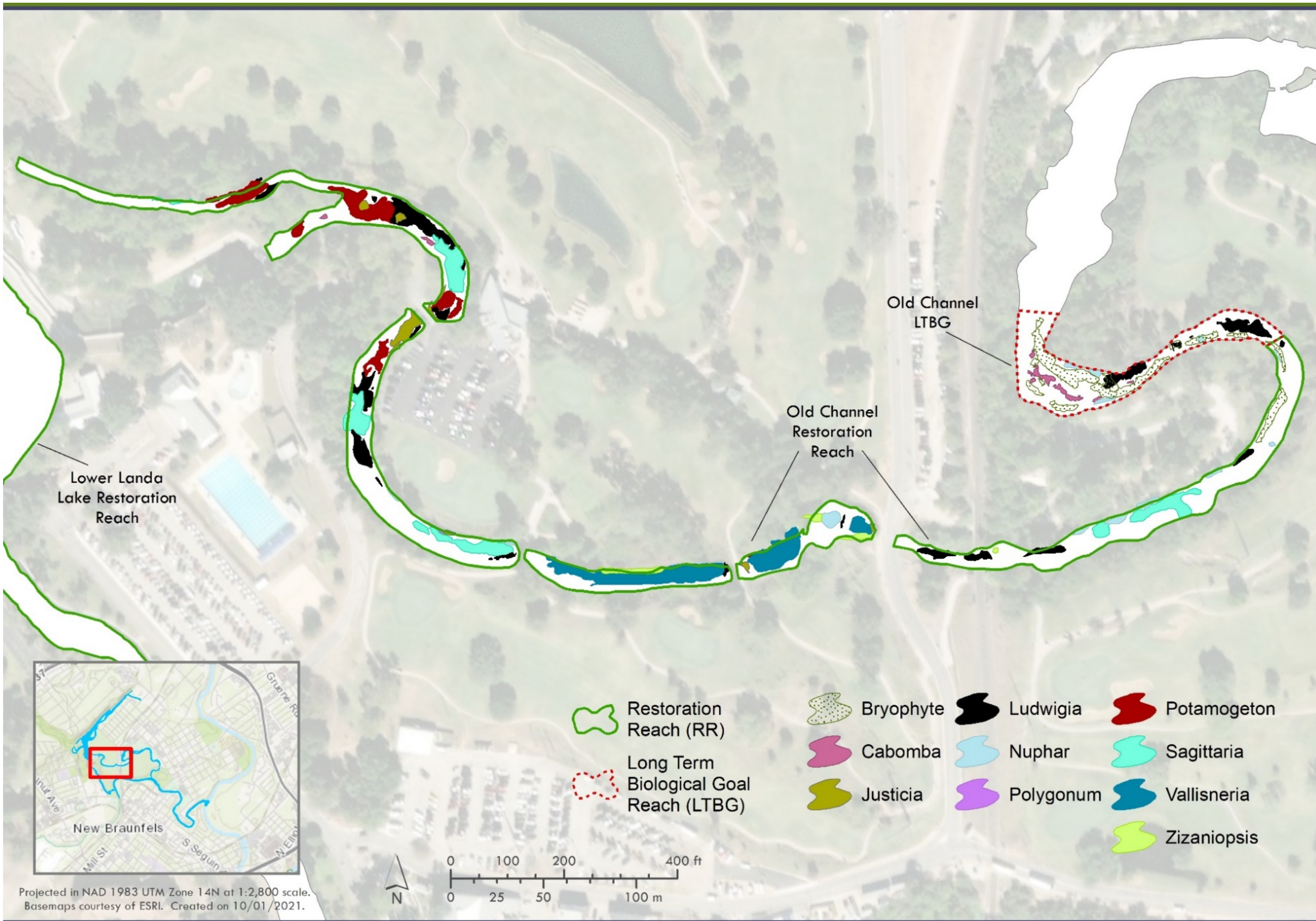


Figure 7 Restored aquatic vegetation in the Old Channel in April 2021.

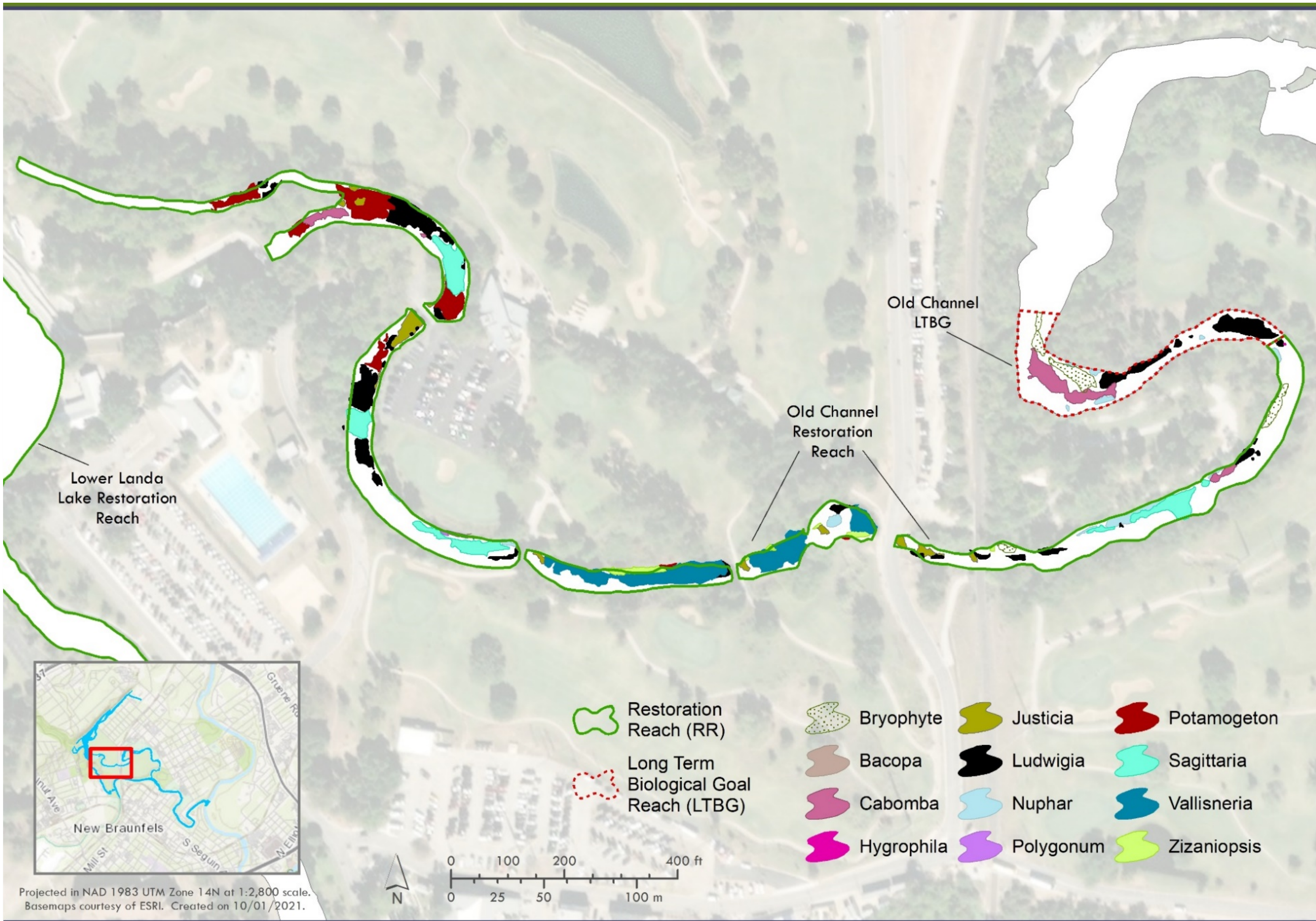


Figure 8 Restored aquatic vegetation in the Old Channel in September 2021.

4.4.2 Landa Lake Restoration Results

This year's activities in the Landa Lake LTBG reach resulted in a total of 4,534 plants installed into the reach (**Table 4**) with a portion of those planted as supplements to older plots. A combined area of 471 m^2 was planted in five restoration plots (**Figure 9**). Activities in the Upper and Lower Landa Lake restoration reaches were limited to gardening and maintenance of Cabomba and Ludwigia to continue towards meeting restoration goals.

Work in Landa Lake progressed well in 2021 with no major changes or differing challenges from previous years. The benthic barrier system implemented over the last two years has been highly successful, resulting in a decrease in the labor necessary to create planting plots. Currently, the benthic barriers provide 1,600 m^2 of exclusion area during each placement. Some barriers are kept in place to inhibit expansion of adjacent vegetation. The methodology for this system is to set the barriers adjacent to areas already planted with target species, where they eliminate less desirable Vallisneria and Sagittaria by blocking light. Afterwards, they are repositioned to continuously add neighboring space for planting plots. On average, it takes about three months for the barriers to effectively eliminate Vallisneria, including the roots and propagules, and four to five months to eliminate Sagittaria; although these timeframes vary based on plant density and maturity. Older plants with more developed root systems can survive longer periods of darkness while using stored energy reserves and may require lengthier periods beneath the benthic barriers for effective removal.

Table 4 **Planting dates and number of native specimens planted within Landa Lake LTBG. Shaded numbers indicate supplemental plantings in pre-existing plots.**

2021 Landa Lake Restoration Plantings			
Landa Lake LTBG Reach			
Date	**Plot**	**Ludwigia**	**Cabomba**
3/18	DD	50	
5/10	G	150	
5/28	13F	200	
6/25	21A	100	
7/1	U1	300	
7/8	21C		958
7/13	21B	83	
7/13	21B	199	
7/20	21C		700
7/26	21B	120	
7/27	21D	200	
7/29	21B	64	
7/30	21D	220	
8/5	21E	200	
8/6	21A	50	
8/9	21E	100	
8/11	21E	460	
8/11	21A	150	
8/19	14Q	130	
8/19	19B	100	
Total		**2,876**	**1,658**

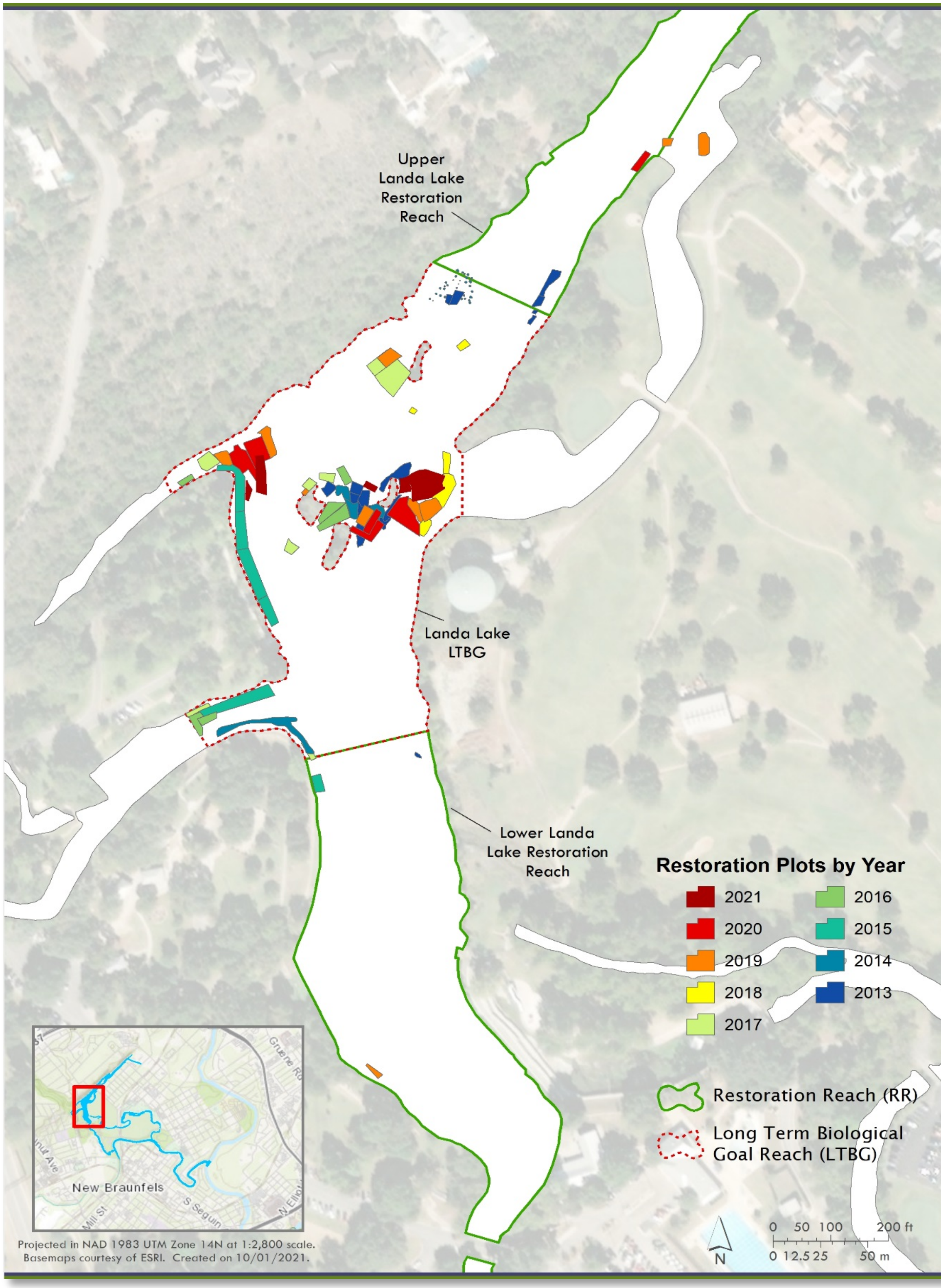


Figure 9 Restoration plots in the Landa Lake LTBG and Landa Lake Upper and Lower Restoration Reaches.

