Low Density Fish Sampling Protocol Study Results – Year One Report

Metrics for Adaptive Management of Habitat Restoration Sites for the Rio Grande Silvery Minnow

Prepared for

U.S. Army Corps of Engineers
Albuquerque District

On behalf of

Tetra Tech

Prepared by

SWCA Environmental Consultants

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LOW DENSITY FISH SAMPLING PROTOCOL STUDY RESULTS - YEAR ONE REPORT METRICS FOR ADAPTIVE MANAGEMENT OF HABITAT RESTORATION SITES FOR THE RIO GRANDE SILVERY MINNOW

Prepared for

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EXECUTIVE SUMMARY

Habitat restoration is needed to reduce risk of extinction and to increase recovery potentials for Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) in the Middle Rio Grande of New Mexico. Several restoration approaches have been implemented to improve habitat for the species including bankline lowering, channel widening, backwater construction, and high flow side channel construction. One metric for evaluating the effectiveness of habitat restoration projects is through monitoring for silvery minnow and the Middle Rio Grande fish community during spring runoff and post-runoff. How the fish community and the silvery minnow respond in the vicinity of habitat restoration projects in the months following recruitment provides a broad measure of project utilization. The use of catch per unit effort metrics during post-runoff monitoring allows for general comparisons among sites and provides an opportunity to assess the effectiveness of the various treatment types.

This report presents initial results from the 2013 collection of baseline main channel fish monitoring data in the vicinity of Middle Rio Grande habitat restoration projects. Additionally, the question persists whether using a beach seine for monitoring the Middle Rio Grande fish community adequately describes size distribution and relative abundance of either the silvery minnow or the Middle Rio Grande fish community. To help address this question, a beach seine and bag seine were used in combination to collect relative abundance fisheries data from main channel habitats adjacent to artificial floodplain habitat restoration sites in the Middle Rio Grande. Samples were collected by rapidly drawing the beach seine in a downstream direction up to the larger oversized bag seine. Samples collected from each site were stratified by three seine haul length groups (5, 10, and 20 m) to cover the variety of mesohabitats available in the Middle Rio Grande. Fish capture for both nets was recorded separately and catch from both nets was compared to the combined catch to determine if using the beach seine singly provided a sufficient description of the size distribution and relative abundance of the Middle Rio Grande fish community and the silvery minnow.

Low snowpack in the spring of 2013 produced runoff volumes insufficient to produce inundation of the constructed restoration sites. Consequently, the 2013 collections were limited to the main channel and the restoration sites would have likely not contributed to the fish community parameters during 2013. Therefore, no extensive analyses or comparisons of fish collection results among restoration sites are presented. These data provide baseline comparison information that can be used in future years when the habitat restoration features inundate and function as intended—providing recruitment habitat. This report, instead, focuses on comparisons of catch between the beach seine and bag seine and between both seines to the combined catch.

The combined net method showed that catches of Middle Rio Grande fish vary by species, size, survey, and between the beach and bag seines. Presumably, the combined catch was the closest approximation to Middle Rio Grande fish community population parameters, and using the beach seine alone would have not produced the same results as using the combined approach. From a catch perspective, no single net produced the same numbers as the combined catch, and the proportion of the fish collected with each net was often less than or equal to 50%, depending

on species. Over all surveys combined, only one species was missed by each gear type; however, the variability in species lists between gear types increased within surveys. The endangered silvery minnow was only present at low abundance in summer and fall of 2013, was not collected with the beach seine during Surveys 1 and 2, but was collected with the bag seine during all four surveys. Length frequency of the most common fish species varied between the bag and beach seines and between both nets combined. In general, a higher proportion of small fish were collected with the beach seine while a higher proportion of larger fish were collected with the bag seine.

Study results demonstrate that using the bag and beach seine combination increases the efficiency of fish community sampling by generating a more complete species list; collecting approximately 43% more fish per sample; collecting approximately 33% more species per sample; providing a more complete transcription of species population length structure; and detecting rare species more frequently than with the beach seine alone. In conclusion, the bag and beach seine combination appears to be well suited for sampling the Middle Rio Grande fish community and the endangered silvery minnow during years of low abundance. Additional samples should be collected using the methods described in this report, especially during years when relative abundance of silvery minnow is at or above average and during years of high runoff to determine effectiveness of restoration projects in the recovery of the silvery minnow population. The precision of the combined seine methodology could also be compared with that derived from beach seines alone as used for the species' long-term monitoring program.

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1 INTRODUCTION

Bosque habitat restoration treatments have been constructed to benefit both fish and terrestrial species in the Middle Rio Grande. Specifically, the endangered Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) may use inundated riparian habitat for spawning and recruitment (Gonzales et al. 2013). Evaluating the effectiveness of habitat restoration projects depends on monitoring the entire fish community, including the silvery minnow, during and after spring runoff. How the fish community and silvery minnow population respond in the vicinity of habitat restoration projects in the months following recruitment provides a broad measure of project effectiveness. The use of catch per unit effort metrics during post-runoff monitoring allows for general comparisons among sites.

Understanding how the abundance of fish stocks increase or decrease relative to management policies, environmental perturbations, or habitat suitability/availability is paramount for maintaining endangered fish populations. The use of relative abundance (catch per unit effort) for assessing the status of fish populations is common for endangered fisheries management because estimating actual abundance is too costly or managers desire to minimize the impact on rare populations (Hubert and Fabrizio 2007).

For relative abundance data to be useful for management purposes, they should reflect the population in question. Relative abundance has numerous underlying assumptions (Hubert and Fabrizio 2007) and these assumptions are rarely assessed for catch per unit effort data collected from lotic habitats (Gonzales et al. 2012). In many instances, assessments for these assumptions cannot be made so managers use other demographic or fish community parameters to infer the suitability of a particular gear type for sampling a fish population (e.g., see Fago 1998; Clark et al. 2006; Mercado-Silvia and Escandon-Sandoval 2008).

The efficiency of fishing gears varies by species, size of fish, and/or habitat/environmental conditions (Hubert and Fabrizio 2007). For example, fish catchability may be high for beach seines in open water areas with little structure but low in habitats with complexity such as large woody debris or shoreline vegetation. The resultant catch could further be confounded by the variability of a species' ability to escape, which depends on the behavior of individuals during herding and capture (Godo et al. 1999).

In this study, we used a beach and bag seine combination to collect relative abundance fisheries data from main channel habitats adjacent to artificial floodplain habitat restoration sites in the Middle Rio Grande of New Mexico. The method was similar to methods reported by Scheurer et al. (2003) and Widmer et al. (2010) and is expected to yield more accurate and precise data than using a beach seine alone (Widmer et al. 2013). Specifically, the technique can be used to determine baseline main channel fisheries data for Middle Rio Grande restoration projects and to determine presence/absence of silvery minnow during periods of low relative abundance for the species. This report provides an assessment of the relative performance of the beach and bag seine for assessing basic fish population criteria, including fish population length structure, presence/absence of fish species, and relative abundance of fish species.

2 METHODS

2.1 STUDY SITES

Main channel habitats adjacent to 12 Middle Rio Grande Bosque Restoration Project sites were sampled. Sites selected for sampling were spaced longitudinally from upstream of I-25 and the Isleta Diversion Dam in Bernalillo County to the Sandia Pueblo Reservation in Sandoval County (Figure 1). Sites 1A and 1B and sites 5D and 5E were on opposites sides of the river and were considered a single site for this study (i.e., 1A/B and 5D/E). Four surveys were conducted in 2013; Survey 1 was conducted In July, Survey 2 in August, Survey 3 in September, and Survey 4 in late October/early November (Table 1).

Table 1. Dates When the Main Channel Adjacent to Each Habitat Restoration Site Was Sampled, 2013

Restoration Site	Dates Sampled	Treatment Type	Control
1A/B	7/10, 8/15, 9/26, 10/30	Treat-Retreat-Revegetation, Bank Terracing, High Flow Channel, Bank Scallop	No
1E	7/10, 8/15, 9/26, 10/30	Treat-Retreat-Revegetation, Bank Terracing, High Flow Channel, Marsh Wetland, Willow Swales, Jetty Jack Removal	No
1G	7/10, 8/15, 9/26, 10/30	Treat-Retreat-Revegetation, Willow Swales, Canoe Ramp	Yes
3A	7/9, 8/13, 9/27, 10/29	Treat-Retreat-Vegetation, Bank Terracing, Open Water, Marsh Wetland, Jetty Jack Removal	No
Route 66	7/9, 8/13, 9/27, 10/29	Treat-Retreat-Revegetation, Wet Meadow Wetland	Yes
4B	7/9, 8/12, 9/24, 11/1	Treat-Retreat-Revegetation, Willow Swales	Yes
4C	7/12, 8/12, 9/24, 11/1	Treat-Retreat-Revegetation, Bank Terracing, High Flow Channel, Jetty Jack Removal	No
5B	7/12, 8/14, 9/25, 10/31	Treat-Retreat-Revegetation, Willow Swales, Jetty Jack Removal	Yes
5C	7/8, 8/14, 9/25, 9/25	Treat-Retreat-Revegetation, Willow Swales, High Flow Channel, Jetty Jack Removal	No
5D/E	7/8, 8/14, 9/25, 10/31	Treat-Retreat-Revegetation, Willow Swales	Yes

Note: Habitat restoration treatment types are listed for each site. Habitat restoration sites are considered control sites if prescribed treatments were not intended to benefit the Middle Rio Grande fish community or the silvery minnow.

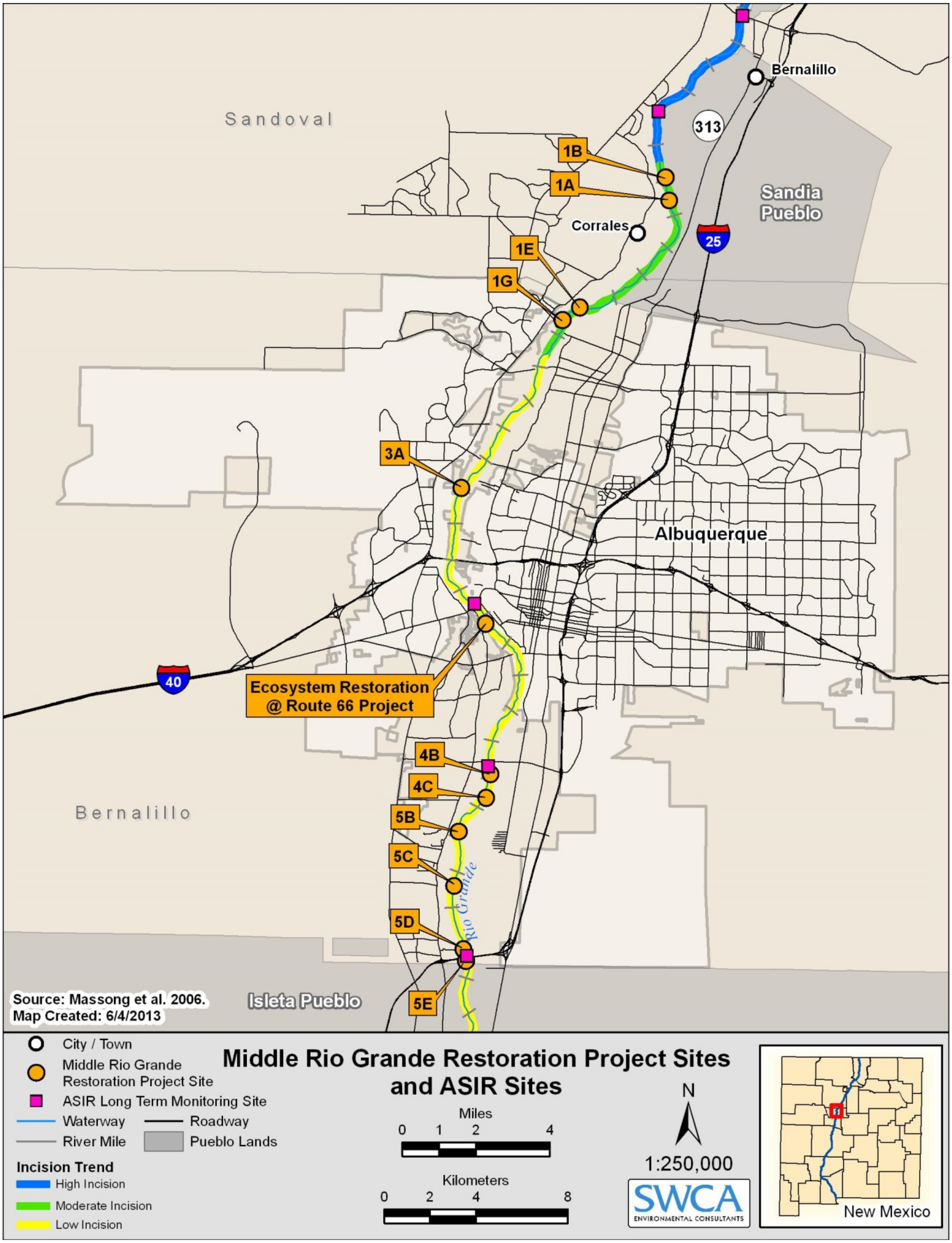

Figure 1. Location habitat restoration sites where main channel habitats were sampled in 2013.

Restoration treatments applied to five of the monitored sites (1A/B, 1E, 3A, 4C, and 5C) were intended to benefit the Middle Rio Grande fish community and the silvery minnow. The other five sites (1G, Route 66, 4B, 5B, and 5D/E) had restoration treatments applied to them that were not intended to provide habitat for the Middle Rio Grande fish community and the silvery minnow. All sites sampled serve as experimental units with the sites where treatments were expected to benefit the Middle Rio Grande fish community serving as the treatment units and the sites where the treatments were not expected to benefit the fish community serving as control sites.

2.2 SAMPLING APPROACH

Seine samples were collected by rapidly drawing a small beach seine (3.1 × 1.8 m [10 × 6 feet] with mesh approximately 3 mm [1/8 inch]) in a downstream direction up to a larger over-sized bag seine (6.0 × 1.5 m [20 × 5 feet] with mesh approximately 3 mm [1/8 inch]). Upon reaching the bag seine, both nets were tilted upwards to capture fish. The bag seine was anticipated to catch adult fish that normally occur as juveniles in fish community monitoring but are normally missed when using the beach seine alone. Seine samples were collected from three length groups, 5, 10, and 20 m. Nine seine samples, three from each length group, were collected from each site during each survey for a total of 90 samples. In total, 360 samples (36 from each site) were collected during Surveys 1 through 4.

For each sample fish were held in color-coded buckets that represented fish from the beach and bag seines. All fish were identified to species and counted separately for each seine net. Standard length (mm) was collected for each individual, and wet weight (+/- 0.10g) was collected from captured silvery minnow. After processing, fish were released to the mesohabitat where they were captured. All collected fish were identified in the field using taxonomic keys provided in Sublette et al. (1990); phylogenetic classification followed Nelson et al. (2004). A head-mounted jeweler's magnifier was used to aid in fish species identification where necessary.

Water depth and water velocity were measured using a Marsh-McBirney Flo-Mate portable velocity meter (Hach Company, Frederick, Maryland) and top-setting wading rod from each sampled mesohabitat. Mesohabitats were visually identified according to definitions adopted from Armantrout (1998) and used by the U.S. Fish and Wildlife Service (Remshardt 2008). All available mesohabitats at each site were sampled at least once. The dominant particle size of the habitat substrate (e.g., sand, small gravel, cobble, etc.) was recorded, as well as presence and type of structure (e.g., woody debris, vegetation, boulders, etc.). Lastly, the area and location of each sampled mesohabitat was recorded with a Trimble GeoXH handheld global positioning system (GPS) unit (Trimble Navigation Limited**,** Sunnyvale, California) with sub-foot accuracy. For this report maps are provided showing mesohabitat identifications and locations at each site for each survey. Fisheries data were not summarized or analyzed relative to mesohabitat association but may be used for future assessments of this type.

2.3 DATA SUMMARY AND ANALYSIS

A relational database (Microsoft Access) was developed for the storage, analysis, and retrieval of fish and environmental data.

2.3.1 Habitat Restoration Monitoring

The number of fish collected was generically summarized as total catch and number of species per survey, by habitat restoration site and by habitat restoration treatment type. Only simple counts are presented which, will be expanded upon when additional data becomes available from subsequent sampling events.

2.3.2 Relative Abundance and Fish Community Composition

The number of fish collected was summarized by species and percent species composition was calculated individually for beach seine, bag seine, and bag and beach seine combined samples for each survey and for all surveys combined.

To determine if the bag seine added information to the beach seine catch, the total number of fish caught per sample was compared across the beach seine, bag seine, and the combined catch with a Kruskal-Wallis one-way analysis of variance (ANOVA) (Zar 1999) for all the data collected during the four surveys (360 samples per group). If significant differences were detected, then a Wilcoxon rank sum test was used to compare differences between each of the groups (Zar 1999). Statistical significance ($P < 0.05$) of multiple comparisons was adjusted with the standard Bonferroni correction ($P = 0.05/n$). If significant differences were found for the combined four survey data sets, then the statistical procedure was repeated for each of the four surveys. The statistical procedure was conducted individually for the six most common species collected during the four surveys to determine if catch varies by species among the beach seine, bag seine, or the combined catch.

2.3.3 Species Richness

To determine if using the beach seine alone was missing species collected from the bag seine, we compared the total number of fish species caught (species richness) per sample across the beach seine, bag seine, and the combined catch with a Kruskal-Wallis one-way ANOVA (Zar 1999) for all the data collected during the four surveys (360 samples per group). If significant differences were detected then a Wilcoxon rank sum test was used to compare differences between each of the groups (Zar 1999). Statistical significance ($P < 0.05$) of multiple comparisons was adjusted with the standard Bonferroni correction ($P = 0.05/n$).

2.3.4 Fish Species Presence/Absence

The presence/absence of fish species was compared between the beach and bag seines. Each sample was binomially coded for each net and a 2×2 contingency table was constructed for each species. Fisher's exact test was used to determine if a particular fish species was present at a higher proportion in the beach seine or bag seine samples (Zar 1999). The analysis was conducted over all the samples collected during the study (360) for each collected species.

2.3.5 Size of Fish

Length frequency distributions were compared to determine if size of fish collected with beach seines provided the same information as size of fish collected with the bag seine. Length frequency histograms for each survey were constructed for the six most commonly collected species to determine if length structure data varied between the beach and bag seines and between each gear type and the combined distribution provided by both gear types for each sample. The Kolmogorov-Smirnov goodness of fit test was used to compare length frequencies between beach and bag seines and between the combined distribution and both nets (Neumann and Allen 2007). A bootstrapped version of the Kolmogorov-Smirnov test that provides correct coverage when the compared distributions are not entirely continuous and that produces unbiased P values when there are ties in the data was used (Sekhon 2011). Each bootstrapped Kolmogorov-Smirnov test was run for 10,000 iterations. The statistical procedure was conducted independently for each of the four surveys.

2.3.6 Seine Haul Length

Using catch per unit effort as an index of abundance assumes that the number of fish captured is proportional to the amount effort expended (Quinn and Deriso 1999). If this assumption fails, catch per unit effort can be a misleading indicator of abundance (Hubert and Fabrizio 2007). In this study, we stratified our sampling effort by seine haul lengths of 5, 10, and 20 m to allow for flexibility of sampling the variety of main channel mesohabitats available in the Middle Rio Grande.

We compared the total number of fish captured among seine haul length groupings with a Kruskal-Wallis one-way ANOVA (Zar 1999) for all the data collected during the four surveys (120 samples per seine haul length strata, 360 total samples). If significant differences were detected then a Wilcoxon rank sum test was used to compare differences between each of the length groups (Zar 1999). Statistical significance ($P < 0.05$) of multiple comparisons was adjusted with the standard Bonferroni correction ($P = 0.05/n$). The analysis was conducted for the total combined bag and beach seine catch.

3 RESULTS

3.1 HABITAT RESTORATION MONITORING

Catch of Middle Rio Grande fishes varied among habitat restoration sites and surveys (Table 2). Over all four surveys combined, more fish were collected from sites 4B and 4C (1,557 and 1,053), while the fewest fish were collected site 3A (283). The maximum number of species collected at one site during one survey was 11 while the minimum number collected was four. In general, more species were collected from northernmost sites and fewer were collected from the southernmost sites.

Among surveys, the number of species collected at each site decreased between Surveys 1 and 4 with an average of three fewer species recorded at each site during Survey 4 than during survey 1. Site 1E was the only site where more fish were collected during Survey 4 than during survey 1.

Table 2. Number of Fish and Species Collected at Each Monitoring Habitat Restoration Site during Surveys 1–4

Site	Feature	Survey 1		Survey 2		Survey 3		Survey4	
		# Collected	# Species	# Collected	# Species	# Collected	# Species	# Collected	# Species
1A-B	High Flow Channel, Scallop	213	10	177	11	335	6	169	9
1E	High Flow Channel	83	11	93	4	206	8	234	8
1G	Control	411	11	94	10	119	9	62	7
3A	Bank Terracing	93	9	75	9	38	6	77	5
RT66	Control	320	10	124	7	128	6	165	8
4B	Control	382	9	141	6	848	10	186	10
4C	High Flow Channel, Bank Terracing	335	11	282	5	124	6	312	7
5B	Control	212	9	178	7	74	4	164	7
5C	High Flow Channel	88	8	128	7	91	7	64	4
5D-E	Control	443	8	397	7	85	6	56	5

Catches of individual species from the vicinity of habitat restoration sites shows that some species are widely and similarly distributed, while the distribution of others appears clumped at upstream or downstream sites (Table 3). Channel catfish (*Ictalurus punctatus*), red shiner (*Cyprinella lutrensis*), fathead minnow (*Pimephales promelas*), river carpsucker (*Carpiodes carpio*), and flathead chub (*Platygobio gracilis*) were widely distributed and found at all sites. Species like white sucker (*Catostomus commersonii*) and longnose dace (*Rhinichthys cataractae*) were common at upstream sites but not at downstream sites. The silvery minnow was collected from all sites except the downstream most site 5D/E.

Table 3. Number of Fish Collected by Habitat Restoration Site for All Surveys Combined

Treatment	High Flow Channel, Scallop	High Flow Channel, Bank Terracing	Control	Bank Terracing	Control	High Flow Channel	Control	High Flow Channel	Control	Control
Species/Site	**1A-B**	**1E**	**1G**	**3A**	**4B**	**4C**	**5B**	**5C**	**5D-E**	**RT66**
Channel catfish	55	41	21	104	376	378	307	209	488	225
Red shiner	120	242	107	64	383	338	190	85	164	231
Fathead minnow	77	103	156	49	137	77	44	18	153	39
Western mosquitofish	87	61	12	6	529	79	18	5	9	25
River carpsucker	4	12	217	8	42	111	24	9	142	103
Flathead chub	192	113	95	28	27	32	35	35	6	26
Longnose dace	280	4	2	0	3	0	0	0	0	0
White sucker	40	28	25	9	18	14	1	2	7	42
Common carp	28	4	18	6	8	8	3	2	10	5
Rio Grande silvery minnow	9	3	7	8	12	6	4	4	0	15
Yellow bullhead	1	2	1	1	3	9	2	2	2	2
White crappie	0	0	0	0	1	0	0	0	0	4
Green sunfish	1		0	0	0	0	0	0	0	1
Largemouth bass	0	0	0	0	2	0	0	0	0	0
Black bullhead	0	0	1	0	0	0	0	0	0	0
Unknown	0	3	24	0	16	1	0	0	0	19
Total	894	616	686	283	1,557	1,053	628	371	981	737

3.2 Relative Abundance and Fish Community Composition

During Surveys 1 through 4 more fish were collected with the beach seine than with the bag seine (Table 4). The highest catch for both nets occurred during Survey 1 while the lowest catch for both nets differed among surveys. The lowest catch for the beach seine occurred during Survey 2 (970) while the lowest catch for the bag seine occurred during Survey 4 (517).

Table 4. Number of Fish Collected per Survey with the Beach Seine, the Bag Seine, and Both Nets Combined

Survey	Bag #	Beach #	Combined #
1	1,157	1,423	2,580
2	719	970	1,689
3	947	1,101	2,048
4	517	972	1,489

3.2.1 Fish Community Composition

Surveys 1–4

A total of 7,806 fish comprising 15 different species was collected during the four main channel surveys (Table 5). Overall, 4,466 fish were collected with the beach seine, while 3,340 were collected with the bag seine. Channel catfish was the most common species collected during surveys for both nets combined and the bag seine, while it was the second most common species collected with the beach seine. Red shiner was the second most common species collected for both nets combined and the bag seine, while it was the most common species collected with the beach seine. Fathead minnow was the third most common species collected for both nets combined and the beach seine, while it was the fourth most common species collected with the bag seine. Other common species included western mosquitofish (*Gambusia affinis*), river carpsucker, and flathead chub. The remaining nine species comprised less than 10% of the total catch. Although not common, 68 silvery minnow were collected during Surveys 1 through 4. More than two times the number of silvery minnow were collected with the bag seine (46) than with the beach seine (22). Only two wild silvery minnow (no marks indicating hatchery origin) were collected with the beach seine, while 25 were collected with the bag seine. No largemouth bass (*Micropterus salmoides*) were collected with the beach seine, while no black bullhead (*Ameiurus melas*) were collected with the bag seine during Surveys 1 through 4.

Table 5. Total Number and Percent Composition of Species Collected with the Bag Seine, Beach Seine, and Both Nets Combined during All Four Surveys

Common Name	Species	Bag #	Bag %	Beach #	Beach %	Combined #	Combined %
Channel catfish	*Ictalurus punctatus*	982	29.40	1222	27.36	2,204	28.23
Red shiner	*Cyprinella lutrensis*	648	19.40	1276	28.57	1,924	24.65
Fathead minnow	*Pimephales promelas*	387	11.59	466	10.43	853	10.93
Western mosquitofish	*Gambusia affinis*	403	12.07	428	9.58	831	10.65
River carpsucker	*Carpiodes carpio*	361	10.81	311	6.96	672	8.61
Flathead chub	*Platygobio gracilis*	235	7.04	354	7.93	589	7.55
Longnose dace	*Rhinichthys cataractae*	105	3.14	184	4.12	289	3.70
White sucker	*Catostomus commersonii*	91	2.72	95	2.13	186	2.38
Common carp	*Cyprinus carpio*	52	1.56	40	0.90	92	1.18
Rio Grande silvery minnow	*Hybognathus amarus*	46	1.38	22	0.49	68	0.87
Yellow bullhead catfish	*Ameiurus natalis*	11	0.33	14	0.31	25	0.32
White crappie	*Pomoxis annularis*	2	0.06	3	0.07	5	0.06
Green sunfish	*Lepomis cyanellus*	1	0.03	1	0.02	2	0.03
Largemouth bass	*Micropterus salmoides*	2	0.06	0	0.00	2	0.03
Black bullhead catfish	*Ameiurus melas*	0	0.00	1	0.02	1	0.01
Unknown	*Unknown*	14	0.42	49	1.10	63	0.81
Total		**3,340**	**100**	**4,466**	**100**	**7,806**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 1

During Survey 1, a total of 2,580 fish from 15 different species were collected (Table 6). Overall, 1,423 fish were collected with the beach seine, while 1,157 were collected with the bag seine. Channel catfish and river carpsucker were the most common species collected with both nets during Survey 1. Red shiner was the third most common species collected for both nets combined and the beach seine, while it was the fourth most common species collected with the bag seine. Conversely, fathead minnow was the fourth most common species collected for both nets combined and the beach seine, while it was the third most common species collected with the bag seine. White sucker was also commonly collected and comprised 7% of the bag seine catch and 5% of the beach seine catch. During Survey 1, a total of 11 wild silvery minnow was collected with the bag seine while zero were collected with the beach seine. Green sunfish (*Lepomis cyanellus*) and black bullhead were not collected with the bag seine, while largemouth bass and silvery minnow were not collected with the beach seine.

Table 6. Total Number and Percent Composition of Species Collected with the Bag Seine, Beach Seine, and Both Nets Combined during Survey 1

Common Name	Bag #	Bag %	Beach #	Beach %	Combined #	Combined %
Channel catfish	311	26.88	460	32.33	771	29.88
River carpsucker	298	25.76	276	19.4	574	22.25
Red shiner	147	12.71	233	16.37	380	14.73
Fathead minnow	178	15.38	171	12.02	349	13.53
White sucker	79	6.83	72	5.06	151	5.85
Western mosquitofish	32	2.77	77	5.41	109	4.22
Flathead chub	35	3.03	48	3.37	83	3.22
Common carp	37	3.2	21	1.48	58	2.25
Yellow bullhead catfish	8	0.69	10	0.7	18	0.7
Rio Grande silvery minnow	11	0.95	0	0	11	0.43
Longnose dace	6	0.52	4	0.28	10	0.39
Largemouth bass	2	0.17	0	0	2	0.08
Green sunfish	0	0	1	0.07	1	0.04
Black bullhead	0	0	1	0.07	1	0.04
Unknown	13	1.12	49	3.44	62	2.4
Total	**1,157**	**100**	**1,423**	**100**	**2,580**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 2

In total, 1,689 fish were collected during Survey 2; 970 with the beach seine and 719 with the bag seine (Table 7). Channel catfish was the most commonly collected species during Survey 2, comprising 56% of the combined catch. Other common species included the red shiner, fathead minnow, flathead chub, and river carpsucker. Notably, river carpsucker and silvery minnow comprised a greater proportion of the bag seine catch (6.26% and 1.53%) than the beach seine catch (1.44% and 0%). Alternatively, longnose dace and white sucker comprised a greater proportion of the beach seine catch (1.03% and 1.34%) than the bag seine catch (0.14% and 0.28%). The only species that was not collected by both nets was silvery minnow.

