Aquatic Habitat Assessment
&
Enhancement Plan

Tarryall Creek - Landis Ranch

Park County, Colorado

Prepared by

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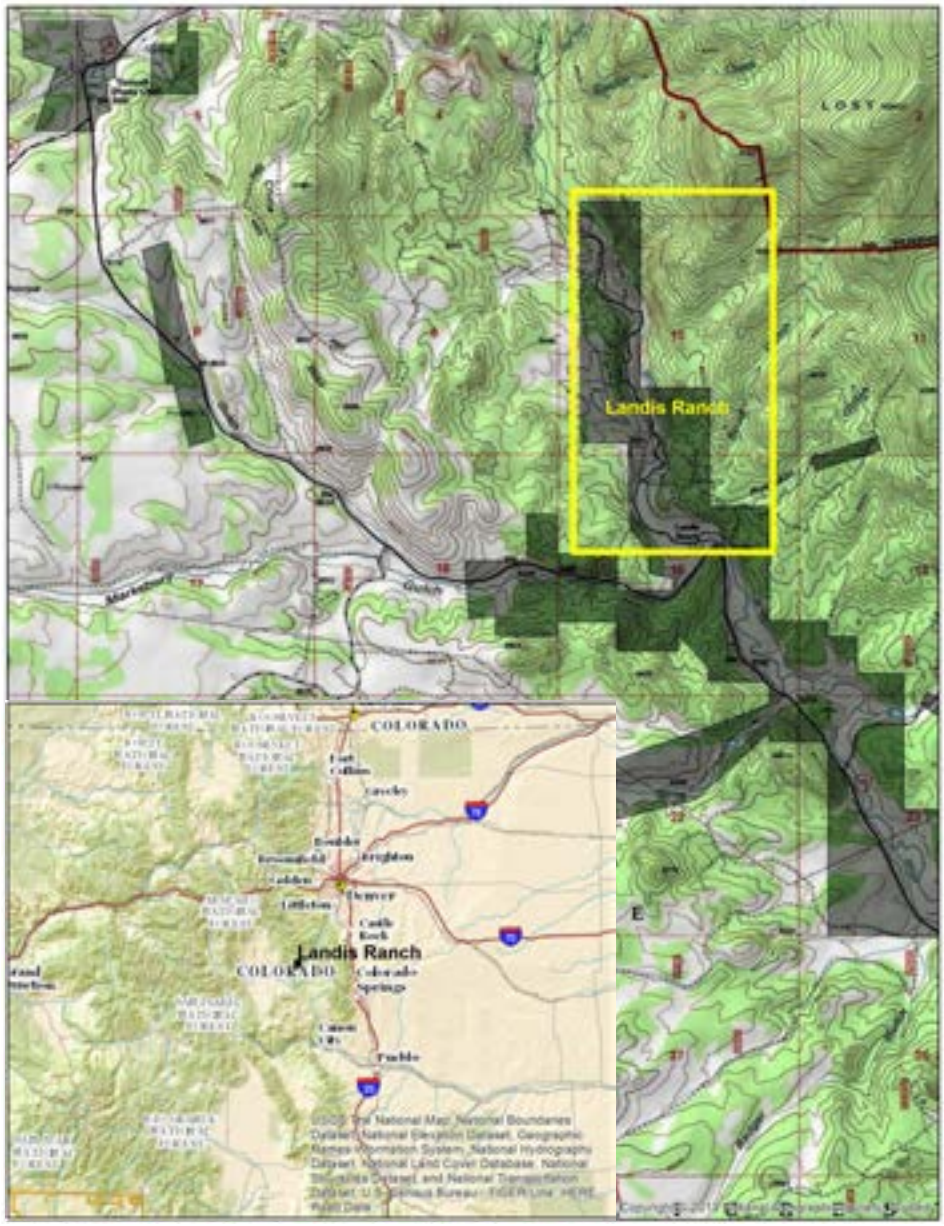
In early 2015, FIN-UP Habitat Consultants, Inc. was contracted by the Coalition for the Upper South Platte (CUSP) to conduct an aquatic habitat assessment for approximately 2 miles of Tarryall Creek on the Landis Ranch, in Park County, Colorado. The aquatic assessment was conducted within the project area during the 1st and 2nd week of April 2015. The results of this study are summarized in this document.



Map 1: Location of the study reach on Tarryall Creek in Park County, CO.

Watershed and Hydrology

Tarryall Creek is a major headwater tributary of the South Platte River, draining the upper third of the South Park basin, including the southern flanks of the Kenosha, Platte River, and Tarryall mountains, and the northeastern flank of the Puma Hills. The stream begins as a series of small tributaries extending from Boreas Pass to Kenosha Pass. These headwater tributaries include Michigan and Jefferson Creeks, as well as the

headwater main stem of Tarryall Creek. From the headwaters, these tributaries flow southeast, across the open low gradient meadows of the northernmost part of South Park. The tributaries come together to form the main stem of Tarryall Creek near the eastern boundary of South Park. Exiting the park, the river descends through a broad mountain valley dividing the Tarryall Mountains to the north and the Puma Hills to the south. Near the downstream boundary of this valley, the stream enters a very narrow granite canyon known locally as Box Canyon. Exiting the canyon, Tarryall Creek flows across several miles of low gradient pasture land, eventually turning northeast near the eastern edge of the Tarryall Mountains, and then descends through very steep canyons to the confluence with the South Platte River at the southern end of Wildcat Canyon. The approximate area of the Tarryall Creek watershed is 413.64 sq. miles.

The geology of Tarryall Creek is composed mostly of weathered granite. Two reservoirs exist on the main stem of the river, and have varying effect on flow, sediment transport, and aquatic organism movement. Tarryall Reservoir, located a few miles downstream of the confluence of the headwater tributaries, is owned and operated by Colorado Parks & Wildlife. It is the largest of the impoundments, and usually operates as a "run-of-the-river" reservoir. Periodic maintenance of the dam occasionally results in impacts to the stream downstream of the facility, including release of sediment in storage behind the dam, and augmented flows resulting in bank damage downstream. A smaller, private impoundment is found several miles downstream near the town of Tarryall, and immediately upstream of the USFS Spruce Grove Campground and Box Canyon. This reservoir, named Bayou Salado, is also a "run-of-the-river, operation, providing private lake fishing for the small community surrounding the reservoir.

Most of the Tarryall River is under private ownership, with agricultural uses such as hay production and cattle grazing being the primary uses of the riparian corridor. To support the hay operations, there are numerous diversion points throughout the watershed, and de-watering of the river during low flows and in times of drought may significantly effect resident populations of fish and other aquatic organisms. In 2002, a significant portion of the lower watershed below Bayou Salado Reservoir was completely de-watered for a period of several weeks.

An automated stream gauge is maintained by the Colorado Division of Water Resources on Tarryall Creek approximately 1,000 feet downstream of the Tarryall Reservoir dam. The location of this gauge is at Latitude 39°13'18.1", Longitude 105°36'09.1", in NW¼SW¼ sec.31, T.09 S., R.73 W., Park County, Hydrologic Unit 1019000104, on the right bank downstream of the CR77 bridge across the creek. The drainage area upstream of the gauge is 355 mi^2. The highest peak flow on record at the gauge is 770 cfs, and occurred during June 1979. This peak flow was nearly equaled this year when the river reached 736 cfs in mid June of 2015.

Project Study Reach

The project study reach consists of approximately two miles of the main stem of Tarryall Creek in the lower portion of the watershed, on private lands managed by the Landis Ranch Home Owners Association. The upstream boundary of the study reach is the

Landis Ranch / US Forest Service Boundary immediately downstream of Box Canyon. The downstream boundary of the study reach is at the Landis Ranch / J Diamond B Ranch property boundary, adjacent to County Road 77. The river corridor in the study reach is communally owned and managed by the HOA. Two diversions are found in the reach. The upper diversion, which irrigates hay meadows on the east side of the project reach, is owned by the Mahcke Family Partnership (#2), and the lower diversion, which irrigates hay meadows on the west and south sides of Tarryall Creek downstream of the project study reach, is owned and operated by the J Diamond B Ranch.

Existing Fish Populations

Tarryall Creek contains resident populations of both native and non-native fishes. The headwaters of Tarryall Creek, upstream of US highway 285, support populations of cutthroat (*Oncorhynchus clarki*) and brook trout (*Salvelinus fontinalis*). Historically, rainbow and brown trout were stocked on both public and private lands throughout the watershed. Other cool water species, such as Northern Pike, have been stocked in the two reservoirs on the main stem of the river, and have been observed in the project study reach. Native white suckers are present throughout the watershed.

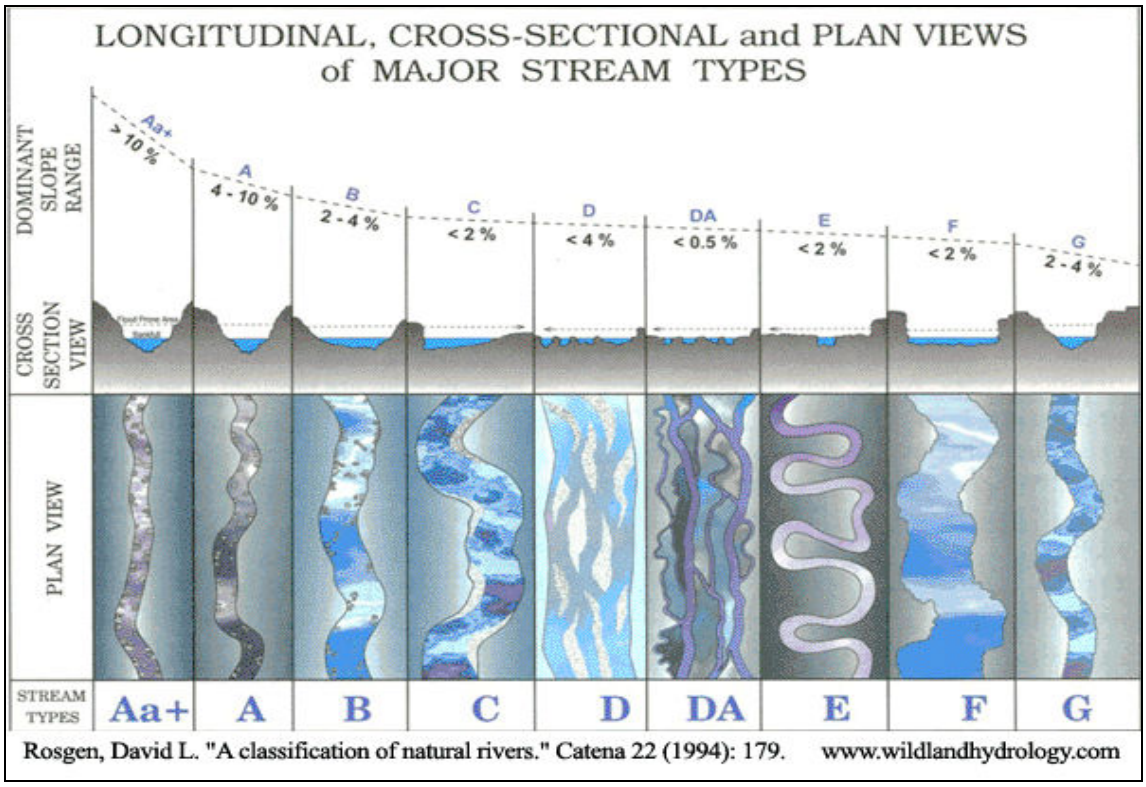
The Landis Ranch Homeowners Association maintains a regular stocking schedule on the property, as well as a feeding program in the upper third of the project study reach. The HOA manages recreation fishing throughout the property, with the lower segment designated as a "put & take" general fishery, and the upper segment managed as "catch & release" and "fly & lure only" waters to provide opportunities to catch trophy sized fish.