Table 5 shows the coverages in square meters of selected species per reach during each mapping event. Ludwigia and Cabomba showed a marked increase across the year, with Ludwigia surpassing 1,000 m^2 for the first time since restoration work began. Cabomba increased to its second highest coverage since 2013. Vallisneria coverage, as usual, remained somewhat steady through 2021. Despite removing large swathes of Vallisneria to plant other species, the footprint of Vallisneria expanded into other areas accounting for additional coverage. Sagittaria continues to expand upstream into previously unvegetated areas, which seems to be a result of Vallisneria overtaking its downstream edge. Approximately 2,300 m^2 of Vallisneria were removed by the project team in 2021 through the utilization of benthic barriers and hand removal to create more planting areas for Cabomba and Ludwigia. Bryophytes decreased markedly again this fall and were uncommon even in their historically prime locations in Landa Lake.

Table 5 **Seasonal cover (m²) of target restoration species in the Landa Lake LTBG and restoration reaches from GIS mapping from September 2020 to September 2021.**

Species	September 2020	February 2021	April 2021	September 2021
Landa Lake LTBG Reach				
Ludwigia	802	956	968	1,129
Sagittaria*	3,806	4,291	4,206	3,625
Cabomba*	401	249	238	432
Potamogeton	0	0	7	0
Vallisneria*	12,033	12,499	11,975	12,531
Hygrophila	0	0	0	0
Bryophyte	298	609	761	427
Upper Landa Lake Restoration Reach				
Ludwigia	31	78	78	70
Sagittaria	738	575	575	929
Cabomba	49	18	18	115
Bryophyte	955	1129	1028	555
Lower Landa Lake Restoration Reach				
Ludwigia	64	23	23	36
Sagittaria	0	12	11	19
Cabomba	241	141	142	123

* These numbers combine naturally occurring and planted Sagittaria, Cabomba and Vallisneria in Landa Lake.

A noteworthy observation from this reach includes the persistence of winter and spring epiphytic algae. The algae reached problematic levels in December. Its growth began smothering most Ludwigia patches throughout the winter and into late spring (**Figure 10**). Attempts to dislodge the algae from Ludwigia patches were ineffective as it would return quickly. Algae persistence contributed to a notable decline in plant health as the enveloped Ludwigia began looking chlorotic and proceeded to lose leaves. In April, algae samples were taken at various locations and sent to algae taxonomists at EnviroScience Inc. (Stow, OH) for expert determination. The green algae *Scenedesmus acutus* and blue-green algae *Phormidium amoenum* were determined to be the major component of the epiphytic algae masses growing on Ludwigia patches in the Three Islands area and upper Landa Lake. By mid-May, epiphytic algae began to rapidly decline in thickness allowing Ludwigia patches time to recover and begin their spring expansion. It will be important to monitor this invasive algae in the upcoming winter and spring time periods to see if this pattern of rapid growth, smothering and then sudden decline is again experienced in 2022.

Figure 10 The blue green algae *Phormidium amoenum* and green algae *Scenedesmus acutus* were growing densely on Ludwigia in Landa Lake throughout the winter and into spring (top). The algae was so thick that Ludwigia health was in decline. By May, the algae disappeared almost completely (bottom).

While Vallisneria dominates the Lower Landa Lake restoration reach, Ludwigia and Cabomba are both present naturally as well. In 2021, Cabomba coverage in this reach was considerable with spring mapping showing 142 m^2. Ludwigia cover totaled 23 m^2. Fall mapping showed 123 m^2 of Cabomba and 36 m^2 of Ludwigia. Coverage in this reach seemed to be impacted by increased recreational use of the paddle boats as well as vegetation mat buildup. Since the coverage of target species neared the final goal for this reach, no restoration plantings were undertaken. Occasional gardening and removal of floating vegetation mats were the only activities conducted in this restoration reach.

Bryophytes and algae typically dominate the Upper Landa Lake Restoration Reach along with some established Sagittaria. Due to depth and cobble substrate, as well as persistent summer algae (*Spirogyra*), only specific locations of this reach are suitable for restoration plantings. Ludwigia and Cabomba were planted in 2019 in a side embayment where the reach diverts into the Pecan Island slough. This area has soft sediment for planting and is relatively shallow. Algae is also persistent here and Ludwigia was almost immediately engulfed by algae following planting. The same pattern has been observed each summer since. In 2021, the project team regularly visited the site to clean *Spirogyra* from the plants in an attempt to lessen competition and improve chances of establishment. By the end of summer, algal growth had receded or completely disappeared and Ludwigia and Cabomba were again expanding their coverages.

Figures 11, 12 and 13 show the mapped cover of aquatic vegetation in the Landa Lake LTBG and Upper and Lower Landa Restoration Reaches throughout 2021.

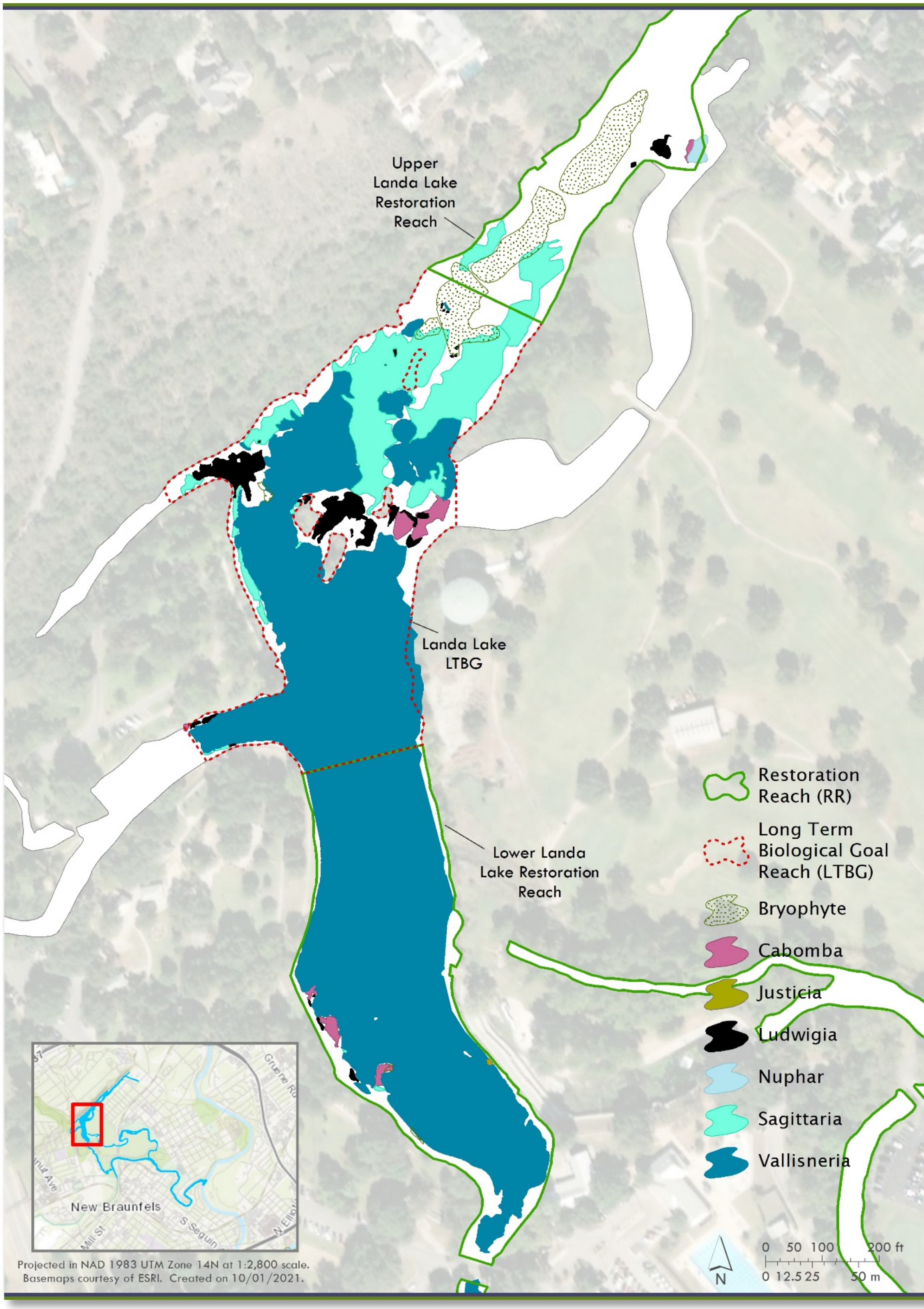


Figure 11 Cover of aquatic vegetation in Landa Lake in February 2021.

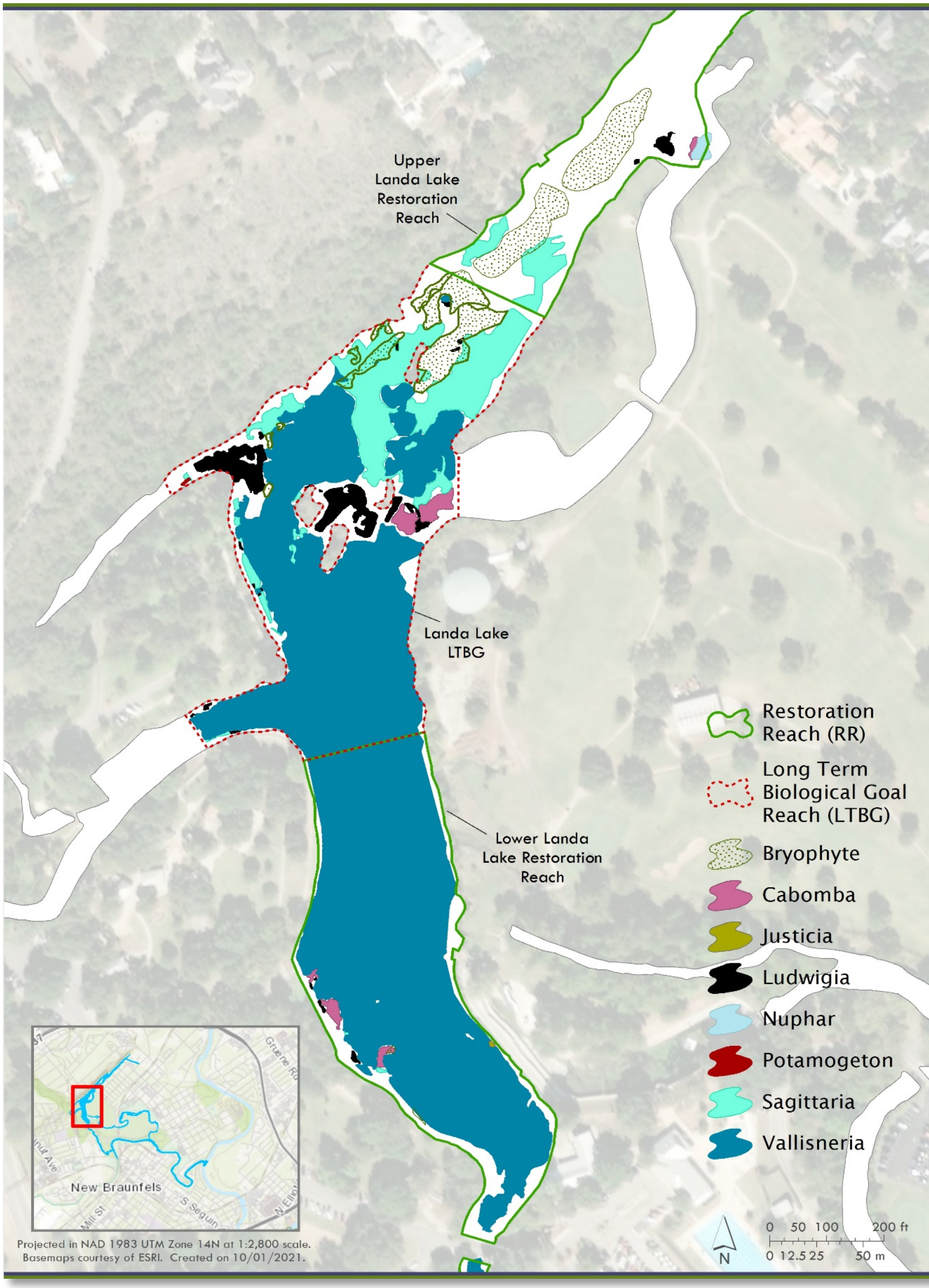


Figure 12 Cover of aquatic vegetation in Landa Lake in April 2021.