Table 7. Total Number and Percent Composition of Species Collected with the Bag Seine, Beach Seine, and Both Nets Combined during Survey 2

Common Name	Bag #	Bag %	Beach #	Beach %	Combined #	Combined %
Channel catfish	409	56.88	534	55.05	943	55.83
Red shiner	136	18.92	244	25.15	380	22.50
Fathead minnow	47	6.54	97	10.00	144	8.53
Flathead chub	42	5.84	40	4.12	82	4.85
River carpsucker	45	6.26	14	1.44	59	3.49
Western mosquitofish	15	2.09	7	0.72	22	1.30
Common carp	9	1.25	7	0.72	16	0.95
White sucker	2	0.28	13	1.34	15	0.89
Rio Grande silvery minnow	11	1.53	0	0.00	11	0.65
Longnose dace	1	0.14	10	1.03	11	0.65
Yellow bullhead catfish	2	0.28	4	0.41	6	0.36
Total	**719**	**100**	**970**	**100**	**1,689**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 3

More fish were collected during Survey 3 than Survey 2. A total of 2,048 fish comprised of 10 species was collected during Survey 3 (Table 8). Western mosquitofish was the most common species collected with both nets; however, percent composition was notably greater for the bag seine (34%) than for the beach seine (25%). Red shiner was the second most common species collected with both nets, followed by channel catfish and longnose dace. Four silvery minnow were collected with the bag (2) and beach seines (2). During Survey 3, no species were missed by the bag or beach seines.

Table 8. Total Number and Percent Composition of Species Collected with the Bag Seine, Beach Seine, and Both Nets Combined during Survey 3

Species	Bag #	Bag %	Beach #	Beach %	Combined #	Combined %
Western mosquitofish	319	33.69	271	24.61	590	28.81
Red shiner	198	20.91	258	23.43	456	22.27
Channel catfish	157	16.58	179	16.26	336	16.41
Longnose dace	94	9.93	166	15.08	260	12.70
Fathead minnow	74	7.81	122	11.08	196	9.57
Flathead chub	82	8.66	76	6.90	158	7.71
River carpsucker	12	1.27	14	1.27	26	1.27
White sucker	4	0.42	8	0.73	12	0.59
Common carp	4	0.42	5	0.45	9	0.44
Rio Grande silvery minnow	2	0.21	2	0.18	4	0.20
Unknown	1	0.11	0	0.00	1	0.05
Total	**947**	**100**	**1,101**	**100**	**2,048**	**100**

Note: Percentages may not sum exactly due to rounding.

SURVEY 4

Fewer fish were collected during Survey 4 than the three prior surveys. In total, 1,489 fish were collected during Survey 4; 517 with the bag seine and 972 with the beach seine (Table 9). During Survey 4, percent composition varied notably for the most commonly collected species with both nets. Red shiner was the most common species collected with both nets comprising 48% of the combined catch and 56% and 32 % of the beach and bag seine catches, respectively. More fathead minnows were collected with the bag seine (88) than with the beach seine (76) and percent composition for this species was notably different, comprising 17% and 8% of the bag and beach seine catch. Silvery minnows were more common during Survey 4 than the previous three surveys; however, the majority (41) of the fish collected were of hatchery origin. A single wild silvery minnow was collected during Survey 4 with the bag seine. Yellow bullhead catfish (*Ameiurus natalis*) and green sunfish were only collected with the bag seine.

Table 9. Total Number and Percent Composition of Species Collected with the Bag Seine, Beach Seine, and Both Nets Combined during Survey 4

Species	Bag #	Bag %	Beach #	Beach %	Combined #	Combined %
Red shiner	167	32.30	541	55.66	708	47.55
Flathead chub	76	14.70	190	19.55	266	17.86
Fathead minnow	88	17.02	76	7.82	164	11.01
Channel catfish	105	20.31	49	5.04	154	10.34
Western mosquitofish	37	7.16	73	7.51	110	7.39
Rio Grande silvery minnow	22	4.26	20	2.06	42	2.82
River carpsucker	6	1.16	7	0.72	13	0.87
Common carp	2	0.39	7	0.72	9	0.60
White sucker	6	1.16	2	0.21	8	0.54
Longnose dace	4	0.77	4	0.41	8	0.54
White crappie	2	0.39	3	0.31	5	0.34
Yellow bullhead catfish	1	0.19	0	0.00	1	0.07
Green sunfish	1	0.19	0	0.00	1	0.07
Total	**517**	**100**	**972**	**100**	**1,489**	**100**

Note: Percentages may not sum exactly due to rounding.

3.2.2 RELATIVE ABUNDANCE

RELATIVE ABUNDANCE OF ALL FISH

Over all four surveys, the total number of fish collected per sample was different among the beach seine, bag seine, and the combined catch (Kruskal-Wallis one-way ANOVA, $P < 0.0001$) (Figure 2). Between the groups, the mean number of fish per sample varied for all contrasts (Wilcoxon rank sum test with Bonferroni adjusted P values, all three $P \leq 0.05$). The mean number collected per sample was greatest for the combined catch (mean = 22 fish/sample), intermediate for the beach seine (mean = 12 fish/sample), and lowest for the bag seine (mean = 9 fish/sample). On average the beach and bag seines produced approximately 57% and 43% of the combined catch per sample, respectively.

During Survey 1, the total number of fish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P < 0.0001$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine but was different between the beach seine and the combined catch and the bag seine and the combined catch

(Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.001$). The number collected was greatest for the combined catch (mean = 28 fish/sample), intermediate for the beach seine (mean = 16 fish/sample), and lowest for the bag seine (mean = 13 fish/sample).

During Survey 2, the total number of fish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P < 0.0001$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine or between the beach and combined catch, but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, $P < 0.01$). The number of fish collected per sample was greatest for the combined catch (mean = 19 fish/sample) and for the beach seine (mean = 11 fish/sample), and lowest for the bag seine (mean = 8 fish/sample).

During Survey 3, the total number of fish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P < 0.001$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine but was different between the beach seine and the combined catch, and the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.05$). The number of fish collected per sample was greatest for the combined catch (mean = 23 fish/sample), intermediate for the beach seine (mean = 12 fish/sample), and lowest for the bag seine (mean = 11 fish/sample).

During Survey 4, the total number of fish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P < 0.0001$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine but was different between the beach seine and the combined catch, and the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.05$). The number of fish collected per sample was greatest for the combined catch (mean = 17 fish/sample), intermediate for the beach seine (mean = 11 fish/sample), and lowest for the bag seine (mean = 6 fish/sample).

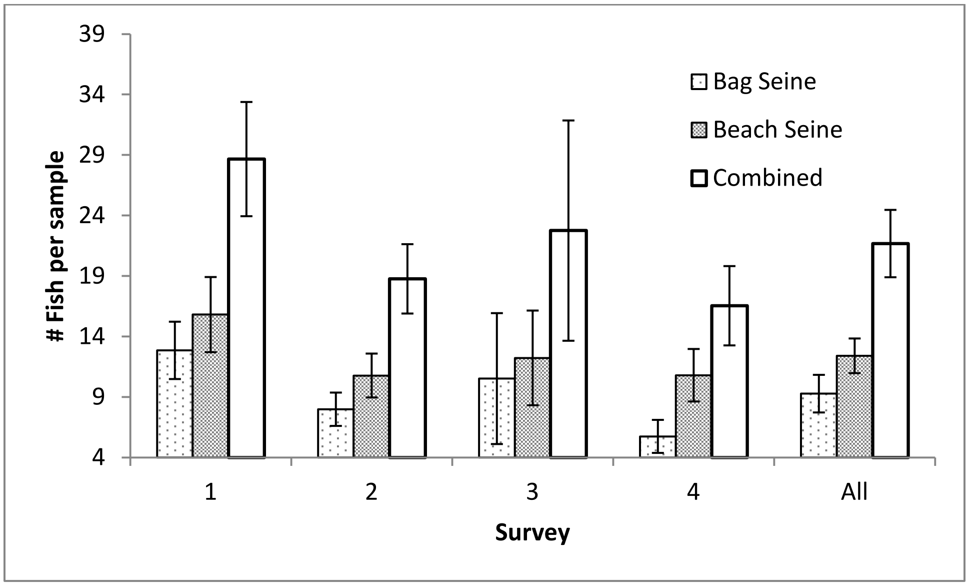

Figure 2. Total number of fish collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined. Error bars are one standard error.

RELATIVE ABUNDANCE OF RIVER CARPSUCKER

Over all four surveys, the total number of river carpsucker collected per sample was different among the beach seine, bag seine, and combined catch (Kruskal-Wallis one-way ANOVA, P = 0.001) (Figure 3). Between the net groups, the mean number of river carpsucker per sample varied significantly between the beach seine and the combined catch but not between the bag and beach seine or between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, $P < 0.001$). The mean number of river carpsucker collected per sample was greatest for the combined catch (mean = 1 river carpsucker/sample) and similar for the bag and beach seines (mean = 1 river carpsucker/sample).

During Survey 1, the number of river carpsucker collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P = 0.009$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine or the bag seine and the combined catch, but was different between the beach seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, $P = 0.008$). The number collected was greatest for the combined catch (mean = 6 river carpsucker/sample) and similar for the beach and bag seines (mean = 3 river carpsucker/sample).

During Surveys 2, 3, and 4, the total of river carpsucker collected per sample did not differ among the three groupings (Kruskal-Wallis one-way ANOVA, $P > 0.05$ for all three tests). The analysis indicates that the main difference in catch of river carpsucker among the groupings was between the beach seine and the combined catch during Survey 1.

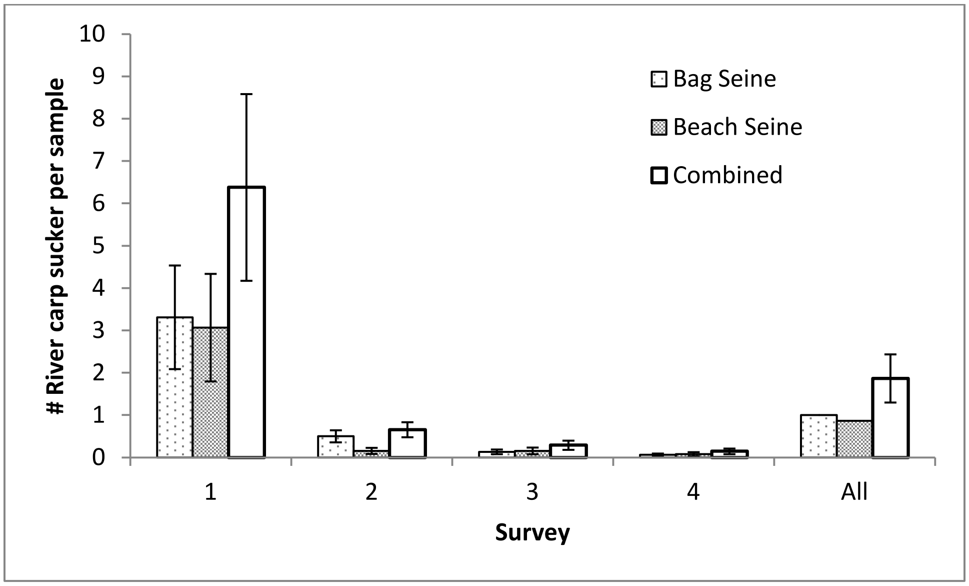

Figure 3. Total number of river carpsucker collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined.

RELATIVE ABUNDANCE OF RED SHINER

Over all four surveys, the total number of red shiner collected per sample was different among the beach seine, bag seine, and combined catch (Kruskal-Wallis one-way ANOVA, P = <0.00001) (Figure 4). Between the groups, the mean number of red shiner per sample varied for all contrasts (Wilcoxon rank sum test with Bonferroni adjusted P values, all three $P \leq 0.02$). The mean number of red shiner collected per sample was greatest for the combined catch (mean = 5 red shiner/sample), intermediate for the beach seine (mean = 4 red shiner/sample), and lowest for the bag seine (mean = 2 red shiner/sample). On average the beach and bag seines produced approximately 66% and 34% of the combined red shiner catch per sample, respectively.

During Survey 1, the total number of red shiner collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, P = 0.004). Between the groups the mean number of red shiner collected per sample was not different between the beach and bag seine but was different between the beach seine and the combined catch, and the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.04$). The number of red shiner collected per sample was greatest for the combined catch (mean = 4 red shiner/sample), intermediate for the beach seine (mean = 3 red shiner/sample), and lowest for the bag seine (mean = 2 red shiner/sample).

During Survey 2, the total number of red shiner collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, P = 0.04). Between the groups the mean number of red shiner collected per sample was not different between the beach and bag seine or between the beach and combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P value, P = 0.03). The number of red shiner collected per sample was greatest for the combined catch (mean = 4 red shiner/sample) and the beach seine (mean = 3 red shiner/sample), and lowest for the bag seine (mean = 2 red shiner/sample).

During Survey 3, the total number of red shiner collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, P = 0.004). Between the groups the mean number of red shiner collected per sample was not different between the beach and bag seine or between the beach and combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P value, P = 0.003). The number of red shiner collected per sample was greatest for the combined catch (mean = 5 red shiner/sample), intermediate for the beach seine (mean = 3 red shiner/sample), and lowest for the bag seine (mean = 2 red shiner/sample).

During Survey 4, the total number of red shiner collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, P = 0.0004). Between the groups the mean number of red shiner collected per sample was different between the bag and beach seine and the bag seine and the combined catch, but was not different between the beach seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.01$). The number of red shiner collected per sample was greatest for the combined catch (mean = 8 red shiner/sample), intermediate for the beach seine (mean = 6 red shiner/sample), and lowest for the bag seine (mean = 2 red shiner/sample).

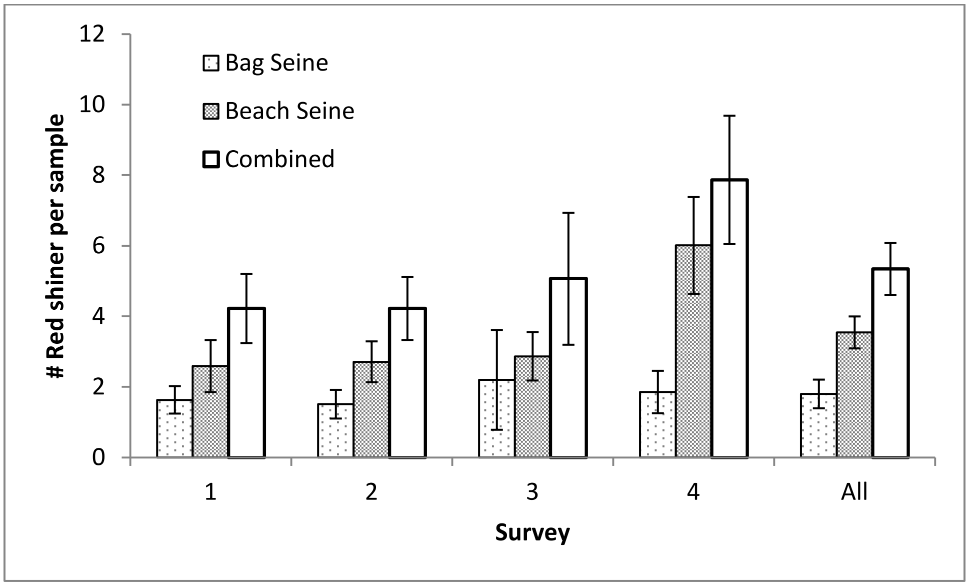

Figure 4. Total number of red shiner collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined.

RELATIVE ABUNDANCE OF WESTERN MOSQUITOFISH

Over all four surveys, the total number of western mosquitofish collected per sample was different among the beach seine, bag seine, and combined catch (Kruskal-Wallis one-way ANOVA, $P = 0.01$) (Figure 5). Between the groups, the mean number of western mosquito fish per sample varied between the beach seine and the combined catch but not between the bag and beach seine and or between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted *P* values, all $P = 0.01$). The mean number collected per sample was greatest for the combined catch (mean = 2 western mosquitofish/sample) and the approximately the same for the bag and beach seines (mean = 1 western mosquitofish/sample).

When compared by survey, the total number of western mosquito fish collected per sample did not differ among the three groupings for Surveys 1 through 4 (Kruskal-Wallis one-way ANOVA, $P > 0.05$ for all four tests). The analysis indicates that the main difference in catch of western mosquitofish among the groupings was between the beach seine and the combined catch during over all four surveys combined.

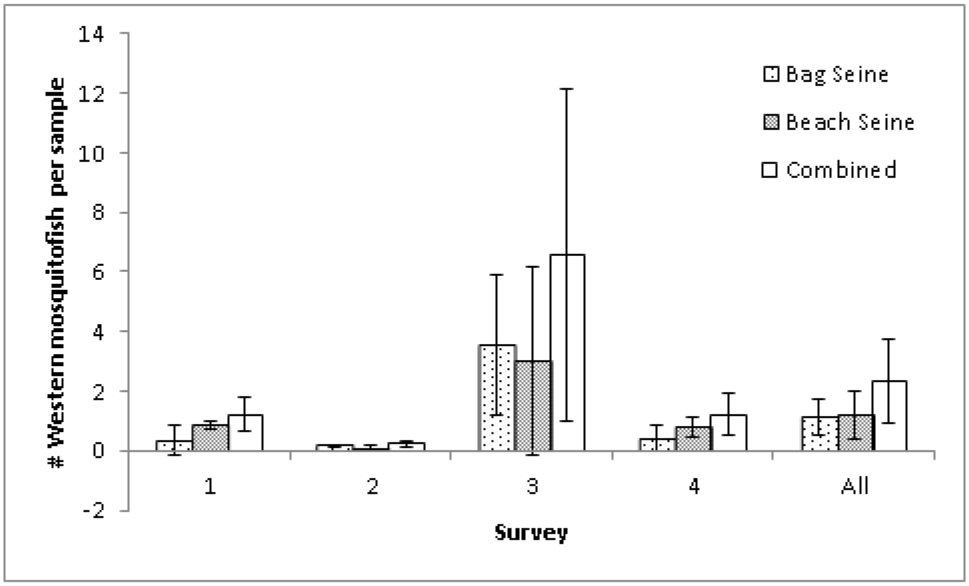

Figure 5. Total number of western mosquitofish collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined.

RELATIVE ABUNDANCE OF CHANNEL CATFISH

Over all four surveys, the total number of channel catfish collected per sample was different among the beach seine, bag seine, and combined catch (Kruskal-Wallis one-way ANOVA, P <0.000001) (Figure 6). Between the groups, the mean number of fish per sample varied between the bag seine and the combined catch and the beach seine and the combined catch but not between the bag and beach seines (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P < 0.00001$). The mean number collected per sample was greatest for the combined catch (mean = 6 channel catfish/sample) and approximately equal between the bag and beach seines (3 channel catfish/sample)

During Survey 1, the total number of channel catfish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P = 0.02$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine or the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P value, $P = 0.03$). The number collected was greatest for the combined catch (mean = 9 channel catfish/sample), intermediate for the beach seine (mean = 5 channel catfish/sample), and lowest for the bag seine (mean = 3 channel catfish/sample).

During Survey 2, the total number of channel catfish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P = 0.02$). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine or the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P value, $P = 0.02$). The number collected was greatest for the combined catch (mean = 10 channel catfish/sample), intermediate for the beach seine (mean = 6 channel catfish/sample), and lowest for the bag seine (mean = 5 channel catfish/sample).

During Survey 3, the total number of channel catfish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, P = 0.007). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine or the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P value, P = 0.009). The number collected was greatest for the combined catch (mean = 4 channel catfish/sample) and approximately equal for the bag and beach seines (mean = 2 channel catfish/sample).

During Survey 4, the total number of channel catfish collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, P = 0.04). Between the groups the mean number of fish collected per sample was not different between the beach and bag seine or the bag seine and the combined catch but was different between the beach seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P value, P = 0.04). The number collected was greatest for the combined catch (mean = 2 channel catfish/sample) and approximately equal for the bag and beach seines (mean = 1 channel catfish/sample).

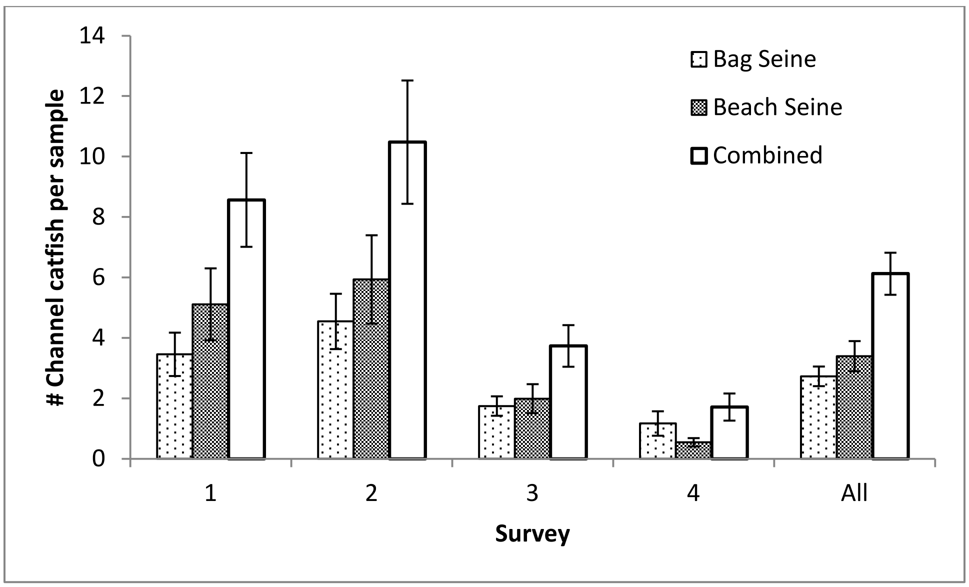

Figure 6. Total number of channel catfish collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined.

RELATIVE ABUNDANCE OF FATHEAD MINNOW

Over all four surveys, the total number of fathead minnow collected per sample was different among the beach seine, bag seine, and combined catch (Kruskal-Wallis one-way ANOVA, P = 0.0002) (Figure 7). Between the groups, the mean number of fathead minnow per sample varied between the beach and bag seine and the bag seine and the combined catch but not between the beach seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.05$). When calculated, the mean number of fathead minnow collected per sample was greatest for the combined catch (mean = 2 fathead minnow/sample) and the approximately the same for the bag and beach seines (mean = 1 fathead minnow/sample).

When compared by survey, the total number of fathead minnow collected per sample did not differ among the three groupings for Surveys 1 through 3 (Kruskal-Wallis one-way ANOVA, $P > 0.05$ for all four tests). During Survey 4, the total number of fathead minnow collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P = 0.05$). Between the groups, the mean number of fathead minnow per sample was not different between the beach and bag seine and the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted *P* value, $P = 0.05$). When calculated, the mean number of fathead minnow collected per sample was greatest for the combined catch (mean = 2 fathead minnow/sample) and the approximately the same for the bag and beach seines (mean = 1 fathead minnow/sample).

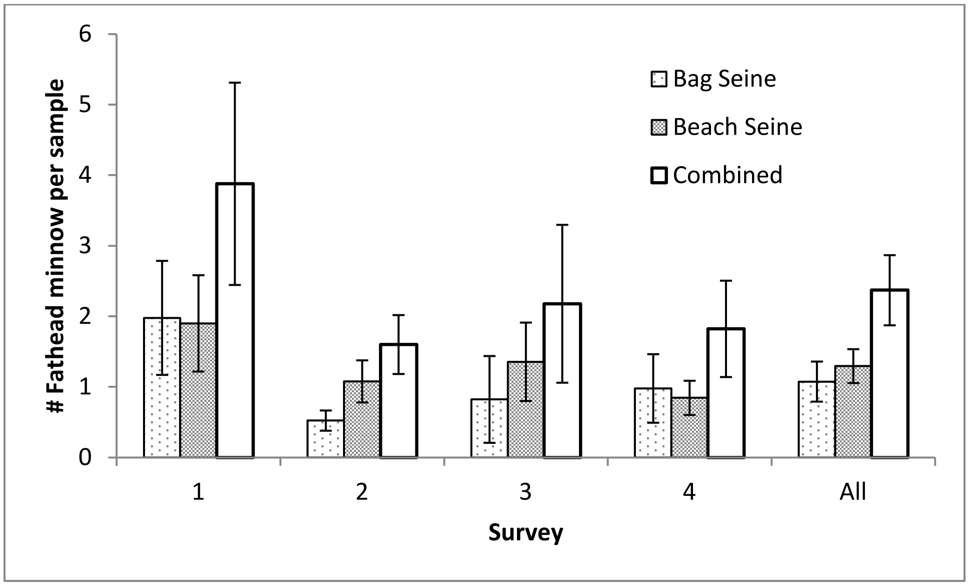

Figure 7. Total number of fathead minnow collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined.

RELATIVE ABUNDANCE OF FLATHEAD CHUB

Over all four surveys, the total number of flathead chub collected per sample was different among the beach seine, bag seine, and combined catch (Kruskal-Wallis one-way ANOVA, $P < 0.0001$) (Figure 8). Between the groups, the mean number of flathead chub per sample was not different between the beach and bag seine and the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted *P* values, $P < 0.0001$). When calculated, the mean number of flathead chub collected per sample was greatest for the combined catch (mean = 2 flathead chub/sample) and the approximately the same for the bag and beach seines (mean = 1 flathead chub/sample).

When compared by survey, the total number of flathead chub collected per sample did not differ among the three groupings for Surveys 1 and 2 (Kruskal-Wallis one-way ANOVA, $P > 0.05$ for both tests). During Survey 3, the total number of flathead chub collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, $P = 0.02$). Between the groups, the mean number of flathead chub per sample was not different between the beach and bag seine and the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted *P* values, *P* = 0.02). When calculated, the mean number of flathead chub collected per sample was greatest for the combined catch (mean = 2 flathead chub/sample) and the approximately the same for the bag and beach seines (mean = 1 flathead chub/sample).

During Survey 4, the total number of flathead chub collected per sample varied among the three groupings (Kruskal-Wallis one-way ANOVA, *P* = 0.007). Between the groups, the mean number of flathead chub per sample was not different between the beach and bag seine and the beach seine and the combined catch but was different between the bag seine and the combined catch (Wilcoxon rank sum test with Bonferroni adjusted *P* values, *P* = 0.005). When calculated, the mean number of flathead chub collected per sample was greatest for the combined catch (mean = 2 flathead chub/sample) and the approximately the same for the bag and beach seines (mean = 1 flathead chub/sample). The analysis indicates that the differences among groups were primarily between the bag seine and the combined catch.

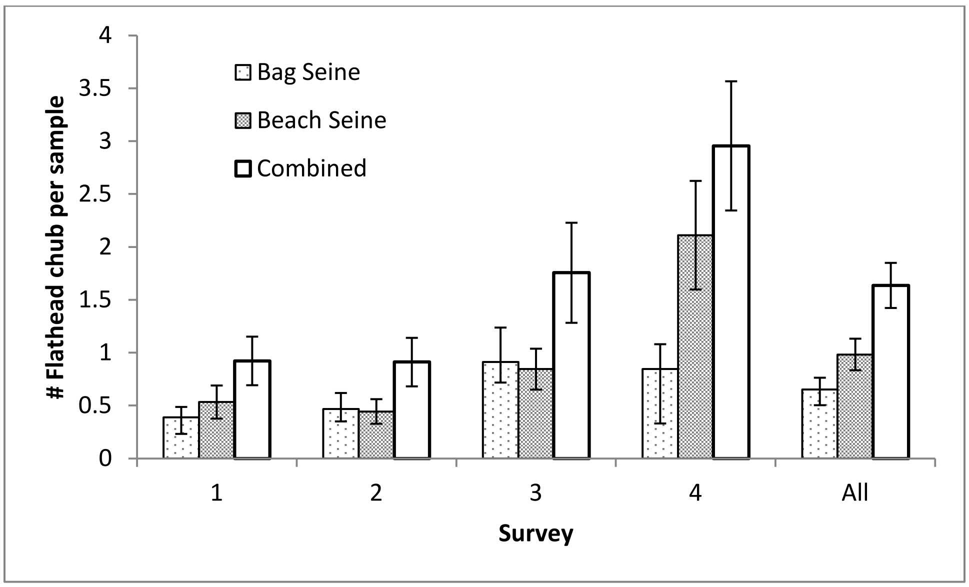

Figure 8. Total number of flathead chub collected per sample with the bag seine, beach seine, and both nets combined during Survey 1 through 4 and for all four surveys combined.

3.3 SPECIES RICHNESS

The number of species collected per sample varied among the bag seine, beach seine, and combined catch (Kruskal-Wallis ANOVA, *P* < 0.00001). Beach and bag seine samples on average had two species while the combined catch samples had three species. Mean number of species detected per sample with the beach and bag seine was the same (mean = 2 species) and was significantly lower than the number for the combined catch (mean = 3 species; Wilcoxon rank sum test, both *P* < 0.0001). The analysis shows, that although both nets collected approximately the same number of species per sample, the species collected were different and on average one species of fish would be missed if the beach seine was used alone (Figure 9).

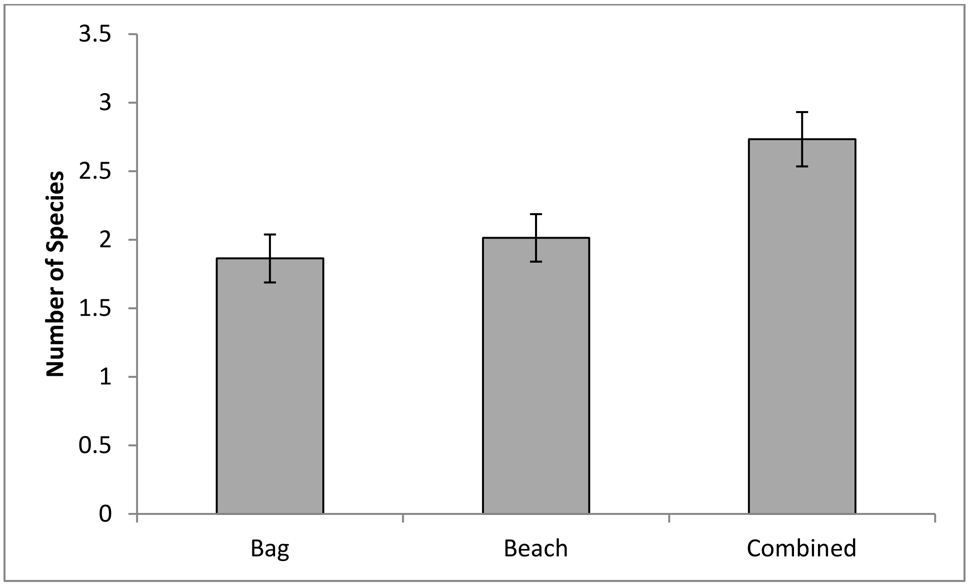

Figure 9. Number of species collected per sample by the bag seine, beach seine, and combined catch during Surveys 1 through 4.