Stream Channel and Habitat Assessment Methods

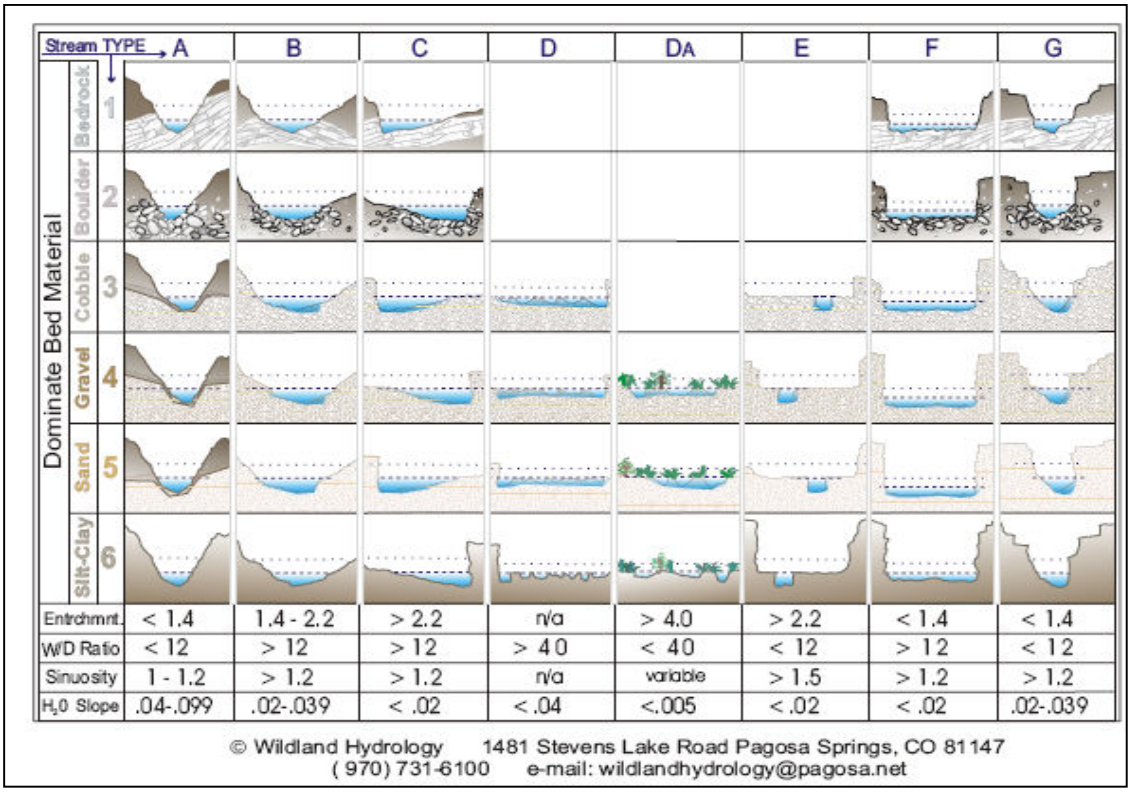
A single study reach was delineated for the Landis Ranch Property, based on valley type, channel morphology, and physical boundaries. The study reach was further delineated, for aquatic enhancement planning purposes, into sub-reaches based on the priority for treatment. A total of 5 priority sub-reaches were identified in the study. The study reach is located entirely on lands owned by the Landis Ranch HOA or its members. The reach begins at a barbed wire fence delineating J Diamond B Ranch / Landis Ranch property boundary, approximately 300 feet downstream the first bridge on Landis Ranch Road, and extends 11,285 feet upstream to another wire fence across the stream demarking the Landis Ranch / Pike National Forest boundary.

Rosgen Stream Classification System

Stream reaches are classified using the Rosgen Stream Classification System (D.L. Rosgen, CATENA, 1994). The Rosgen classification system groups streams by similar channel geomorphology, gradient, sinuosity and function. The classification system is stratified into three progressive levels, based on channel form, dominant substrate, and gradient. A graphic depiction of the Level 1 classification is shown in the diagram below.

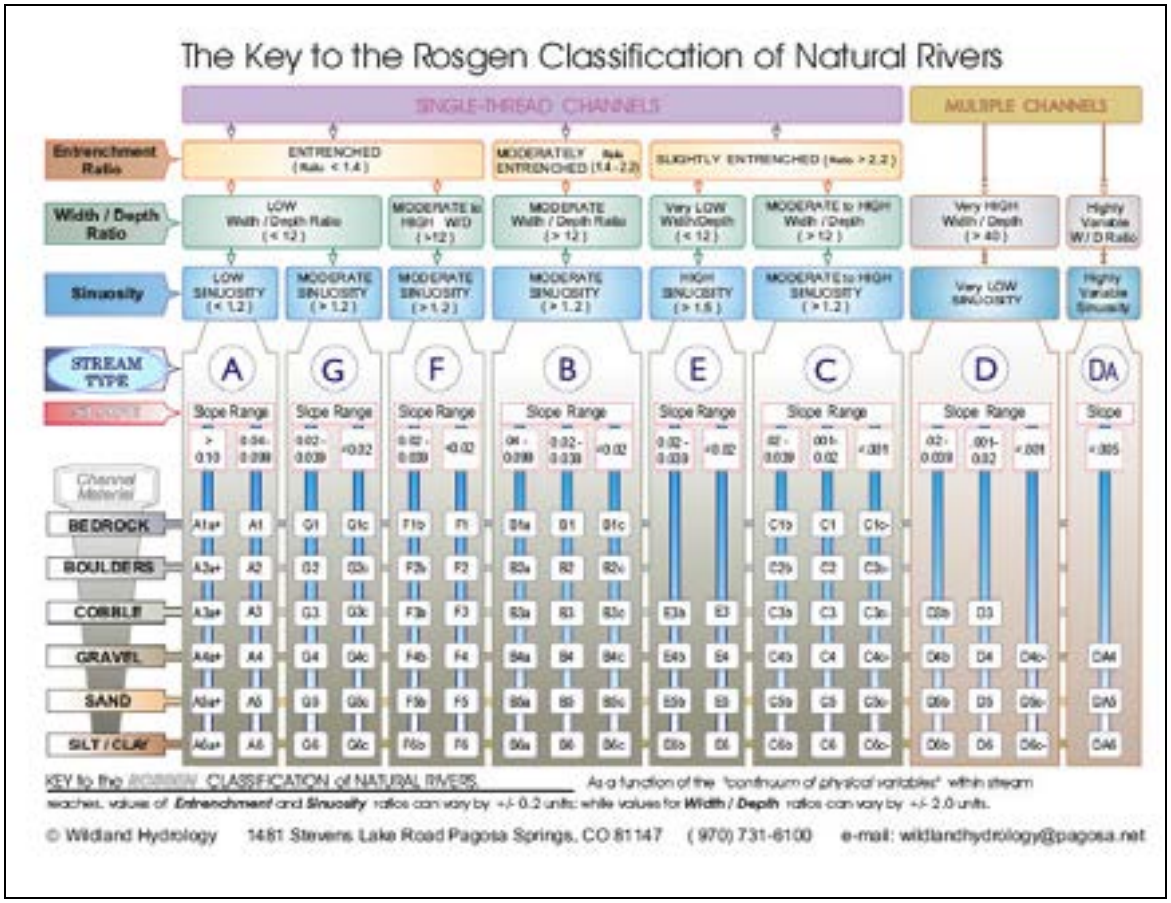


Generally, A type channels are typically found near the headwaters of mountain streams. Lower gradient B channels are characteristic of streams flowing though alluvial plains and broad mountain valleys below the headwaters. C and E channels tend to be found in lower elevation reaches with broad floodplains and low gradients. Each of these channel type supports different assemblages of aquatic habitats, and each can be important in



providing habitat complexity for trout. F and G channels are typically found in areas that have been subjected to some disturbance, such as a flood or significant down-cutting of the stream channel. Frequently, in recovering F type channels, a new C channel will begin to form in the flat bottom of the F channel, establishing a new floodplain at a lower elevation.

The Level 2 classification stratifies dominant substrate composition, and ranges from 1, bedrock or native bed material, to 6, which represents fine particles of less than 1/4" diameter. A diagram of the Level 2 classification is shown on the following page. Level 3 of the Rosgen system includes more detailed gradient and sinuosity values. For example, a Rosgen A3a channel would be a steep (<10%), deeply entrenched, and confined channel that exhibits low width/depth ratios and low sinuosity. Channel materials are typically unconsolidated, non-cohesive materials, dominated by cobbles, but also containing some boulders, gravel and sand. The A3a type is generally found in landforms associated with slump/earth-flow and debris torrent erosional processes, and would likely exhibit fluvial entrainments, mass wasting of steep adjacent slopes and debris scour. A detailed diagram of the Level 3 Rosgen classification system is shown below. The Rosgen classification system has been widely adopted by water professionals throughout the west, and is a useful tool for evaluation and comparative analysis of similar stream channels and habitat conditions.



Stream Channel Morphology:

Stream channel morphology was analyzed in detail during this assessment, and was determined by both plan and profile surveys conducted along the entire length of the study reach. The longitudinal profile of Tarryall Creek within the study area was observed to exhibit relatively low channel bed, water surface, and bank full gradient; with only slight entrenchment, and pool frequency consistent with "B" and "C" channels. The average slope of the channel, water surface and bank full elevation throughout the study reaches was estimated at approximately 0.5%. Stream channel sinuosity was generally low to moderate. LP plots of the study reach are presented in the charts below.

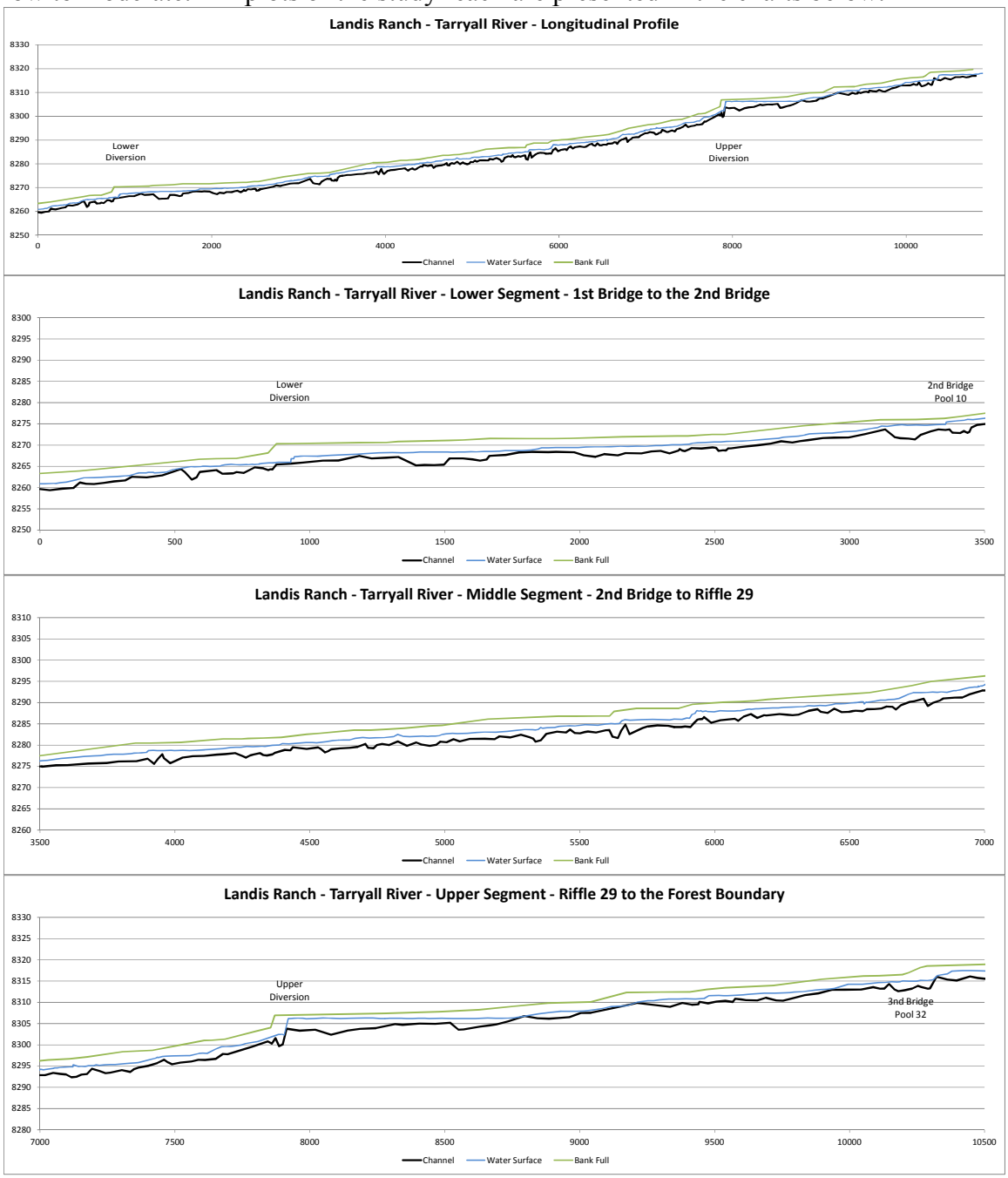


Chart 1: Longitudinal Profile of the study reach on the Tarryall River at Landis Ranch.