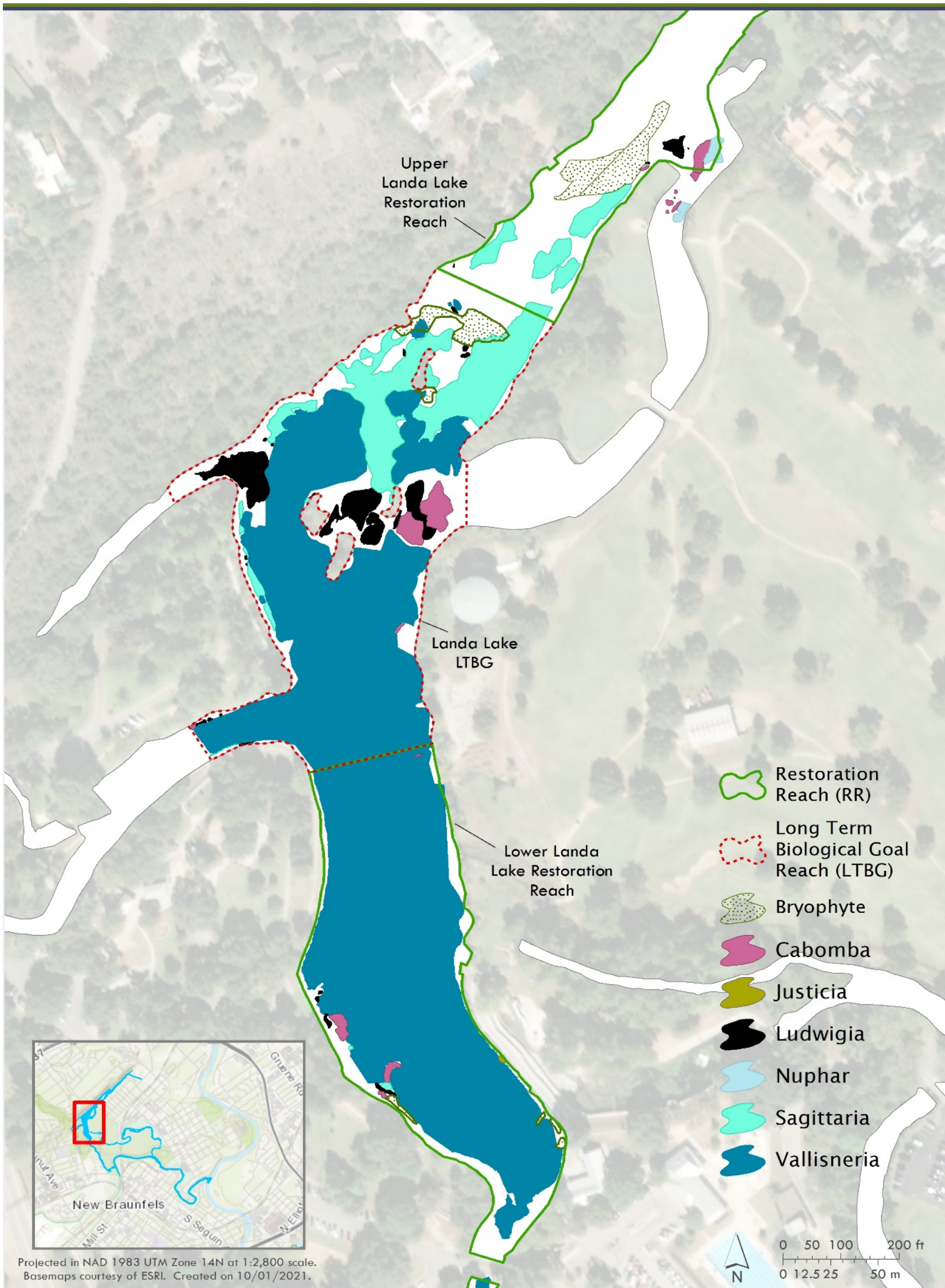


Figure 13 Cover of aquatic vegetation in Landa Lake in September 2021.

4.4.3 Upper Spring Run Restoration Results

No active restoration plantings occurred in this reach for the year. Ludwigia plantings continue to show sporadic coverages. Thus, the restoration team focused more resources into Landa Lake and Old Channel reaches which have produced greater results.

Baseline mapping in February 2021 showed a small amount of Ludwigia coverage in the Upper Spring Run LTBG reach but as the year went on this decreased (**Table 7**). In contrast, Ludwigia located in the Upper Spring Run Restoration Reach showed a notable increase over the year. Ludwigia was initially planted in multiple locations in both reaches but has only persisted in a few plots. Due to the repeated attempts at establishing Ludwigia in this reach coupled with the long-term observations of its sporadic growth, the project team does not believe this restoration site is capable of long-term sustainability of the species even though current coverage is adequate.

Table 6 **Seasonal cover (m^2) of target restoration species in the Upper Spring Run LTBG and restoration reaches from September 2020 to September 2021.**

Species	September 2020	February 2021	April 2021	September 2021
USR LTBG Reach				
Ludwigia	61	19	12	38
Sagittaria	1,372	1,358	1,391	1,576
Cabomba	0	0	0	<1
Hygrophila	0	0	0	0
Bryophyte	0	0	0	171
USR Restoration Reach				
Ludwigia	12	6	6	43
Sagittaria	1,101	900	872	1,324
Cabomba	232	62	68	178
Hygrophila	0	0	0	0
Bryophyte	182	246	20	103

Despite repeated planting efforts, Cabomba also has not done well and has yet to establish in the Upper Spring Run LTBG Reach. However, Cabomba continues to do very well in the upper locations of the Upper Spring Run Restoration Reach at the confluence with Bleiders Creek. At this location both native and planted Cabomba has expanded and maintained itself over multiple years. Some patches of restored Ludwigia in this area have also survived since 2016.

Sagittaria expanded dramatically in both reaches this year. Past observations and monitoring have shown that Sagittaria expands to some degree each year, but then becomes stunted or damaged once recreational season begins, then resumes expansion as the recreational season ceases.

Another noteworthy observation was reduced bryophyte coverage throughout the year. This is the second consecutive year for this event. In previous years, bryophytes were common in the majority of the Upper Spring Run in January, and then coverage dropped in summer, usually rebounding in the fall. However, in 2020 and 2021 bryophytes were notably reduced or absent across all mapping events, and seemingly replaced by various algae or nothing at all.

The Upper Spring Run stretch is dominated by rocky substrate with some pockets of silt and clay. The inconsistent sediments tend to promote irregular and patchy native plant growth, especially for Ludwigia and Cabomba. As at other sites, summer senescence seems to impact Ludwigia cover in the Upper Spring Run as the plants shed top growth, greatly reducing their biomass and in some instances failing to recover. Finally, the Upper Spring Run stretch becomes excessively dense with bryophyte growth or algae during some seasons and flow conditions, making it more difficult for restored plants to establish. Shallow and wadable areas are prone to recreational disturbances. **Figures 14, 15 and 16** show the baseline, spring and fall maps of aquatic vegetation in the Upper Spring Run LTBG and restoration reaches.

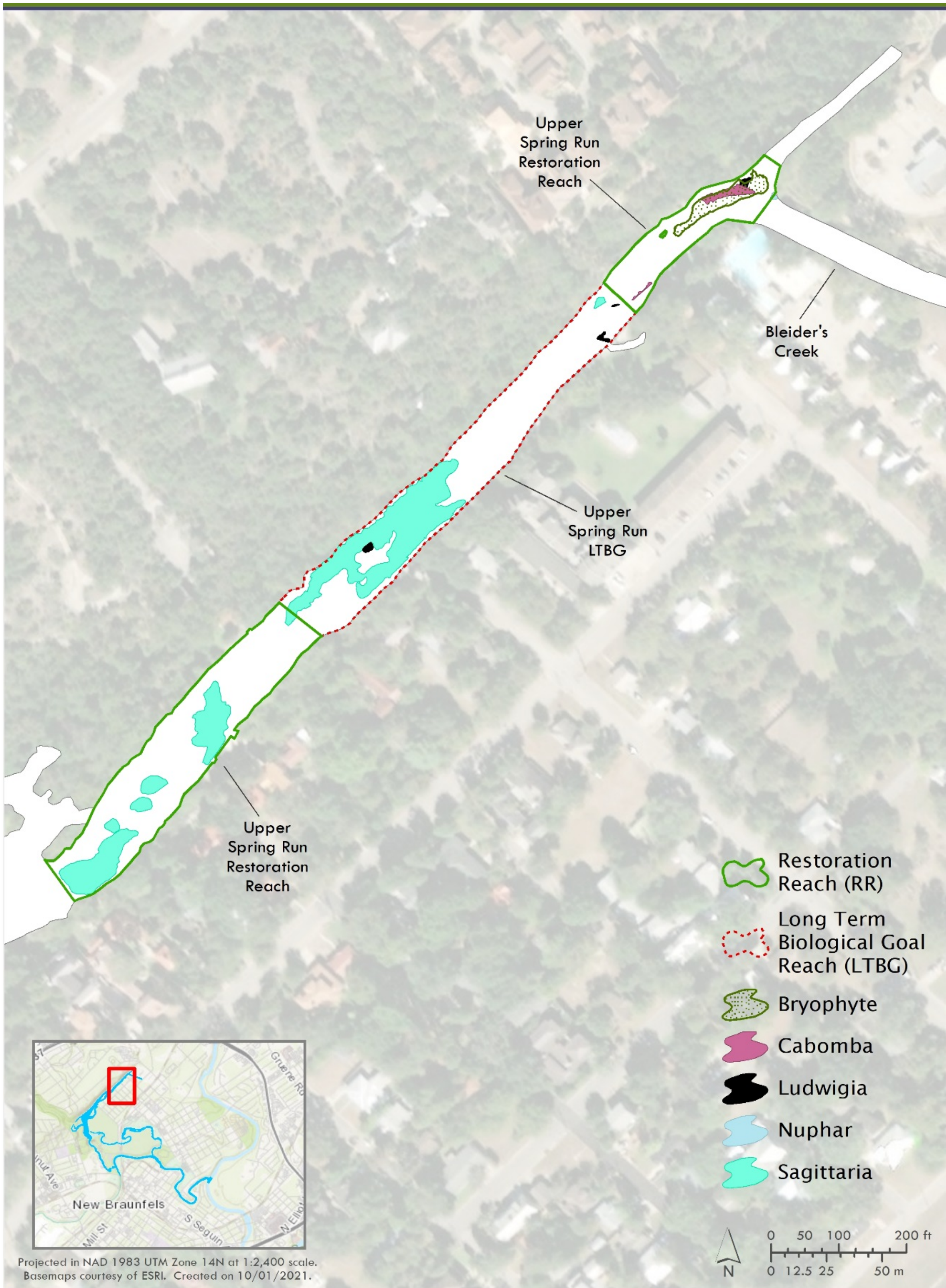


Figure 14 Cover of vegetation in the Upper Spring Run LTBG and restoration reaches in February 2021