3.4 Species Presence Absence

Over all species collected during Surveys 1 through 4, only the red shiner, fathead minnow, and flathead chub were collected in different proportions with the bag and beach seines (Fisher's Exact Test, $P \leq 0.05$). The proportion of samples containing each of these species was greater for beach seine samples. Although not statistically significant, the silvery minnow was not collected with the beach seine during Surveys 1 through 3, but was collected with the bag seine during these surveys (Figure 10).

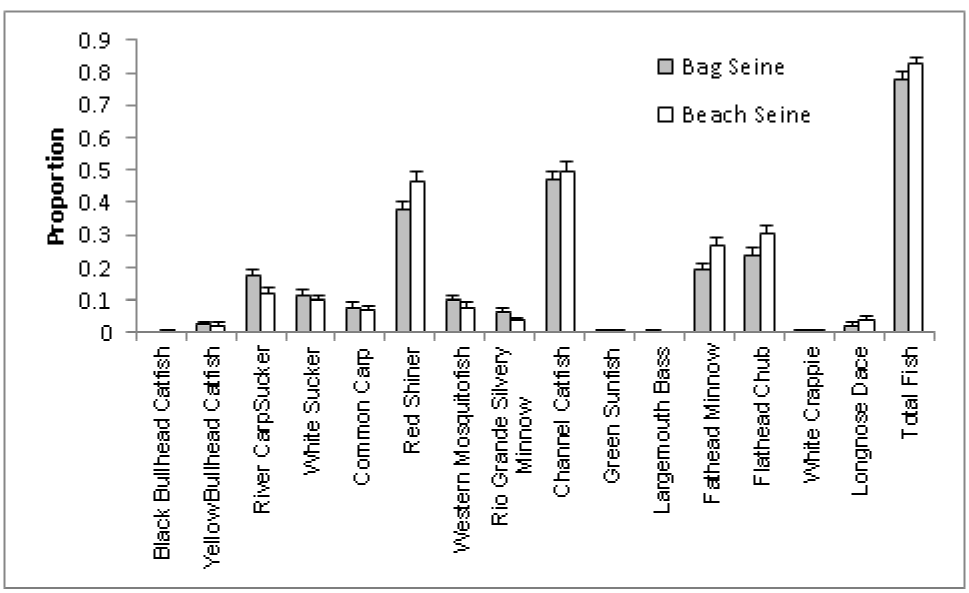

Figure 10. The proportion of samples where each species collected during Surveys 1 through 4 was present in bag seine and beach seine collections.

3.5 SIZE OF FISH

3.5.1 LENGTH FREQUENCY OF ALL FISH

Length frequency of all fish collected during Survey 1 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, P <0.0001). When comparing the length frequency derived from each net to the combined length frequency, both bag seine and beach seine were significantly different (Bootstrapped Kolmogorov-Smirnov test, both P <0.0001). In general, a greater proportion of small fish were collected with the beach seine than with the bag seine, while the bag seine tended to collect larger fish than the beach seine (Figure 11).

Length frequency of all fish collected during Survey 2 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, P <0.0001). When comparing the length frequency derived from each net to the combined length frequency both bag seine and beach seine were significantly different (Bootstrapped Kolmogorov-Smirnov test, both P < 0.007).

During Survey 3, length frequency was different between the bag seine and the beach seine (Bootstrapped Kolmogorov-Smirnov test, P = 0.007), but not between the bag seine and the combined length frequency, or the beach seine and the combined length frequency.

Length frequency of all fish collected during Survey 4 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, P <0.0001). When comparing the length frequency derived from each net to the combined length frequency, both bag seine and beach seine length frequencies were significantly different from the combined length frequency (Bootstrapped Kolmogorov-Smirnov test, both P <0.0001). During Survey 4 a small mode for fish 40 mm and larger is absent from the beach seine length frequency.

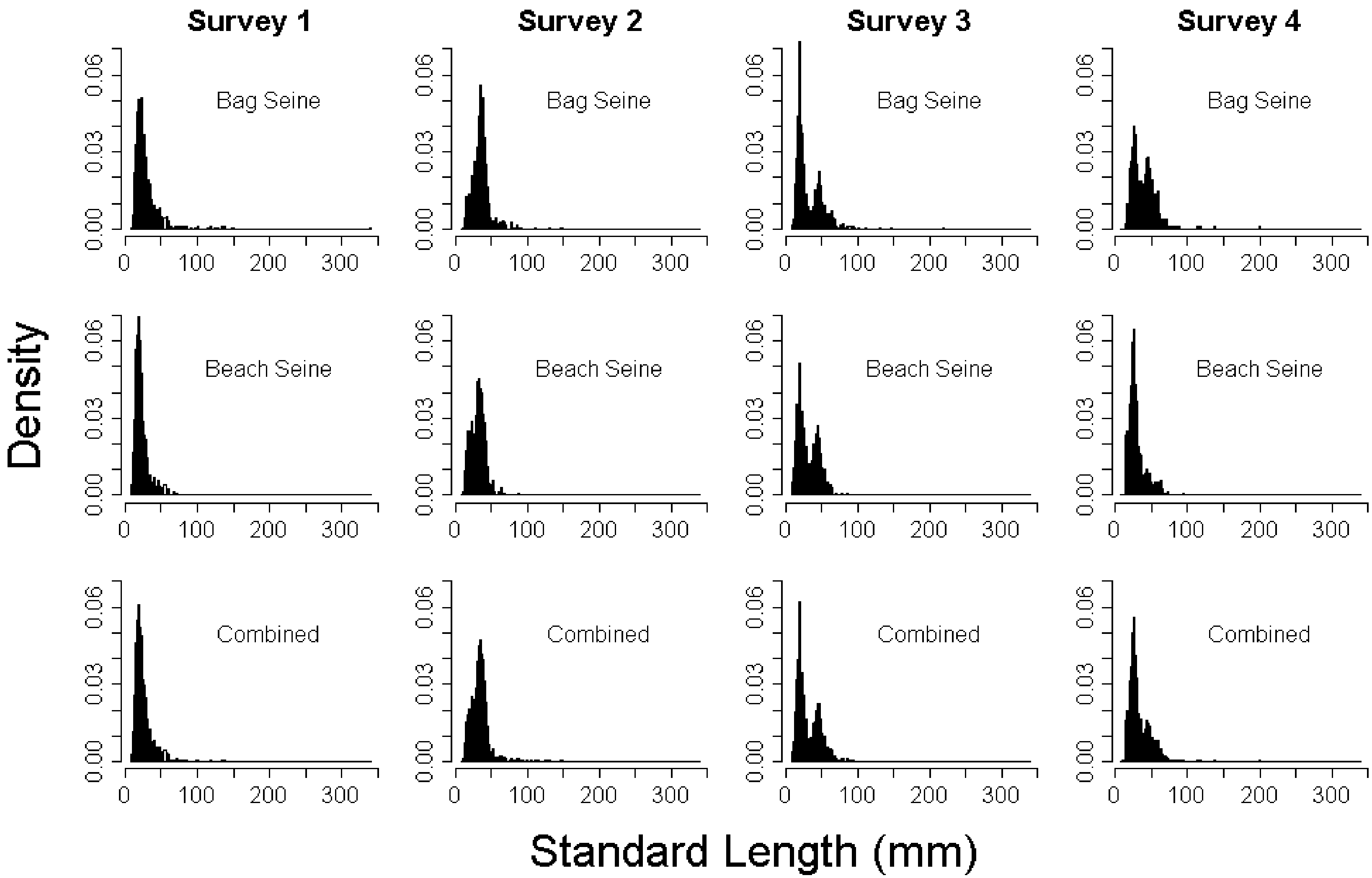

Figure 11. Length frequency of all fish collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

3.5.2 Length Frequency of River Carpsucker

Length frequency of river carpsucker collected during Survey 1 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, P <0.0001). River carpsucker length frequency derived from the beach and bag seine was significantly different from the combined length frequency (Bootstrapped Kolmogorov-Smirnov test, both $P \leq 0.05$). In general, a greater proportion of small river carpsucker were collected with the beach seine than with the bag seine and one 340 mm adult was collected with the bag seine (Figure 12).

Length frequency of river carpsucker collected during Survey 2 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, $P = 0.006$). When comparing river carpsucker length frequency derived from each net to the combined length frequency only the beach seine was significantly different from the combined length frequency (Bootstrapped Kolmogorov-Smirnov test, both $P = 0.04$).

During Survey 3, river carpsucker length frequency was different between the bag seine and the beach seine (Bootstrapped Kolmogorov-Smirnov test, $P = 0.003$), but not between bag seine and the combined length frequency or the beach seine and the combined length frequency. During Survey 3, the majority of river carpsucker collected with the beach seine were smaller than 50 mm, while the majority collected with the bag seine were larger than 50 mm. Length frequency of river carpsucker collected during Survey 4 was not different for any contrasts.

3.5.3 Length Frequency of Red Shiner

Length frequency of red shiner collected during Survey 1 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, P <0.0001). Both the bag seine red shiner length frequency and the beach seine red shiner length frequency were significantly different than the combined seine red shiner length frequency (Bootstrapped Kolmogorov-Smirnov test, both $P \leq 0.05$). In general, a pronounced mode of red shiner smaller than 25 mm was present for the beach seine, and a pronounced mode for fish larger than 25 mm was present for the bag seine (Figure 13).

During Surveys 2 through 4, length frequency of red shiner was different between the bag seine and the beach seine (Bootstrapped Kolmogorov-Smirnov test, all three tests $P \leq 0.02$), but not between the bag seine and the combined length frequency or the beach seine and the combined length frequency.

3.5.4 Length Frequency of Western Mosquitofish

Length frequency of western mosquitofish collected during Surveys 1 and 2 was not different for any contrasts. During Surveys 3 and 4, length frequency of western mosquitofish was different between the bag seine and the beach seine (Bootstrapped Kolmogorov-Smirnov test, both tests $P \leq 0.02$), but not between bag seine and the combined length frequency or the beach seine and the combined length frequency (Figure 14).

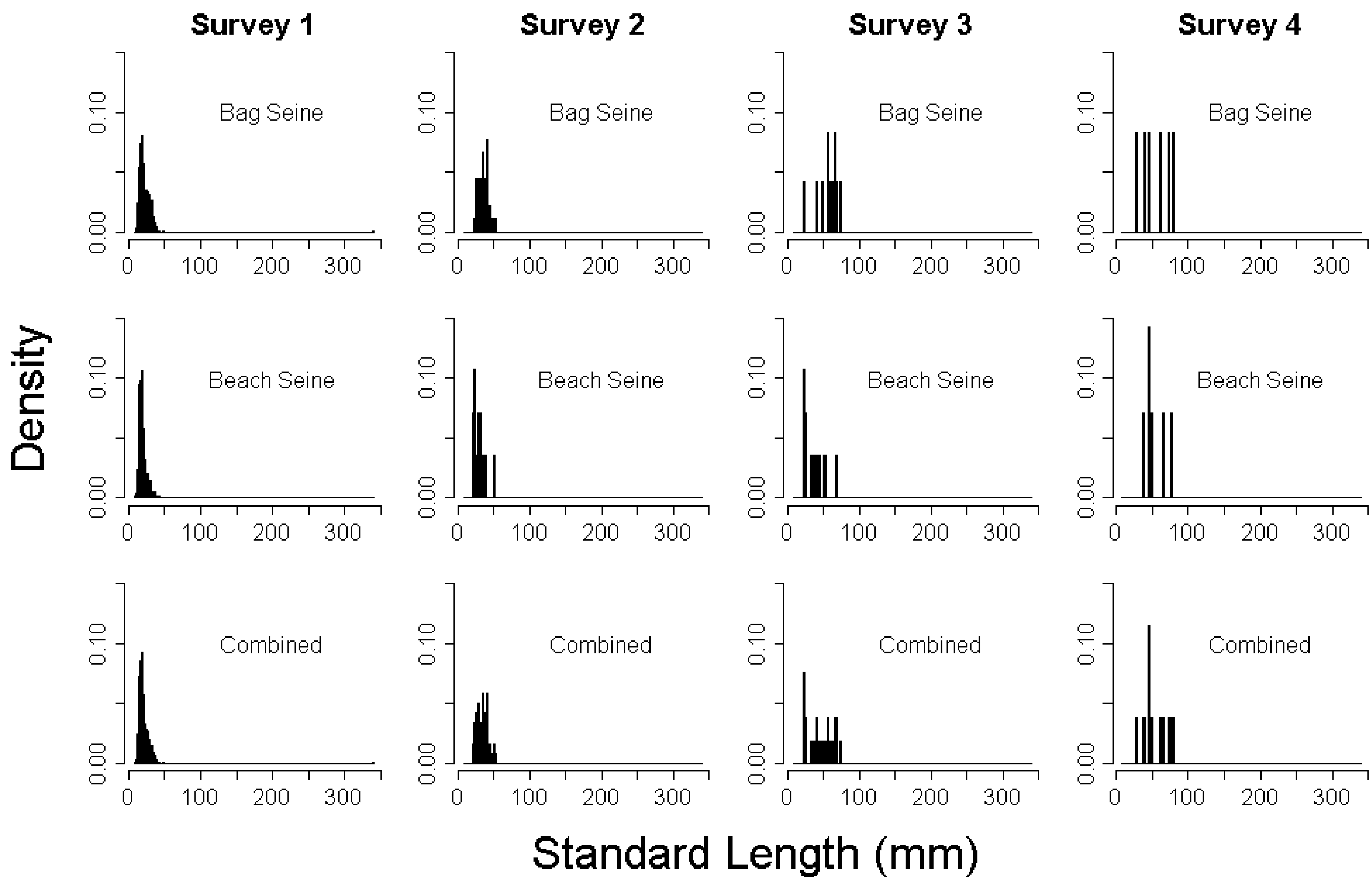

Figure 12. Length frequency of river carpsucker collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

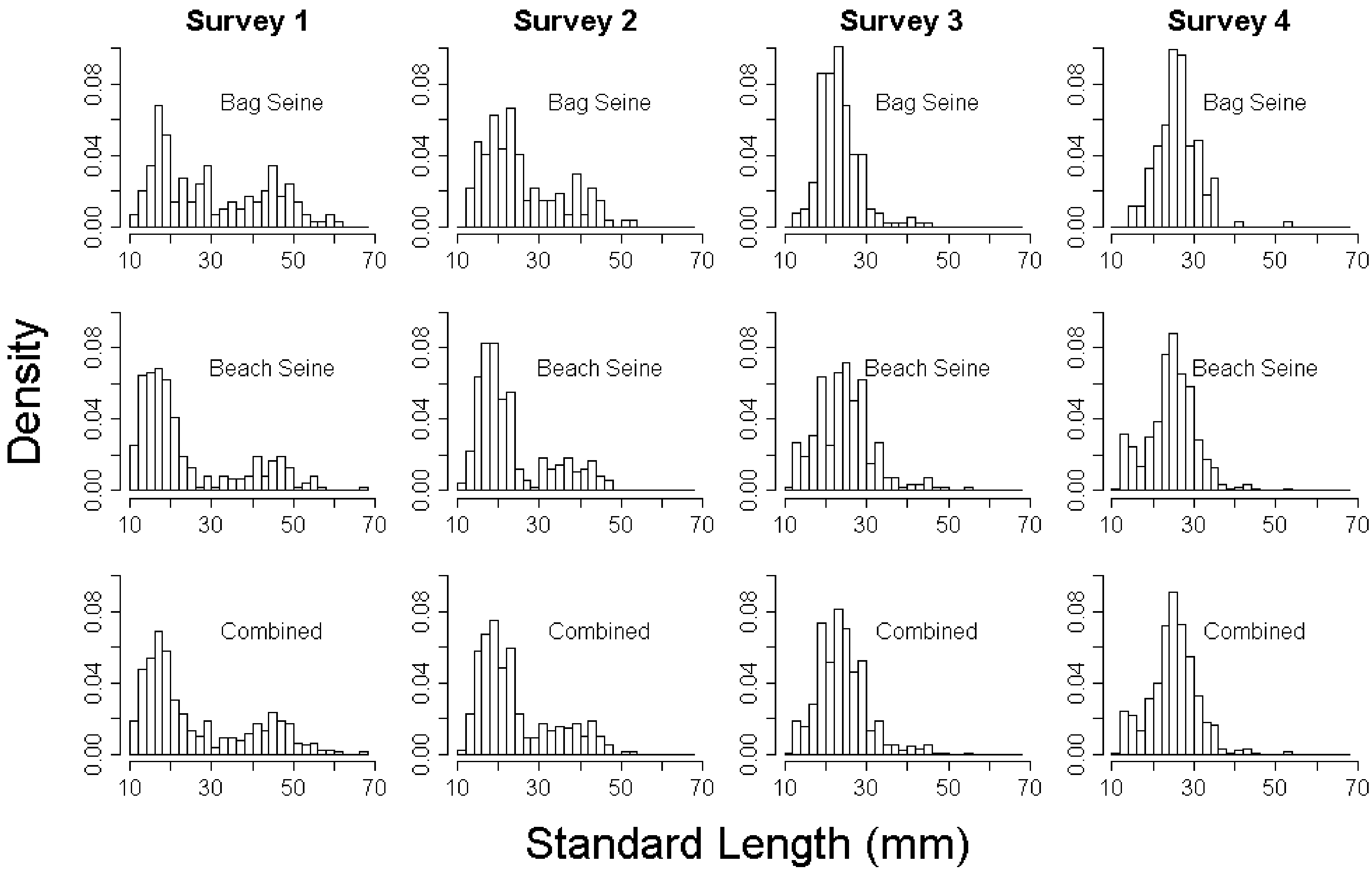

Figure 13. Length frequency of red shiner collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

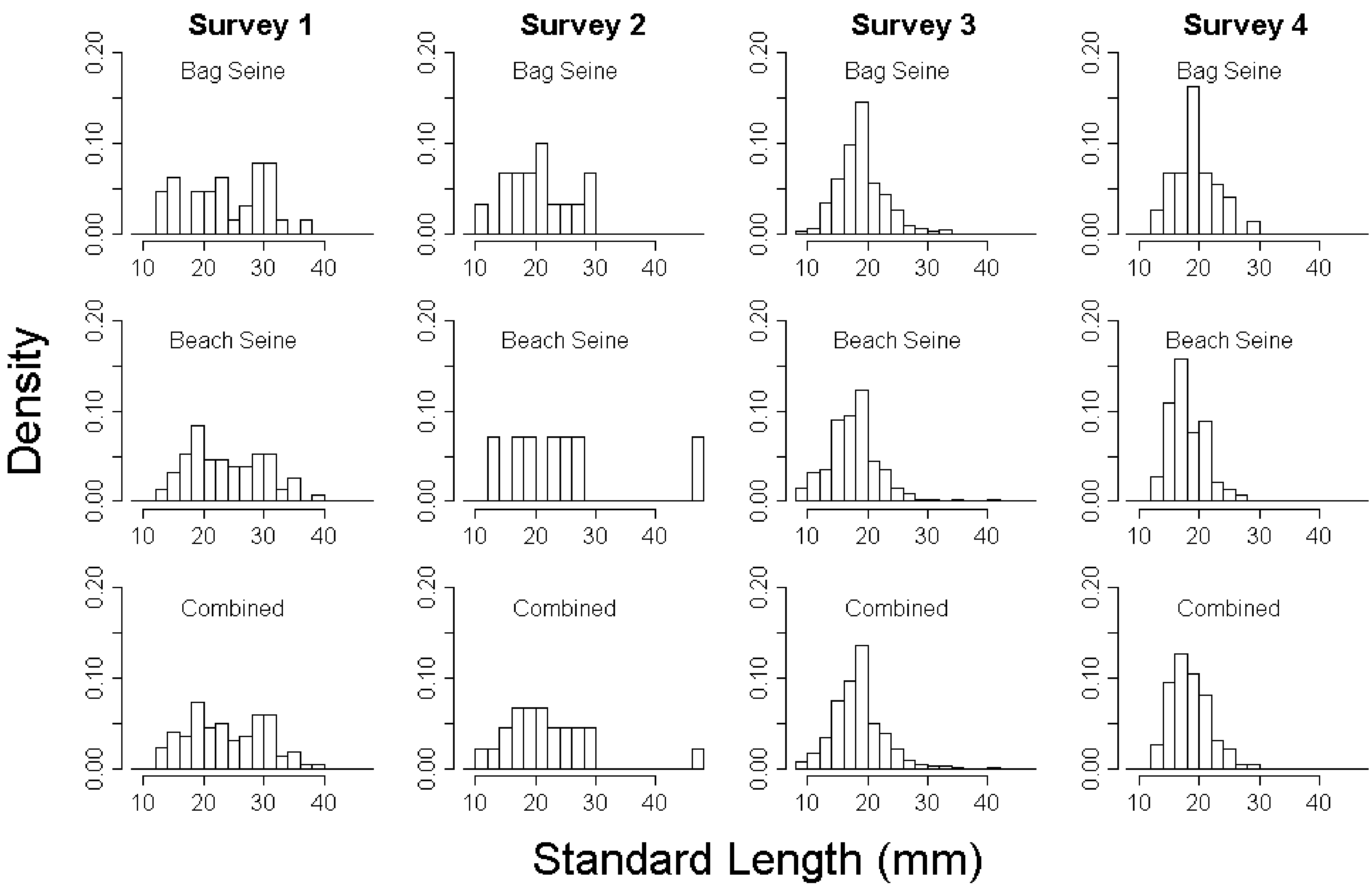

Figure 14. Length frequency of Western mosquitofish collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

3.5.5 LENGTH FREQUENCY OF CHANNEL CATFISH

Length frequency of channel catfish collected during Survey 1 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, P <0.0001). When comparing channel catfish length frequency derived from each net to the combined channel catfish length frequency, both bag seine and beach seine were significantly different from the combined length frequency (Bootstrapped Kolmogorov-Smirnov test, both $P \leq 0.006$). During Survey 1, more large channel catfish were collected with the bag seine than with the beach seine (Figure 15).

Length frequency of channel catfish collected during Survey 2 was different between the bag seine and beach seine (Bootstrapped Kolmogorov-Smirnov test, $P < 0.0001$). When comparing channel catfish length frequency derived from each net to the combined channel catfish length frequency, both bag seine and beach seine were significantly different from the combined length frequency (Bootstrapped Kolmogorov-Smirnov test, both $P \leq 0.05$). The mode of the beach seine derived channel catfish length frequency is slightly left of the mode of the bag seine derived channel catfish, indicating that the bag seine collected slightly larger fish than the beach seine alone.

During Survey 3, channel catfish length frequency was different between the bag seine and the beach seine (Bootstrapped Kolmogorov-Smirnov test, $P = 0.01$), but not between bag seine and the combined channel catfish length frequency or the beach seine and the combined channel catfish length frequency. Similar to Surveys 1 and 2, the beach seine picked up more small channel catfish than the bag seine. Length frequency of river carpsucker collected during Survey 4 was not different for any contrasts.

3.5.6 LENGTH FREQUENCY OF FATHEAD MINNOW

Fathead minnow length frequency was different between the bag seine and the beach seine for Surveys 1, 2, and 4 (Bootstrapped Kolmogorov-Smirnov test, all three tests $P \leq 0.01$). No difference was found for fathead minnow length frequency during Survey 3 or for any (Surveys 1–4) bag seine or beach seine derived length frequencies relative to the combined length frequency (Figure 16).

3.5.7 LENGTH FREQUENCY FLATHEAD CHUB

Flathead chub length frequency was different between the bag seine and the beach seine for Surveys 1, 3, and 4 (Bootstrapped Kolmogorov-Smirnov test, all three tests $P \leq 0.05$). No difference was found for flathead chub length frequency during Survey 3 or for any bag seine or beach seine derived length frequencies relative to the combined length frequency during Surveys 1, 2, and 3. During Survey 4, flathead chub length frequency derived from each net relative to the combined flathead chub length frequency were significantly different (Bootstrapped Kolmogorov-Smirnov test, both $P \leq 0.03$). The majority of the beach seine flathead chub catch was composed of individuals smaller than 40 mm, while the majority of the bag seine flathead chub catch consisted of individuals larger than 40 mm (Figure 17).

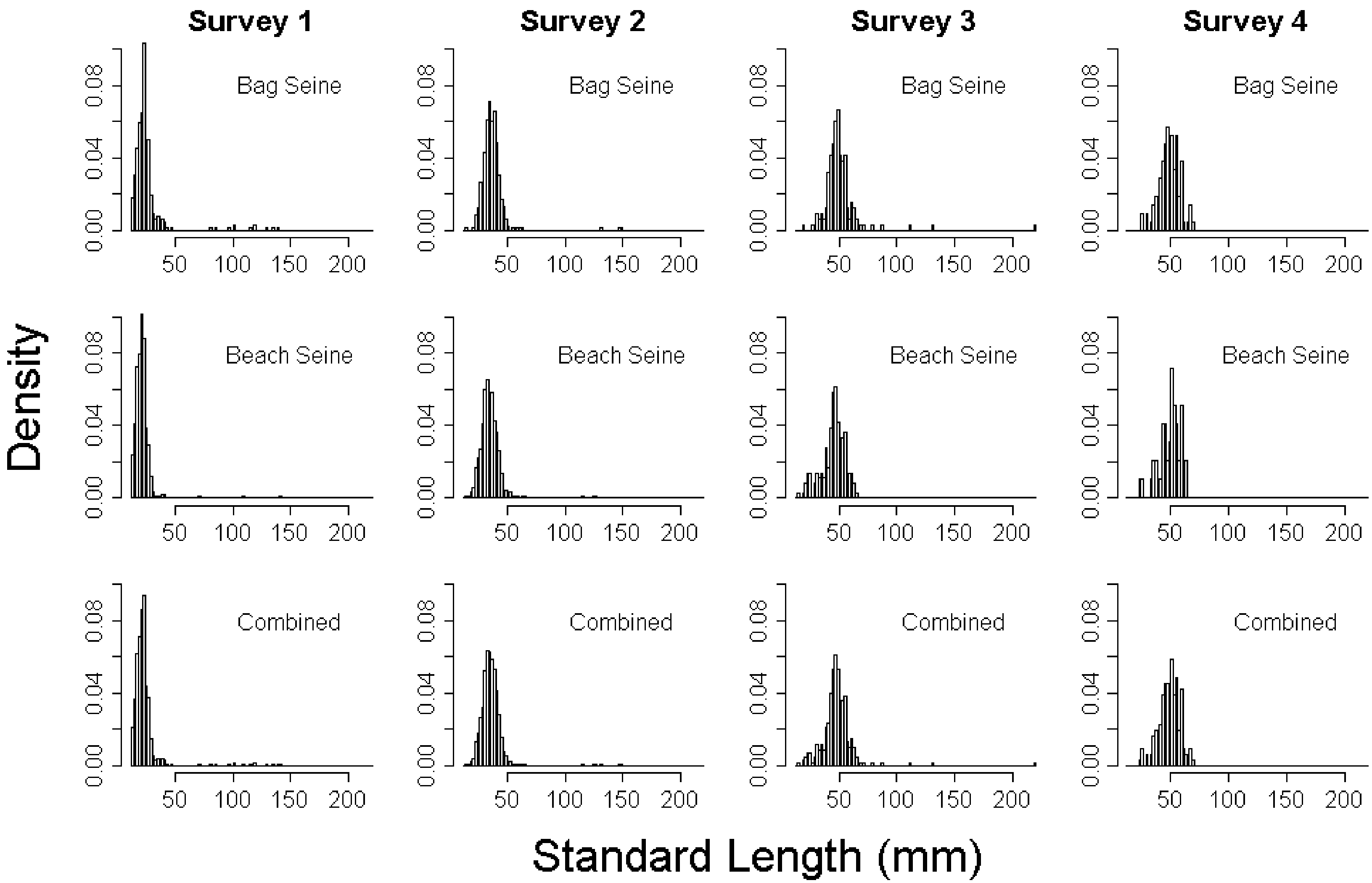

Figure 15. Length frequency of channel catfish collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

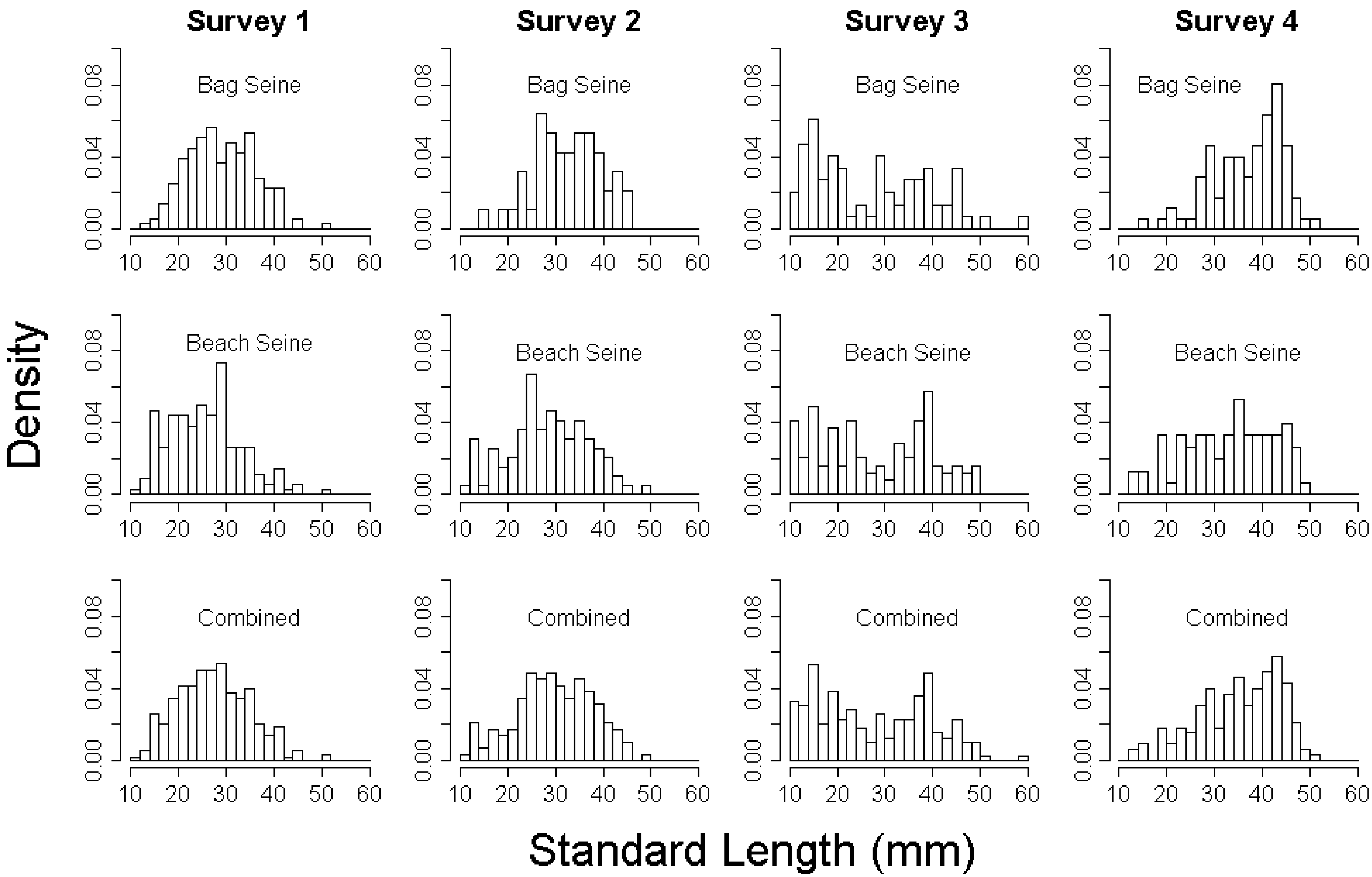

Figure 16. Length frequency of fathead minnow collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