Map 2: Locations of Cross Sections in the Tarryall Creek study reach on the Landis Ranch.

Eight cross-sections were surveyed in the study reach, and the locations are shown in Map 2 on the previous page. Cross sections were surveyed across the entire valley bottom, in order to determine bank full width, width/depth ratio, flood prone width, and entrenchment of the river channel. Channel cross-sectional profiles throughout most of the study area were within the range of natural variability for B and C channels in fair to good condition. All of the cross sections exhibited a mostly low channel entrenchment ratio (flood prone channel width/ bank full channel width). The width/depth ratios observed were found, for the most part, to be consistent with what would be expected to occur in "B" and "C" channels, with the exception of the 800 foot segment immediately upstream of the lower diversion structure. A table of the cross section profile metrics is shown in Table 1 below, and plots of all cross sections surveyed may be found in the appendices.

LANDIS RANCH - TARRYALL RIVER CROSS SECTIONS								
XS #	1	2	3	4	5	6	7	8
Flood Prone Width	159.5	132.7	103.4	120.5	87.0	144.3	168.2	140.9
Bank Full Width	75.6	47.8	44.7	39.3	41.6	46.2	45.3	46.1
Mean Depth	1.49	2.06	2.26	1.94	1.96	1.76	2.31	2.39
W/D Ratio	50.68	23.18	19.74	20.22	21.18	26.18	19.58	19.31
Entrenchment	0.47	0.36	0.43	0.33	0.48	0.32	0.27	0.33

Table 1: Landis Ranch study reach cross-sections.

The chart below shows a comparison of channel cross sections through riffles in the study reach. The upper chart shows a typical channel cross section through Riffle 22. The lower chart shows the over-wide cross section through Riffle 5, upstream of the lower diversion structure. Width/depth ratios along this segment of the river were more than 2 times greater than in the other segments in the river, and appeared to be the result of river over-widening caused by the diversion structure itself.

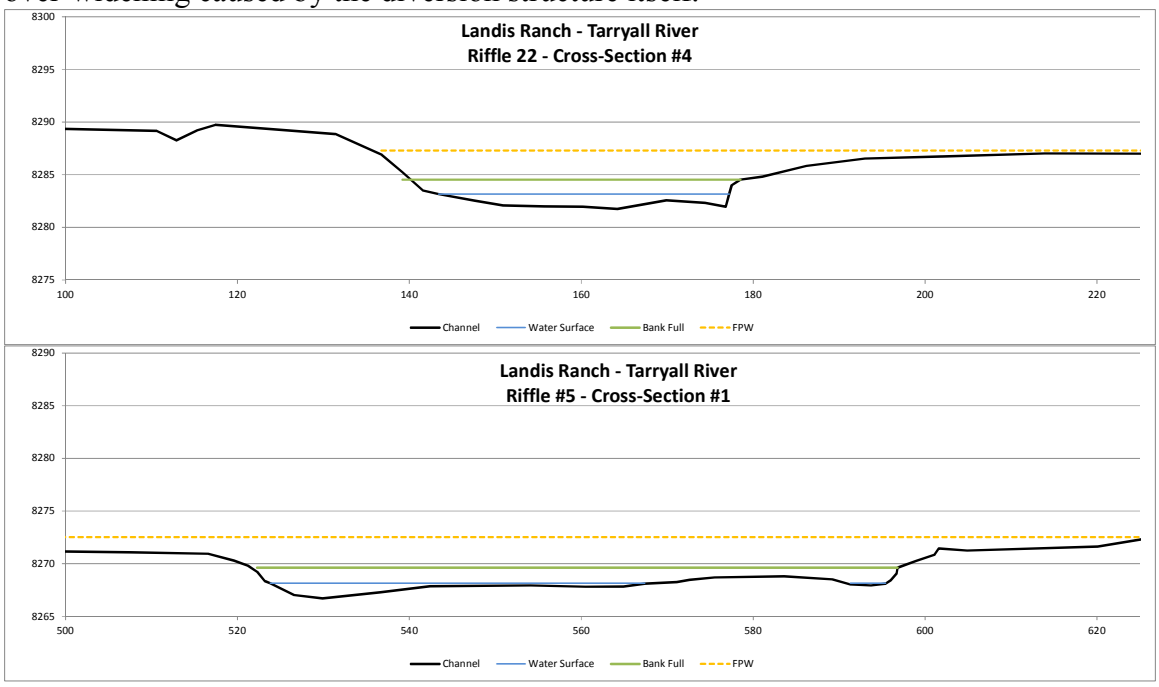


Chart 2: Comparison of cross section profiles in the Tarryall River study reach.

Comparison of channel cross section at Riffle 22 (upper photo) and the over-wide channel in Riffle 5, upstream of the lower diversion structure in the lower segment of the study reach on Tarryall Creek within the Landis Ranch.

Based on the observed reach longitudinal profile, channel cross-section characteristics, and stream substrate composition, the channel in the study area was classified as C3. There were limited segments in the upstream third of the study reach that were classified as B3c, exhibiting less sinuosity, narrower riparian buffer zone, and a pool/riffle sequence more akin to a B channel type. The stream appears to be vertically stable within most of the study reach; however, there does appear to be periodic high shear forces occurring along many of the banks, particularly along the segments of the river where active hay production is occurring.

Aquatic and Riparian Habitat Assessment Protocols:
The aquatic assessment is intended to characterize existing habitat conditions and evaluate current management and restoration potential. The stream reach is analyzed using a basin-wide stream habitat survey protocol developed by the US Forest Service and Colorado Division of Wildlife for smaller rivers and streams in the Rocky Mountain Region (Winters and Gallagher, 1997). This protocol is a modified basin-scale aquatic habitat inventory based on the Hankin & Reeves survey method. All meso-habitat types within a delineated reach are measured for multiple attributes, including physical dimension, morphic form, bank condition and composition, substrate class, and cover for salmonids. A brief description of meso-habitat types used in the protocol may be found in Table 2 below.

Type #	Meso-Habitat	Description
1	Glide	Exhibits uniform depth & laminar flow velocity. Little or no habitat complexity or cover.
2	2nd Channel Pool	Pool located on a secondary channel thread. Not included in total main thread habitat assessment.
3	Backwater Pool	Pool found on side of channel formed by an eddy. Not included in total main thread habitat assessment.
4	Trench Pool	Pool formed by a constriction in the channel. Typically associated with boulders or root-wad constrictions.
5	Plunge Pool	Pool formed by scour created by flow over an object. Typically associated with dams, boulders or large wood.
6	Lateral Scour Pool	Pool formed by a meander bend scour. Typically associated with the outside bends of meandering streams.
7	Dam Pool	Pool formed upstream of an obstruction in the channel. Typically associated with beaver or woody debris accumulations in the channel.
8	2nd Channel Riffle	Riffle in a secondary channel thread. Not included in total main thread habitat assessment.
9	Bedrock Riffle	Riffle dominated primarily by bedrock substrate. Gradient from < ½% to 6%, high and low gradient indicated by either a O or P structural association.
10	Boulder Riffle	Riffle dominated primarily by boulder substrate. Riffle dominated primarily by bedrock substrate. Gradient from < ½% to 6%, high and low gradient indicated by either a O or P structural association.
11	Cobble Riffle	Riffle dominated primarily by cobble substrate. Riffle dominated primarily by bedrock substrate. Gradient from < ½% to 6%, high and low gradient indicated by either a O or P structural association.
12	Gravel Riffle	Riffle dominated primarily by gravel substrate. Riffle dominated primarily by bedrock substrate. Gradient from < ½% to 6%, high and low gradient indicated by either a O or P structural association.

Type #	Meso-Habitat	Description (continued from previous page)
13	Sand Riffle	Riffle dominated primarily by sand substrate. Riffle dominated primarily by bedrock substrate. Gradient from < ½% to 6%, high and low gradient indicated by either a O or P structural association.
14	Rapid	High gradient (>6%) riffle. Typically lacks velocity shelter or pocket water association.
15	Cascade	Highest gradient riffle habitat. Typically associated with falls or very steep step-pool and pocket-water forms.

Table 2: A brief description of Meso-Habitat Types (Winters, 1997).

The advantage of the Winters protocol is that it is a repeatable method, and therefore can be used to quantify changes in habitat resulting from management, habitat enhancement, or natural events. For the purposes of the stream and riparian habitat study, all directional references are from a fisheries biologist's perspective, with left and right banks determined looking upstream along the channel.

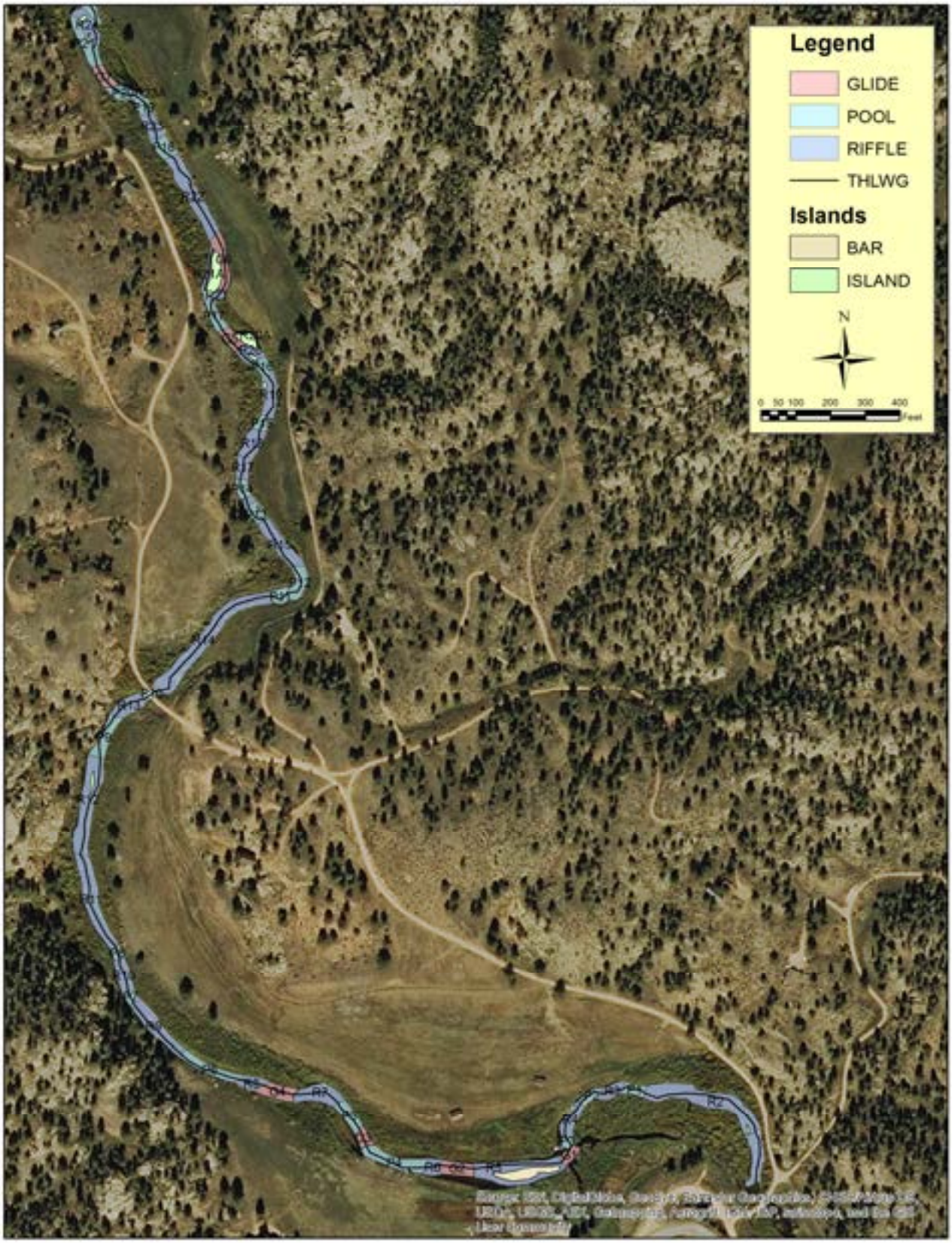
The failed lower diversion structure between Pool 3 & Glide 1, in the lower segment of the study reach on Tarryall Creek within the Landis Ranch.