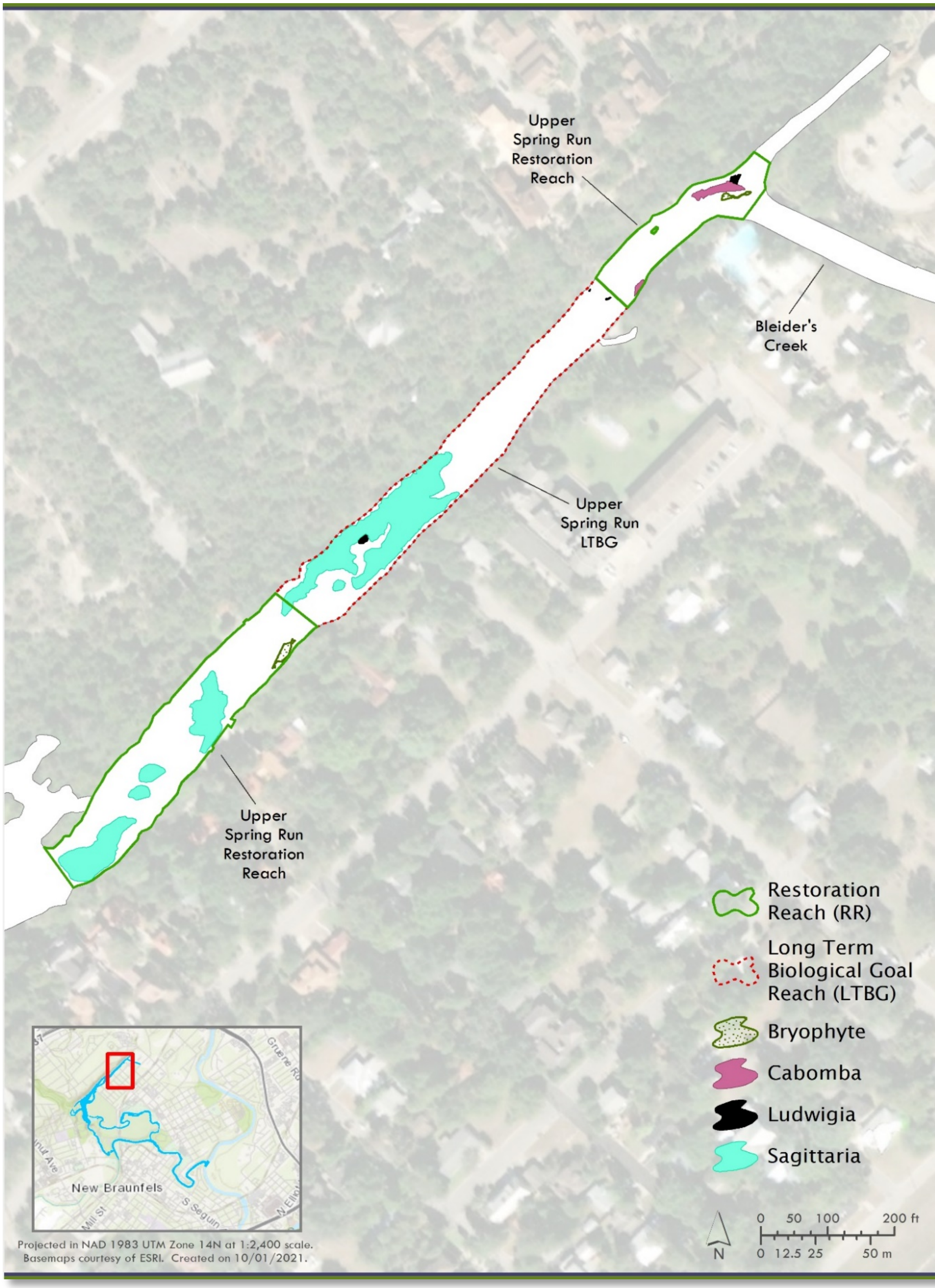


Figure 15 Cover of vegetation in the Upper Spring Run LTBG and restoration reaches in April 2021

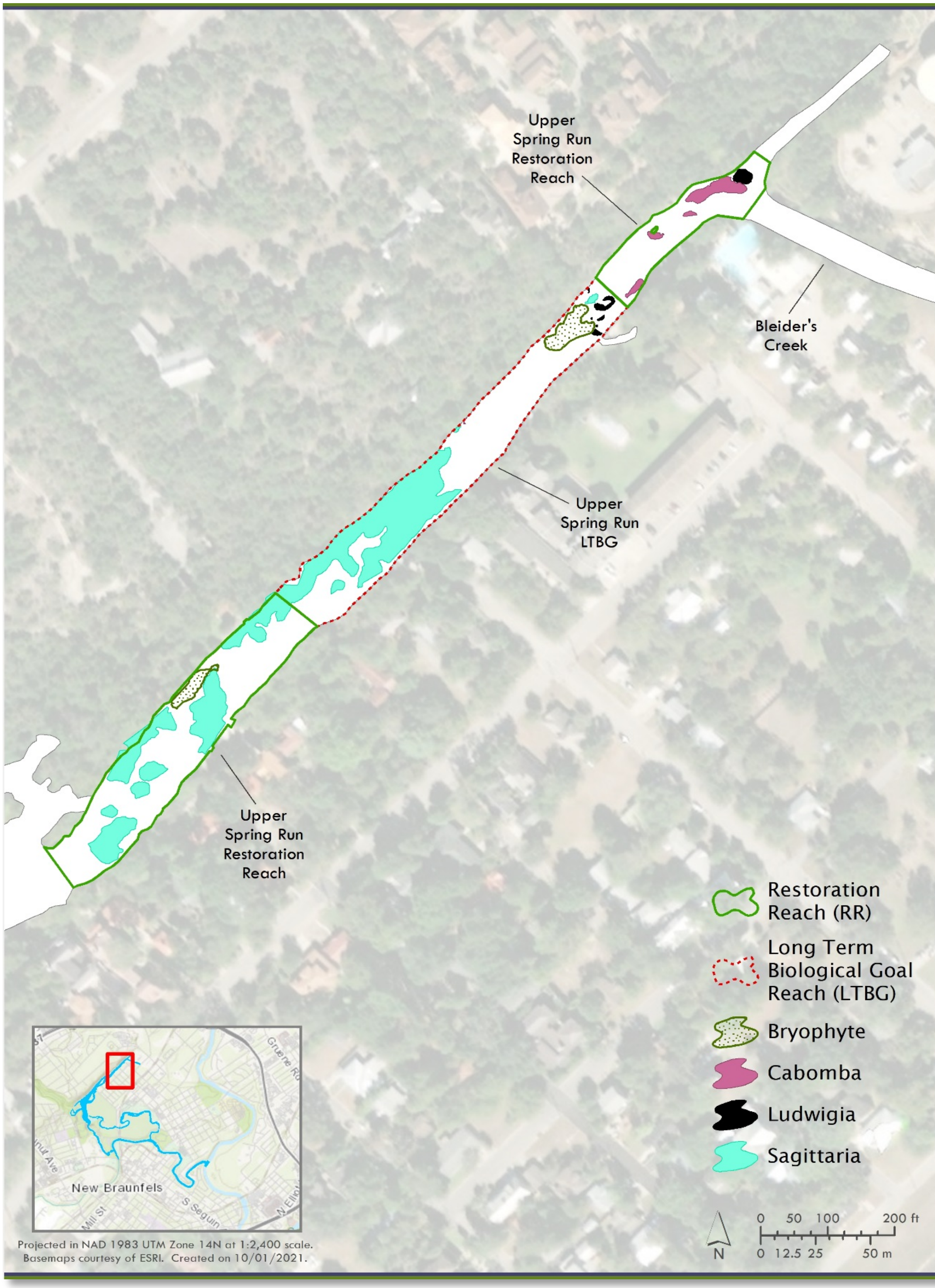


Figure 16 Cover of vegetation in the Upper Spring Run LTBG and restoration reaches in September 2021

4.4.4 Upper New Channel Restoration

No work was conducted in this reach for 2021 per discussions with the City of New Braunfels. This reach is subject to high recreational activity as well as occasional, but significant, scouring flood events which can drastically alter the growing conditions. The few plantings done in this reach to date have not succeeded. These planting efforts have either been overtaken by Hygrophila or presumably scoured away by flow pulses or recreation. Naturally established Ludwigia has persisted in this reach, although commonly intermixed with Hygrophila. A few naturally occurring Cabomba patches have developed, expanded, and then disappeared within a year as the riverbed changes from accumulated silt to gravel. It is our professional opinion that this reach no longer be considered in future restoration plans due to this volatility and its limited potential for success as defined by meeting HCP goals for coverage. The project team will continue to monitor conditions in this reach through the HCP biological monitoring program. If opportunities become available to improve the habitat in this reach, then planned activities will be adjusted accordingly.

5 Restoration Summary

Following the guidance of the annual workplan, the project team's main objective for 2021 restoration activities was to increase Ludwigia and Cabomba coverage in Landa Lake, specifically focusing on three areas where these species have already established well: Spring Run #3 Confluence, Three Islands, and Pecan Slough Confluence. The project team's current method has evolved from the earlier practice of dispersed plantings of individual plots throughout areas of Landa Lake, and now focuses effort on creating new planting locations adjacent to pre-existing plots. This has been successful by creating larger stands of the target species. These larger core sizes of plantings help the target species persist longer and reduces the likelihood of encroachment by other competing species.

In the Old Channel restoration reach, the 2021 focus was to return some coverage of Ludwigia and Cabomba lost to the expansion of other species, and to strategically continue Hygrophila gardening. Sagittaria and Potamogeton, both of which exceed their coverage goals in this reach, were removed and replaced with Ludwigia.

In the Old Channel LTBG reach no active planting was done. All plants expanded on their own. This reach increasingly continues to exhibit a sustainable aquatic plant community.

In the Landa Lake LTBG reach, continued control or removal of Vallisneria and Sagittaria resulted in the highest Ludwigia coverage to date. Cabomba also benefited from these strategic activities to a lesser extent. Interestingly, by fall 2021 several dozen square meters of Cabomba were overtaken by expanding Ludwigia, counteracting some gains for the species. However, Vallisneria and Sagittaria remain the primary competitors with these more desirable species. Due to these ongoing improvements in native aquatic vegetation coverage, Landa Lake has much-improved deep-water habitat for Fountain Darters compared to years past.

Finally, work in the Upper New Channel was not prioritized this year based on the observations previously discussed. The project team recommends that this reach be removed from the future restoration workplans except for periodic monitoring.

Table 7 includes the annual cover changes and highlights the current status of project goals. With some exceptions, goals are being met on an annual basis (square meters planted). Final goals for many species per their locations are presently exceeded, and for other species and locations the final goals are very approachable. For a few species, such as Sagittaria and Potamogeton in certain reaches, the established goals may require amending based on observed results of previous years' restoration attempts and available on-site habitat conditions. Finally, locations such as Upper Spring Run LTBG reach and New Channel have final goals that, in our professional opinion, are not compatible with observed field conditions and should be reconsidered.

Table 7 Summary of 2021 Native Aquatic Vegetation Restoration Efforts in the Comal System

Reach	Aquatic Vegetation Species	Native Aquatic Vegetation Coverage (m^2)					
		Fall 2020	Fall 2021	Gain / (Loss)	Total Planted Area (2021)	Annual Restoration Goal 2021	HCP Long-term Program Goal
LTBG Reaches							
Old Channel	Ludwigia	324	397	73	163	50	425
	Cabomba	190	340	150	18	15	180
	Sagittaria	7	0	(7)	0	50	450
Landa Lake	Ludwigia	802	1,129	327	218	35	900
	Cabomba	402	432	30	253	30	500
	Vallisneria	12,033	12,531	498	0	75	12,500
	Potamogeton	0	0	0	0	5	25
New Channel	Ludwigia	N/D	N/D		0	15	100
	Cabomba	N/D	N/D		0	20	2500
Upper Spring Run	Ludwigia	62	38	(24)	0	5	25
	Cabomba	0	1	1	0	5	25
	Sagittaria	1,372	1,576	204	0	5	850
Restoration Reaches							
Landa Lake Upper	Ludwigia	32	70	38	0	n/a	25
	Cabomba	50	115	65	0	20	250
	Sagittaria	739	929	190	0	50	250
Landa Lake Lower	Ludwigia	64	36	(28)	0	10	50
	Cabomba	241	123	(118)	0	5	125
	Sagittaria	0	19	19	0	25	100
Old Channel	Ludwigia	642	933	291	163	n/a	850
	Cabomba	68	142	74	18	n/a	200
	Sagittaria	915	807	(108)	0	n/a	750
	Vallisneria	859	1,081	222	0	n/a	750
	Potamogeton	752	622	(130)	0	n/a	100