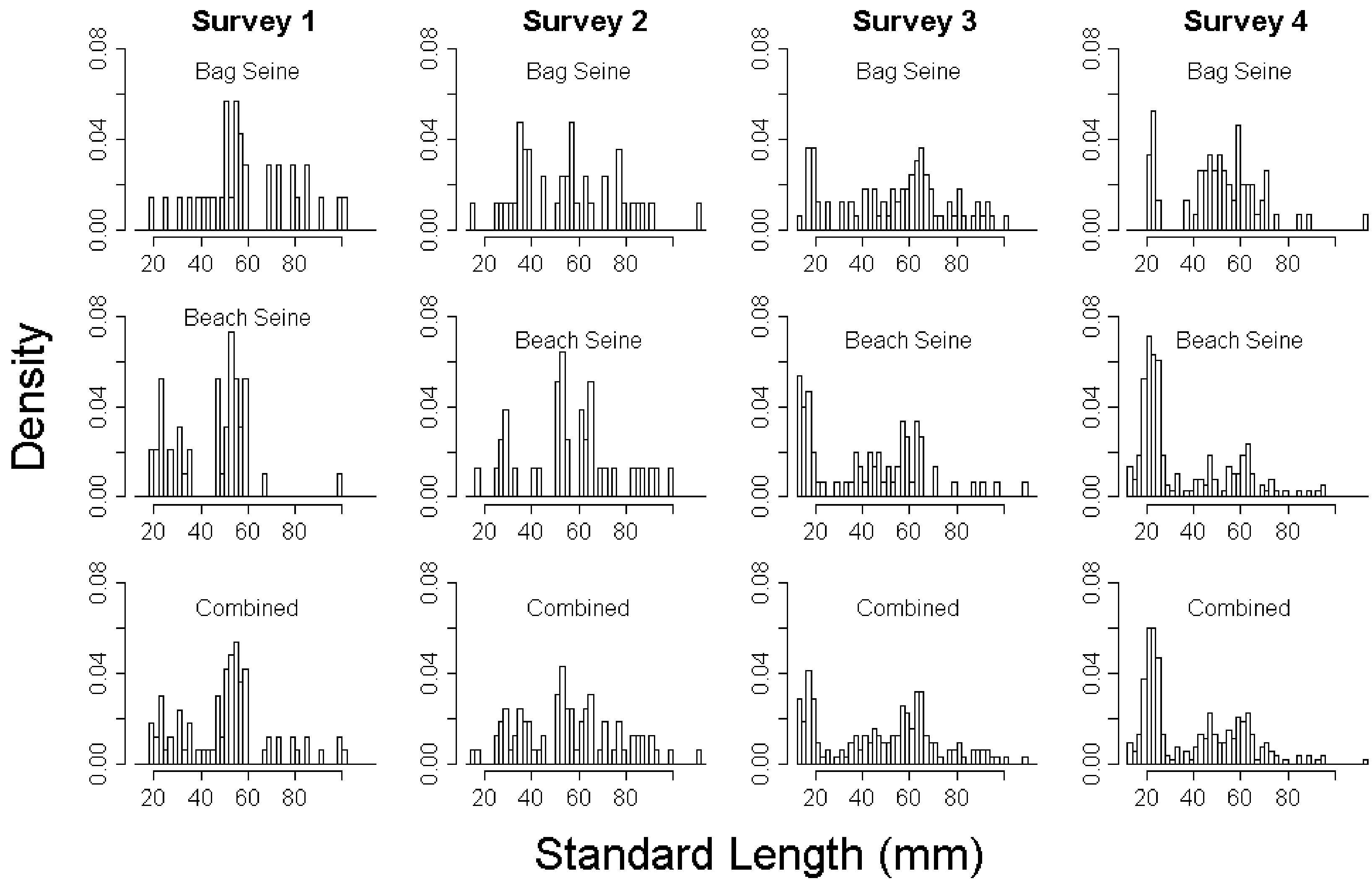

Figure 17. Length frequency of flathead chub collected during Surveys 1 through 4. Each figure column represents a single survey starting from the left column with Survey 1 through 4, which is the right most figure column.

3.6 Seine Haul Length

The total number of fish collected per bag seine sample was different among seine haul length group used for the study (Kruskal-Wallis one-way ANOVA, P = 0.006) (Figure 18). Number collected per bag seine sample was different between the 5- and 20-m, and the 10- and 20-m seine haul length groups (Wilcoxon rank sum test with Bonferroni adjusted P values, both $P \leq 0.05$) and no difference was observed between the 5- and 10-m seine haul length groups. The mean number of fish collected per bag seine sample was greatest for the 5-m length group (mean = 11 fish/sample), intermediate for the 10-m length group (mean = 9 fish/sample), and lowest for the 20-m length group (mean = 8 fish/sample).

The total number of fish collected per beach seine sample was different among the seine haul length groups used for the study (Kruskal-Wallis one-way ANOVA, P = 0.05). Number collected per beach seine sample was different between the 5- and 20-m length groups (Wilcoxon rank sum test with Bonferroni adjusted P values, P = 0.05) and no difference was observed between the 5- and 10-m or the 10- and 20-m seine haul length groups. The mean number of fish collected per bag seine sample was greatest and the same for the 5- and 10-m length groups (mean = 14 fish/sample) and lowest for the 20-m length group (mean = 10 fish/sample).

The total number of fish collected per combined beach and bag seine sample was different among the seine haul length groups used for the study (Kruskal-Wallis one-way ANOVA, P = 0.007). The number collected per combined sample was different between the 5- and 20-m groups (Wilcoxon rank sum test with Bonferroni adjusted P values, P = 0.007) and no difference was observed between the 5- and 10-m or the 10- and 20-m seine haul length groups. The mean number of fish collected per combined sample was greatest for the 5-m length group (mean = 24 fish/sample), intermediate for the 10-m length group (mean = 23 fish/sample), and lowest for the 20-m length group (mean = 18 fish/sample).

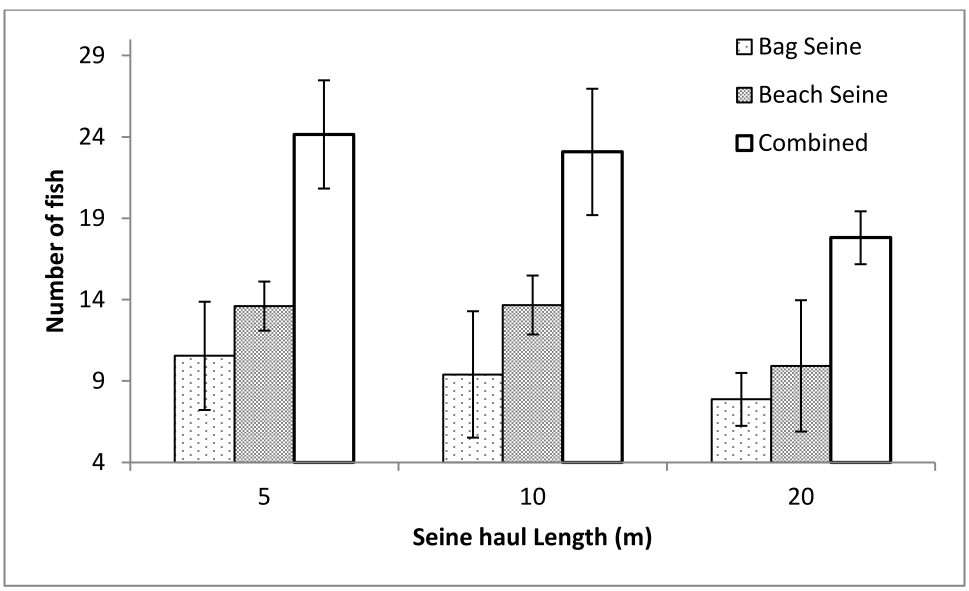

Figure 18. Number of fish collected per sample for each seine haul length sample strata.

4 DISCUSSION

4.1 HABITAT RESTORATION MONITORING

Samples collected from main channel habitats adjacent to habitat restoration sites during 2013 will serve as a baseline for determining effectiveness of habitat restoration sites for the Middle Rio Grande fish community and the silvery minnow. Catches of fish varied among sites and surveys and no discernible difference was evident between control and treatment sites. The silvery minnow was detected at all sites except the downstream most site (5D/E), indicating that the species was distributed throughout the Angostura Reach of the Middle Rio Grande during 2013.

When additional data become available, then analyses will be conducted to assess differences in relative abundance between control and treatment sites, and to quantify longitudinal fish distribution. Mesohabitat use by Middle Rio Grande fish and the silvery minnow will also be useful for determining fish preference of mesohabitats dependent on type, depth, velocity, and substrate composition. This analysis will provide managers with data that can be used to determine if habitat restoration sites, which provide habitat to Middle Rio Grande fishes during overbanking, contribute to main channel abundance and what types of main channel mesohabitats provide suitable habitat for Middle Rio Grande fishes. Ideally, monitoring would occur during inundation on habitat restorations sites, in the main channel during low abundance (2013; little to no overbanking), average abundance (some overbanking), and high abundance (high overbanking) years for silvery minnow so that contrasts among mesohabitats and sites could be made among and between survey years.

4.2 RELATIVE PERFORMANCE OF BEACH AND BAG SEINE

Fisheries data collected using the beach and bag seine combo show that catches of Middle Rio Grande fish vary by species, size, survey, and between the beach and bag seines. Presumably, the combined catch is the closest approximation to Middle Rio Grande fish community population parameters, and using the beach seine alone would have not produced the same results as using the combined approach.

From a catch perspective, no single net produced the same numbers as the combined catch, and the proportion of the fish collected singly with each net was often less than or equal to 50%, depending on species. Catchability of fish is affected by life history, fish size, environment (Hubert and Fabrizio 2007), and the ability of a particular species to escape capture (Godo et al. 1999). The number of fish collected per sample differed between both nets and between each net and the combined catch. On average the beach and bag seines produced approximately 57% and 43% of the combined catch, respectively. In general, the beach seine collected more fish per sample than the bag seine; however, this trend varied by survey and by species. Red shiner was more commonly collected with the beach seine, while river carpsucker was more commonly taken with the bag seine. Fathead minnow collections were greatest with the bag seine during Surveys 1 and 4 and greatest with the beach seine during Surveys 2 and 3. The variability in catch between both nets and the combined catch indicates that the combined catch metric would be the most suitable for monitoring trends in relative abundance for Middle Rio Grande fishes.

Species richness varied between both nets and the combined catch but not between bag and beach seines. Both nets collected the same number of fish species per sample; however, the species richness analysis indicates that they were not picking up the same species per sample and were on average picking up one different species per sample between them. Over all surveys combined, only one species was missed by each gear type; however, the variability in species lists increased slightly within surveys. It is worth noting that the endangered silvery minnow is a strong swimming species (Bestgen et al. 2010), and was only present at low abundance in summer and fall of 2013 (Dudley and Platania 2013). In addition, the species was not collected with the beach seine during Surveys 1 and 2, but was collected with the bag seine during all four surveys. This indicates that the species was successful at evading the beach seine and the bag seine provided suitable coverage to allow for capture of missed individuals. Species richness and a complete species list would be generated faster using the combined bag and beach seine combination than using the beach seine alone.

Presence/absence of fish species by seine type was similar for the majority of fish collected during surveys. However, the proportion of samples containing three (red shiner, fathead minnow, and flathead chub) of the six most common species differed significantly between the bag and beach seines. These species were present in a greater proportion of beach seine samples than they were in the bag seine samples. In, general common species were present for a greater proportion of beach seine samples than for bag seine samples. Conversely, less common and larger species such as common carp, white sucker, and river carpsucker were present in a greater proportion of bag seine samples than for beach seine samples.

Population length structure of the most common fish species collected varied between the bag and beach seines and between both nets and the combined length frequency histograms. In general, a higher proportion of small fish were collected with the beach seine while a higher proportion of larger fish were collected with the bag seine. Silvery minnow length structure was not analyzed for this report because the sample size was too small. However, it is worth noting that silvery minnow collected during Surveys 1 through 3 were larger (mean = 69 mm) than those collected during Survey 4 (mean = 41 mm). The majority collected during Survey 4 were silvery minnow of hatchery origin (41 out of 42 individuals). These fish were noticeably thinner and smaller than silvery minnow collected during Surveys 1 through 3. Over all surveys combined, 35 fish were collected that were 100 mm or larger, 27 with the bag seine and eight with the beach seine. The largest fish collected with the bag seine was a 340 mm river carpsucker, while the largest fish collected with the beach seine was a 141 mm channel catfish. The largest channel catfish was collected with the bag seine and measured 220 mm. In addition, five white suckers were collected with the bag seine that were over 120 mm, while the largest white sucker collected with the beach seine was 76 mm.

The number of fish collected was lowest for the 20-m seine haul length group and similar between the 10- and 5-m seine haul length groups. The bag and beach seine combination method does not provide for closure outside the intended seine zone. The longer 20-m seine hauls may actually reduce efficiency because the larger the distance between the two nets the greater the amount of un-netted area there is available for fish to escape and the more likely it is that the beach seine will hang up on a bed structure. The analysis indicates that the longer 20-m seine hauls result in reduced capture efficiency and this effort could be spent collecting more 5- and 10-m seine hauls.

Study results demonstrate that using the bag and beach seine combination increases the efficiency of the beach seine alone by generating a more complete species list, collecting approximately 43% more fish per sample, collecting approximately 33% more species per sample, providing a more complete transcription of species population length structure, and detecting rare species. In conclusion, the bag and beach seine combination appears to be well suited for sampling the Middle Rio Grande fish community and the endangered silvery minnow during years of low abundance. Additional samples should be collected using the methods described is this report, especially during years when overbanking occurs and relative abundance of silvery minnow is at or above average, and precision should be compared with that derived from beach seines alone as used for the species' long-term monitoring program.

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APPENDIX A
MAPS OF SAMPLED MESOHABITATS

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Figure A.1. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1A/B during Survey 1.

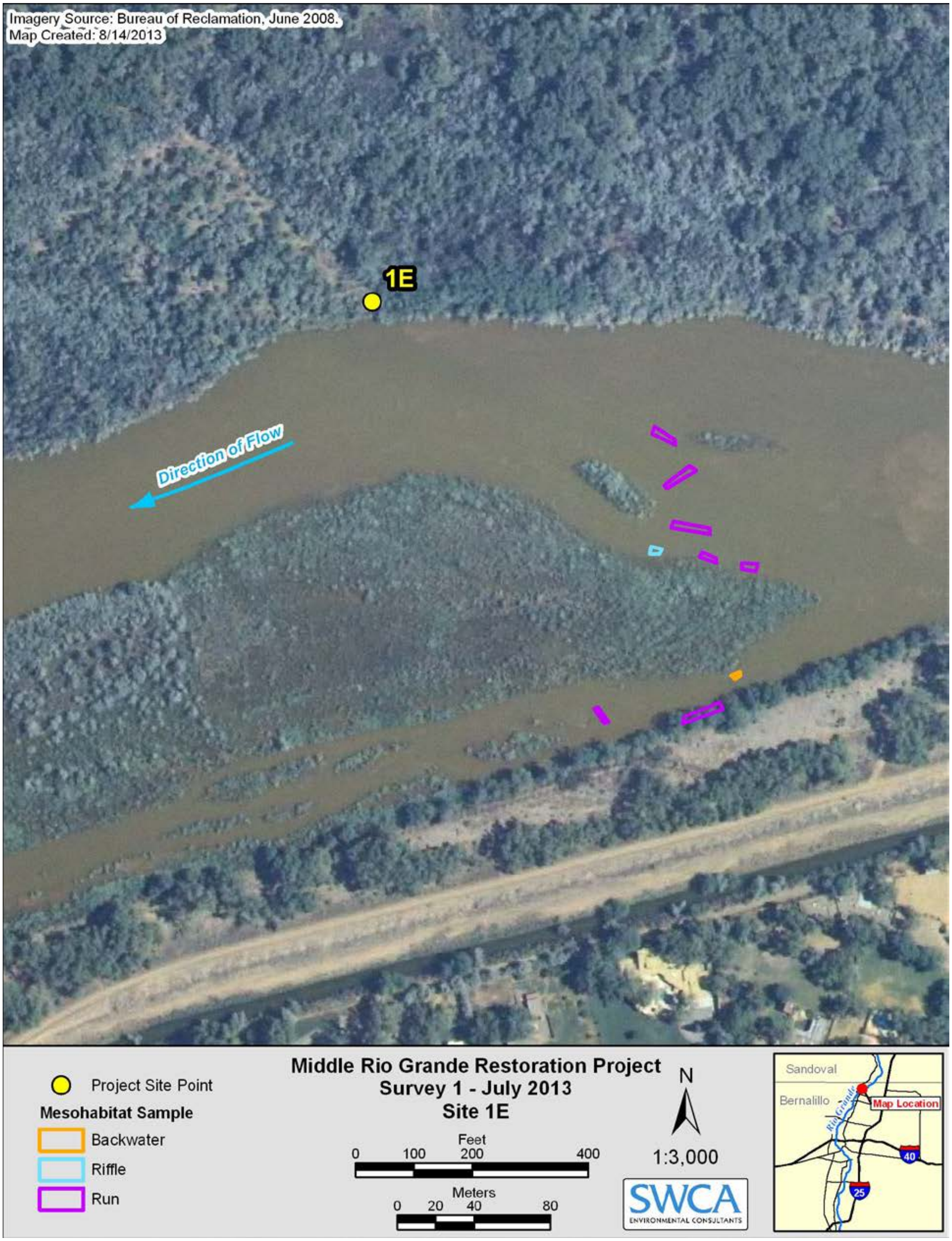

Figure A.2. Mesohabitats Sampled from the Main Channel of the Middle Rio Grande at Site 1E during Survey 1.

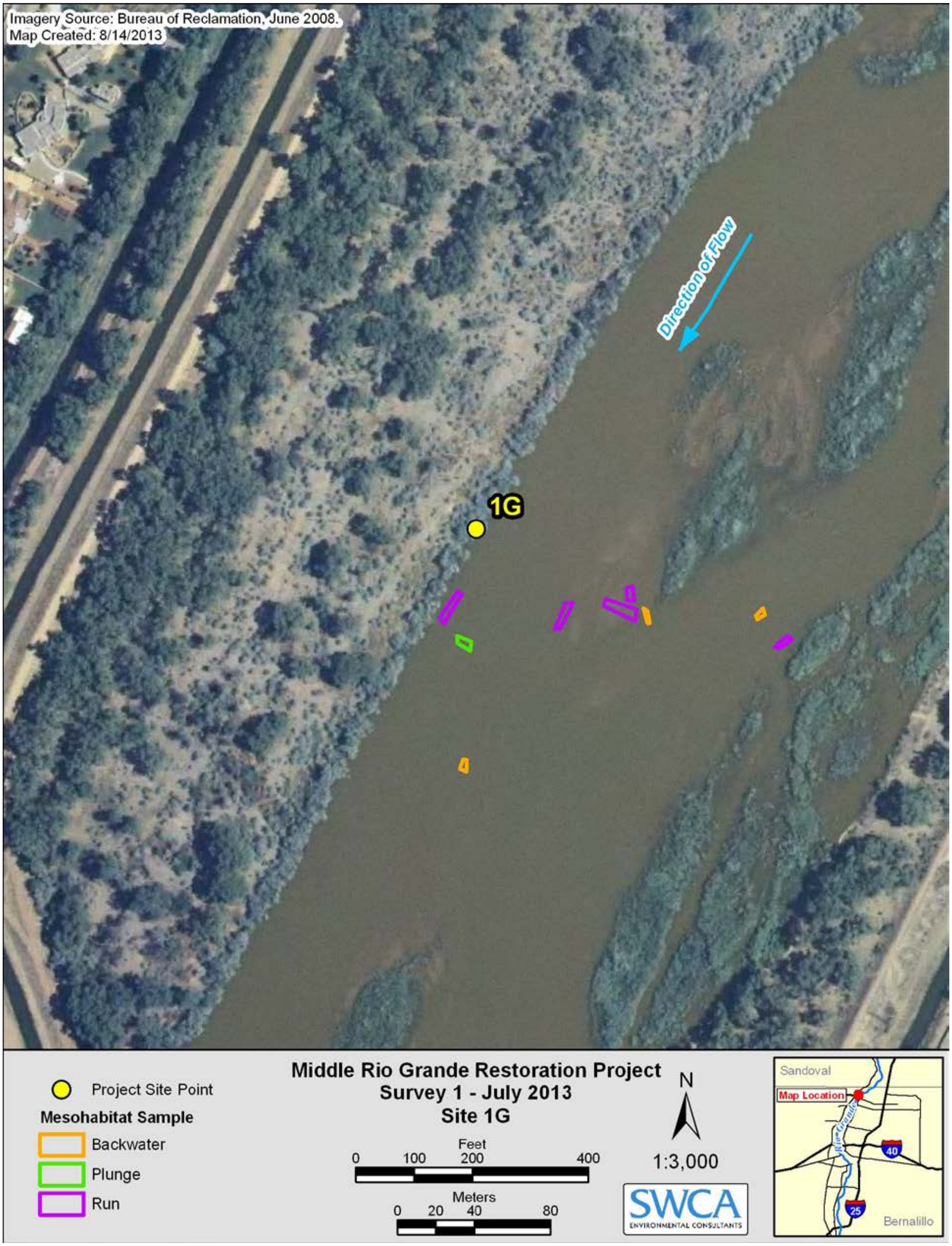

Figure A.3. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1G during Survey 1.

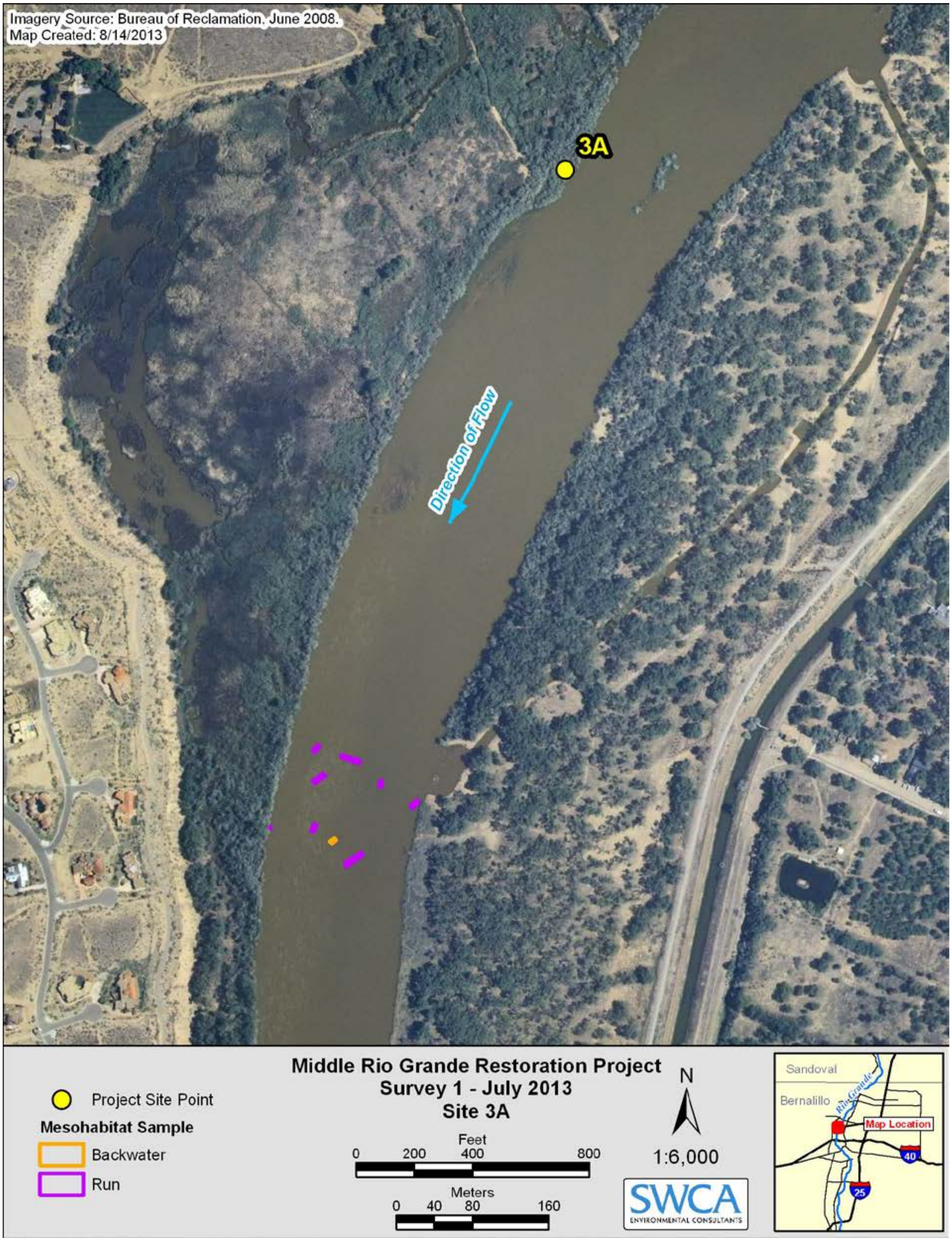

Figure A.4. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 3A during Survey 1.

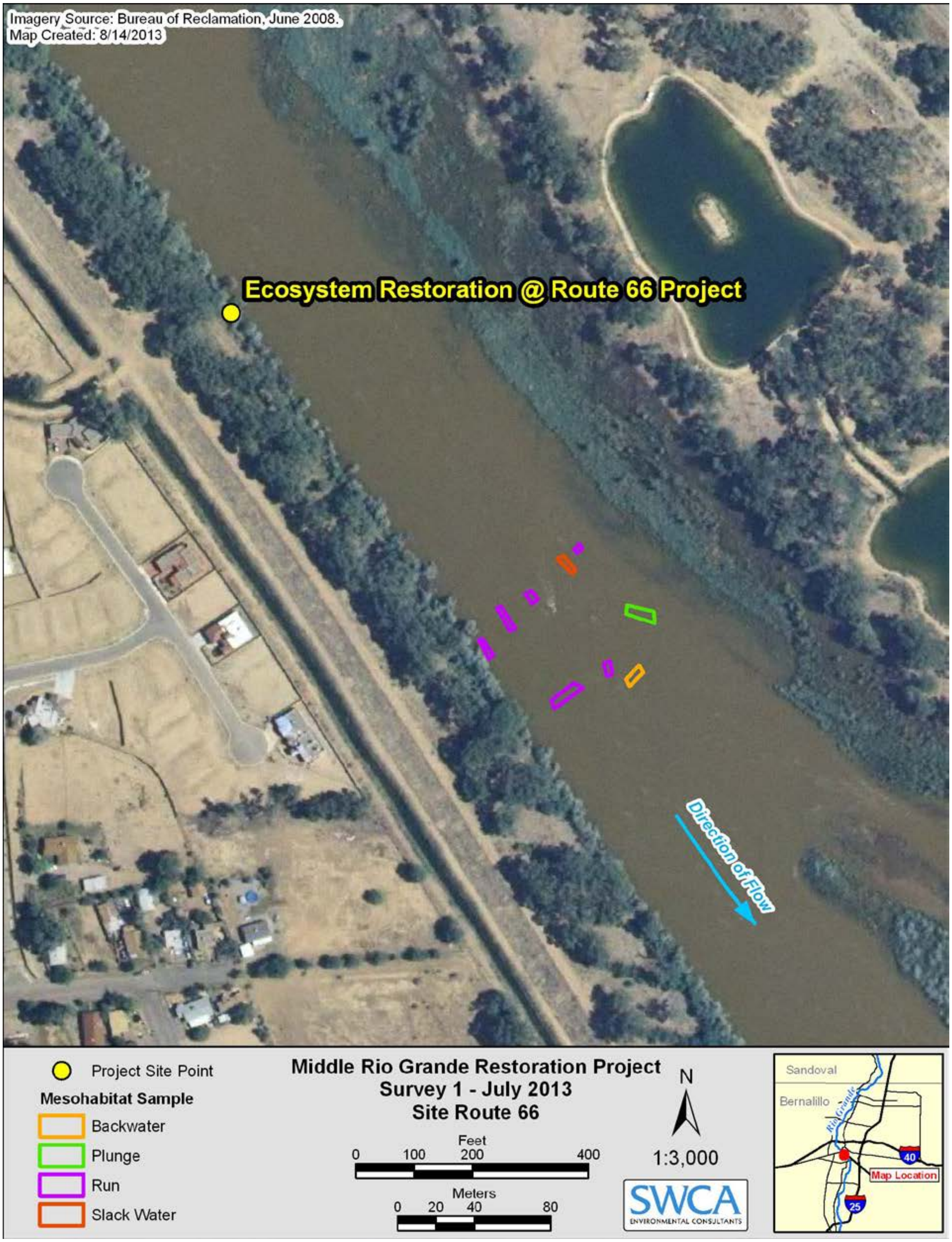

Figure A.5. Mesohabitats sampled from the main channel of the Middle Rio Grande at site RT 66 during Survey 1.