Aquatic Habitat Survey Results:
A rapid assessment of aquatic habitat was undertaken within the reach, and a detailed stream habitat inventory was conducted concurrently with the morphological surveys in April 2015 within the project study reach. Discharge was estimated during the survey, based on the gauge record at Tarryall Reservoir, and was assumed to be approximately 40 cubic feet per second, which is within the low range of the estimated base flow of the stream.

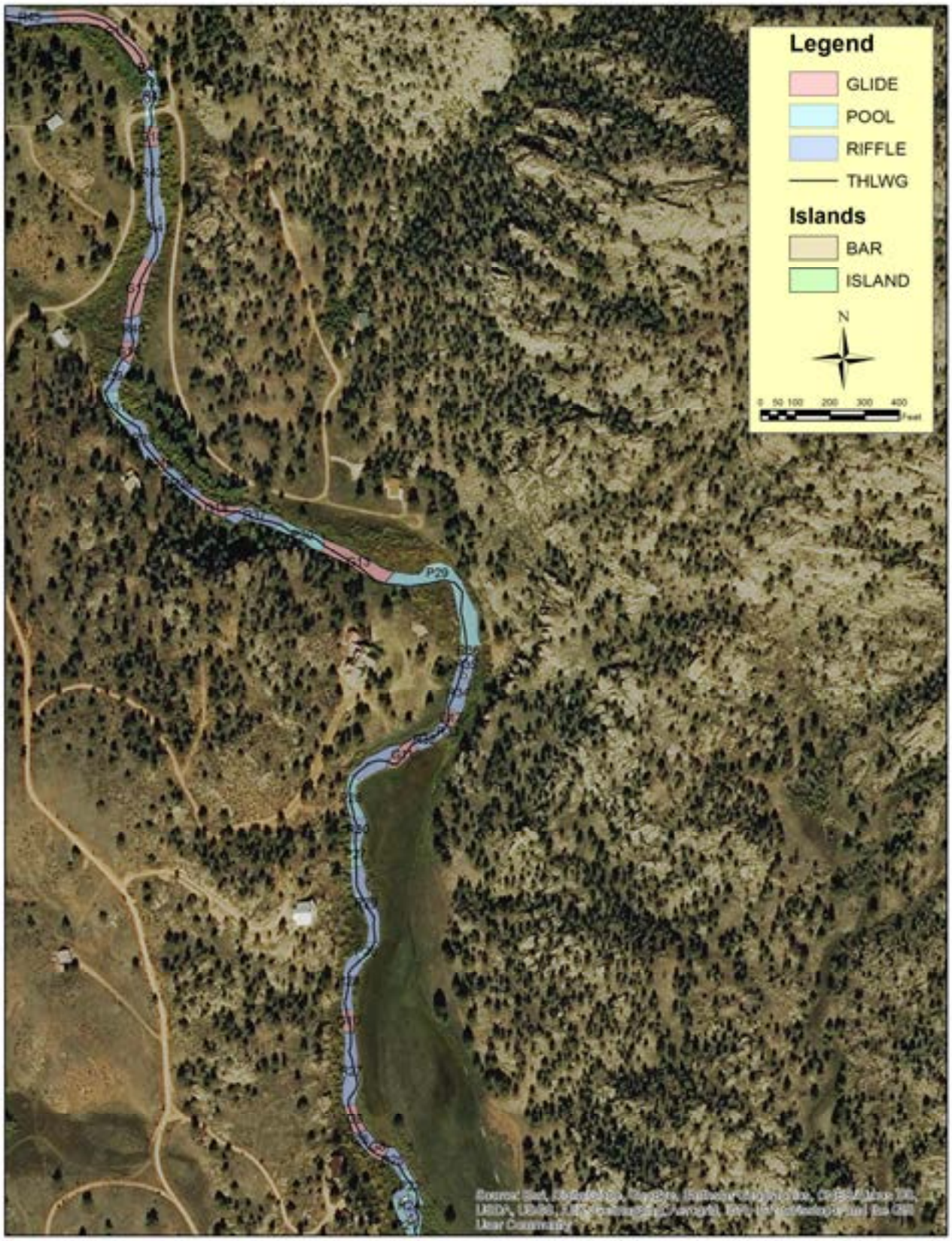
Gabion drop structure near the upstream boundary of the study reach.

Reach 1 Study Reach:
Reach 1 was characterized by a moderately sinuous channel through depositional material composed mostly of larger gravels, cobble, and small boulders. The reach exhibits a broad valley bottom with extensive riparian floodplain and low (< 1%) gradient. Relatively high sediment load was observed in Reach 1, and is likely supplied by both upstream and locally derived sources. Upstream sediment sources may include agricultural practices on private lands, and road/trail/river interactions on USFS lands immediately upstream of the reach. Local sediment sources are typically from failing stream banks, mostly associated with hay production along several segments of the reach. Our initial reconnaissance indicates that Reach 1 exhibits generally fair to good quality aquatic habitat for resident trout.

There were 98 individual meso-habitats measured in the reach (30 pools, 49 riffles and 19 glides), along a length of 10,985 feet of stream, and comprising a total wetted area of 404,599 ft^2. Maps of the surveyed habitats are presented on the following pages. The total area of the reach consisted of 58.1% riffles and 17.8% pools, with the remaining 24.1% consisting of glide habitat (Chart 3). The average wetted width of the stream was



Map 3: Locations of Meso-Habitat Units in the lower half of the Study Reach.



Map 4: Locations of Meso-Habitat Units in the upper half of the Study Reach.

35.7 feet throughout the reach. Stream banks were generally stable and vegetated throughout the reach, consisting mostly of willow, with occasional alder and sedge. There were 3,379 feet of actively eroding stream banks contributing sediment directly into the stream. This accounted for approximately 15% of the total length of banks in the reach.

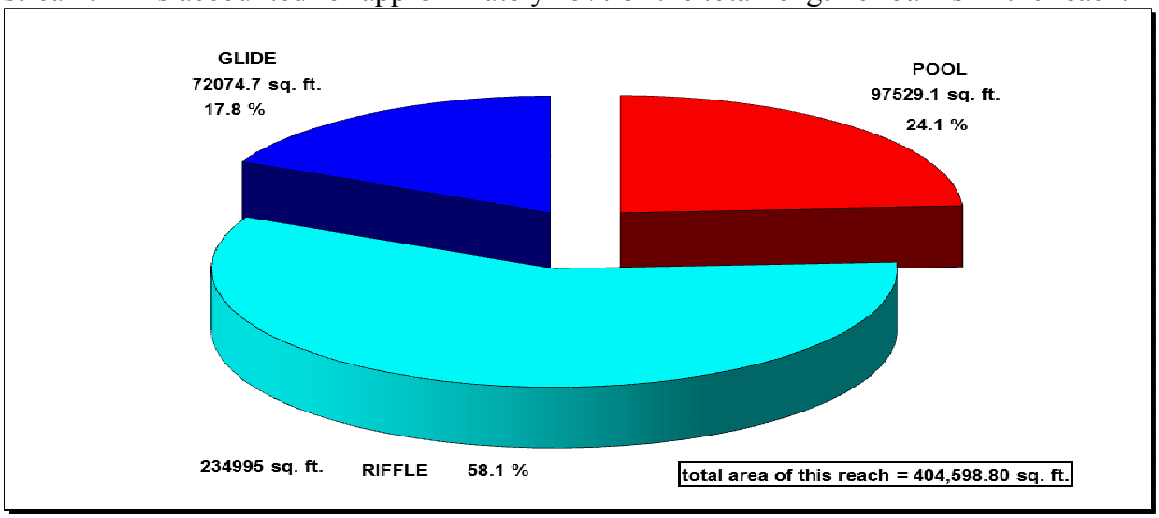


Chart 3 - Distribution of Pool, Riffle and Glide habitats in the study reach on Tarryall Creek within the Landis Ranch.

Riffle habitat consisted of a relatively equal distribution of higher gradient pocket-water dominated boulder riffles, and lower gradient cobble riffles (Chart 4). The boulder pocket water riffle form (Type 10) was the most common habitat type in terms of wetted area and accounted for 29% of the total reach. The pocket-water features in these riffles were considered fair quality, providing velocity shelter and in-channel cover for resident fish. Low gradient cobble dominated riffles (Type 11) were the next most common riffle habitat form, accounting for 23% of the wetted area of the reach. These riffles tended to exhibit more laminar flow and less habitat complexity, with little or no velocity shelter or cover. Gravel dominated riffles (Type 12) were also present in the reach, accounting for 5% of the wetted area, and were typically associated with in sediment deposition in segments around the diversion structures and other grade control features.

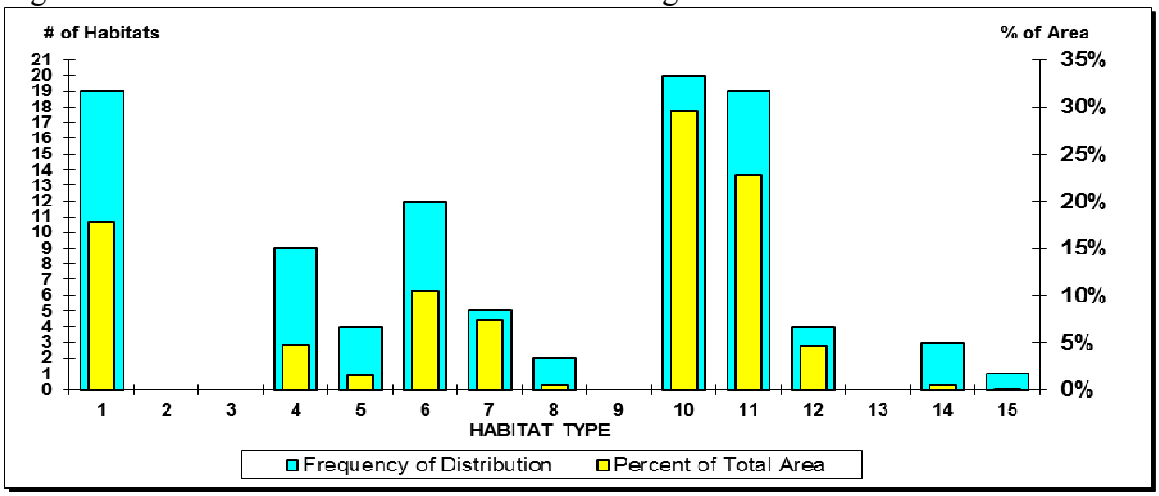


Chart 4 - Distribution of Meso-Habitat Types as a percentage of # of habitats and as a percentage of wetted perimeter of Reach 1 on Tarryall Creek.