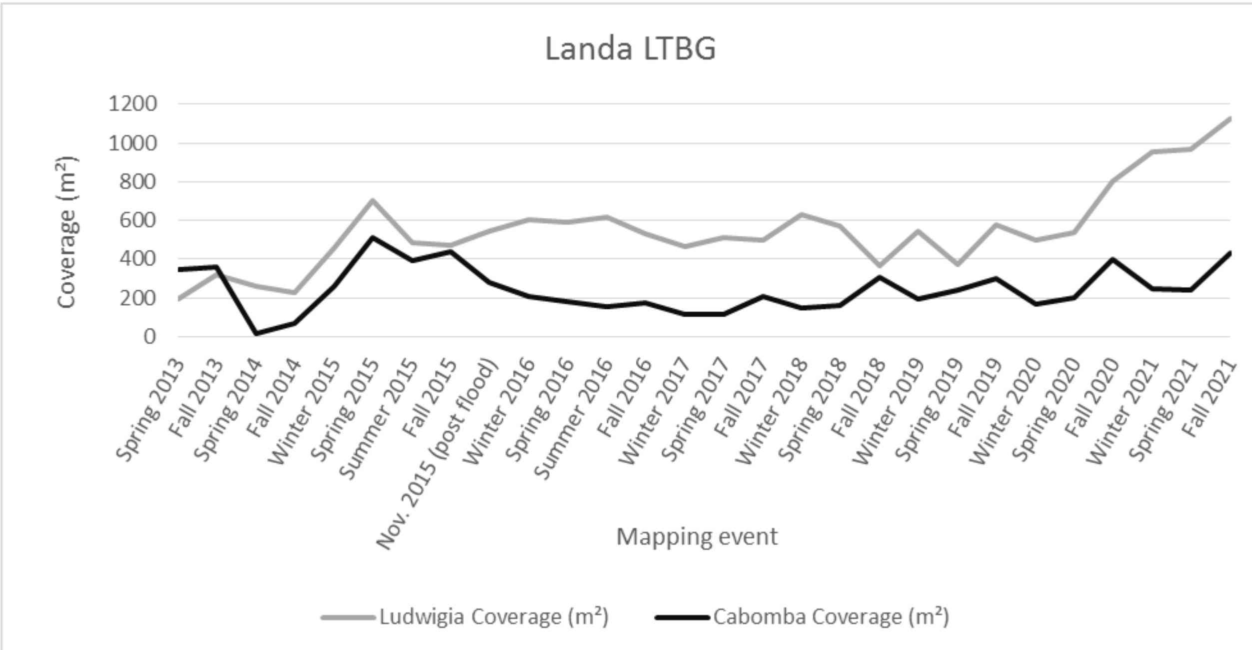
N/D – No data available

An important caveat to note regarding Table 7 is that Sagittaria and Vallisneria are no longer planted in any reach as part of the current restoration regime but are still considered target species for habitat. Instead, these two species are allowed to expand on their own in areas where they were originally planted or where they already exist naturally. Currently, we have refrained from planting more Sagittaria in the Old Channel LTBG reach to prevent competition with more desirable Ludwigia and

Cabomba. Future strategies entail removing some Sagittaria and possibly Potamogeton from the Old Channel restoration reach in order to create increased planting space for Ludwigia and Cabomba.

Figure 17 tracks the long-term changes in Ludwigia and Cabomba coverage since restoration began in 2013. These graphs highlight the inherent fluctuation in coverage of these two species. There are several explanations for this pattern. First, senescence is a natural process in which plants undergo a reduction in biomass as a seasonal reaction (reduced daylight, cooler water temperatures) or a lifecycle change (maturation, post-blooming). In some cases, plants recover and regrow their biomass. In other cases, senescence leads to death as the plant has entered its final life stage and lacks the energy to recover. Second, cover loss can be caused by competition and later complete exclusion by the more aggressive expansion of other native species as previously detailed in this report. These two factors together commonly lead to a reduction in cover that is equal to or higher than the amount planted, making consistent year to year coverage difficult. Despite the fluctuation, coverage is generally increasing. The alteration in methodology toward creating larger contiguous patches of Ludwigia and Cabomba is anticipated to reduce losses and improve sustainability. Expectations are that the coverage trend will show a more consistent pattern within the next year and annual gains will be greater than achieved in the past. The native aquatic plant restoration and maintenance activities conducted in 2021 continue to enhance the aquatic ecosystem of the Comal River and provide valuable lessons learned. Additionally, the continued decline and subsequent rarity in non-native aquatic vegetation in the Comal system has been an incredible success story in this on-going habitat restoration project.

Appendix A includes maps of 2021 plots overlaid with the Fall 2021 vegetation distribution to gauge planting area versus resulting plant coverage discussed in the body of the report.



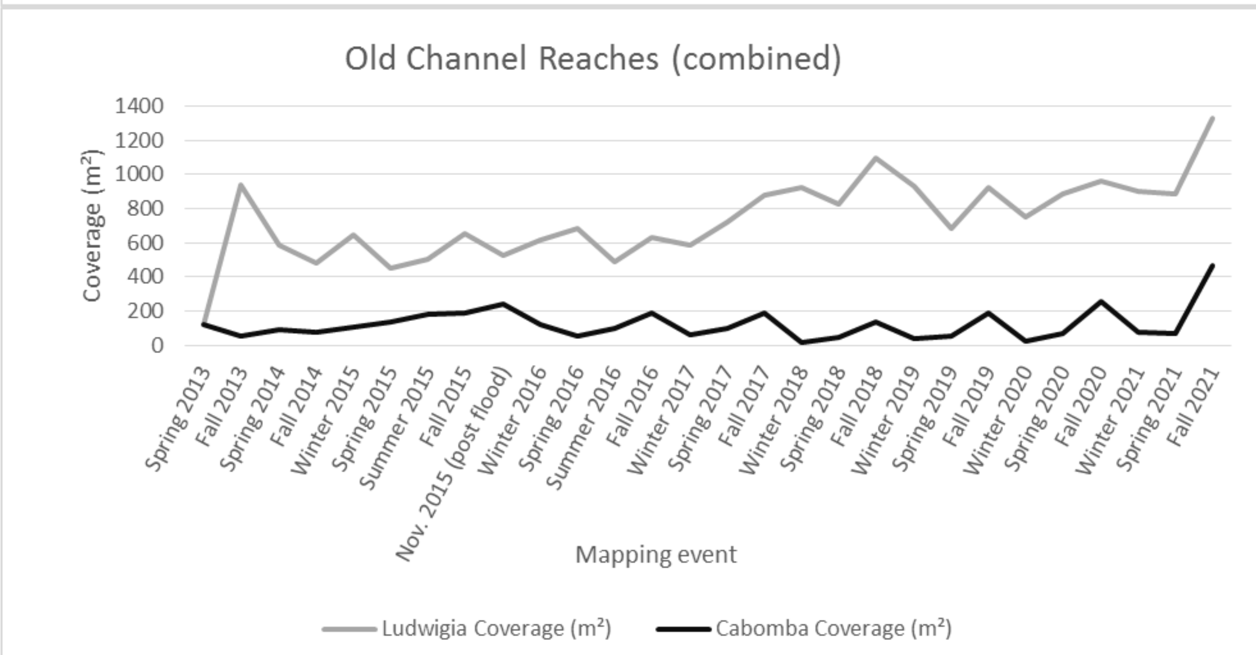


Figure 17 The nine-year trend for coverages for Ludwigia and Cabomba in the Landa Lake LTBG Reach (top) and the combined reaches of the Old Channel (bottom).

6 References

BIO-WEST 2013a. 2013 Restoration Plan for Aquatic Vegetation in Landa Lake and Old Channel Reach. May 13, 2013. Prepared for City of New Braunfels, TX, 72pp.

BIO-WEST 2013b. 2013 Aquatic Vegetation Restoration in Landa Lake and the Old Channel of the Comal River. November 20, 2013 Prepared for City of New Braunfels, TX 80pp.

BIO-WEST 2014. 2014 Aquatic Vegetation Restoration in Landa Lake and the Old Channel of the Comal River. November 20, 2014 Prepared for City of New Braunfels, TX 68pp.

BIO-WEST 2015. 2015 Aquatic Vegetation Restoration in Landa Lake and the Old Channel of the Comal River. November 20, 2015 Prepared for City of New Braunfels, TX 72pp.

BIO-WEST 2016. 2016 Aquatic Vegetation Restoration in Landa Lake and the Old Channel of the Comal River. November 10, 2016 Prepared for City of New Braunfels, TX 72pp.

(USGS) United States Geological Survey. 2019. National Water Information System: Web Interface for USGS Gage No. 08169000 for the period January 1, 2019 to October 1, 2019. [http://waterdata.usgs.gov]

7 Appendix A

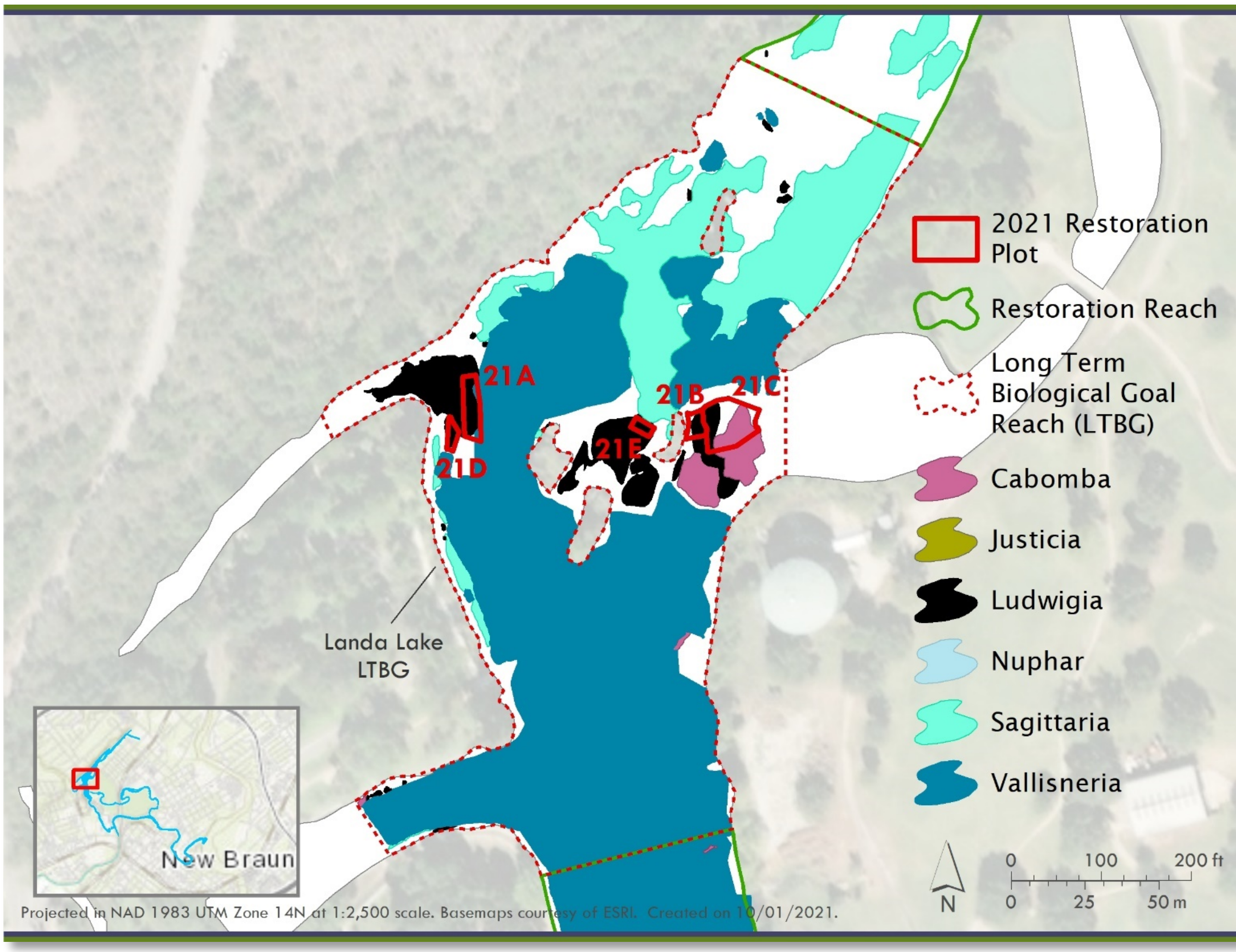


Figure A1 Plots planted in Landa Lake LTBG in 2021 and their resulting vegetation cover in fall 2021.