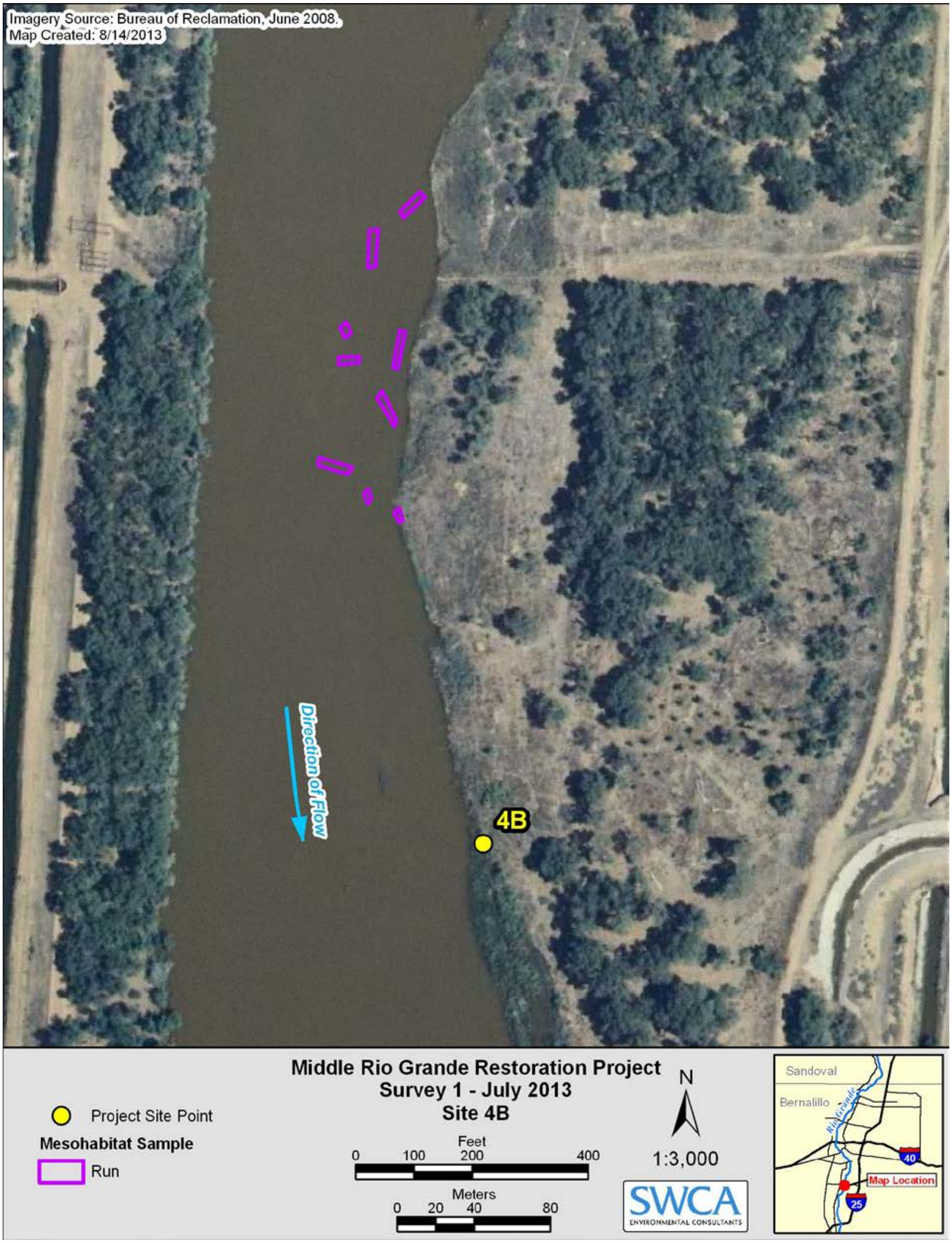

Figure A.6. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4B during Survey 1.

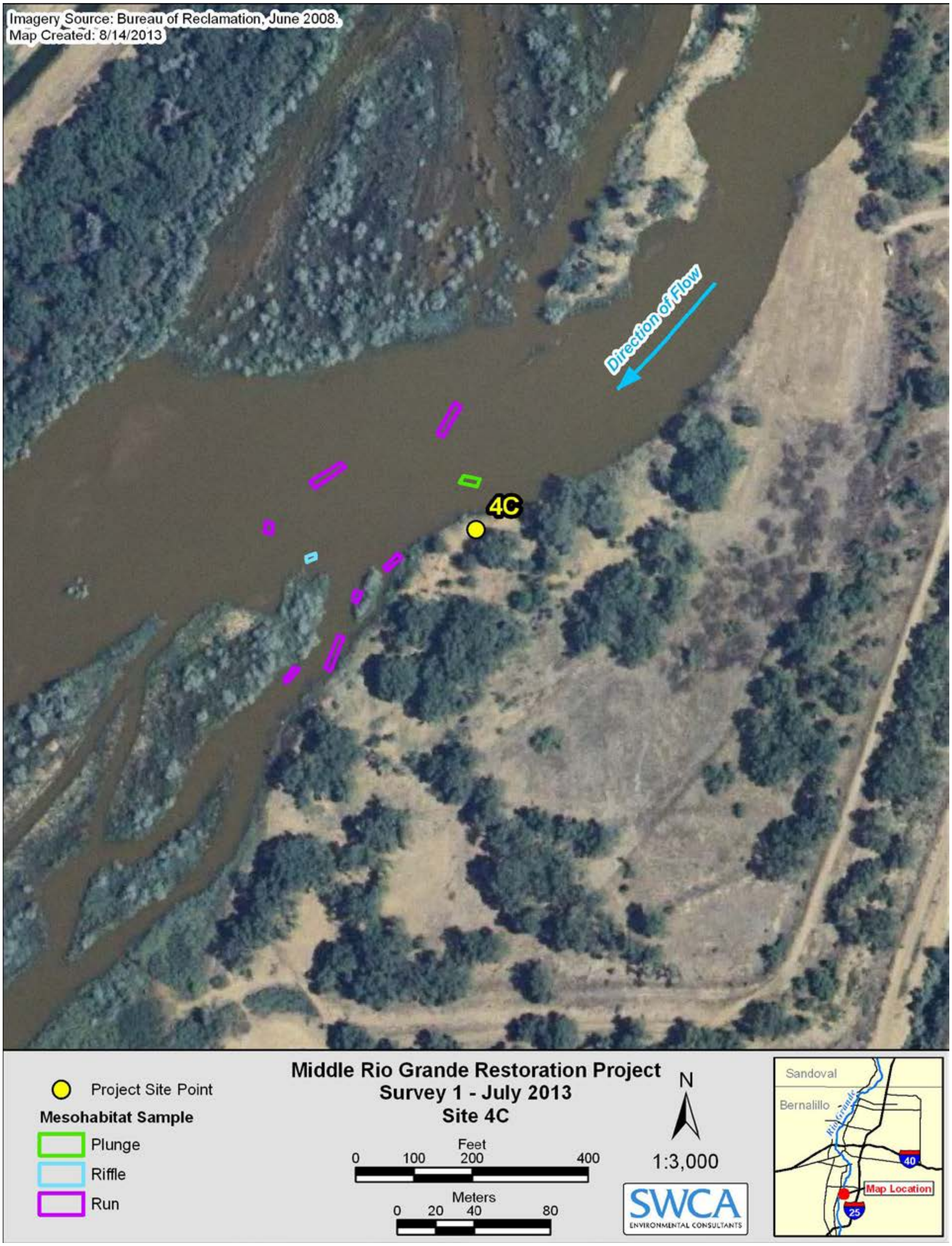

Figure A.7. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4C during Survey 1.

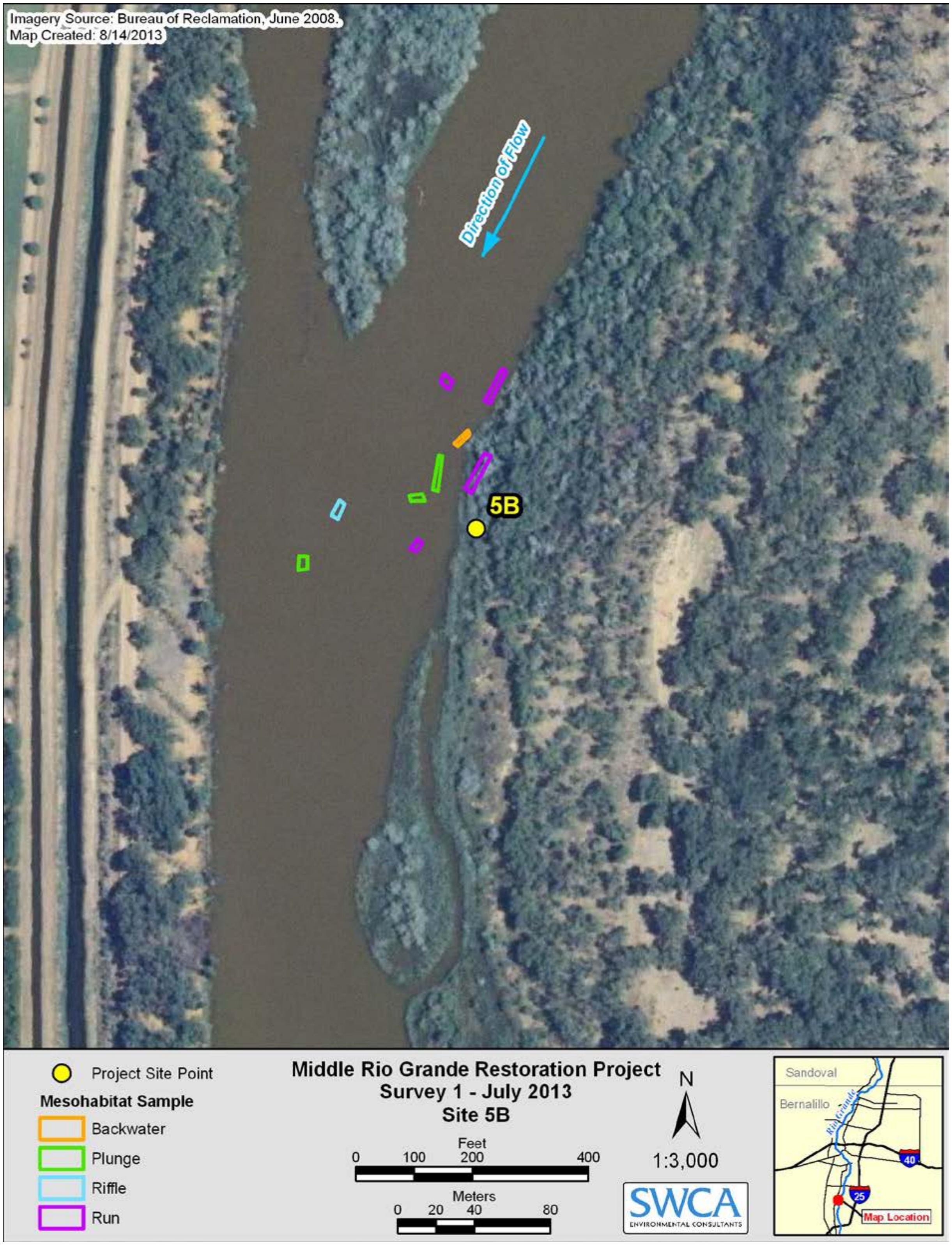

Figure A.8. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5B during Survey 1.

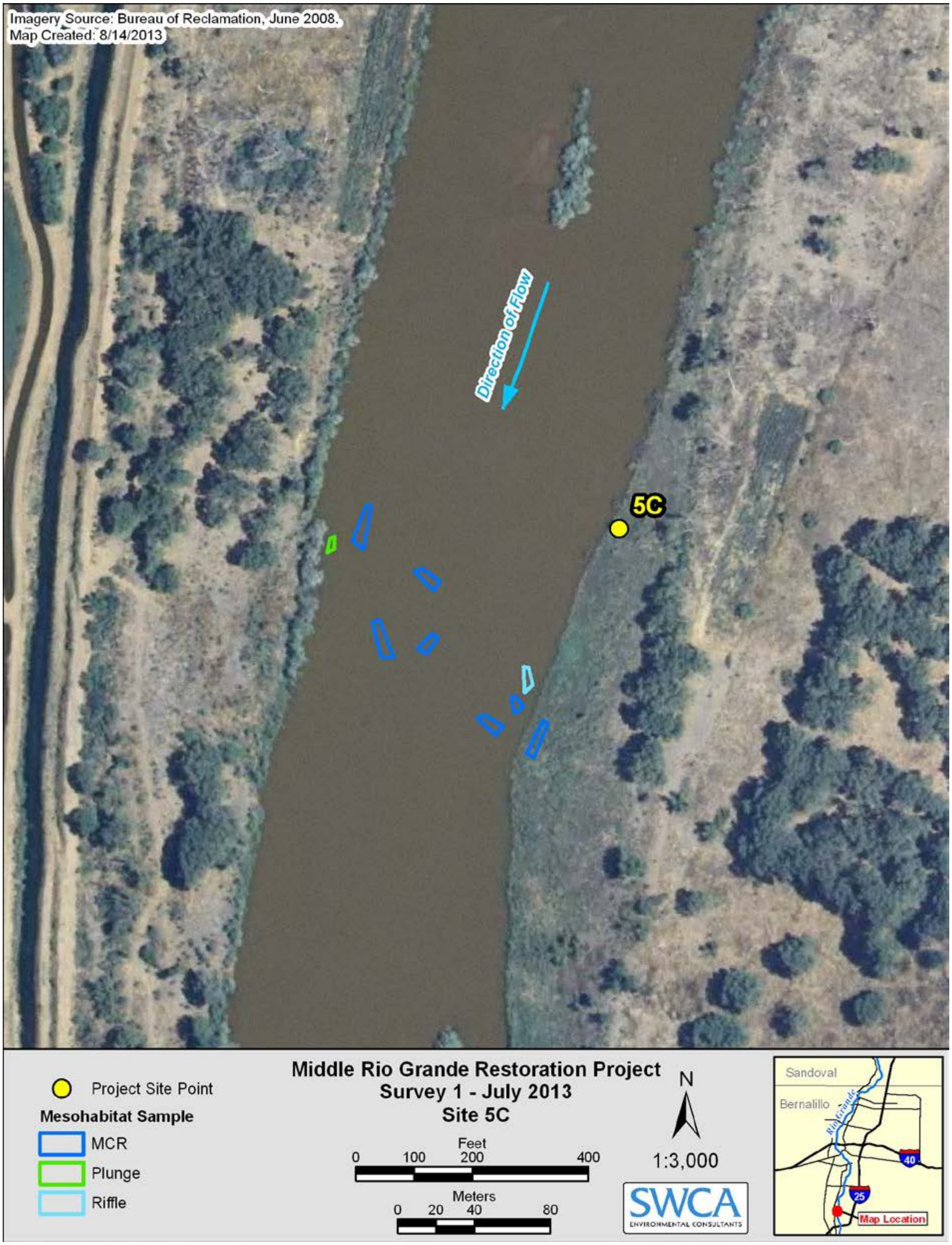

Figure A.9. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5C during Survey 1.

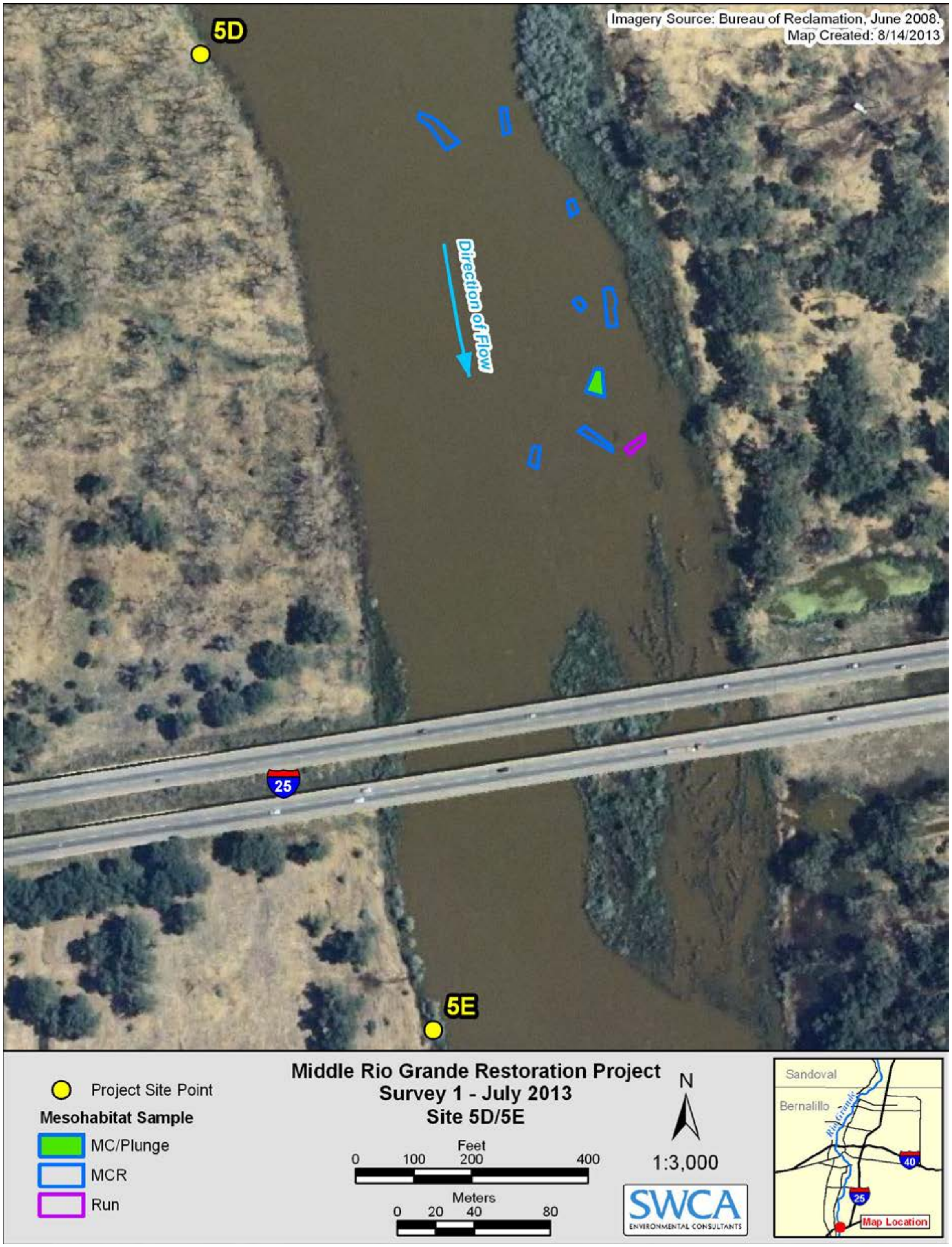

Figure A.10. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5D/E during Survey 1.

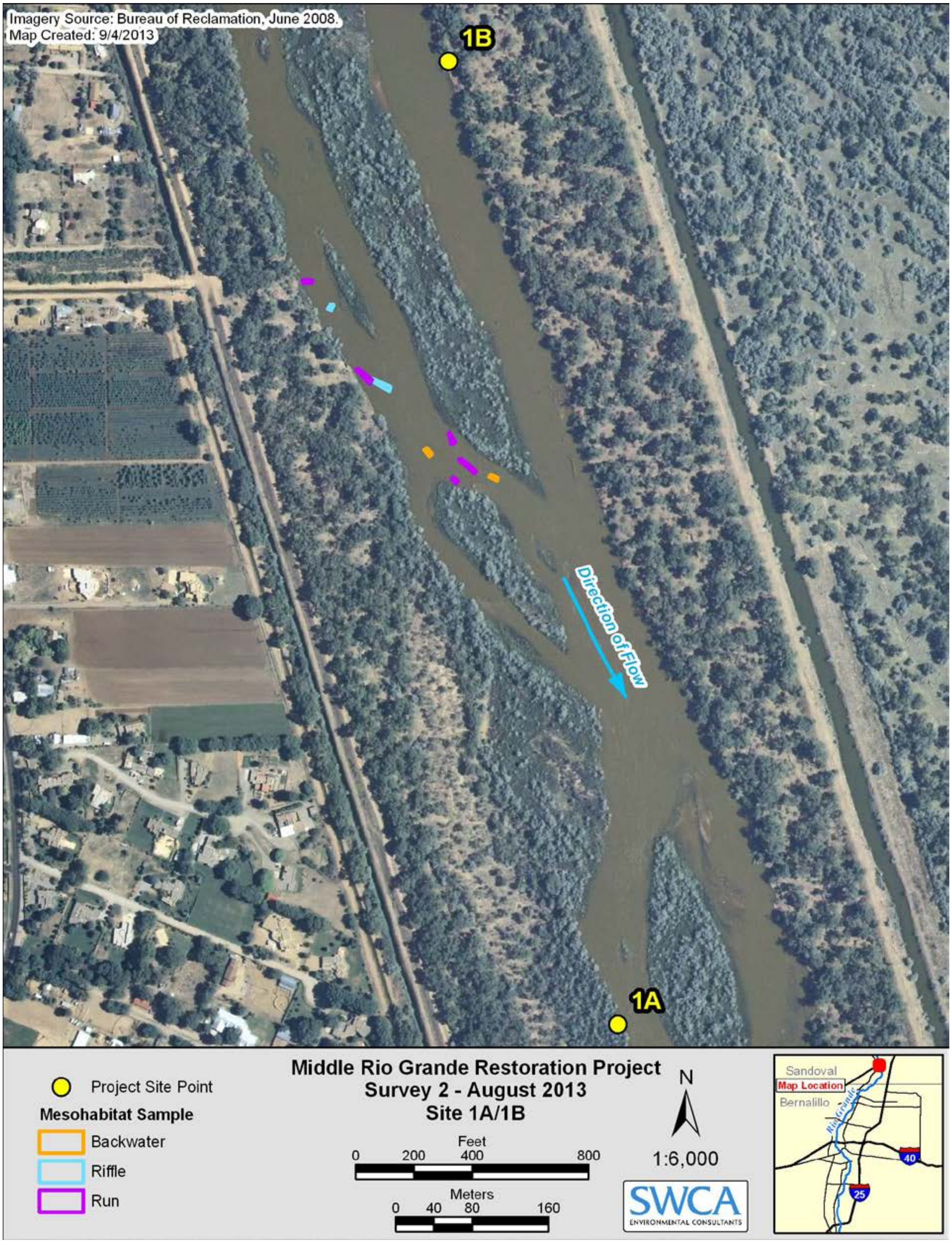

Figure A.11. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1A/B during Survey 2.

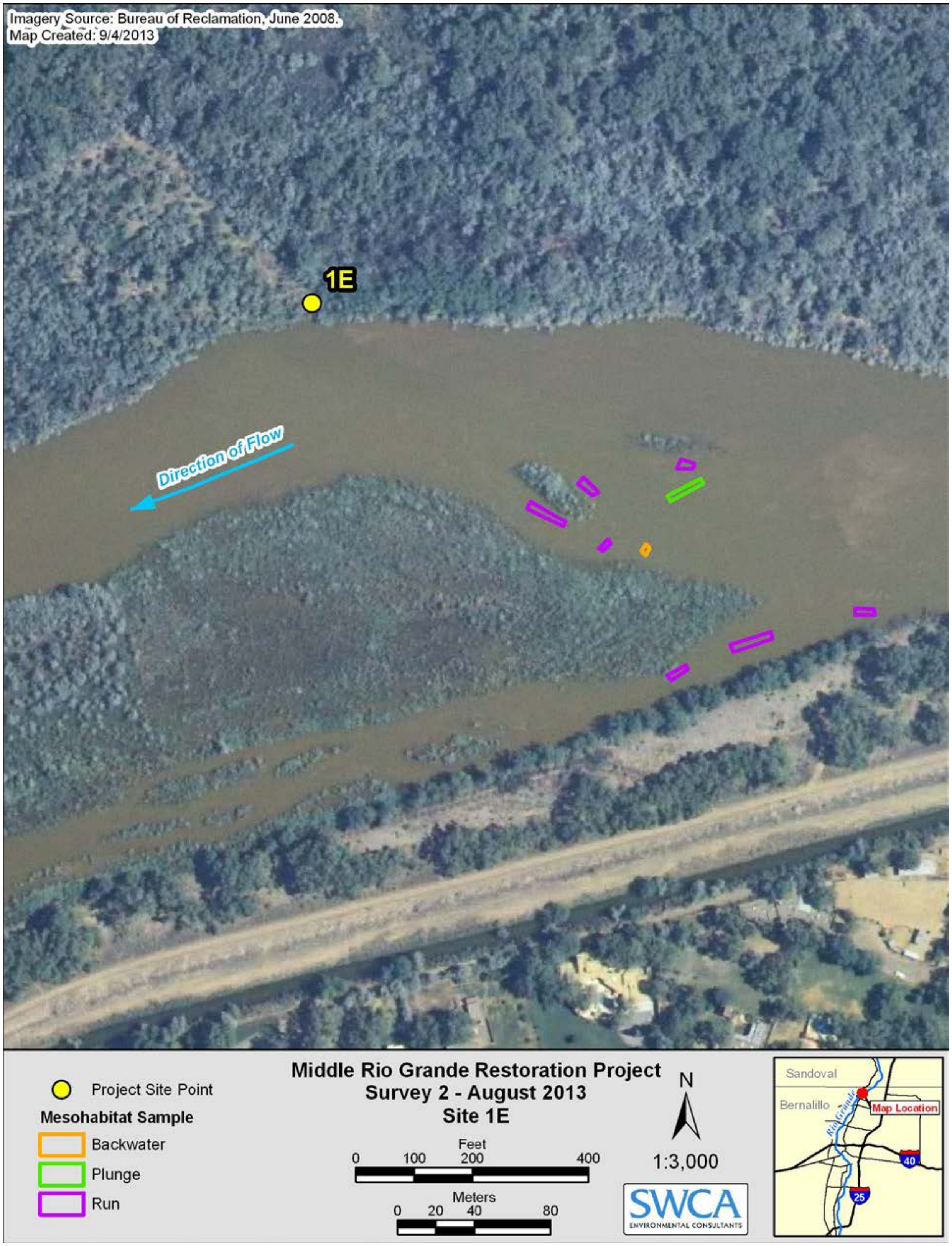

Figure A.12. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1E during Survey 2.

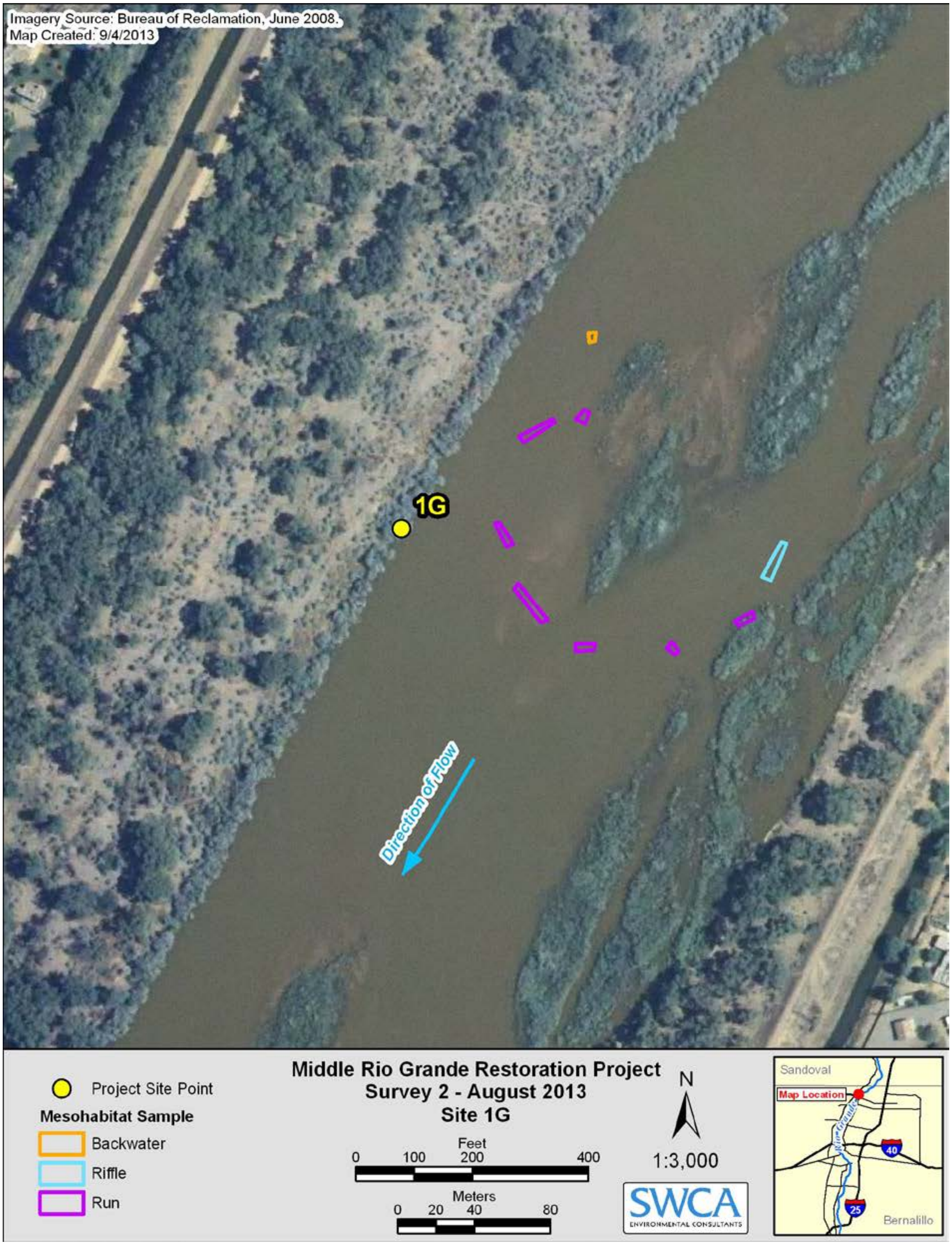

Figure A.13. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1G during Survey 2.