Approximately 1% of the reach consisted of high gradient rapids and cascades, which were associated with the existing structures within the reach. One of the cascades, at the drop structure at the upper diversion, exhibited characteristics consistent with a barrier to migration of salmonids and other aquatic organisms. The average width of all the riffles observed in the reach was 38.6 feet.

The availability of cover for trout was observed to be poor in all riffles, amounting to less than 1% of the total wetted area of this meso-habitat form. The dominant cover type found in the riffle habitats was in-channel object cover (Type 2), and was typically associated with boulders in the Type 10 riffles. Large wood was present within riffles in the reach, but was relatively rare, with only 11 individual pieces being observed in this habitat form.

Typical boulder dominated pocket water riffle (R28) in the Tarryall Creek study reach.

The availability of pool habitat was within the lower range expected in B3c and C3 channels, comprising approximately 24% of the total wetted area. Lateral scour pools (Type 6) are the most abundant, comprising 10% of the total wetted area of the reach (Chart 4). Lateral scour pools are a common feature in C channels, and we would expect this to be the dominant form within the study reach. Dam pools were the next most common pool type, accounting for 7% of the wetted area of the reach, and were mostly associated with grade control and diversion structures placed in the channel. Individual dam pools were relatively large in size in comparison to other pools forms, due to the relatively high elevation of the forming structures to the bank full elevation of the river channel, and these habitats were storing significant quantities of sediment.

Trench pools and plunge pools were the least dominant pool forms, comprising 5% and 1% of the reach respectively. The trench pools were mostly associated with boulder constrictions in the channel throughout the reach. Plunge pools were typically found immediately below structural features such as the diversions. The average wetted width of all pool types found within the reach was 32.4 feet.

Most of the pools in Reach 1 exhibited some in-filling of sediment, mostly consisting of smaller particles of decomposed granite. The average pool depth in Reach 1 was 1.56 feet. Residual pool depth (RPD) in Reach 1 was found to range from 0.3 to 2.4 feet, with an average of 1.12 foot throughout the reach. Maximum pool depths ranged from 1.7 to 3.9 feet, with the average maximum depth found to be 2.4 foot. Residual pool depth (RPD) in Reach 1 was considered to only fair, but is likely adequate to provide over-wintering habitat for salmonids in this segment of Tarryall Creek. Cover for trout accounted for slightly less than 20% of the total wetted area of the pools, and was considered fair for a stream of this size.

Sediment deposition observed in Pool 12 within the Tarryall Creek study reach.

Glide habitats were quite common, comprising nearly 18% of the reach. Glide habitats appeared to mostly be the result of sediment inundating and filling segments of the river that would otherwise exhibit a pool meso-habitat form. Some of the glide habitats observed may also be the result of armoring of the channel bed and lack of scour. Cover for trout was very limited in these features, comprising less than 1% of the wetted perimeter of the habitat. The average width of glide habitats in Reach 1 was 36.1 feet.

Sediment deposition observed in Glide 16 within the Tarryall Creek study reach.

All forms of cover for adult trout accounted for approximately 5% of the wetted area of Reach 1 (Chart 5). In-channel object cover (Cover Type 2) was the most dominant type observed in the reach, being mostly associated with the higher gradient pocket water riffles and perimeters of the pools in the stream channel. Pool depth cover (Cover Type 5) was the next most dominant form, and overhead cover was the least dominant form of cover observed in the reach. Pool depth cover greater than 1.5 feet deep is a good indicator of over-wintering capacity of the stream, and was considered to be fair for a stream of this size. Large wood was relatively lacking in the study reach, with only 35 pieces observed over the two mile length of the river. Large wood is an important habitat forming feature in streams like Tarryall Creek, creating additional scour and habitat complexity. The lack of large wood may be a limiting factor for resident trout populations in the reach.

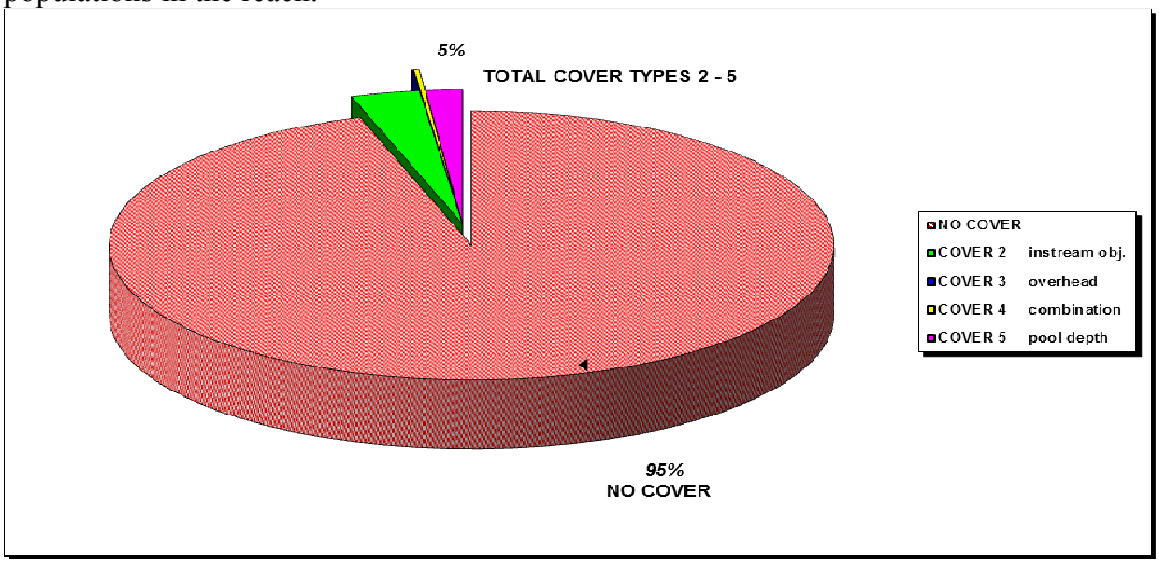


Chart 5 - % of cover for trout to the total wetted perimeter in Reach 1 on Tarryall Creek.

Stream bank stability was generally good throughout the reach (Chart 6). Typically, well vegetated stream banks were found on both sides of the stream, with the exception of segments where hay production extends to the waters edge. Stream bank stability was primarily influenced by robust deep rooted riparian vegetation, which was mostly dominated by willow along the banks. More than 60% of the bank rock content on either side of the river was comprised of smaller particles of soil and decomposed granite (Chart 7). The remainder of the river banks consisted of larger materials ranging from small cobble to large boulders and parent bedrock. River banks comprised of smaller materials (Type 7 & 8) are susceptible to erosion due to shear along the bank at high flow. In areas where deep rooted riparian vegetation has been altered or removed, we observed unstable banks that were in varying states of collapse into the river.

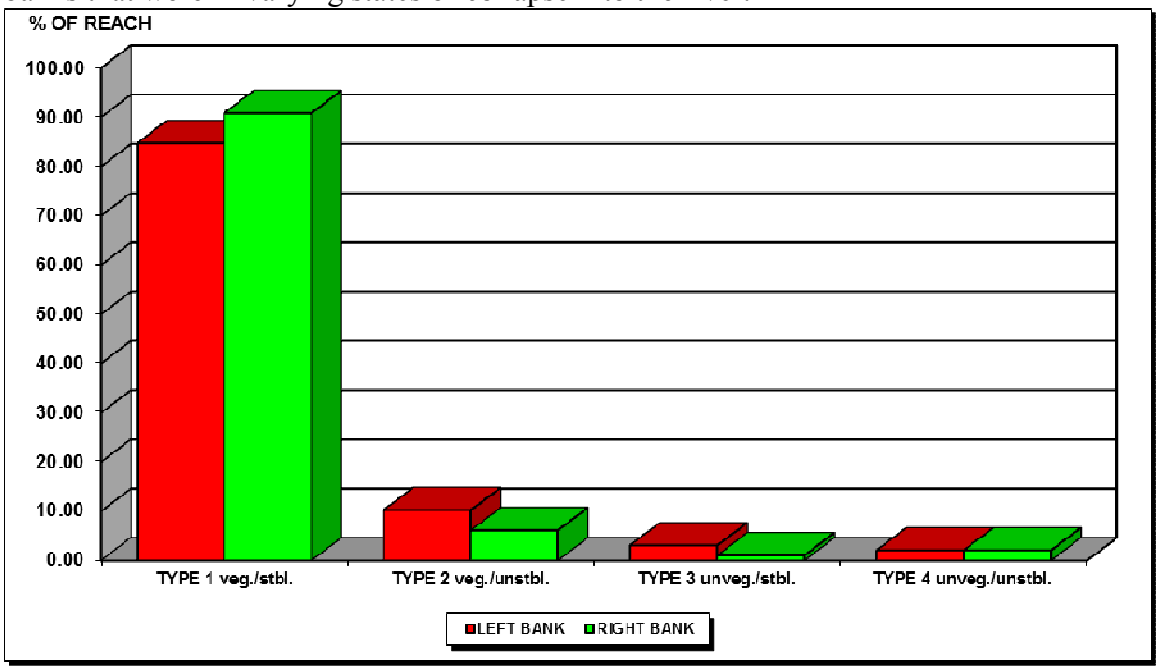


Chart 6 - Percentage of stable banks to unstable banks in Reach 1 on Tarryall Creek.