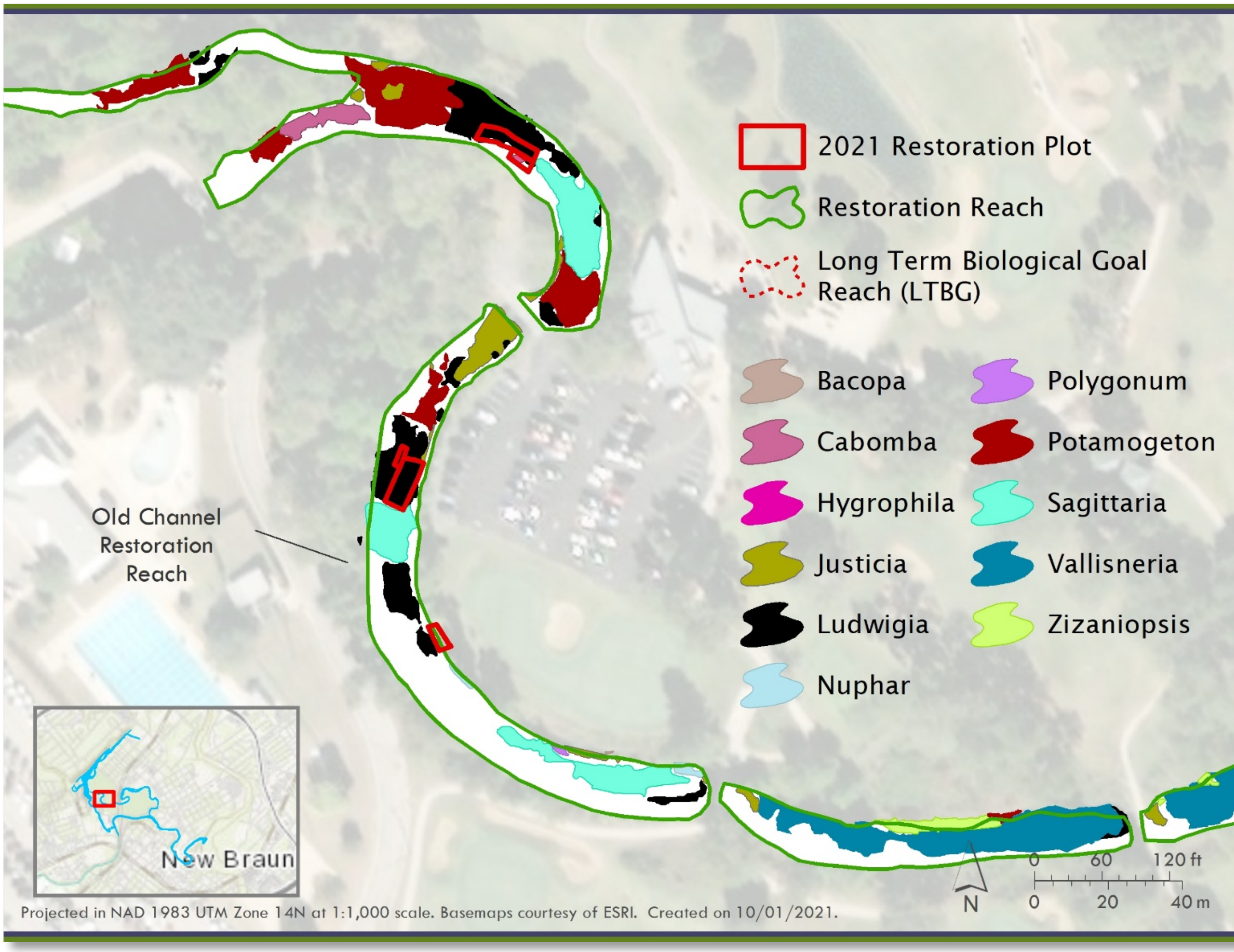


Figure A2 Plots planted in Old Channel restoration reach in 2021 and their resulting vegetation cover in fall 2021.

H2 | **Control of Harmful Non-Native Animal Species**

CoNB Control of Harmful Non-Native Animal Species (EAHCP § 5.2.5)

The CONB continued to implement a non-native fish and animal species management program focused on the removal of tilapia (*Oreochromis sp.*), nutria (*Myocastor coypus*) and vermiculated sailfin catfish (family Loricariidae). In 2021, divers utilized primarily polespears and spearguns for capture of non-native fish species and baited box traps to capture nutria. Tilapia were targeted primarily in the main body of Landa Lake, near the confluence of Blieders Creek/ Landa Lake and in the Upper Spring Run while sailfin catfish were targeted primarily in the downstream portion of Landa Lake. Efforts to capture nutria were focused primarily around Landa Lake, in the Upper Spring Run area and along Blieders Creek. **Table 1** summarizes the number of non-native fish and animal species removed from the Comal River system in 2021.

Table 1. Summary of Non-Native Fish & Animal Species Removal (January – December 2021)

Species	Number Removed	Biomass (lbs.)	Average Biomass (lbs./individual)
Vermiculated Sailfin Catfish	62	143.2	2.31
Tilapia	835	2381.6	2.85
Nutria	13	107.1	8.24

H3 | **Gill Parasite Monitoring in the Comal River System**

BIO-WEST, Inc.
1405 United Drive, Suite 111
San Marcos, Texas 78666

MEMORANDUM

TO:	**Mark Enders, City of New Braunfels**
FROM:	BIO-WEST, Inc.
DATE:	October 11, 2021
SUBJECT:	**2021 Gill Parasite Monitoring in the Comal River**

Introduction

To benefit populations of the federally-endangered Fountain Darter *Etheostoma fonticola*, the Edwards Aquifer Habitat Conservation Plan (EAHCP) proposed to conduct studies aimed at monitoring and reducing concentrations of the non-native gill parasite *Centrocestus formosanus* in the Comal River. BIO-WEST was contracted to conduct these studies in 2013. Studies initially included data collection targeted at identifying the current distribution, abundance, and density of the free-swimming cercariae of *C. formosanus* as well as its host snail, *Melanoides tuberculatus*. They also included studies to document current prevalence of *C. formosanus* in host snails and Fountain Darters, and pilot studies to evaluate host snail removal as a means of potentially reducing *C. formosanus* concentrations. Additionally, during this time period, data was also collected on the abundance and density of the cercariae of another exotic trematode parasite, *Haplorchis pumilio*, which also has the potential to negatively impact Fountain Darter populations. Lastly, repeat monitoring was implemented to track host snail and parasite cercariae concentration through time.

From 2014 through 2018, parasite cercariae monitoring was conducted three times per year (Winter, Spring, and Summer seasons) at three transects (Landa Lake [LL], Old Channel Reach [OCR], and RV Park [RVP]; **Figure 1**). In 2019, at the request of the City of New Braunfels and Edwards Aquifer Authority, monitoring efforts were decreased to one event per year, and a fourth sampling transect was added at Pecan Island (PI) due to concerns of potentially high parasite concentrations at this location (**Figure 1**). Similarly, in 2020 and again in 2021, BIO-WEST biologists conducted a single summer-season parasite monitoring event at the four previously sampled transects in the Comal River system. This data collection took place on August 23-24, 2021, and included quantification of cercariae densities for both *C. formosanus* and *H. pumilio* at each transect. This data was combined with previously collected data from 2014-2020 and the full dataset was analyzed with updated statistical techniques to examine the relationship between discharge and parasite concentrations. Details of the methods utilized, a summary of the results and subsequent analyses, a discussion on the utility of this information, and recommendations for further research and monitoring are provided below.

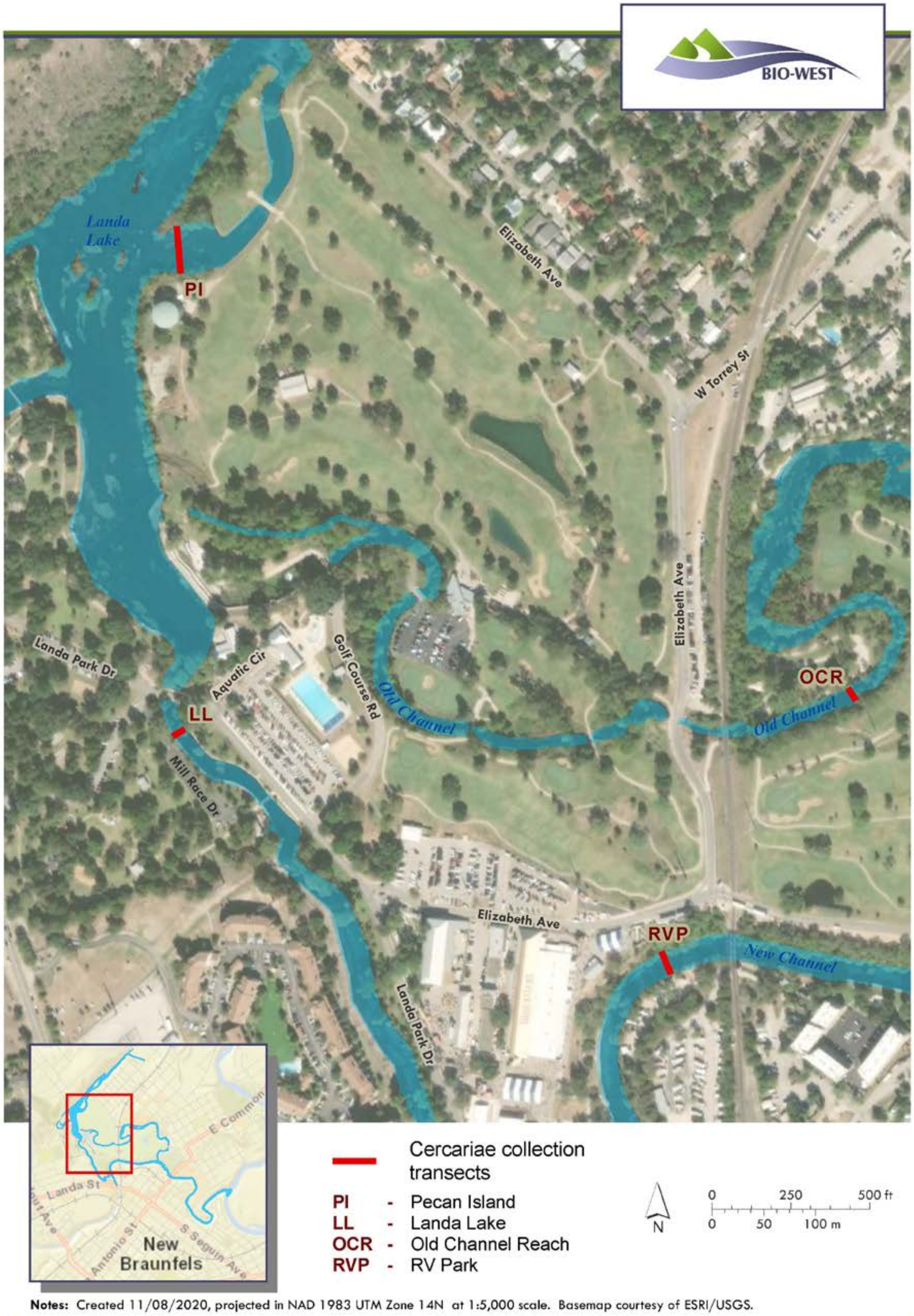


Figure 1. Map of cercariae collection transects in the Comal River system.

Methods

Data Collection

At each transect, 5-Liter (L) water samples were collected from six points evenly distributed throughout the water column both vertically and horizontally. Three evenly spaced sampling stations were established across the stream channel, perpendicular to flow. At each station, two 5-L samples were collected, one at 60% stream depth, and one approximately 5 centimeters (cm) below the water surface, totaling six samples per site. Cercariae were collected using a modified live-well pump attached to an incremental wading rod which pumped water through clear acrylic tubing to collection buckets. At time of collection, each water sample was immediately treated with 5 milliliters (ml) of formaldehyde to kill all parasite cercariae. Each sample was then filtered using a specialized filtration device consisting of three progressively finer nylon filters, with the final filter having pores of 30 microns (µm). After filtration of each sample, the 30-µm filter containing cercariae was removed from the filtration device and placed in a Petri dish. Each sample was then stained with a Rose Bengal solution and fixed with 10% formalin, at which point the Petri dish was closed and sealed with Parafilm for storage. After fixation and staining, the samples were then observed using high-power microscopy (40-100 X magnification) and all cercariae were identified to species and enumerated in the BIO-WEST laboratory.

Data Analysis

Random forest regression models were used to examine relationships between river discharge and density of *C. formosanus* and *H. pumilio* cercariae in the water column. In 2020, general additive models were used for this analysis; however, preliminary analysis for 2021 demonstrated that random forest models yielded similar or higher predictive performance. Random forest regression is a type of decision tree model that generates a large number of trees via bagging, which in combination are used to make predictions. These models are advantageous for assessing ecological data due to their ability to depict nonlinear trends and prevent overfitting.

For all sampling events, discharge values (cfs) specific to each site were taken or calculated from USGS gaging stations on the Comal River (USGS gages 08168913, 08168932, 08169000) at 10:00 am on the day of collection. Specifically, discharge data for LL and PI were taken from the Comal River New Channel gage (08168932), data for OCR were taken from the Comal River Old Channel gage (08168913), and data for the RVP site were calculated as the difference of the Comal River at New Braunfels gage (08169000) and Old Channel gage (08168913). Discharges were then standardized by median discharge (discharge(x)/Q50) for the study duration to make observations comparable between sites. In addition to standardized discharge; year, season, and site were included as predictor variables to provide more information for the models and potentially identify any temporal or spatial variation in cercariae densities.