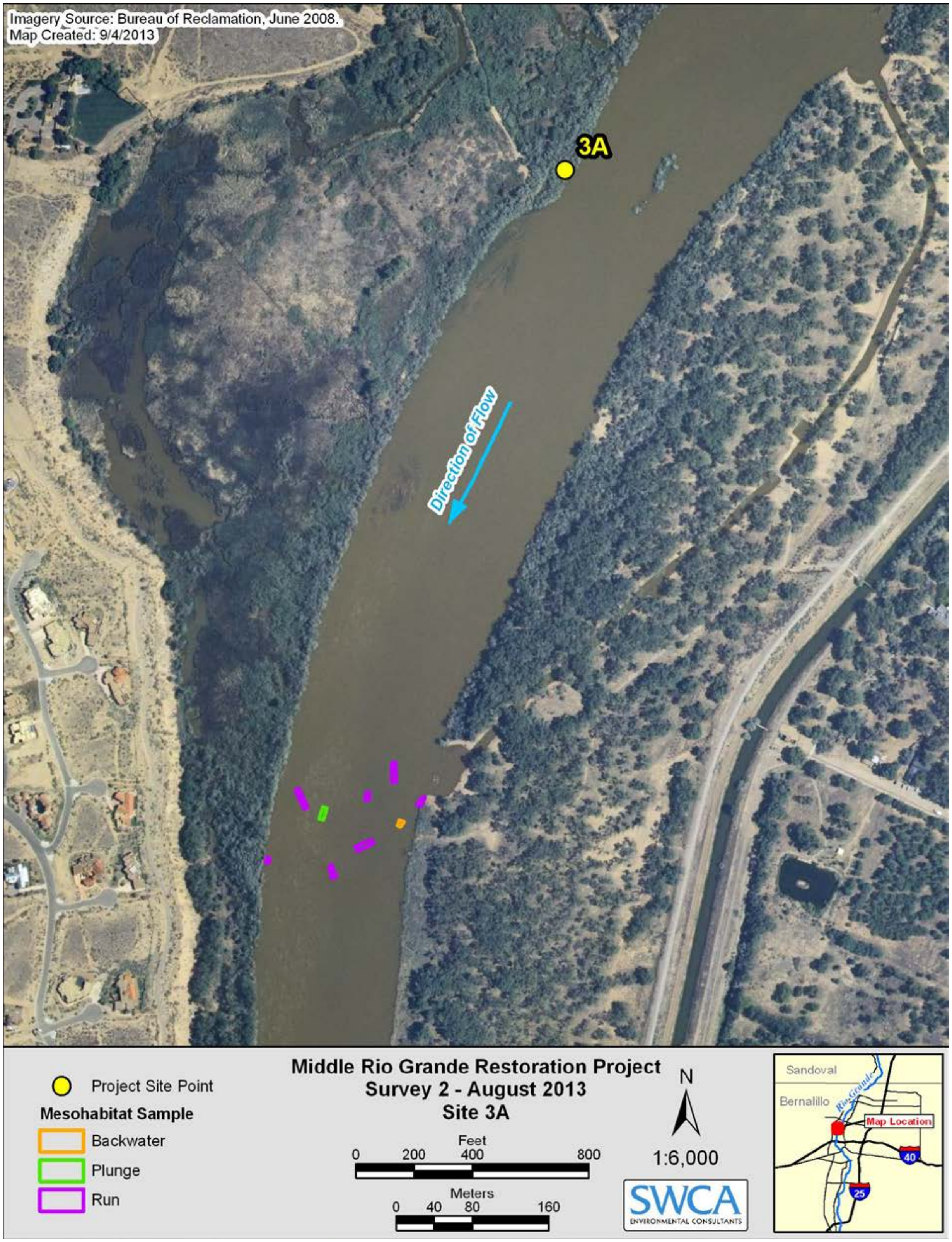

Figure A.14. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 3A during Survey 2.

Figure A.15. Mesohabitats sampled from the main channel of the Middle Rio Grande at site RT 66 during Survey 2.

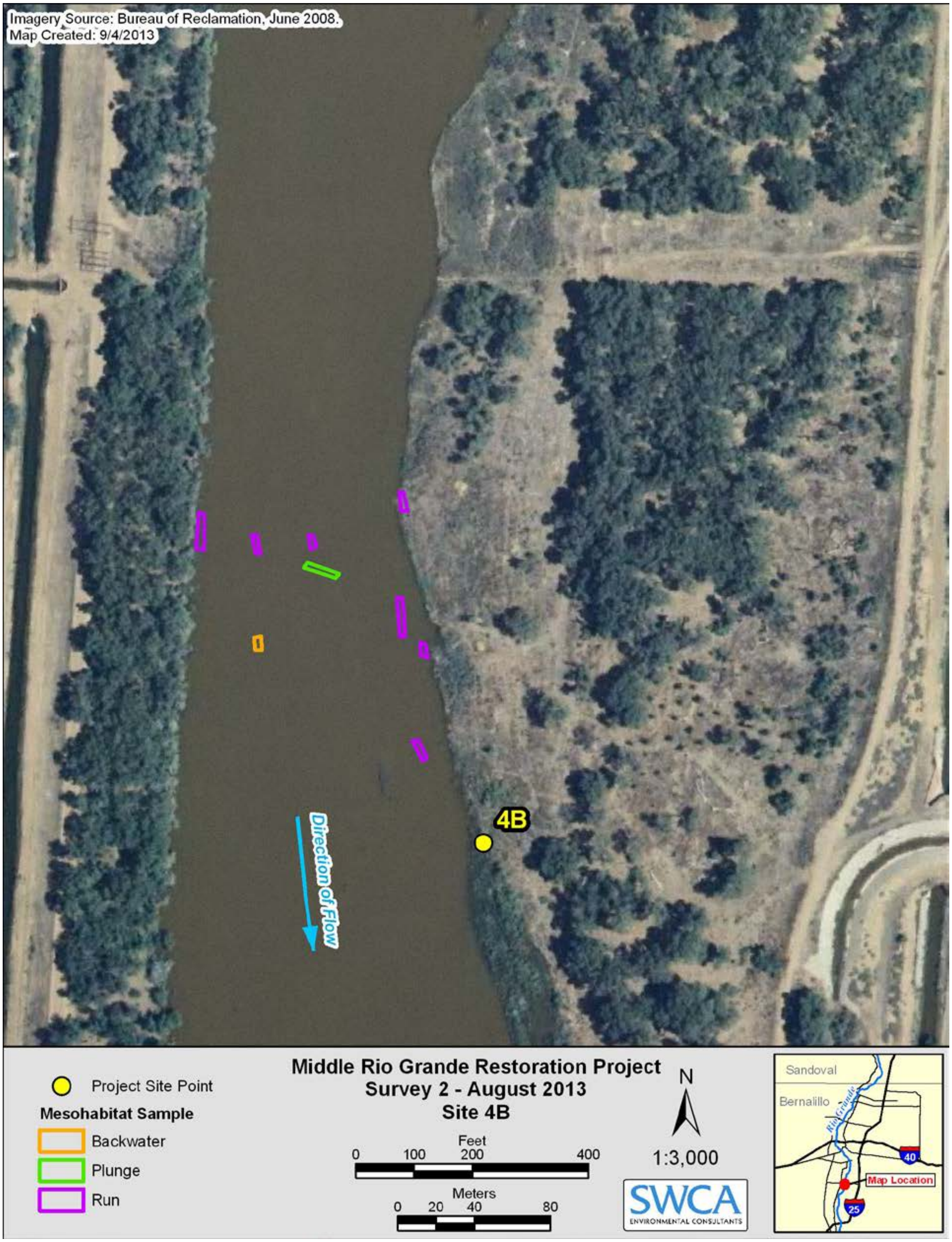

Figure A.16. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4B during Survey 2.

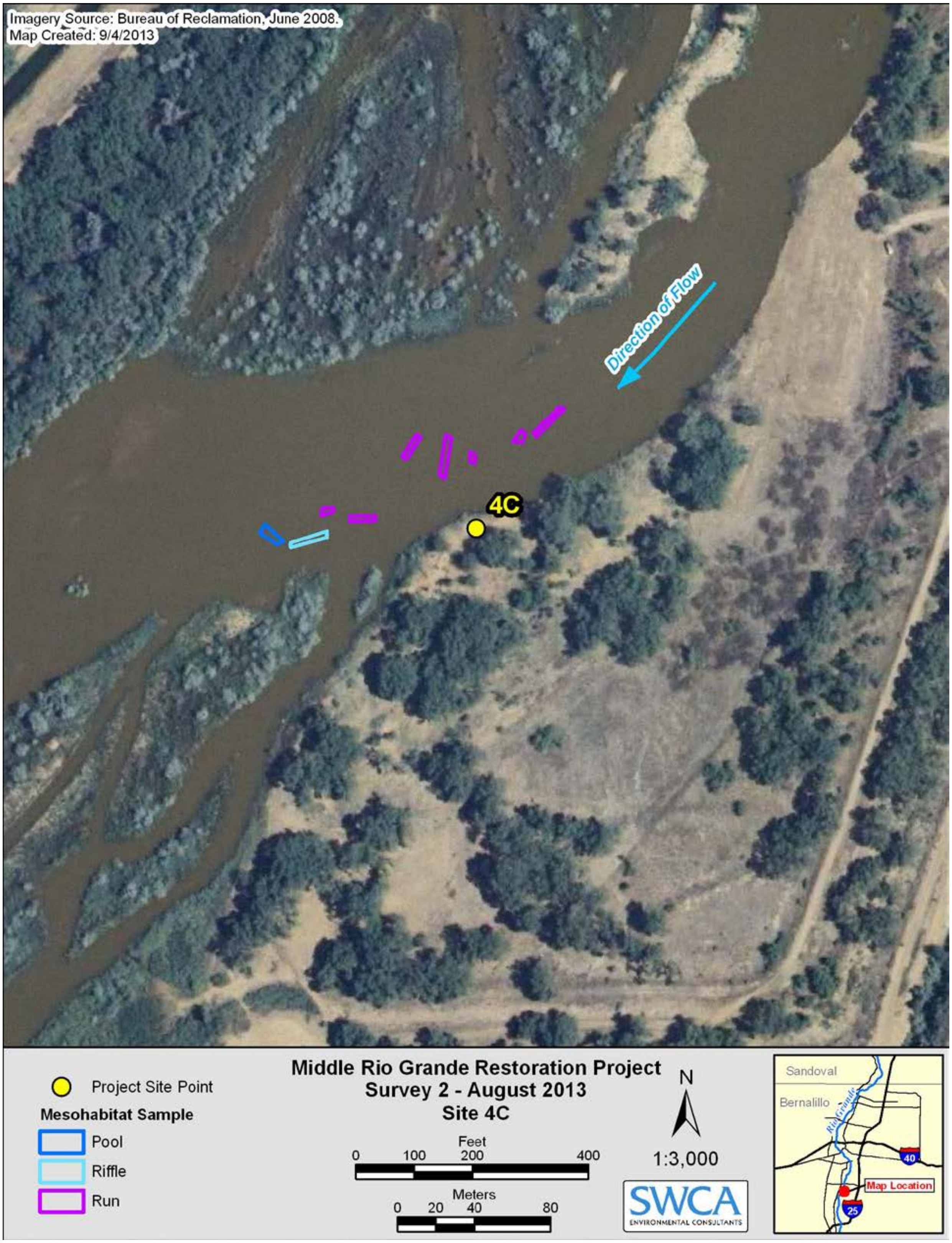

Figure A.17. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4C during Survey 2.

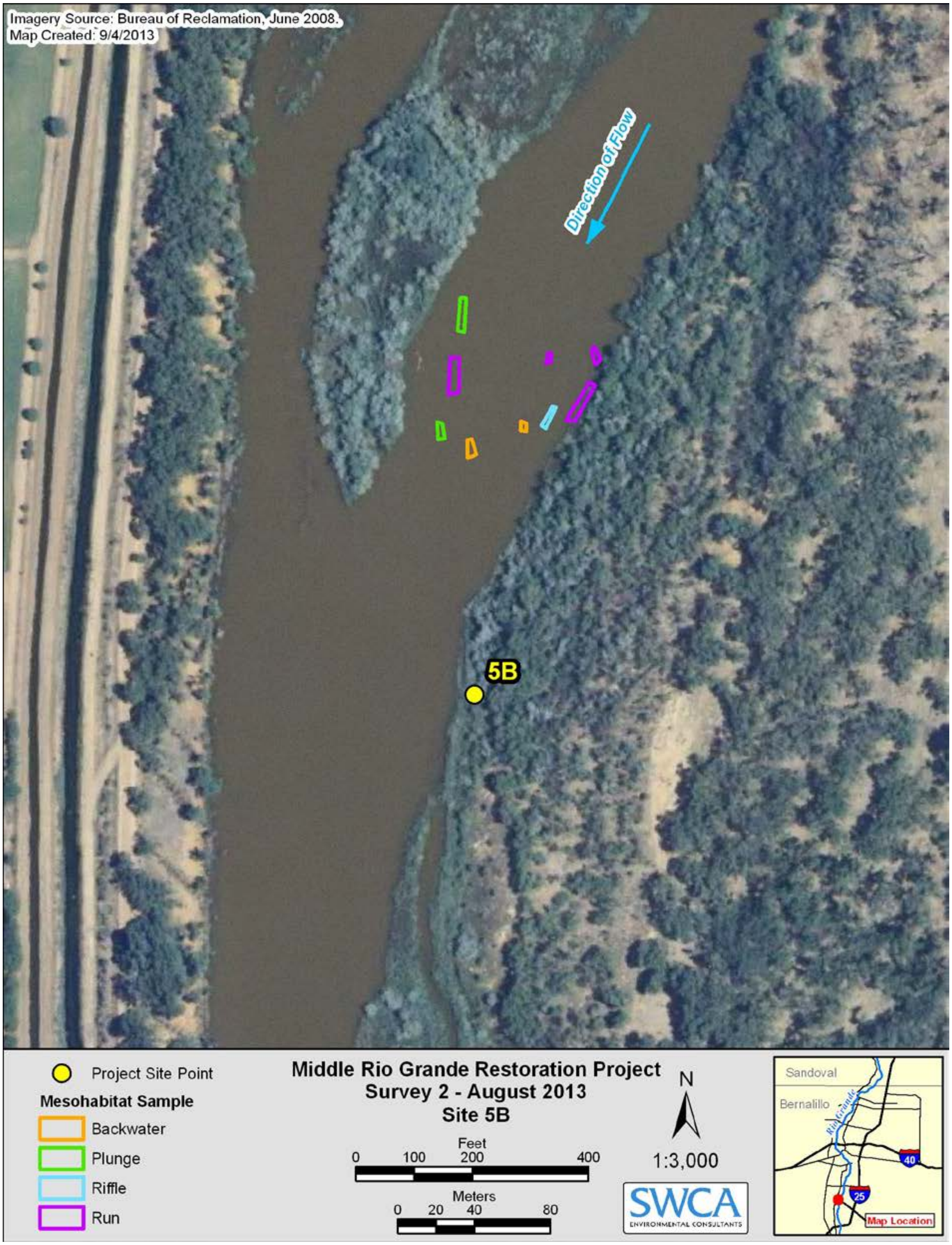

Figure A.18. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5B during Survey 2.

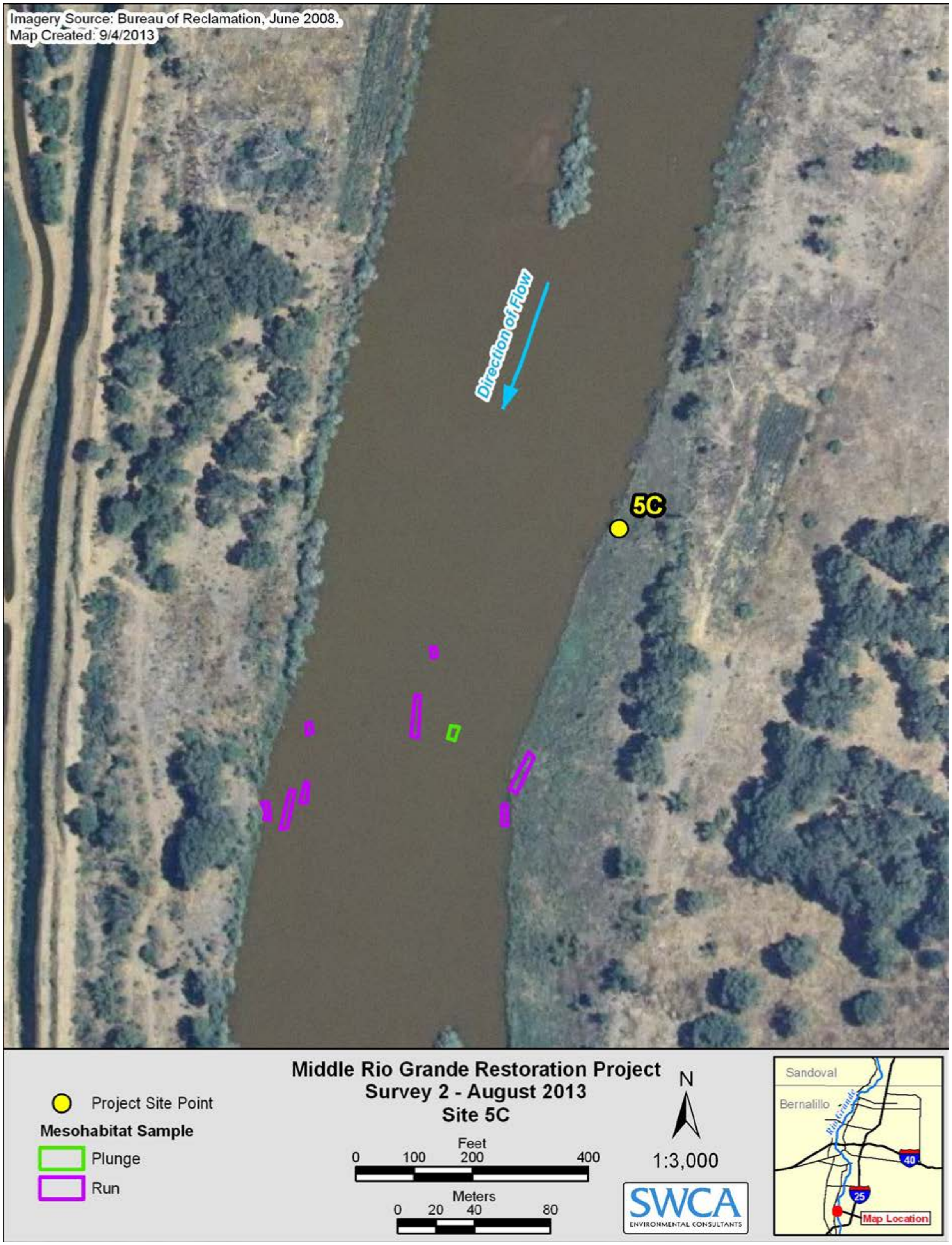

Figure A.19. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5C during Survey 2.

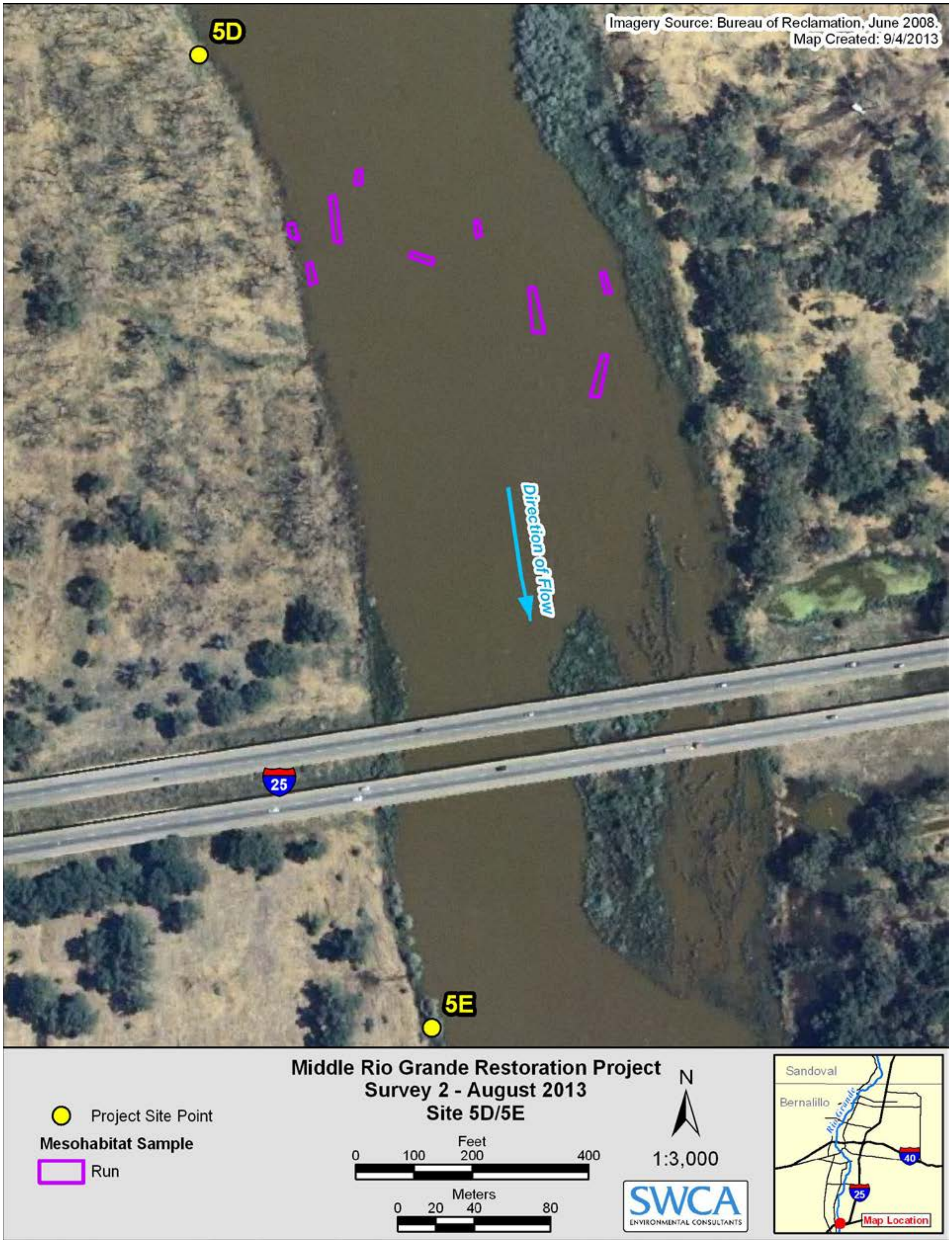

Figure A.20. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5D/E during Survey 2.

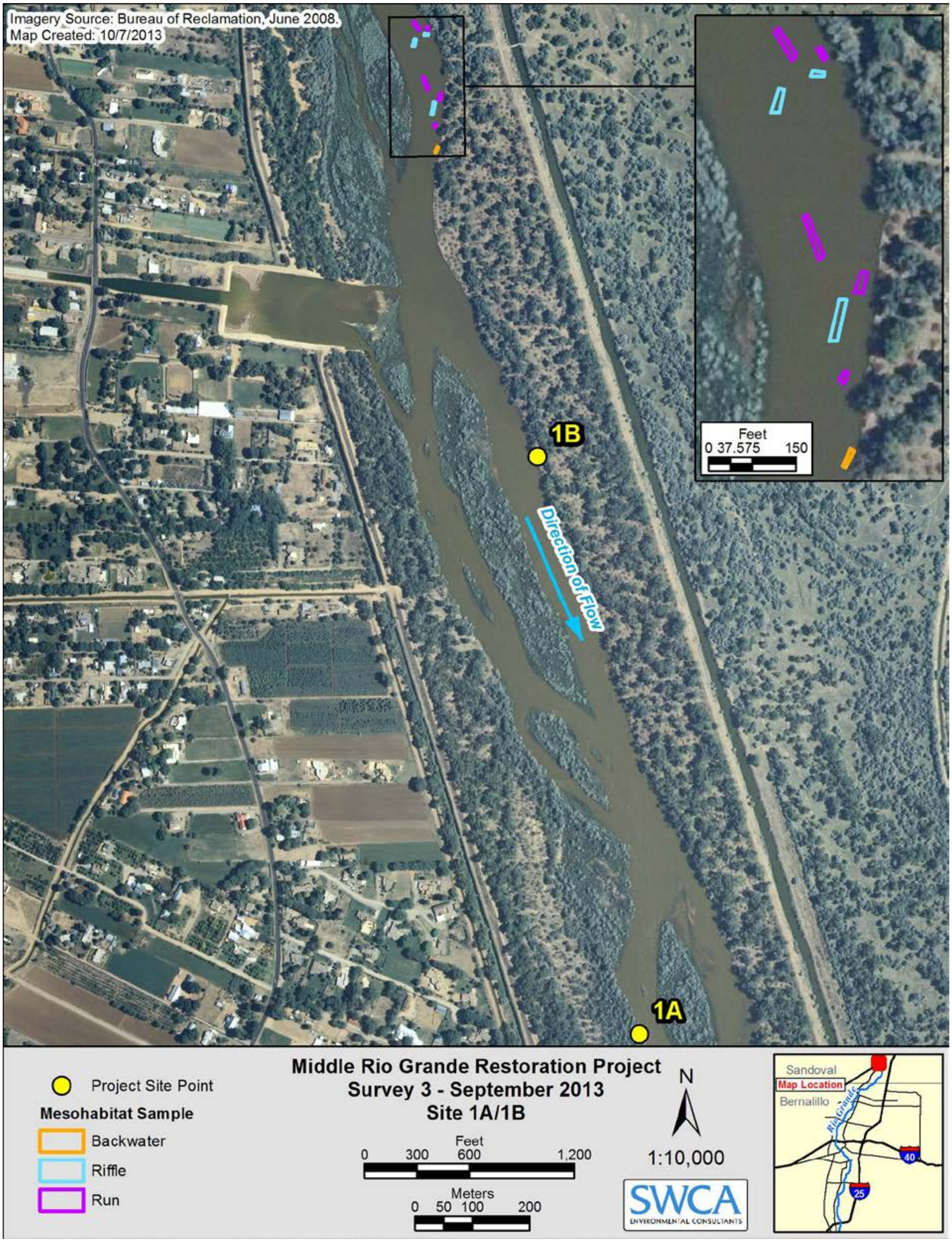

Figure A.21. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1A/B during Survey 3.

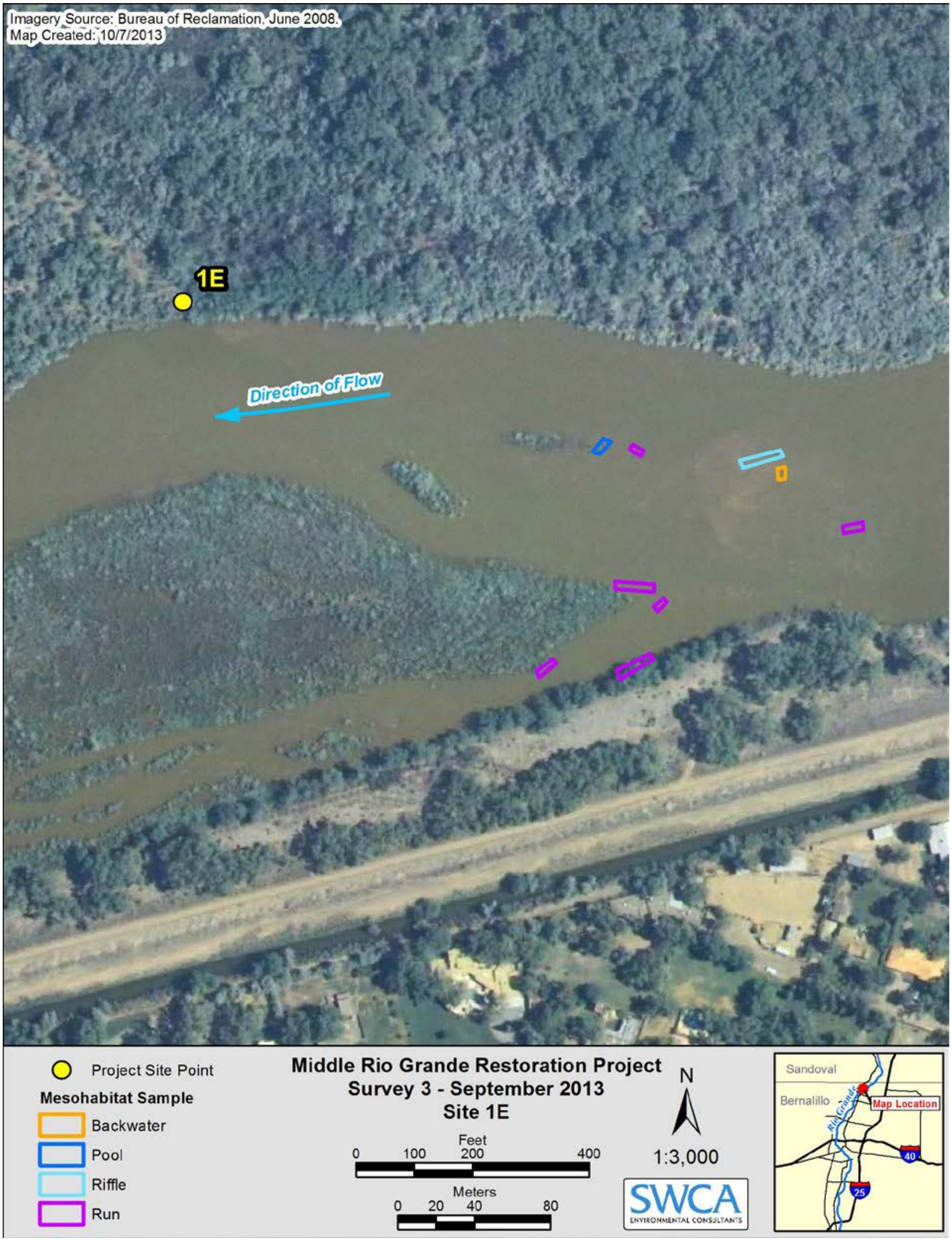

Figure A.22. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1E during Survey 3.