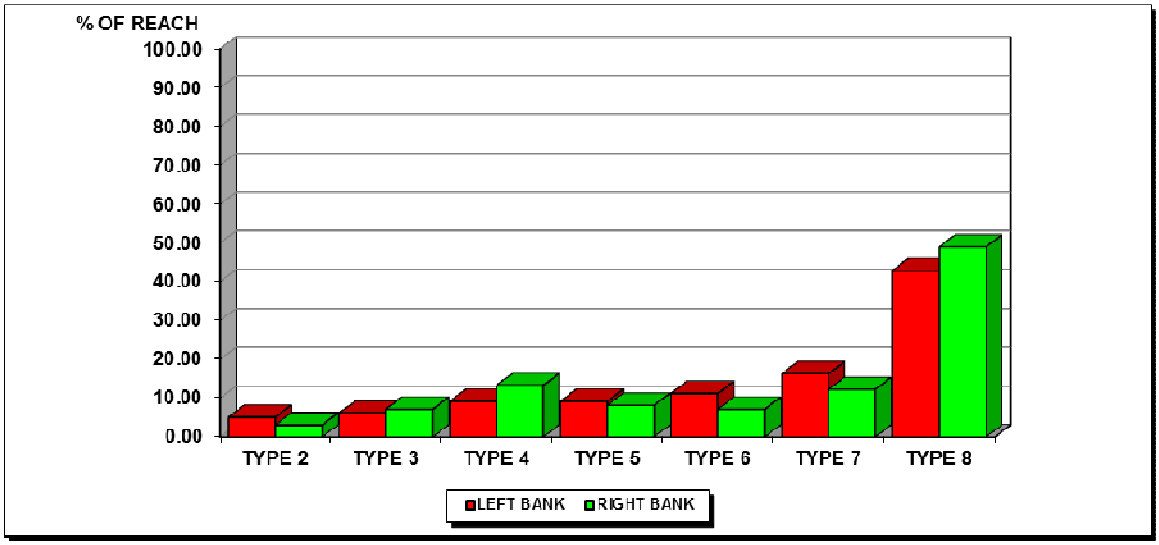
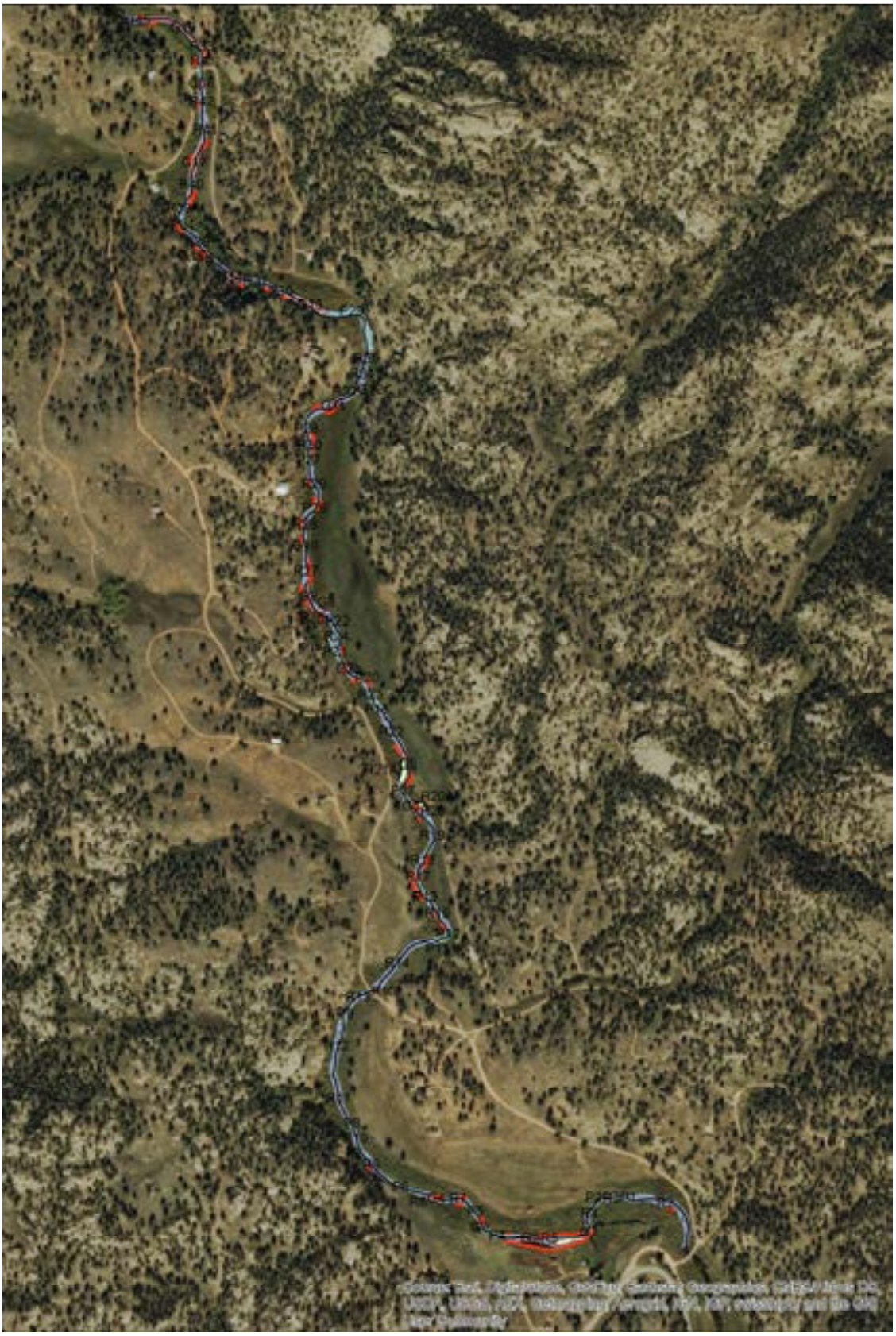


Chart 7 - Percentage of bank rock content sizes in Reach 1 on Tarryall Creek.



Map 5: Locations of active eroding banks on the Landis Ranch study reach. Red lines indicate areas of active bank erosion and collapse.

Active stream bank erosion in the study reach was a concern, comprising more than 15% of the total river bank length in the reach. Actively eroding banks in the reach were typically associated with areas where hay production is occurring immediately adjacent to the river, as well as in segments upstream and downstream of the lower diversion structure. Smaller lengths of active stream bank erosion occur throughout the reach, and a plot of these areas is shown in Map 5 on the previous page.

Eroding river banks observed along Riffle 21&Glide 6 in the Tarryall Creek study reach.

Summary:

In general, the Tarryall Creek study reach on the Landis Ranch is in fair to good condition, and can support a quality recreational fishery for the benefit of the members of the home owners association. The river exhibits adequate habitat to support adult sport fish, but only very limited habitat for juvenile and young-of-the-year. The river is not at its full potential, however, and we identified several issues that may lead to a decline in the fishery over the long term. The stream morphology and habitat assessment are a "snap-shot" view of the existing river conditions in the early spring of 2015. Because we do not have previous data available, we cannot develop a trend analysis from the existing data. That being the case, it is clear, however, that several concerns identified during the assessment have the potential to degrade the reach and further limit the recreational fishery.

We identified the two irrigation diversion structures as the most significant threat to the long term health of the river in the study reach. The lower structure, which has mostly failed, has resulted in significant over-widening of the river channel for several hundred feet upstream. Subsequent deposition of sediment and further weakening of adjacent

The upper diversion structure in the Tarryall Creek study reach.

stream banks is continuing to make this situation worse. The upper diversion structure, while structurally sound, is a significant barrier to aquatic organism passage, and effectively splits the upstream and downstream halves of the reach into two separate and isolated ecosystems. Reconstruction of these structures to allow for fish passage, sediment transport, and restoration of river dimension, pattern and profile will substantially benefit the overall health of the river within this reach.

As stated in the habitat narrative above, the number of actively eroding stream banks in the study reach is a concern, and these should be addressed before the river over-widens to the point where it will no longer transport its sediment load. Natural bank erosion processes are expected, however, they typically do not exceed 5% to 10% of the total bank length. Streams with erosion rates of greater than 20% of stream bank length are generally considered degraded. Treatments of eroding banks should incorporate riparian buffers and adjustments to agricultural operations in addition to any mechanical treatments.

In order for the study reach to attain its full potential, habitat enhancements may be considered to build in additional complexity and cover throughout the reach. In particular, a few of the numerous glide habitats observed may be converted into pool habitat through manipulation of flow and scour to deepen these features. Pocket-water habitat could be significantly increased using large wood and strategic boulder placements in many of the habitat limited Type 11 riffles. Improving in-channel object cover would substantially improve holding cover for adult fish in the reach during period of high run-off flows. Additionally, there are several sites where secondary channels could be modified to create back-water pool habitats, providing critical high-flow habitat refugia for young-of-the-year and juvenile trout.

Restoration and Enhancement Plan:

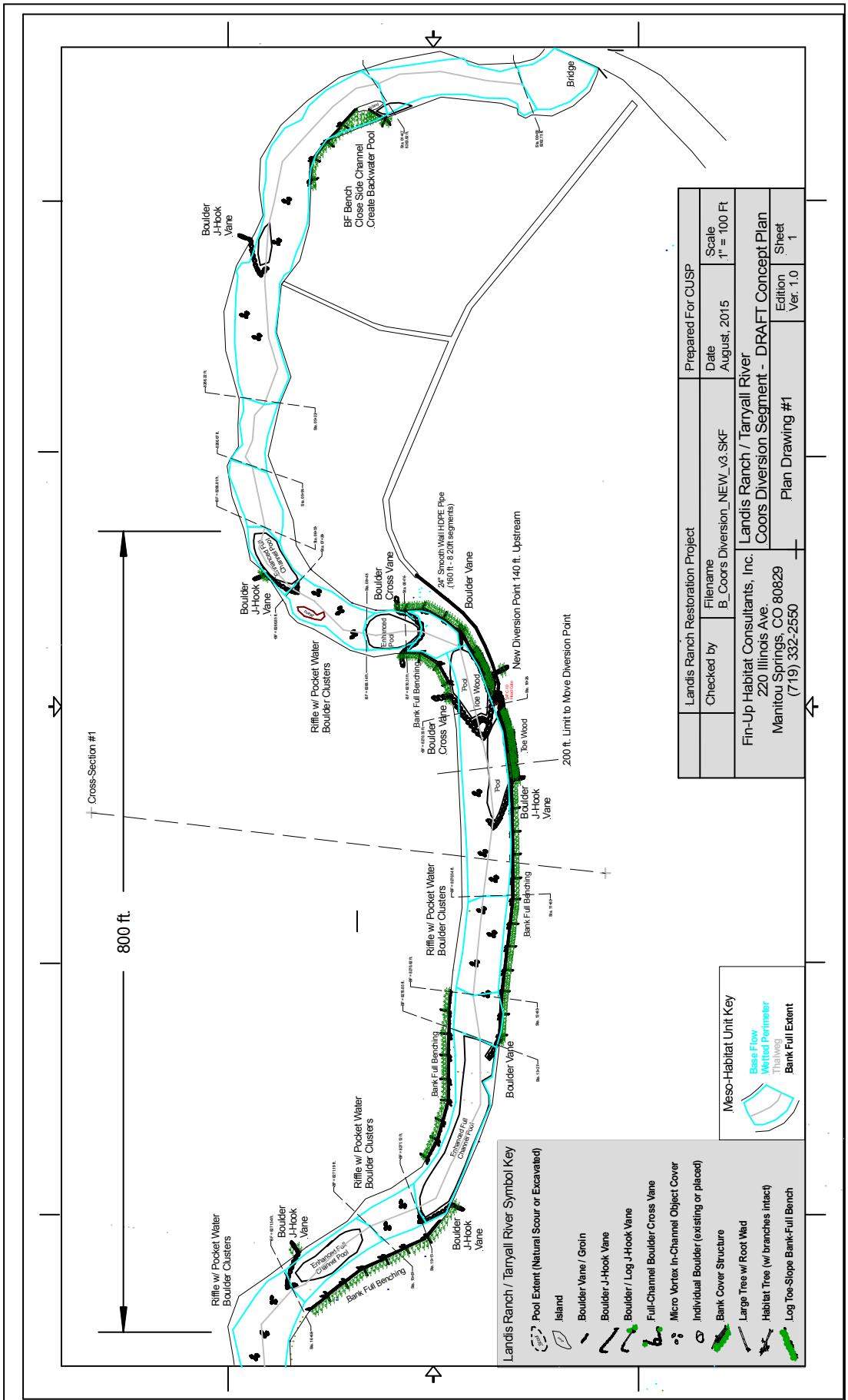
Based on the results of the aquatic assessment, we have identified five priority projects that should be considered to address issues with channel morphology, aquatic organism passage, and overall health and long term sustainability of the fishery on the Landis Ranch. These projects are described in detail below, and are ranked in order critical need. Rankings were based on how great a threat the given issue is to the long term morphological and biological function of the reach. While it would be advantageous to implement all of the projects at once, we recognize the realities of budgets and funding, and the work may be implemented over a period of several years, with the highest priority work being accomplished first.

Priority #1: Lower Diversion Structure Reconstruction & Channel Realignment.