Random forest models were fit using 500 trees and tuned to maximize predictive performance. Statistics calculated to assess each model's performance included mean of squared residuals, percent variation explained, and correlation between observed and predicted cercariae densities. Percent relative importance was also calculated for each predictor variable. Lastly, partial dependence plots are provided to display cercariae density trends with standardized discharge. All random forest analyses were conducted using R (4.1.1) statistical software.

Results

In 24 individual five-liter samples collected in 2021, 20 total *C. formosanus* and 18 *H. pumilio* cercariae were detected, resulting in an overall system wide mean of 0.2 (±0.05) and 0.2 (±0.04) cercariae/L (±SE), respectively (**Table 1**). These densities are considerably lower than overall mean cercariae densities from early in the study, which were as high as 4.8 (±0.5) and 0.6 (±0.09) in 2014 for *C. formosanus* and *H. pumilio*, respectively. Since 2014, overall annual cercariae densities have steadily declined (**Table 1**).

Both models performed well with correlations between observed and predicted values ≥0.60, though model correlation and percent variation explained was much higher for *C. formosanus* (0.91 and 83.14%, respectively) than *H. pumilio* (0.60 and 35.84%, respectively) (**Table 2**). Standardized discharge was the most important predictor for both *C. formosanus* (62.85%) and *H. pumilio* (52.39%). Moreover, relative importance values >10% for year (21.36–27.95%) and site (11.08–14.38%) show adding spatiotemporal predictors improved model performance (**Figure 2**). Partial dependence plots displaying relationships between parasite density and standardized discharge showed a nonlinear relationship. As standardized discharge increased from ~0.10 to 0.50, predicted parasite density decreased from ~10.00–2.00 cercariae/L for *C. formosanus* and ~0.60–0.20 cercariae/L for *H. pumilio*. Lastly, parasite density showed little variation at standardized discharge values greater than 0.50 (**Figure 3**).

Discussion and Recommendations

Parasite monitoring from 2014-2021 suggests that cercariae concentrations of both species have declined throughout monitoring events but have remained stable at lower concentrations in more recent years. This data also suggests that parasite concentrations generally show an inverse relationship with discharge. If cercariae production is assumed constant, concentrations naturally become diluted under high flow conditions and concentrations logically increase under low flow conditions. Both random forest models outperformed the general additive models used in 2020. Including spatiotemporal predictors also likely improved predictive power. Based on this, random forest regression provides useful insight on trends in parasite concentrations and will be beneficial for additional analysis or forecasting in the future.

Partial dependence plots for both species confirmed a nonlinear, inverse relationship between parasite concentration and standardized discharge. Differences in each model's predictive performance and rates of change in cercariae densities across standardized discharge values suggest that flow conditions have a greater influence on *C. formosanus* concentrations compared to *H. pumilio*. Specifically, *C. formosanus* concentrations increase about 3-fold when standardized discharge dropped below 0.5, meaning when river discharge is less than half of the median.

Incorporating other variables, such as reach-specific host snail abundance/density or hydrologic conditions along greater temporal gradients (e.g., seasonal flow conditions) could provide more meaningful ecological insight on both species, as well as improve predictive performance for *H. pumilio*. From 2013-2018, BIO-WEST collected data on snail distribution and densities throughout the study reaches. However, this data is not available for recent years (2019 – 2021).

Collecting current data on snail distribution and density could aid in development of a more robust model to predict parasite concentrations. Additionally, long-term data on snail infection rates would be valuable to understand the relationship between snail abundance/density and cercariae concentrations. Lastly, no current data is available on the number and intensity of infected fish in the system, or on definitive host (i.e., bird) infection rates. Data collection on infection rates in all three of the parasites hosts would allow a more thorough understanding of parasite population dynamics.

In summary, results from this analysis show that random forest regression models can be used to better inform the EAHCP process specific to *C. formosanus*. Incorporating additional data, as described above, could provide better ecological insight on mechanisms driving parasite population dynamics for both species and could enhance the utility of the *H. pumilio* model. At a minimum, continued monitoring of parasite concentrations in the Comal Springs/River system is important to provide data at flow levels not yet observed, as well as to confirm if parasite concentrations spike under future low-flow scenarios. Specifically, parasite concentrations increase sharply at flows less than half of the median (144.5 cfs at Comal River gage), suggesting that close monitoring of parasite concentrations at flows below this level are particularly important.

Table 1. Mean cercariae/liter (±SE) collected during parasite monitoring events from 2014-2020.

C. formosanus						*H. pumilio*					
Transect	**Year**	**Season**				**Transect**	**Year**	**Season**			
		Winter	**Spring**	**Summer**	**OVERALL**			**Winter**	**Spring**	**Summer**	**OVERALL**
LL						**LL**					
	2014	4.4 (±0.4)	6.1 (±0.5)	13.3 (±0.6)	**7.9 (±1.0)**		2014	0.2 (±0.09)	0.3 (±0.08)	0.9 (±0.24)	**0.5 (±0.11)**
	2015	2.6 (±0.3)	2.6 (±0.3)	3.4 (±0.3)	**2.9 (±0.2)**		2015	0.5 (±0.09)	0.3 (±0.06)	0.2 (±0.03)	**0.3 (±0.04)**
	2016	0.8 (±0.9)	2.3 (±0.8)	1.9 (±0.8)	**1.6 (±2.2)**		2016	0.03 (±0.03)	0.3 (±0.08)	0.2 (±0.08)	**0.2 (±0.04)**
	2017	1.3 (±0.1)	1.4 (±0.3)	1.0 (±0.2)	**1.2 (±0.1)**		2017	0.06 (±0.04)	0.03 (±0.03)	0.03 (±0.03)	**0.04 (±0.02)**
	2018	0.8 (±0.1)	1.5 (±0.2)	1.6 (±0.4)	**1.3 (±0.2)**		2018	0.1 (±0.07)	0.1 (±0.04)	0.1 (±0.04)	**0.1 (±0.03)**
	2019			0.4 (±0.1)			2019			0.0 (±0.0)	
	2020			0.3 (±0.1)			2020			0.03 (±0.03)	
	2021			0.2 (±0.07)			2021			0.07 (±0.04)	
OCR						**OCR**					
	2014	0.4 (±0.1)	1.0 (±0.2)	2.0 (±0.3)	**1.1 (±0.2)**		2014	0.1 (±0.04)	0.1 (±0.07)	0.2 (±0.09)	**0.1 (±0.04)**
	2015	1.4 (±0.2)	1.9 (±0.2)	2.4 (±0.2)	**1.9 (±0.1)**		2015	0.2 (±0.06)	0.3 (±0.07)	0.1 (±0.03)	**0.2 (±0.03)**
	2016	2.0 (±1.1)	1.2 (±0.9)	1.8 (±1.2)	**1.7 (±1.1)**		2016	0.1 (±0.07)	0.1 (±0.07)	0.1 (±0.07)	**0.1 (±0.04)**
	2017	0.7 (±0.1)	0.6 (±0.2)	0.5 (±0.1)	**0.6 (±0.1)**		2017	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	**0.0 (±0.0)**
	2018	0.6 (±0.1)	0.3 (±0.1)	0.2 (±0.1)	**0.4 (±0.1)**		2018	0.0 (±0.0)	0.0 (±0.0)	0.03 (±0.03)	**0.01 (±0.01)**
	2019			0.4 (±0.1)			2019			0.2 (±0.06)	
	2020			0.4 (±0.1)			2020			0.2 (±0.1)	
	2021			0.1(±0.04)			2021			0.03 (±0.03)	
RVP						**RVP**					
	2014	3.8 (±0.3)	7.8 (±0.9)	4.8 (±0.4)	**5.6 (±0.2)**		2014	0.7 (±0.11)	0.9 (±0.25)	1.6 (±0.50)	**1.0 (±0.20)**
	2015	4.5 (±0.7)	3.1 (±0.3)	3.6 (±0.3)	**3.7 (±0.2)**		2015	0.4 (±0.06)	0.4 (±0.07)	0.2 (±0.06)	**0.3 (±0.04)**
	2016	2.1 (±1.1)	2.5 (±0.8)	2.3 (±0.8)	**2.3 (±0.6)**		2016	0.2 (±0.10)	0.2 (±0.10)	0.1 (±0.07)	**0.2 (±0.05)**
	2017	2.0 (±0.6)	2.3 (±0.2)	1.5 (±0.2)	**1.9 (±0.2)**		2017	0.2 (±0.16)	0.2 (±0.08)	0.1 (±0.07)	**0.2 (±0.06)**
	2018	1.6 (±0.2)	1.5 (±0.3)	2.1 (±0.2)	**1.7 (±0.2)**		2018	0.1 (±0.07)	0.2 (±0.10)	0.2 (±0.07)	**0.2 (±0.05)**
	2019			0.9 (±0.1)			2019			0.1 (±0.06)	
	2020			0.6 (±0.2)			2020			0.1 (±0.1)	
	2021			0.2 (±0.08)			2021			0.5 (±0.13)	
Pecan Island						**Pecan Island**					
	2019			0.03 (±0.03)			2019			0.0 (±0.0)	
	2020			0.1 (±0.1)			2020			0.0 (±0.0)	
	2021			0.1 (±0.07)			2021			0.03 (±0.03)	
OVERALL						**OVERALL**					
	2014	2.9 (±0.5)	4.9 (±0.8)	6.7 (±1.2)	**4.8 (±0.5)**		2014	0.3 (±0.08)	0.4 (±0.12)	0.9 (±0.22)	**0.6 (±0.09)**
	2015	2.9 (±0.3)	2.5 (±0.2)	3.2 (±0.2)	**2.9 (±0.1)**		2015	0.4 (±0.04)	0.3 (±0.04)	0.2 (±0.03)	**0.3 (±0.02)**
	2016	1.6 (±0.2)	2.0 (±0.2)	1.9 (±0.1)	**1.9 (±0.1)**		2016	0.1 (±0.04)	0.2 (±0.05)	0.1 (±0.04)	**0.1 (±0.03)**
	2017	1.3 (±0.2)	1.4 (±0.2)	1.0 (±0.1)	**1.2 (±0.1)**		2017	0.1 (±0.06)	0.07 (±0.03)	0.04 (±0.03)	**0.07 (±0.02)**
	2018	1.0 (±0.1)	1.1 (±0.2)	1.3 (±0.2)	**1.1 (±0.1)**		2018	0.07 (±0.03)	0.1 (±0.04)	0.1 (±0.03)	**0.09 (±0.02)**
	2019			0.4 (±0.1)			2019			0.1 (±0.02)	
	2020			0.3 (±0.1)			2020			0.1 (±0.03)	
	2021			0.2 (±0.05)			2021			0.2 (±0.04)	

Table 2. Summary of optimal hyperparameters and predictive performance for random forest regression models used to examine trends in cercariae density in the Comal Springs/River system.

	C. formosanus	***H. pumilio***
Model Hyperparameters		
# of trees	500	500
# of variables tried per split	4	1
node size	5	5
Model Performance Statistics		
mean of squared residuals	0.83	0.08
% variation explained	83.14	35.84
correlation	0.91	0.60

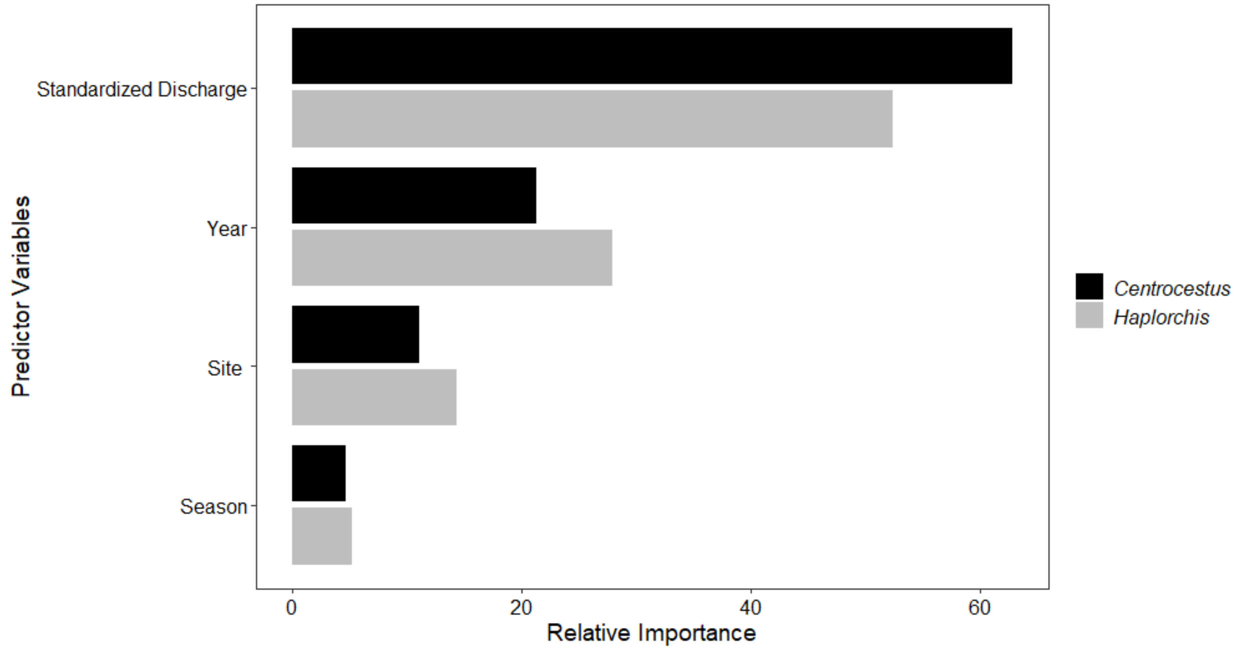


Figure 2. Bar graph displaying the relative importance (%) of variables used to predict *Centrocestus* and *Haplorchis* concentrations in the Comal Springs/River system.