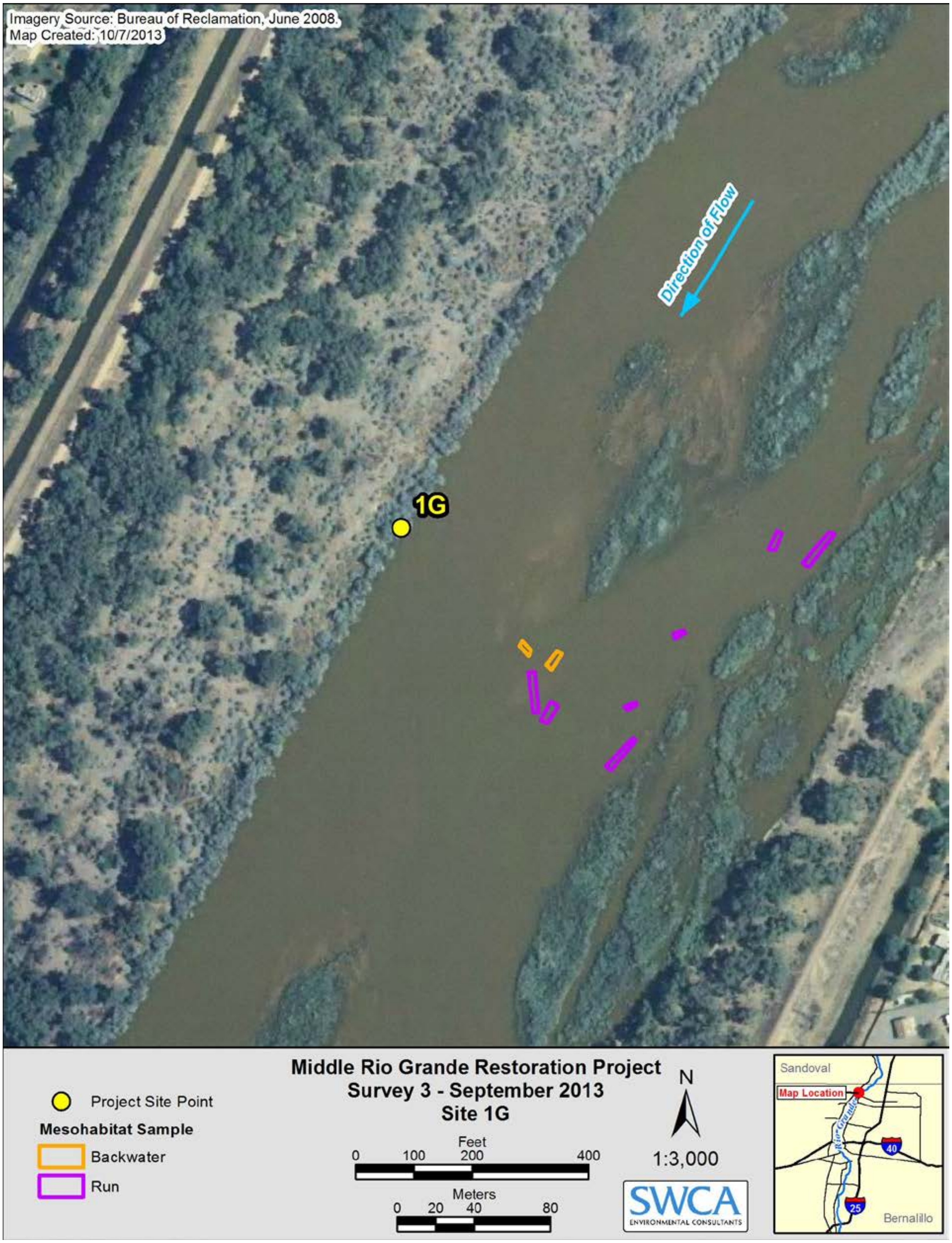

Figure A.23. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1G during Survey 3.

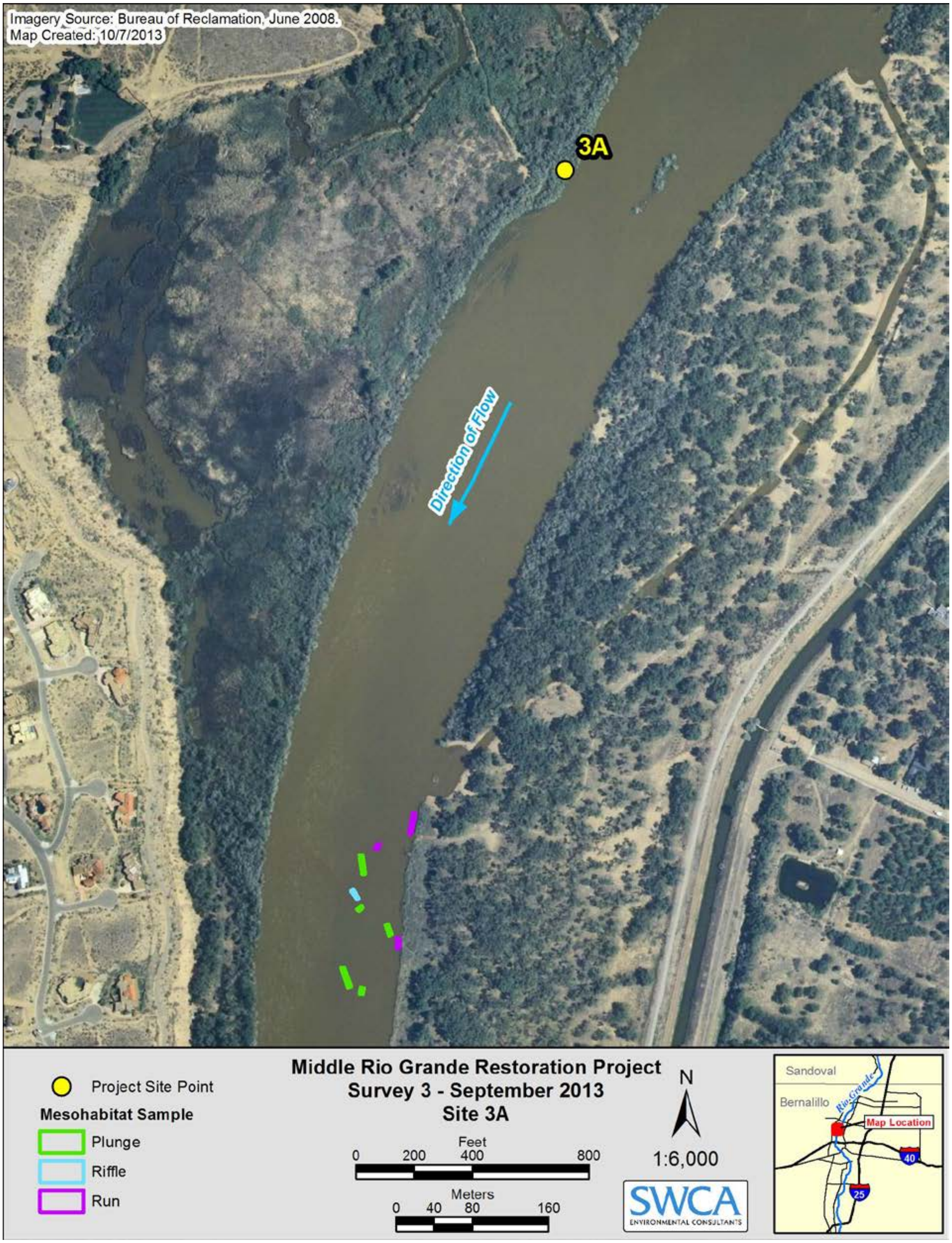

Figure A.24. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 3A during Survey 3.

Figure A.25. Mesohabitats sampled from the main channel of the Middle Rio Grande at site RT 66 during Survey 3.

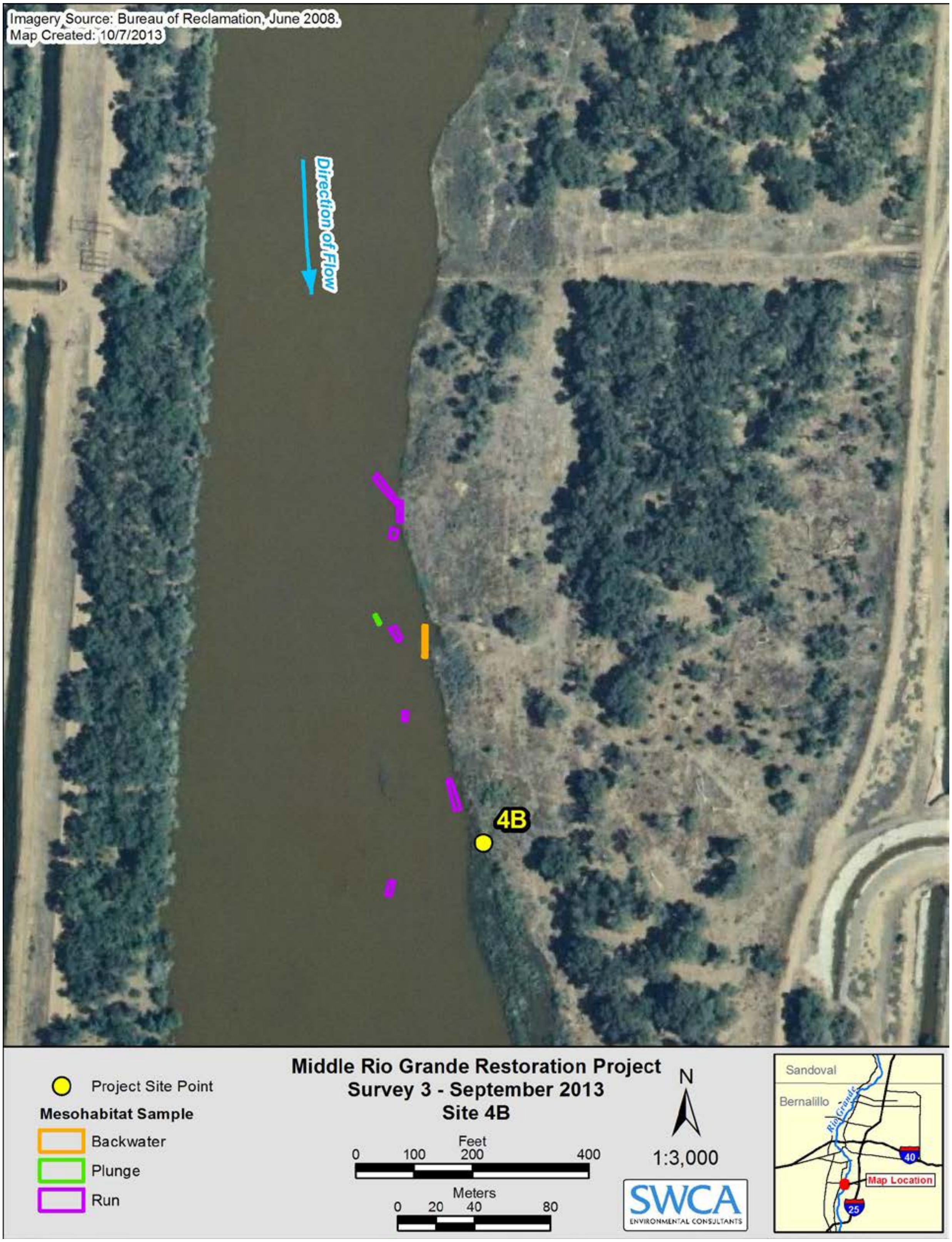

Figure A.26. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4B during Survey 3.

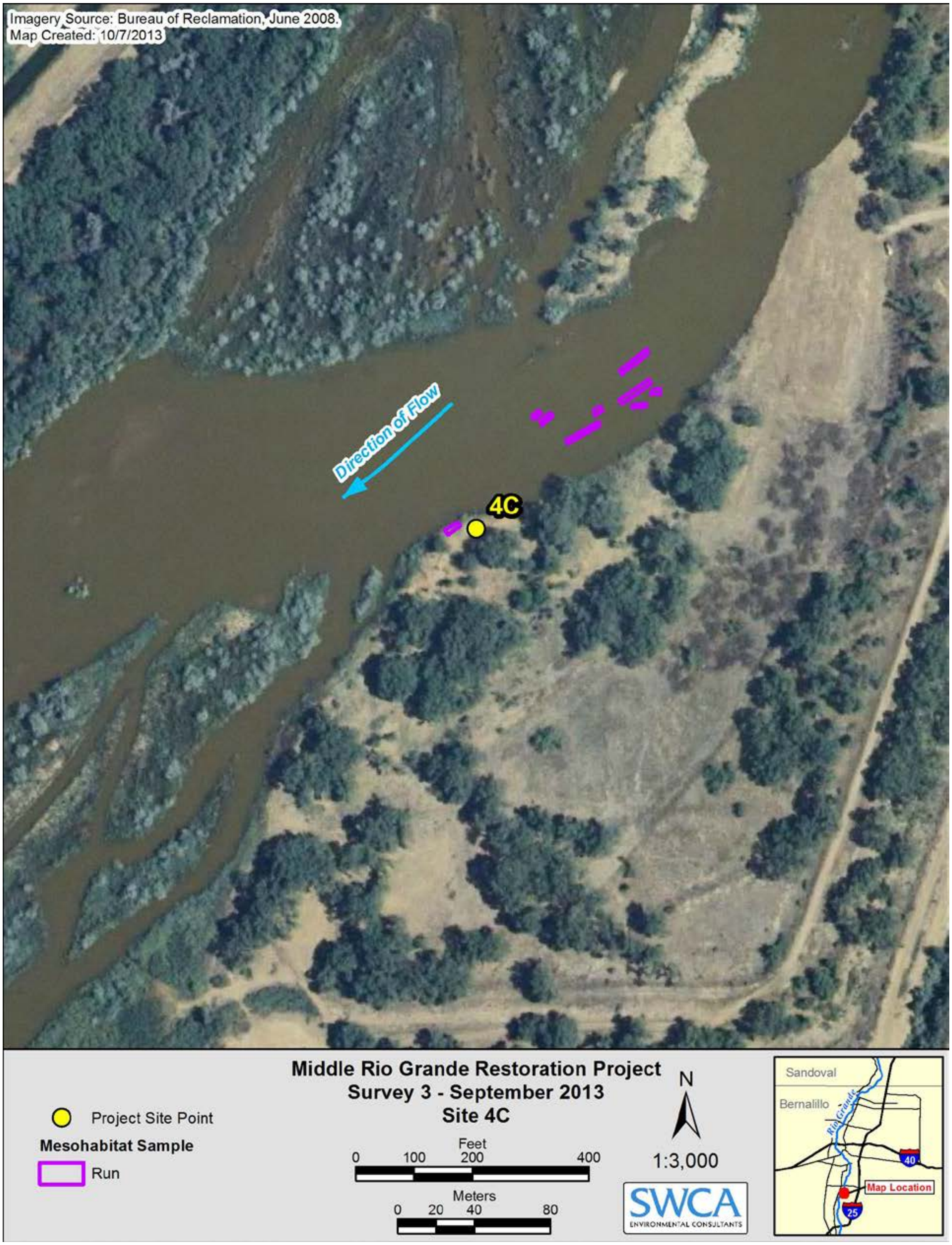

Figure A.27. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4C during Survey 3.

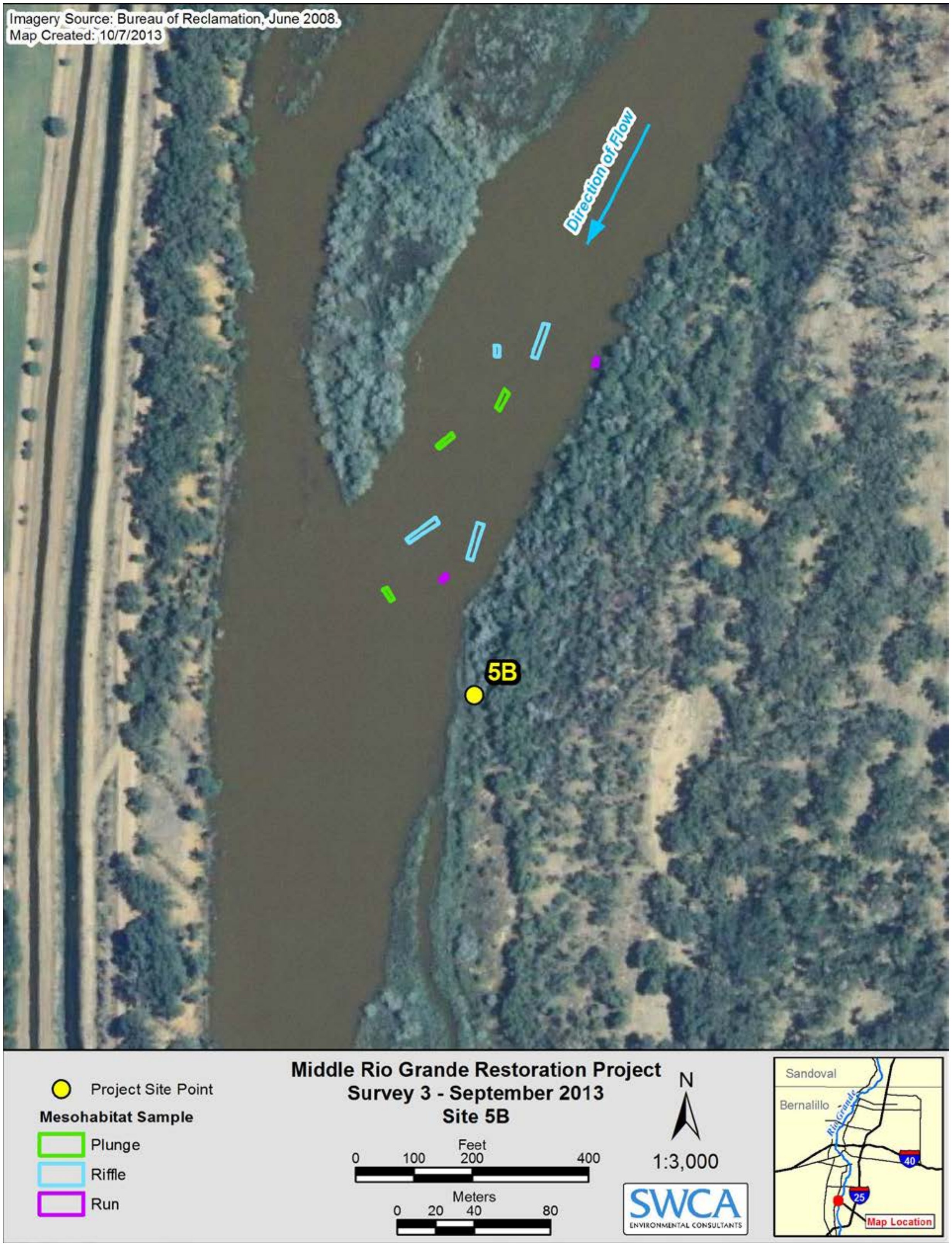

Figure A.28. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5B during Survey 3.

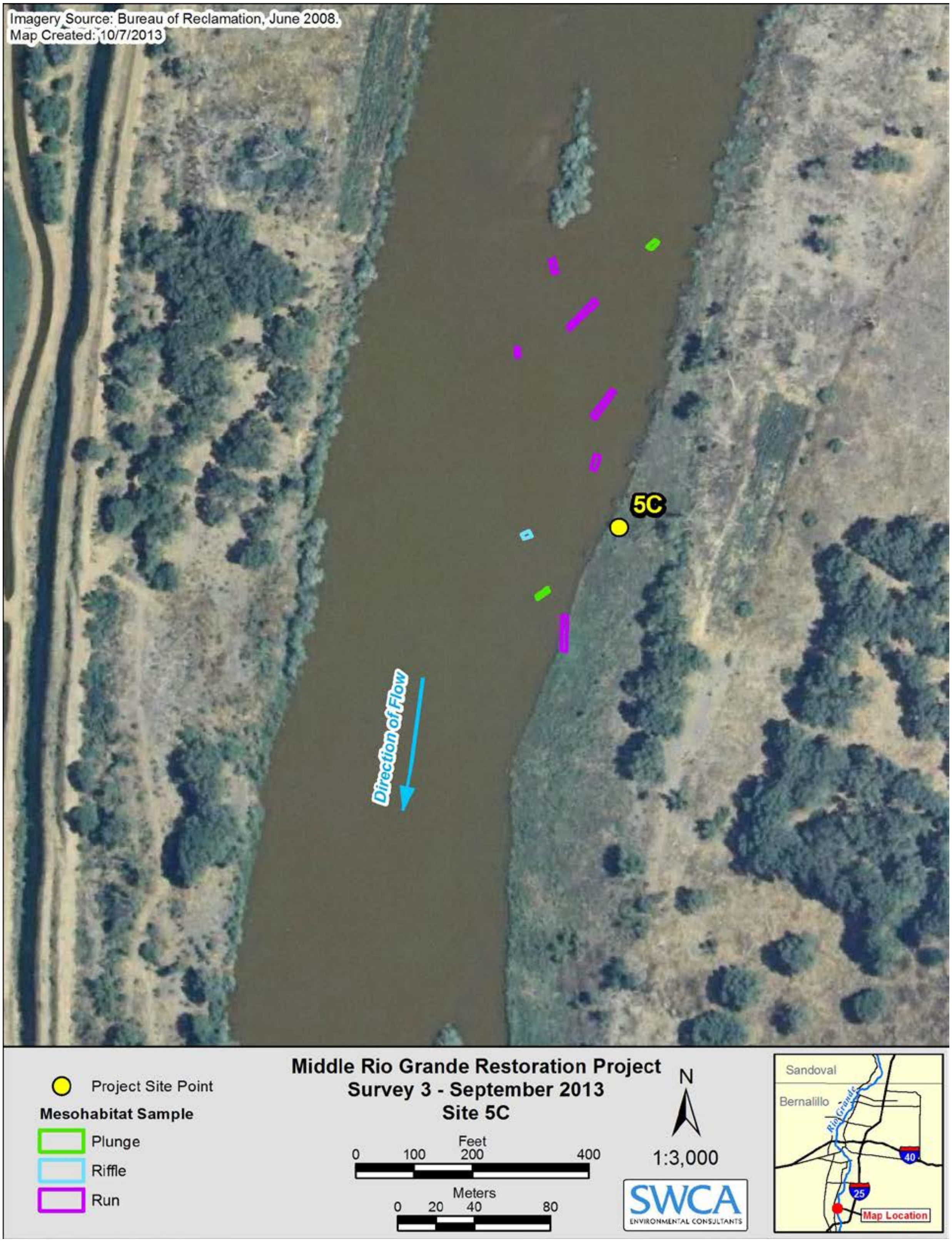

Figure A.29. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5C during Survey 3.

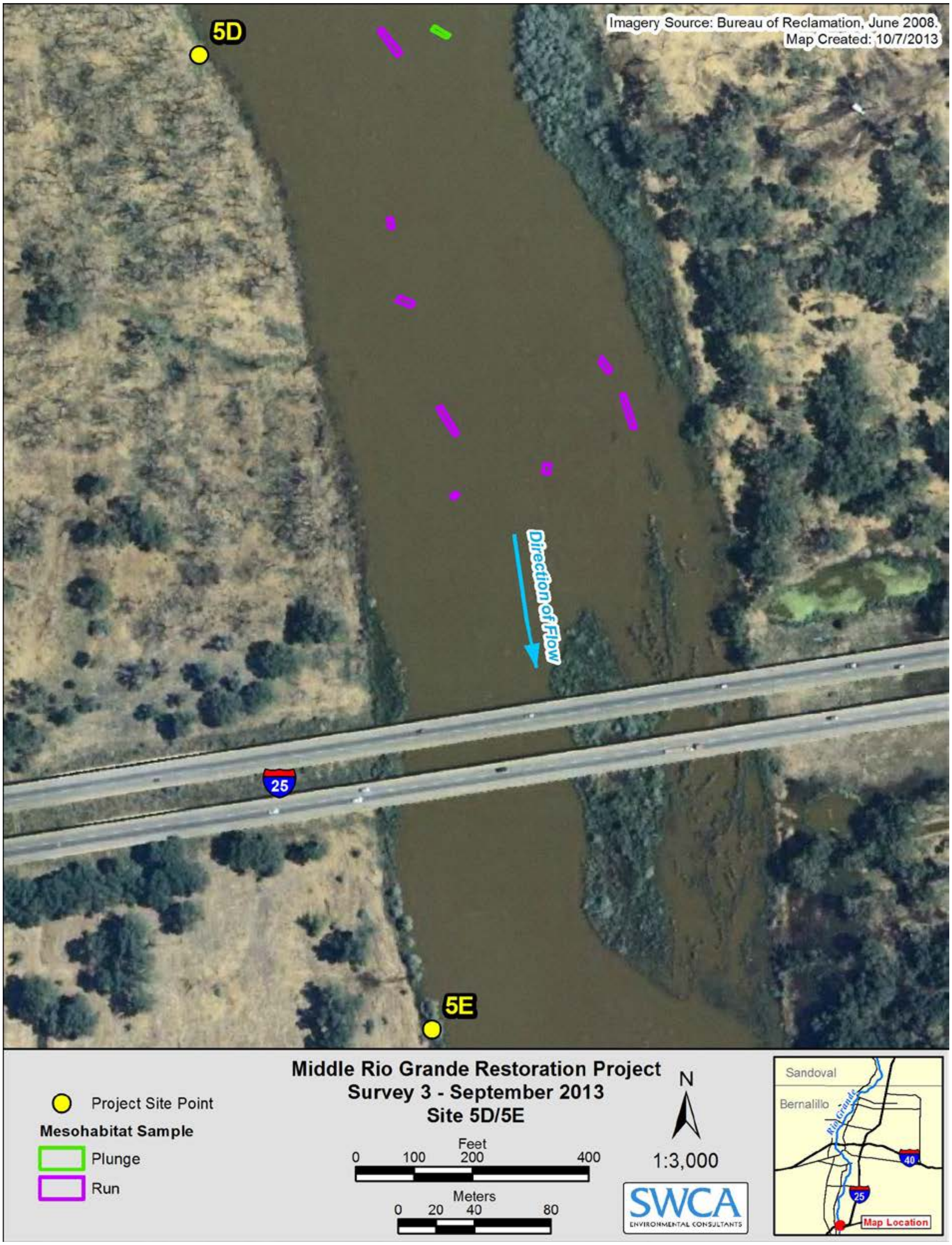

Figure A.30. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5D/E during Survey 3.

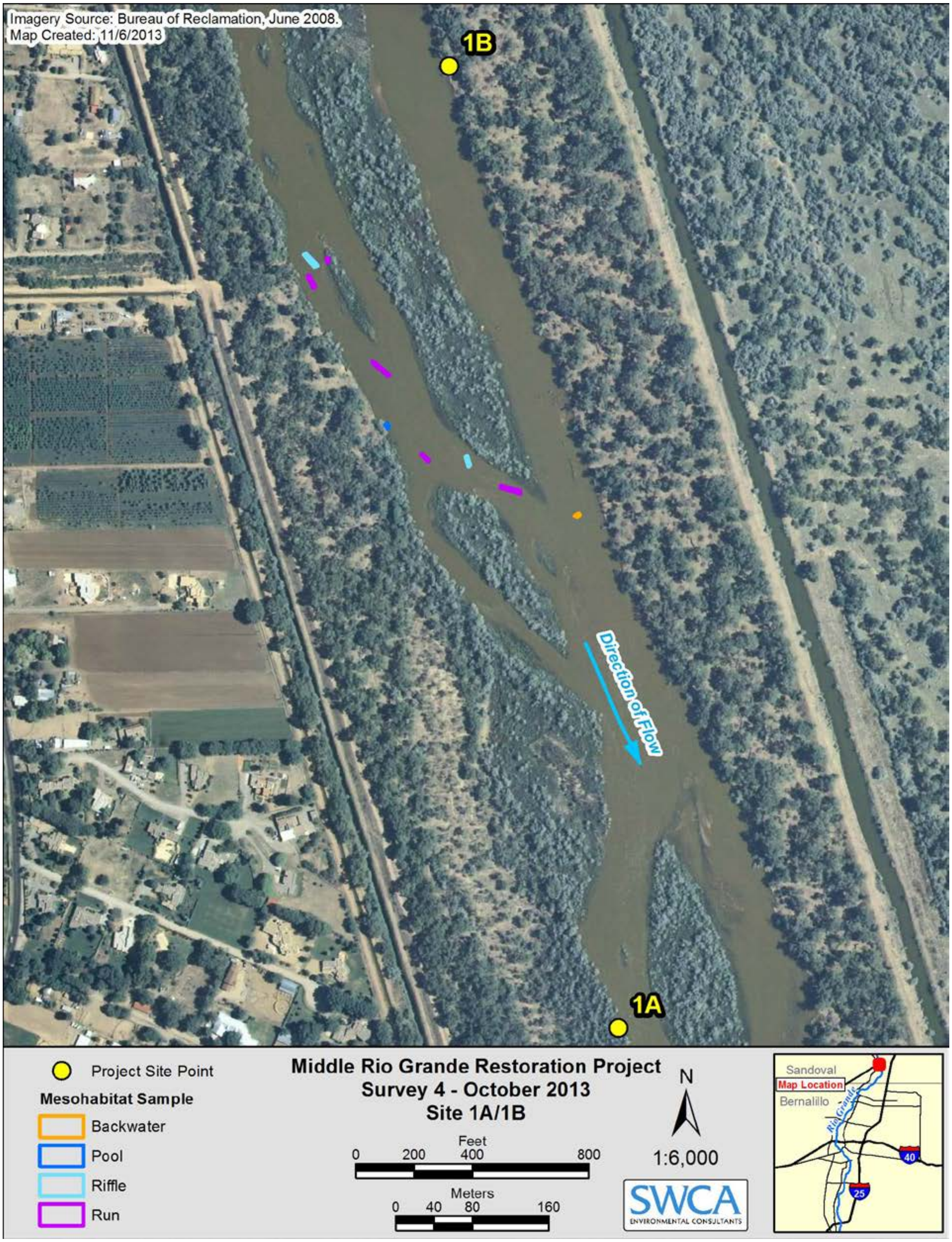

Figure A.31. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1A/B during Survey 4.