The lower diversion structure, also known as the Coors Diversion, will need to be reconstructed before the beginning of the next irrigation season. At present, if the structure is replaced with a similar structure at the same diversion point, the channel upstream will continue to aggrade and over-widen. The rebuilt structure will continue to function at great risk of failure due to lateral migration of the channel on the north side of the feature, and will continue to require regular maintenance. There is an opportunity here that will soon close to relocate the diversion structure 140 feet upstream, at a location that is considerably less susceptible to lateral migration. A large boulder cross-vane would be constructed at this new diversion point, maintaining a stage at the head gate to provide 11 cfs to the diversion point at base flows. A 24" Waterman C-10 head gate will be installed upstream of the south leg of the structure where it ties into the river bank. The head gate will be attached to 24" HDPE smooth wall plastic pipe, which will convey diverted flow to the existing ditch at the original diversion point. A second boulder cross vane will be constructed immediately downstream of the existing diversion point to provide a grade control, and to limit the hydraulic jump of the diversion to less than 18", enhancing aquatic organism passage through the diversion point. We have made a preliminary inquiry with the Colorado Division of Water Resources, and have confirmed that we may move the diversion point up to 200 feet without necessitating a re-adjudication of the water right.

The diversion and downstream cross vanes will provide a channel dimension control for additional toe-wood and bank full benching to significantly reduce the width/depth ratio of the river. We have established a target W/D ratio of 25 – 26 for this 800 foot segment, beginning at the old diversion point and extending upstream into Riffle 7. In addition to the cross vanes, four boulder J-Hook vanes and two smaller boulder vanes will be utilized to redirect the thalweg and reduce shear along the river bank. These features, combined with strategic placement of boulder pocket water clusters throughout the segment, will provide for enhanced habitat and complexity within this very limited segment.

A drawing of the proposed restoration is provided on the next page. A high resolution drawing may also be found in the appendices to this document. We have listed this project as the highest priority for the project due to the limited time available to accomplish the work. All necessary materials, including boulders and over 80 pieces of large wood are available on site. We estimate it would take approximately 10 days to complete at a cost of $59,000.00. Timeline for construction would be fall/winter 2015.



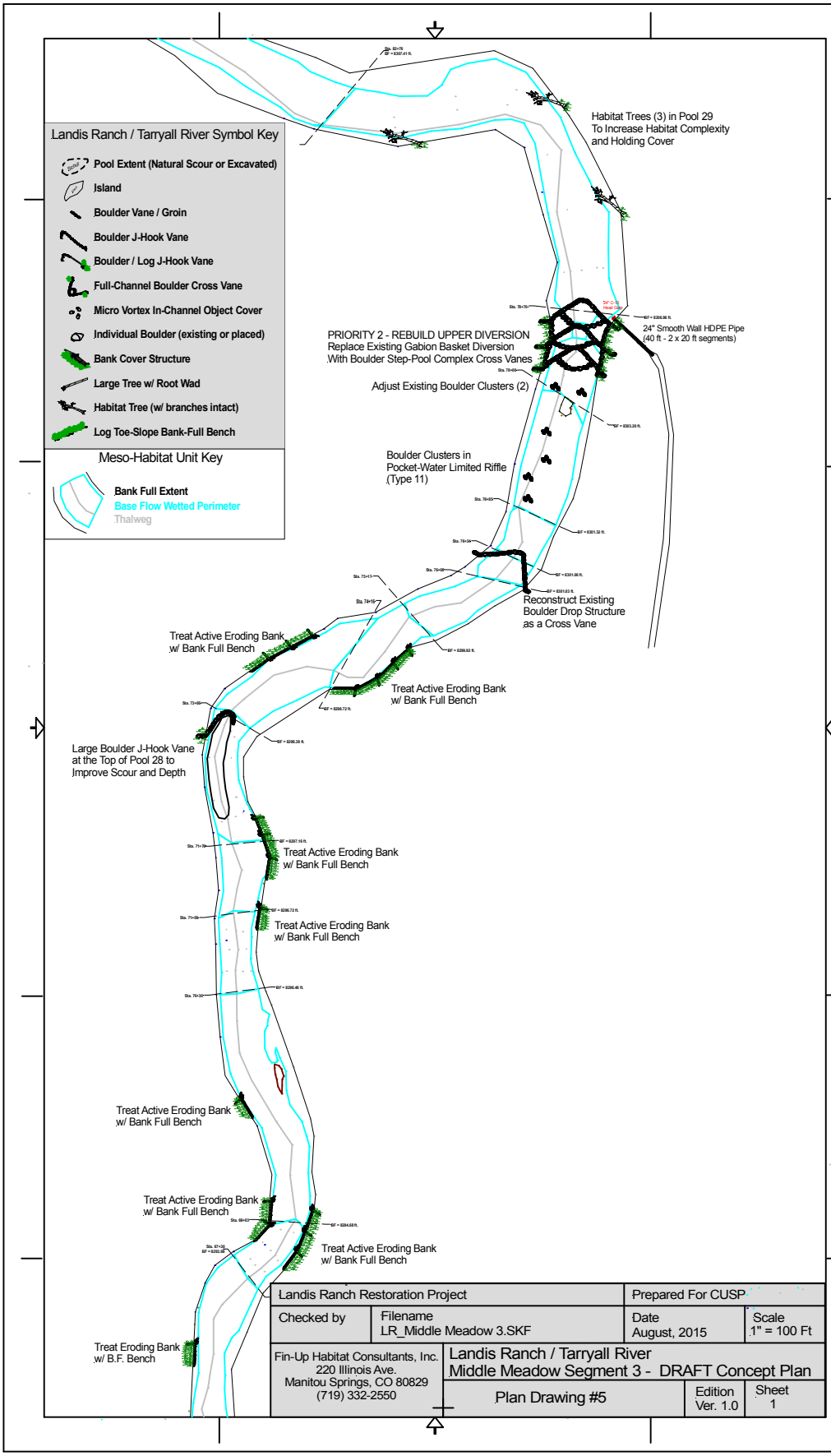
Drawing 1: Restoration Site Plan for the Lower Diversion Structure (Priority #1), and other habitat enhancements (Priority #5)

Priority #2: Upper Diversion Structure Removal and Replacement.
The upper diversion structure is a significant barrier to fish migration, and is also at risk of failure over the long term due to the materials used in construction. The diversion drop structure consists of a series of wire gabion baskets stacked in the river channel perpendicular to the direction of flow, with a head gate and narrow sand-out channel on the northeast side of the structure. Gabion baskets for river control structures are notorious for failure due to corrosion of the containment wire, and are occasionally referred to as "time-release landslides", due in part to their short lifespan and high rate of failure. While frequently utilized in the past as a cost savings measure, or where adequate large rock was unavailable, these structures are generally not recommended any more for long term use in perennial rivers and streams.

The upper diversion structure may have already partially failed in the center, but the greatly accelerated flow through the center of the feature precluded a closer inspection. The longitudinal profile survey indicated that the feature has a hydraulic jump elevation of nearly 4 feet, with only a shallow and small pool feature below, severely limiting maximum burst velocity for fish attempting passage through the structure. The structure also presents a safety hazard for fishermen or other river recreationists in the large pool immediately upstream, who might be swept through the structure during high flows.

The priority #2 project would remove the existing structure, and replace it with a series of boulder cross vanes interlinked with each other to create a step pool cascade. The step pool cascade would tie together the existing channel slope above and below the diversion point while creating a "fish ladder" of sorts to allow for aquatic organism passage. The structure would begin approximately 75 feet downstream of the existing diversion, allowing the existing diversion point to be maintained. A considerable quantity of large boulders, of specific size and shape, will be required to successfully complete the new diversion, and we recommend that rock be imported from a nearby commercial quarry to ensure that properly sized materials are available for the work. We estimate it would take approximately 3 days to complete at a cost of $40,250.00. Timeline for construction would be the fall of 2016.

Example of linked cross vanes creating a boulder step-pool cascade. West/Trail Creek Restoration Project 2012, Douglas County, CO.



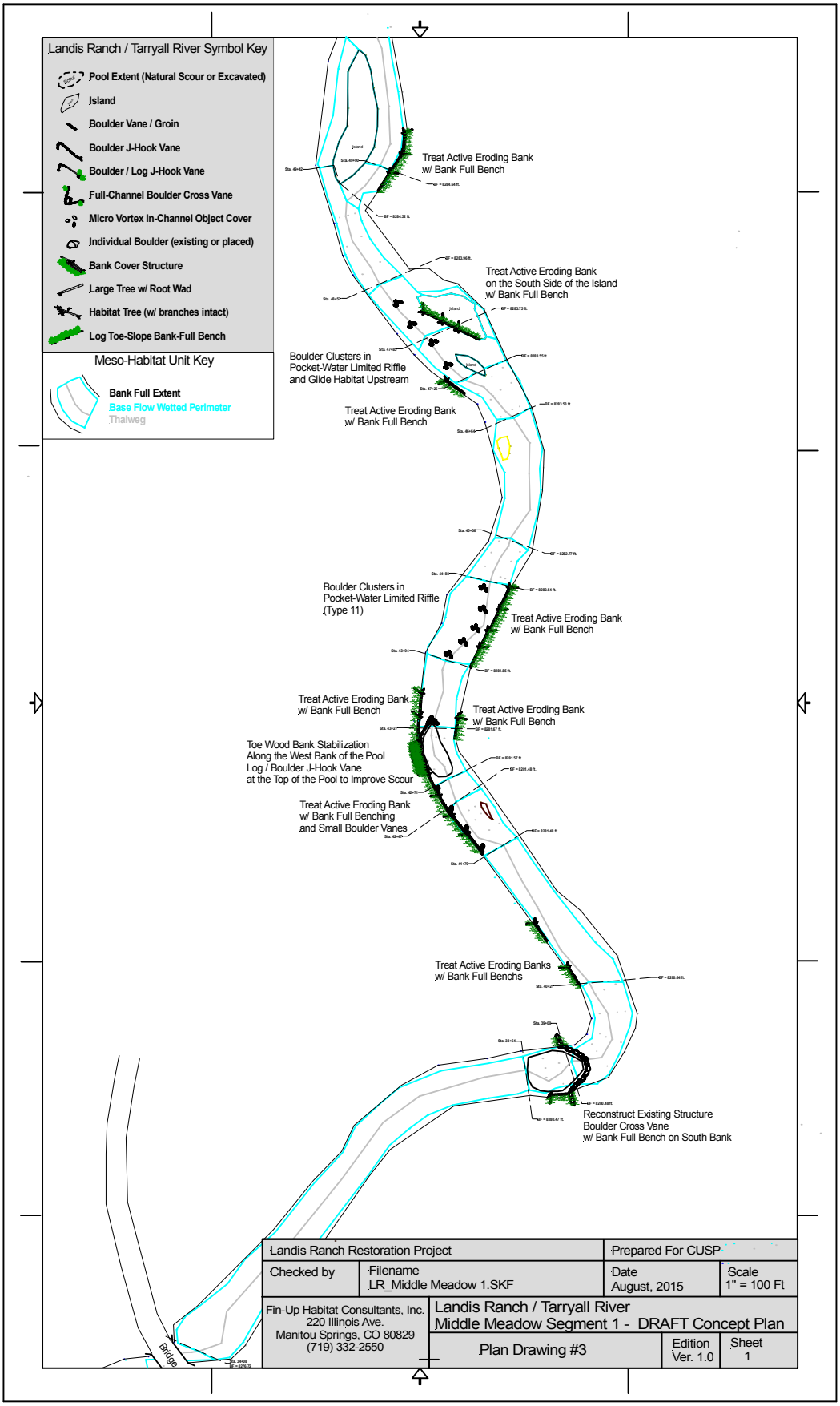
Drawing 5: Restoration Site Plan for the Upper Diversion Structure (Priority #2), existing drop structure replacement (Priority #4) and river bank stabilization & other habitat enhancements (Priority #3).

Priority #3: Hay Meadow River Bank Stabilization and Habitat Improvements.
The 3rd priority project should address the actively eroding and unstable river banks immediately adjacent to the hay meadows in the middle of the study reach. This segment would extend from the 2nd bridge across Tarryall Creek upstream to the 2nd diversion structure. Extensive bank full benching, utilizing large wood for toe slope armoring and native willow/sedge mat transplants harvested within the project area, will be constructed in this segment. Where appropriate, toe wood will be utilized in lieu of bank full benching to create deep pool habitat and complexity. In addition to the river bank mechanical treatments, extensive hand planting of willow can be accomplished by HOA volunteers under the direction of CUSP project staff.