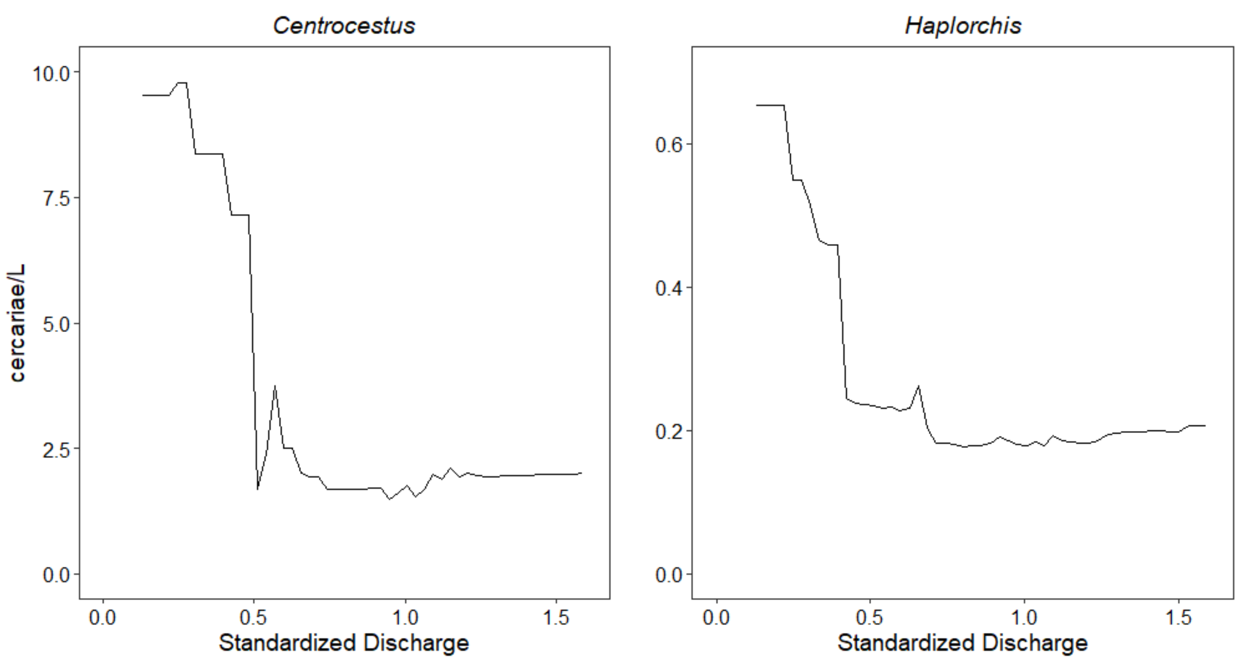


Figure 3. Partial dependence plots displaying the response of cercariae densities as a function of standardized discharge for *Centrocestus* and *Haplorchis* in the Comal Springs/River system.

H4 | **Riffle Beetle Riparian Habitat Restoration**

BIO-WEST

MEMORANDUM

To: Mark Enders, Watershed Prgm Manager, City of New Braunfels

From: Casey Williams (BIO-WEST)

Date: December 9, 2021

Subject: Progress on the Riffle Beetle Riparian Restoration Project for 2021

This memorandum is intended to provide a summary of riparian restoration activities conducted in 2021 along Spring Run #3 and the western shoreline of Landa Lake as part of the Riffle Beetle Restoration Project.

- January 2021– Trimmed all of the herbaceous and grassy material along the south side of Spring Run #3 to help clean up the area and improve growth for spring.
- February - Continued to maintain the area with occasional trimming, checking on fencing and enclosures and readjusting/mending as necessary.
- March and April- Planted several hundred *Eleocharis rostellata* along the water's edge at Spring Run #3 and *Carex emoryi* along the Western Shoreline.
- May to December- Distributed Turk's cap and Inland Sea Oat seed along the hillside and planted several Black walnut and Sycamore saplings.
- May to December- Maintained sediment capture devices and removed sediment when necessary to help keep BMP's functional.

Overall, the area continues to fill in nicely with plants and density of plants increasing. The biggest issue this year was sediment accumulation from several large rainfall events. Stormwater runoff from large storms (>2") causes sediment catchment structures installed along the hillslope adjacent to Spring Run #3 to accumulate sediment to their full capacity. Although the logs stayed in place the sediment load proved to be too much in rainfall events of 2" or more. During larger storms it was observed that sediment made it down to Spring Run #3, filled in around some of the spring openings. It is recommended that gabion baskets filled with mulch are placed in strategic areas to help create sediment control structures that can handle sediment volume from large storms and help filter the water.

Figure 1   Coir log showing a buildup of debris behind the capture device.

Figure 2   Sediment captured by coir log. This shows how overwhelmed with sediment the coir logs can become after a heavy rainfall.

Figure 3   Sediment removed from behind log to allow for more sediment to be captured.

Figure 4   Seeds spread along Spring Run #3 hill side include Inland sea oats and Turk's cap.

Figure 5   Spreading seeds along the hill side adjacent to spring run #3.

Figure 6 Vegetation cover is slowly expanding along the hill side adjacent to spring run #3. As more sediment is captured along the hillside the opportunity for more vegetation to establish increases. Better sediment capture devices will help speed this along.

H5 | **Native Riparian Habitat Restoration**

CoNB Native Riparian Habitat Restoration (EAHCP § 5.7.1)

The primary riparian restoration activities conducted in 2021 include: 1) removal and control of non-native riparian vegetation along Landa Lake at Pecan Island, 2) planting of native vegetation in areas where non-native vegetation was previously treated/ removed, 3) establishment of erosion/ sediment control berms and, 4) maintenance of previously restored areas within the riparian zone of Landa Lake and the Old Channel for the Comal River. **Figure 1** illustrates the areas where riparian restoration activities occurred for the first time in 2021.

Figure 1. Riparian zone along the mid-section of Landa Lake along the Landa Lake Golf Course where non-native vegetation removal and native planting occurred in 2021.

The non-native vegetation species targeted in 2021 include, but were not limited to, elephant ear (*Colocasia* sp.), privet (*Ligustrum* sp.), Chinese tallow (*Triadica sebifera*), giant cane (*Arundo donax*), and chinaberry (*Melia azedarach*). Approximately 76 Ligustrum (including 74 large trees and 2 small trees/ saplings), 280 Chinese tallow (including 218 large trees and 62 small trees/ saplings) and 3 Chinaberry (including 2 large trees and 1 small tree/ sapling) were removed/ treated throughout the riparian zone in 2021, primarily along Landa Lake on and in the vicinity of Pecan Island.

Maintenance activities, including the re-treatment of re-emergent non-native vegetation and supplemental planting, occurred within previously restored areas extending from the upstream portion of Landa Lake through the Old Channel of the Comal River to the end of the Old Channel LTBG reach.

In 2021, approximately 723 native plants were planted and 5lbs. of native grass seed distributed within the riparian zone along Landa Lake primarily within and adjacent to the Pecan Island area where extensive non-native vegetation removal occurred in 2021. The species and the total number of plants introduced into riparian areas in 2021 is shown in **Table 1**.

Table 1. Native Plants Planted within Riparian Zones Throughout the Comal River System in 2021

Native Plants	
American Beauty Berry	8
Big Muhly	30
Brushy Bluestem	9
Corralberry	12
Damianita	3
Emory Sedge	24
Frogfruit	122
Gamagrass	30
Inland Sea Oats	119
Lindheimer Muhly	56
Nolina	5
Palmetto	17
Persimmon	3
Pickerelweed	6
Pigeonberry	1
Rockrose	50
Skullcap	8
Straggler Daisy	40
Sumac	2
Switchgrass	66
Texas Lantana	24
Texas Mountain Laurel	9
Texas Sage/ Cenizo	6

Table 1. Native Plants Planted within Riparian Zones Throughout the Comal River System in 2021	
Tropical Sage	5
Turk's Cap	58
Woodland Sedge	10
Native Plant Seed Distributed	
Little Bluestem	1lb.
Sideoats Gramma	1lb.
Virginia Wildrye	1lb.
Indian Blanket	1lb.
Mexican Hat	0.25lb
Riparian Recovery Seed Mix	0.75lb
	Total # of native plantings: 723 (plus approx. 5 lbs seed distributed)

Photo Log

Photo 1. Photo of the southern portion of Pecan Island along Landa Lake where extensive removal of non-native vegetation (primarily Chinese tallow and Ligustrum) occurred in 2021. Note the number of tree stumps shown in the photo which are the remnant of removed non-native trees. The Pecan Island was previously dominated by non-native trees.

Photo 2. Photo of the southern portion of Pecan Island showing erosion/ sediment control berms and native plantings in the area where non-native trees were removed. The sediment control berms were constructed using trunks and slash from removed non-native trees.

Photo 3. Photo of Pecan Island area showing the area where non-native trees were removed and native plants were planted. Wire caged were utilized to protect planted tree saplings.

Photo 4. Photo showing riparian zone along Landa Lake near the dead end of Elizabeth Ave where non-native vegetation removal and native planting occurred in 2021.

Photos 5 & 6. Riparian zone along Landa Lake near the outflow into the Mill Race of the Comal River near the Landa Park Train Depot. The photo on the left shows the riparian zone prior to restoration in late 2020. The photo to the right was taken in Oct 2021. The initial restoration of this area occurred in late 2020 with supplemental planting occurring in 2021.

H6 | **Impervious Cover and Water Quality Protection**

CoNB Impervious Cover and Water Quality Protection (EAHCP § 5.7.6)

In 2021, the City constructed two stormwater treatment projects within the Comal River watershed in proximity to the upper portion of the Comal River system (**Figure 1**). A summary of these projects is included below:

- **Construction of a bioretention basin at the Headwaters at the Comal:** This bioretention basin captures and treats stormwater runoff from existing impervious cover within the NBU well yard area prior to discharging to the Upper Spring Run of Landa Lake. The project included the removal of existing asphalt and installation of a 2,600 ft^2 vegetated bioretention basin with underdrain system and outfall. The basin has a total capture volume of approximately 1911 ft^3 and is designed to reduce total suspended solid (TSS) loading to Landa Lake by approximately 350-400 lbs/ year. Construction of the basin was completed in February 2021. NBU/ Headwaters at the Comal will assume the responsibility for maintenance of the basin upon completion. **Photos 1 & 2** show the project prior to and following construction.

Photo 1. Project area within the NBU Well Yard at the Headwaters at the Comal prior to construction of the bioretention basin

Photo 2. Photo of the completed bioretention basin at the NBU Well Yard at the Headwaters at the Comal

- **Construction of a bioretention basin at the corner of Elizabeth Ave and Landa Park Drive:** The bioretention basin captures and treats stormwater runoff from an impervious street segment (Elizabeth Ave) and parking lot prior to discharging to the Mill Race of the Comal River. Construction was completed in late 2021. The project included the removal of existing asphalt and installation of a 1,300 ft^2 vegetated bioretention basin with underdrain system and outfall. The basin has a total capture volume of approximately 1,722 ft^3 and is designed to reduce TSS loading to Landa Lake by approximately 365 lbs/ year. CoNB will assume the responsibility for maintenance of the basin in the future to ensure that it remains functional. **Photo 3** shows the completed bioretention basin.

Photo 3. Photo of the completed bioretention basin at the intersection of Landa Park Dr and Elizabeth Ave

Figure 1. Map showing the locations of the two stormwater treatment projects constructed in 2021.