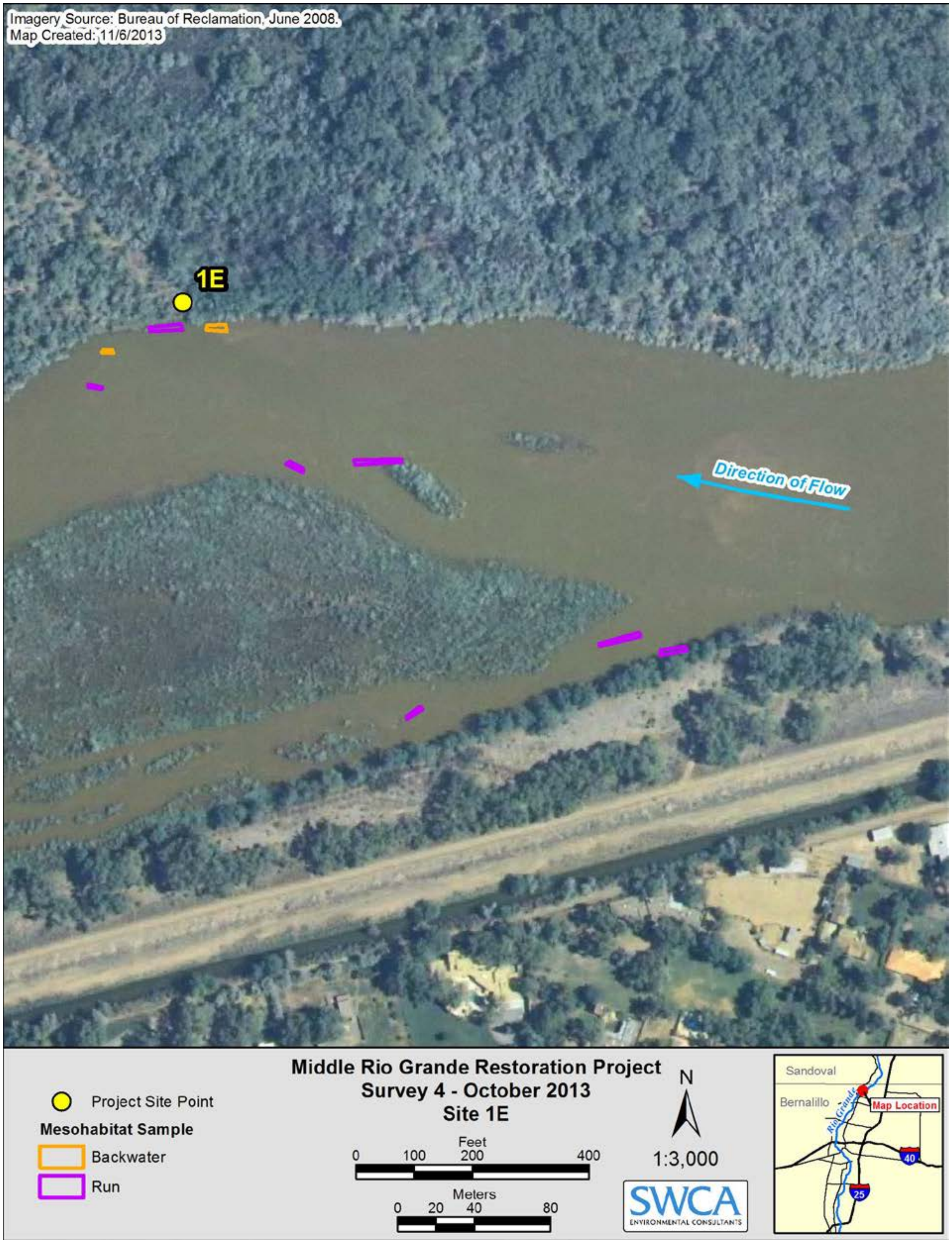

Figure A.32. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1E during Survey 4.

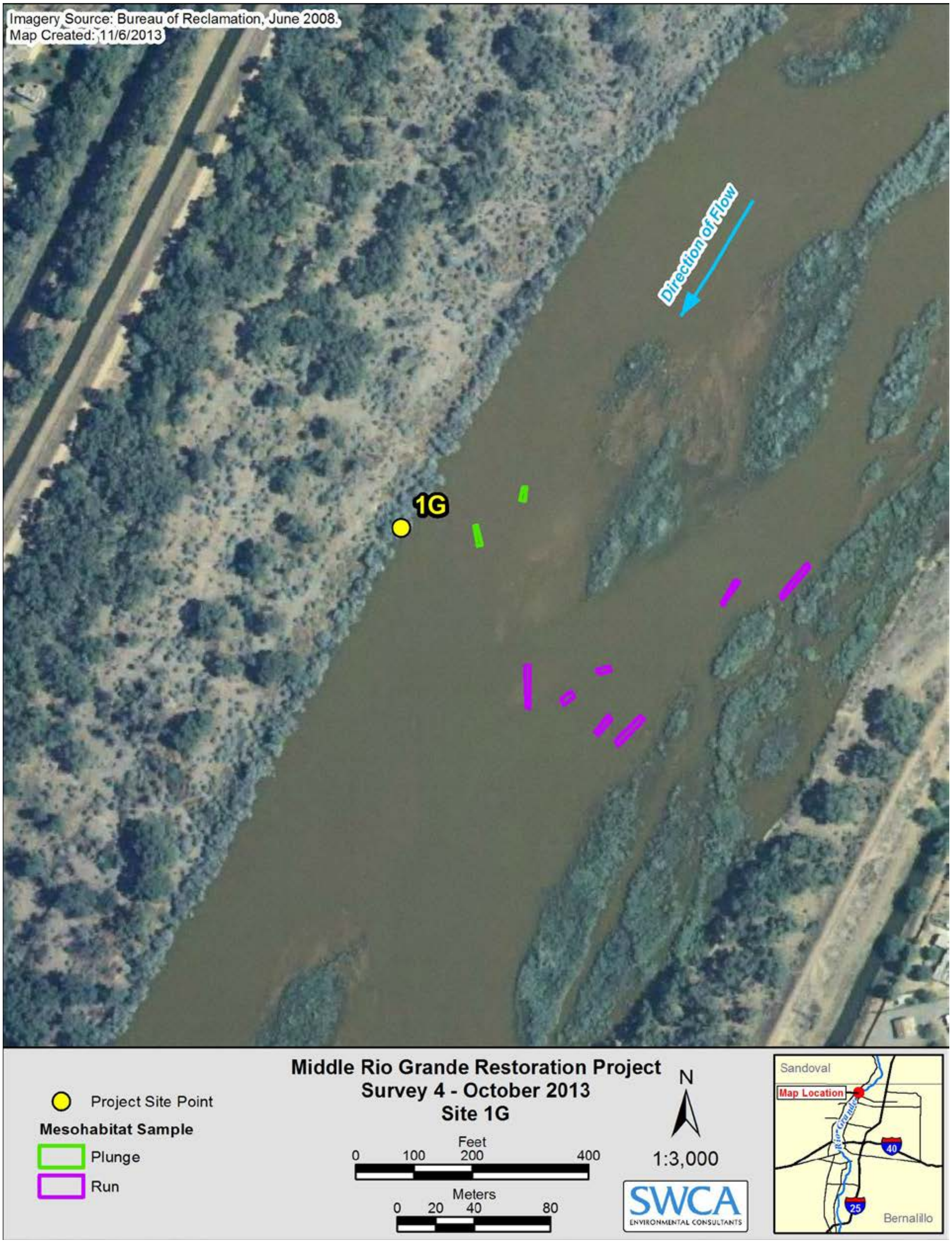

Figure A.33. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 1G during Survey 4.

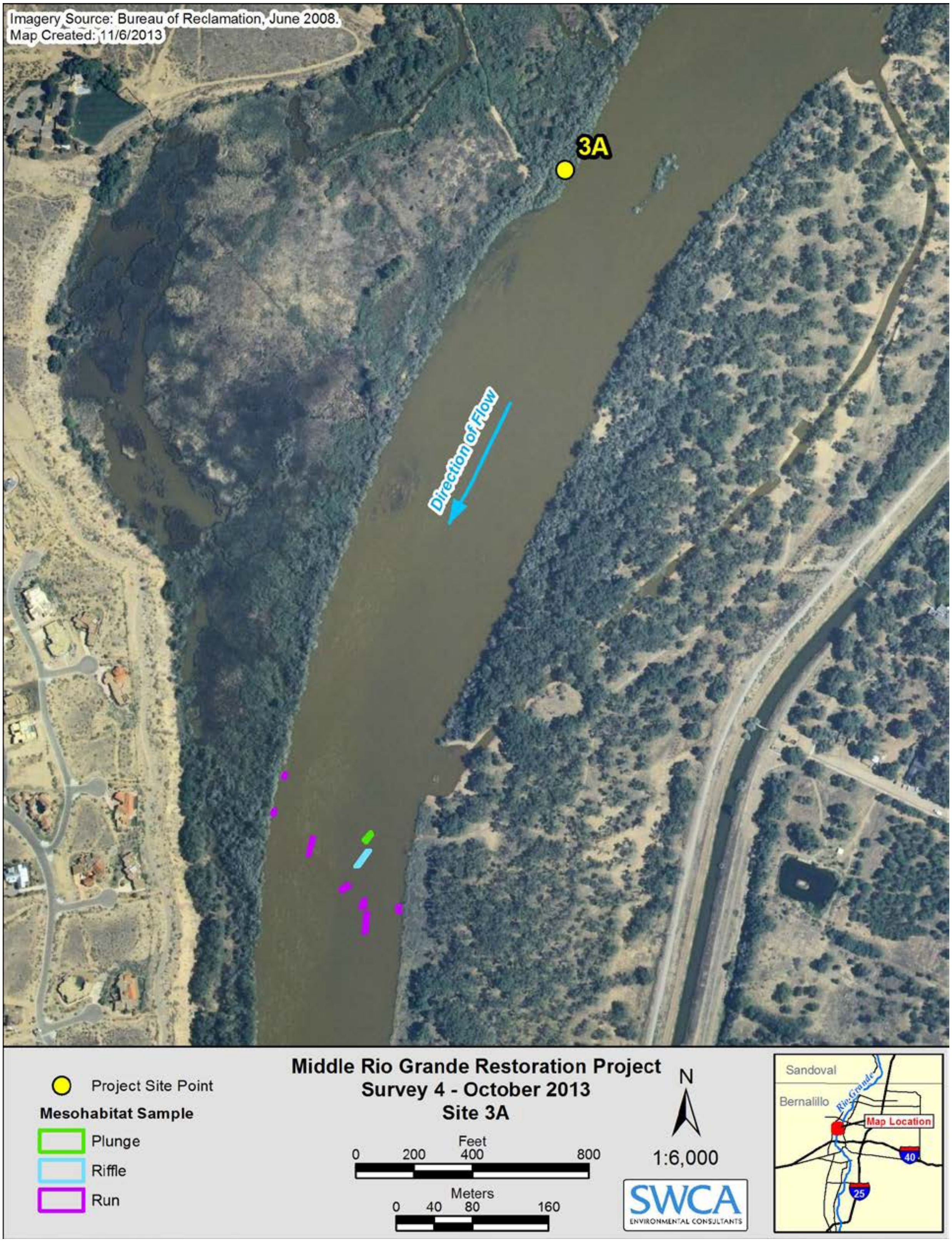

Figure A.34. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 3A during Survey 4.

Figure A.35. Mesohabitats sampled from the main channel of the Middle Rio Grande at site RT 66 during Survey 4.

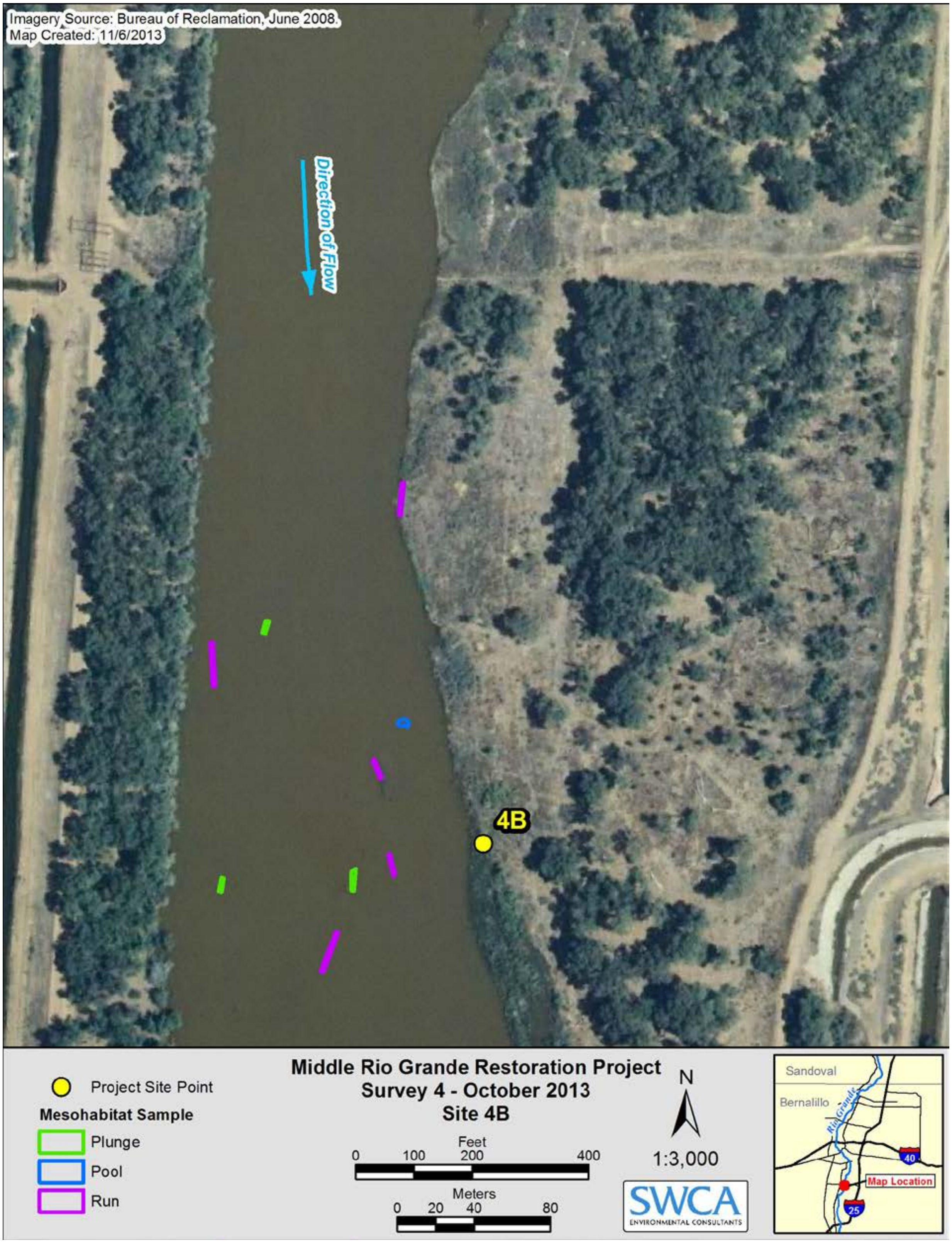

Figure A.36. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4B during Survey 4.

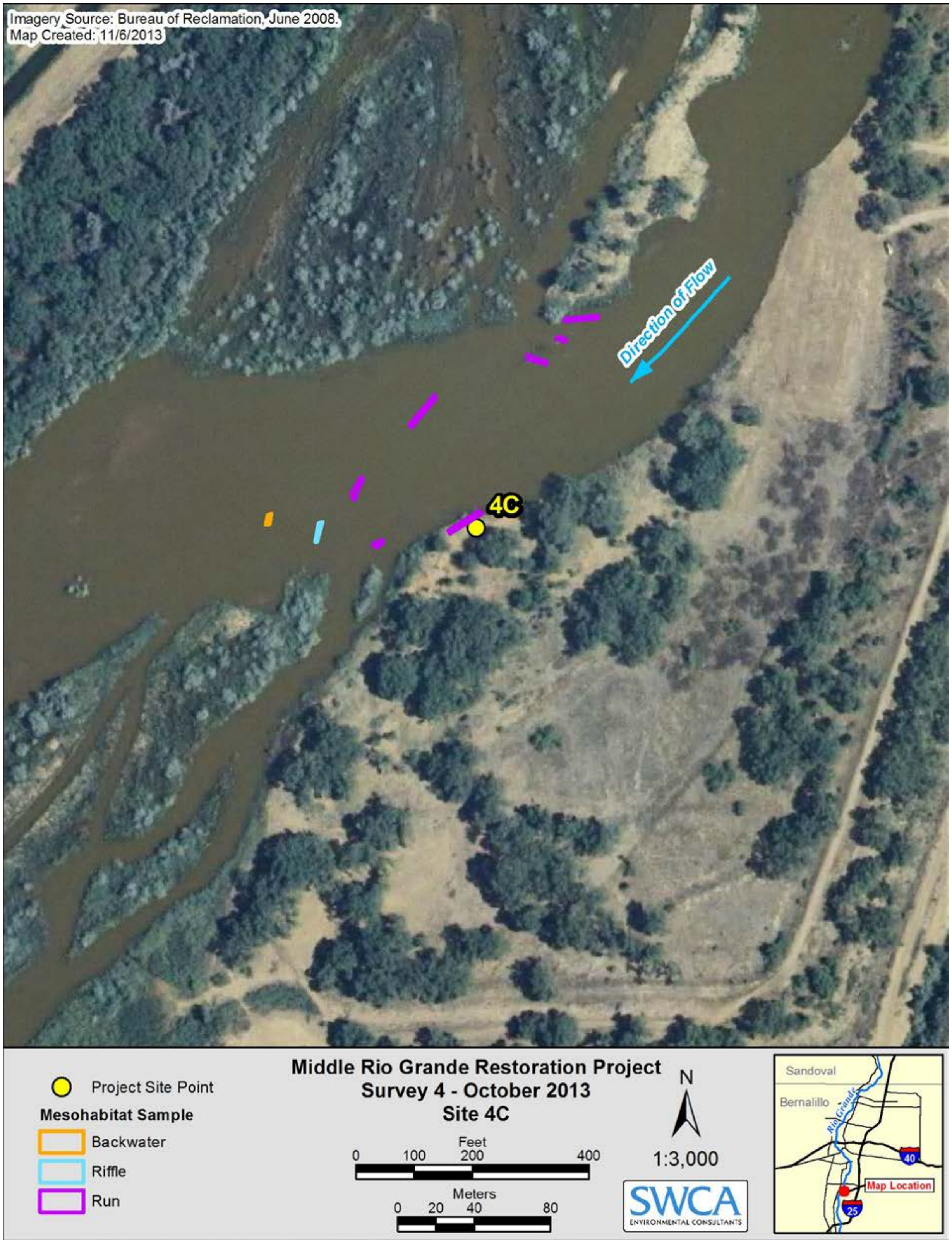

Figure A.37. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 4C during Survey 4.

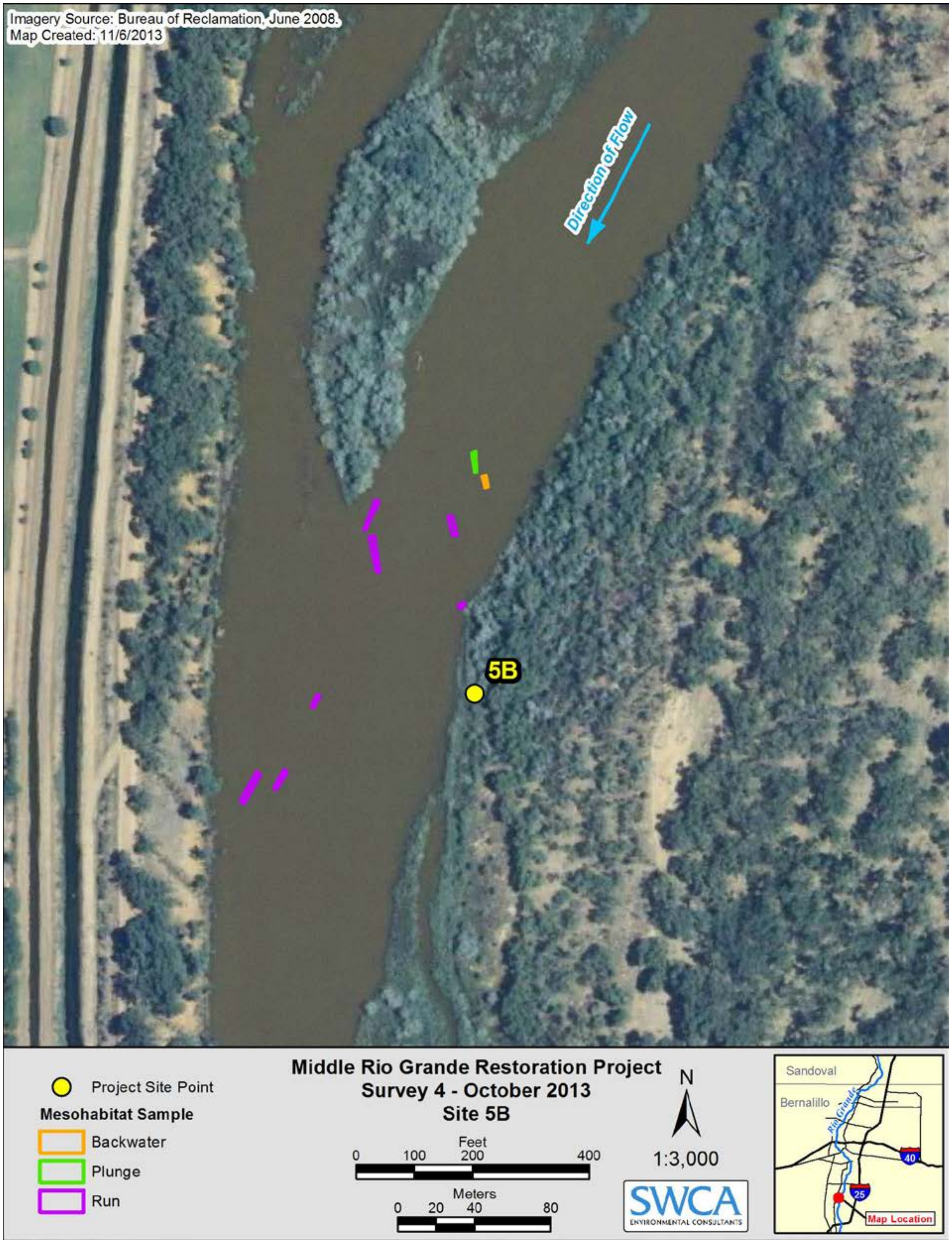

Figure A.38. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5B during Survey 4.

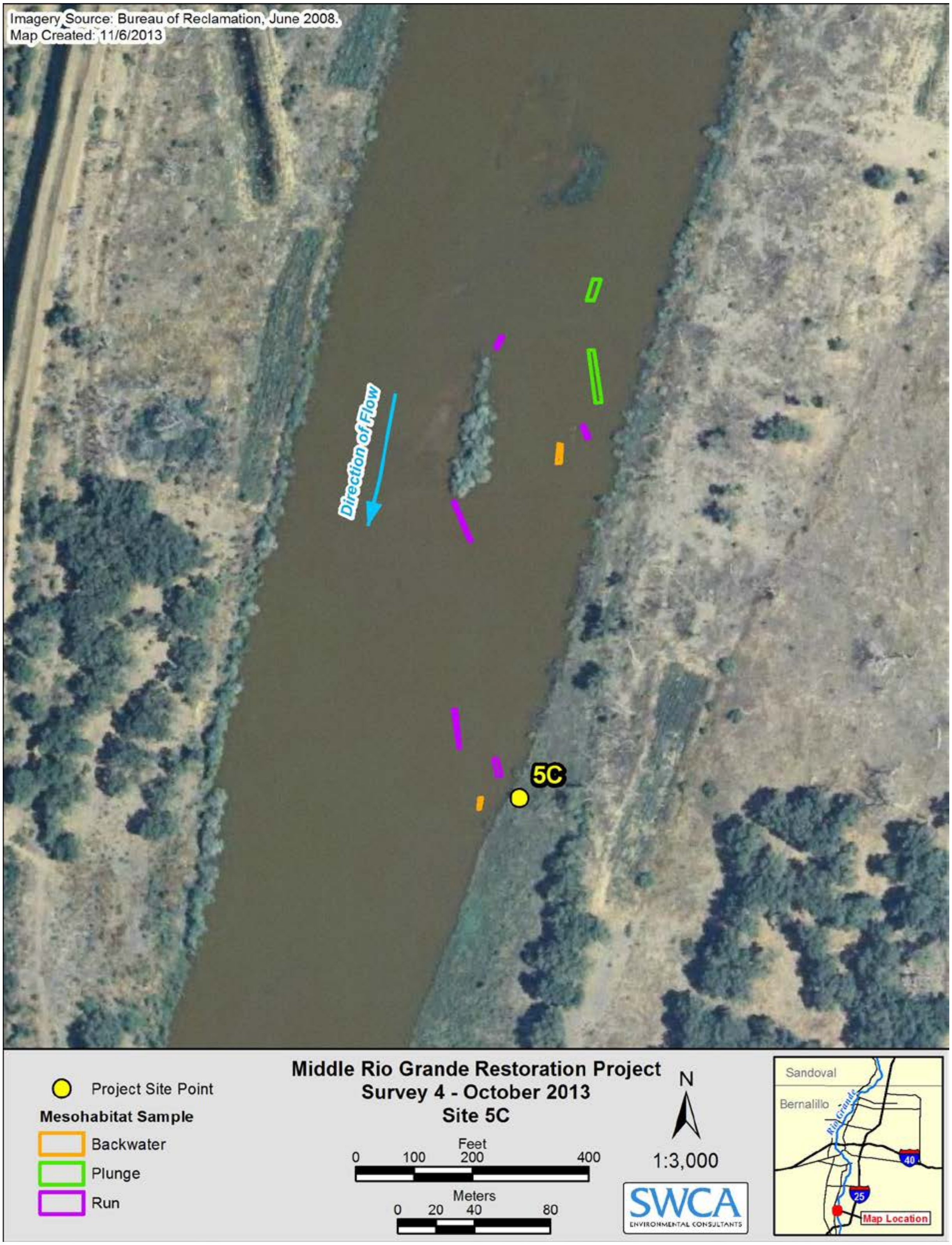

Figure A.39. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5C during Survey 4.

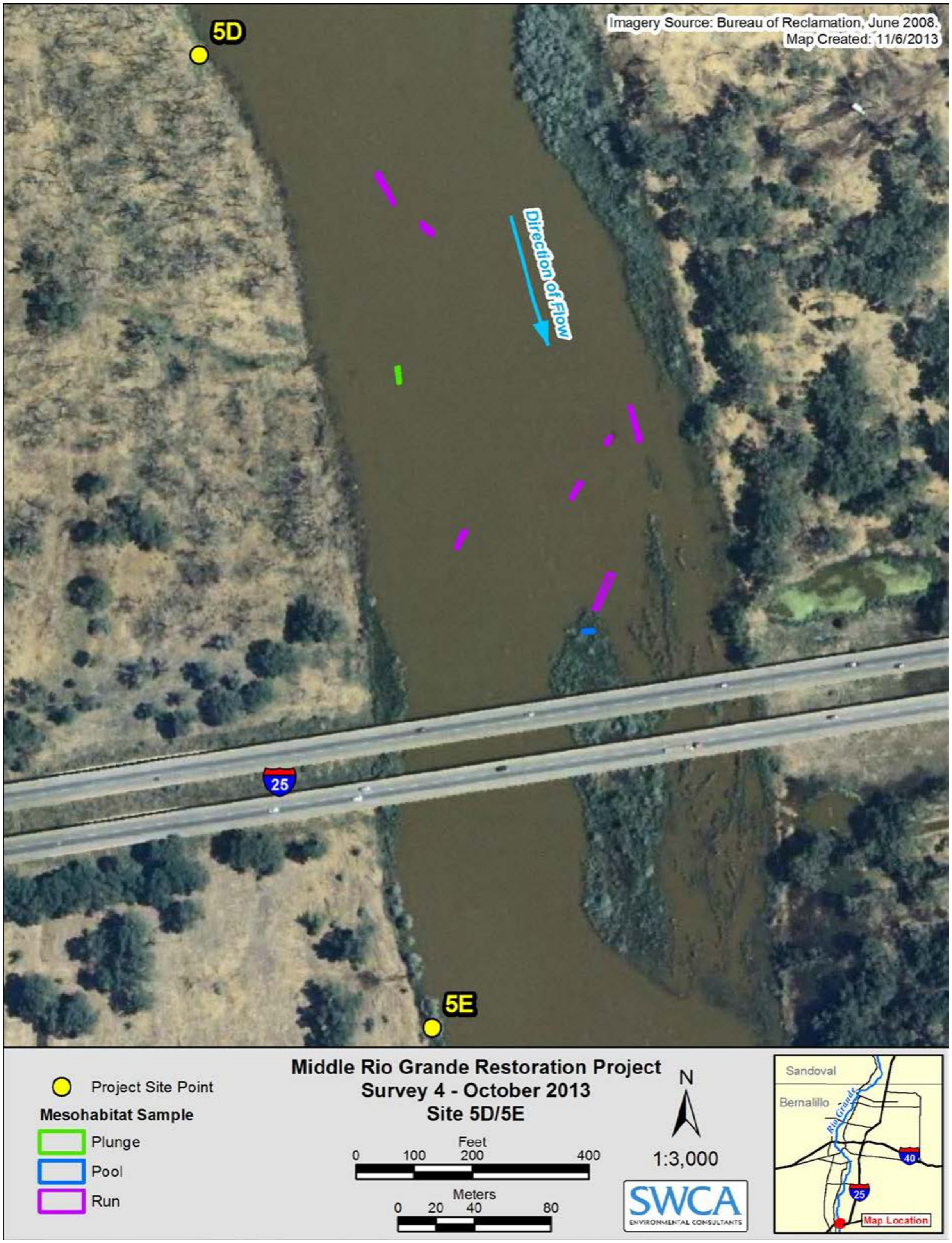

Figure A.40. Mesohabitats sampled from the main channel of the Middle Rio Grande at site 5D/E during Survey 4.