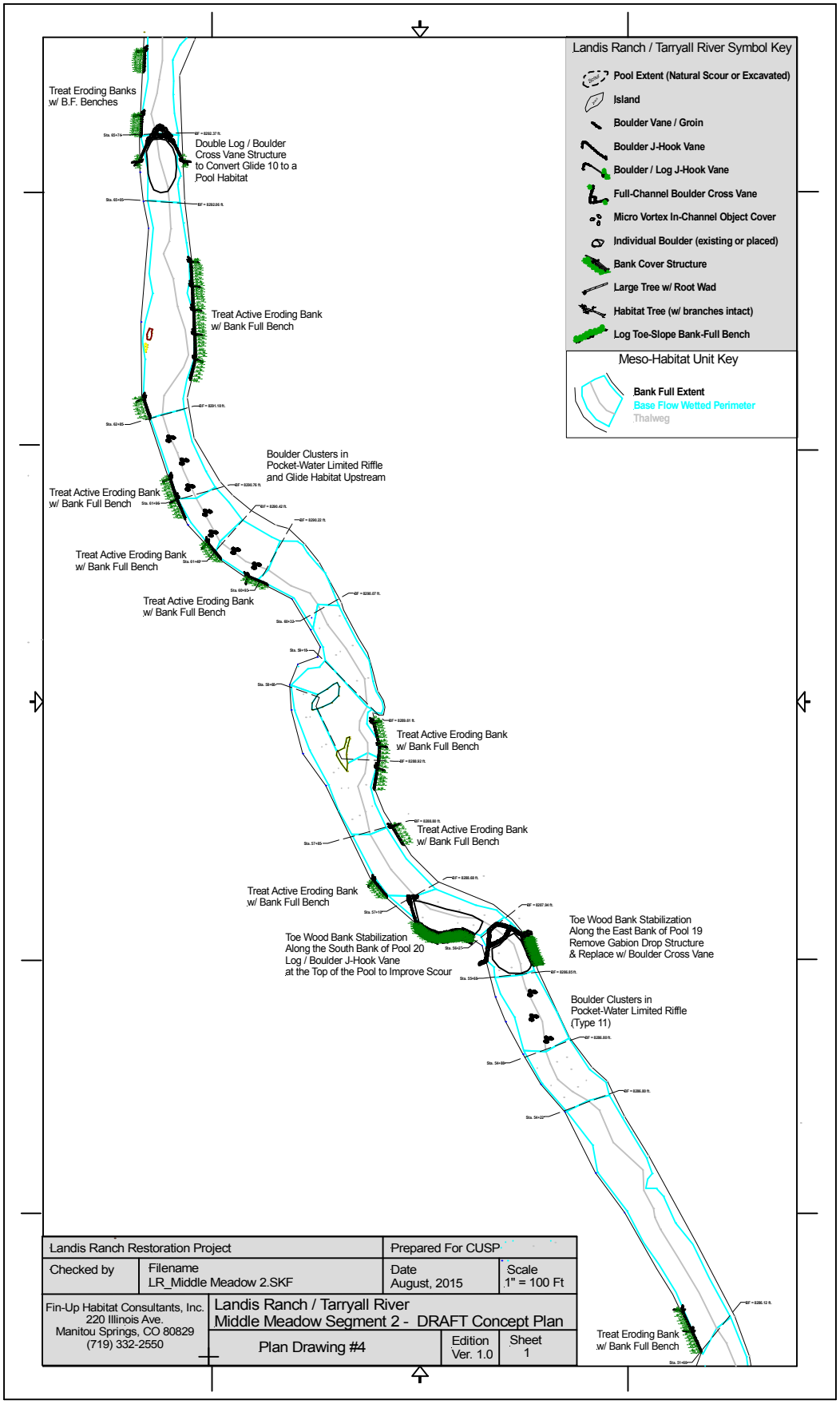

Example of bank full benching techniques on the South Platte River.

Generally, we prefer to enter a segment of the river only once, and complete all recommended treatments and objectives, as this does less damage to the stream bed/banks, and adjacent riparian areas. In the case of priority project #3, we strongly recommend that the in-channel habitat features and enhancements be completed in conjunction with bank stabilization work. Two log/boulder J-Hook vanes, one boulder J-Hook Vane, 1 double log cross vane and up to twenty-five boulder clusters will be installed to increase holding areas and cover within the segment. The additional cost of building the habitat enhancements concurrent with the bank stabilization will be minimal, as most of the materials are available on site, and it will significantly reduce the recovery time of affected vegetation following construction. Drawings of the proposed restoration in priority #3 are provided in Drawings #3 & #4 on the next page and Drawing #5 on the previous page. High resolution drawings may also be found in the appendices to this document.

We strongly recommend that a riparian buffer strip be negotiated with the owner of the hay meadows before undertaking this work. At a minimum, we would recommend a 10-15 foot buffer between the active hay operations and the river's edge. If livestock grazing is going to occur, temporary electric riparian fencing should be considered to protect the emergent vegetation on the newly restored river banks. We estimate it would take approximately 7 – 10 days to complete at a cost of $58,250.00. Timeline for construction would be late fall 2016 or the summer of 2017. We should note that fencing is not included in our estimate for the cost of this work.



Drawing 3: Restoration Site Plan for river bank stabilization & other habitat enhancements in the middle segment of the study reach (Priority #3) and existing drop structure replacement (Priority #4).



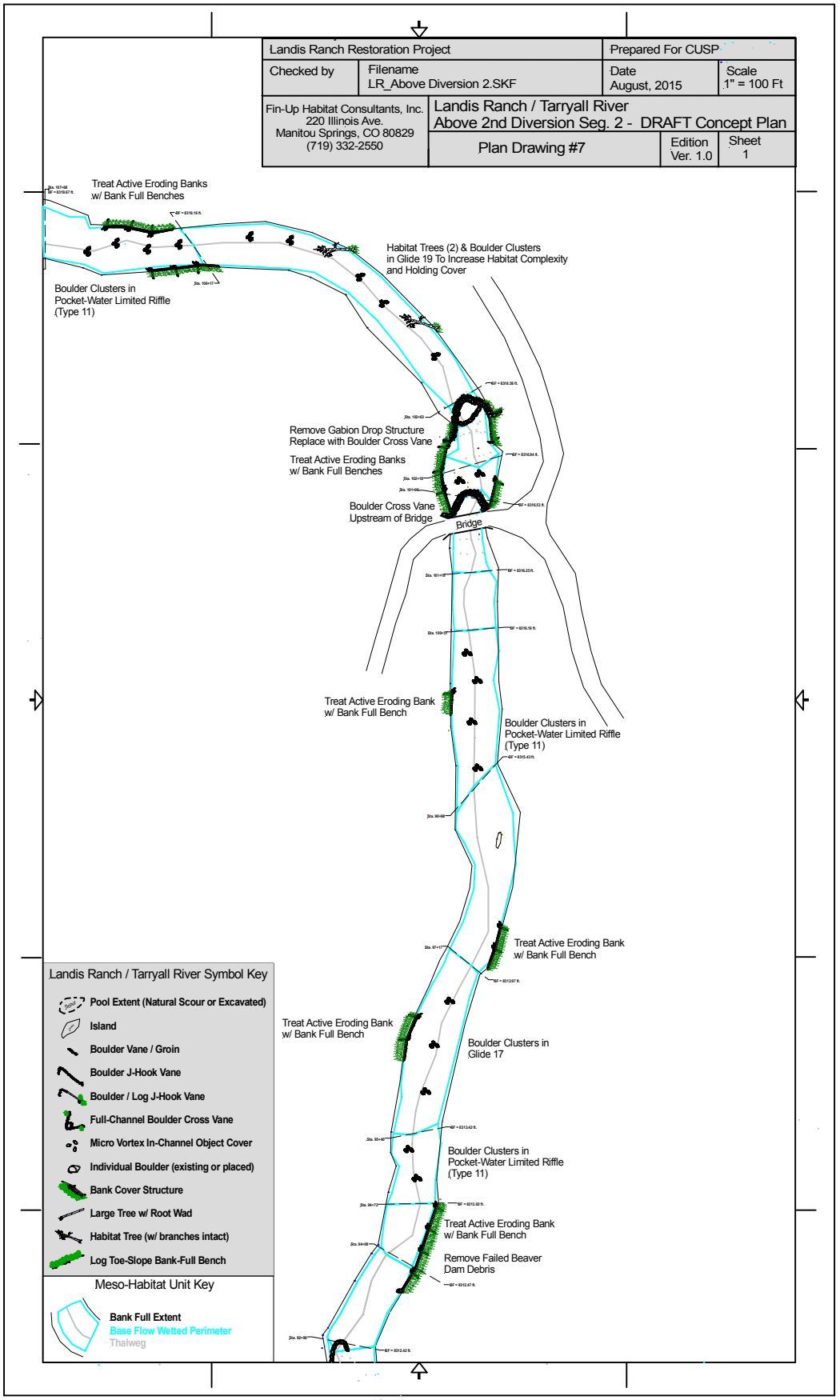
Drawing 4: Restoration Site Plan for river bank stabilization & other habitat enhancements in the middle segment of the study reach (Priority #3) and existing drop structure replacement (Priority #4).

Priority #4: Existing Structure Repair and Reconstruction.
We identified four existing full channel drop structures during the assessment that are currently non-functioning, at risk of failure, or performing in a manner that is causing undesirable effects upstream and downstream of the structure. Two of the structures are constructed of gabion baskets filled with small cobble, and are likely nearing the end of their useful lifespan. The lower gabion drop structure is located at Riffle 23A. This structure will be replaced with a full channel boulder cross vane, with a small step pool feature in the center of the structure to aid in aquatic organism passage. The second gabion drop structure is several yards upstream of the third bridge at Riffle 44, and has accumulated a large quantity of sediment immediately upstream, resulting in a homogeneous glide habitat. This structure will need to be carefully removed to control sediment movement out of the long glide upstream. This drop structure will also be replaced by a boulder cross vane with a small pocket water step pool in the center.

The other two existing drop structures designated for maintenance and/or replacement are constructed from larger boulders. One of these structures, located at Riffle 33, has partially failed on the left side. The center is also set at an elevation that has created deposition of sediment in the glide habitat above. This structure will be reconstructed as a boulder cross vane, lowering the center of the structure, to allow for improved sediment transport and scour in the glide immediately upstream. Ideally, this structure will function as the riffle crest, allowing us to convert the glide into a pool habitat with greater depth and complexity.

The other boulder drop structure is located several hundred feet upstream of the second bridge, dividing Pool 11 and Pool 12. The structure consists of a relatively straight boulder drop perpendicular to the flow of the river, immediately below a very sharp 90 degree meander bend in the river. The structure is relatively flat across its entire length, at an elevation that reduces the river's sediment transport function through the feature. The structure ties into the river bank at an angle perpendicular to the channel orientation, resulting in degradation and over-widening of the river banks in the pool downstream. We will completely reconstruct this structure as a boulder cross vane, lowering the center of the structure to ½ bank full elevation or less, and repair the eroding banks downstream with log bank-full benching.

Drawings of the proposed restoration in priority #4 are provided in Drawings #3, #4, #5 and #7. High resolution drawings may also be found in the appendices to this document. We have broken out this work as a separate priority primarily for planning and budgeting purposes. It will likely be cheaper, and more cost efficient to perform this work in conjunction with work on priority #3 and priority #5, in order to eliminate the need to re-open segments of river that have already been treated. If the work is undertaken as a separate project, we estimate that it would take 4 days to complete at a cost of $28,000.00. Timeline for construction would be late 2016 or 2017



Drawing 7: Restoration Site Plan for existing drop structure replacement (Priority #4), and river bank stabilization & other habitat enhancements in the upper segment of the study reach (Priority #5).

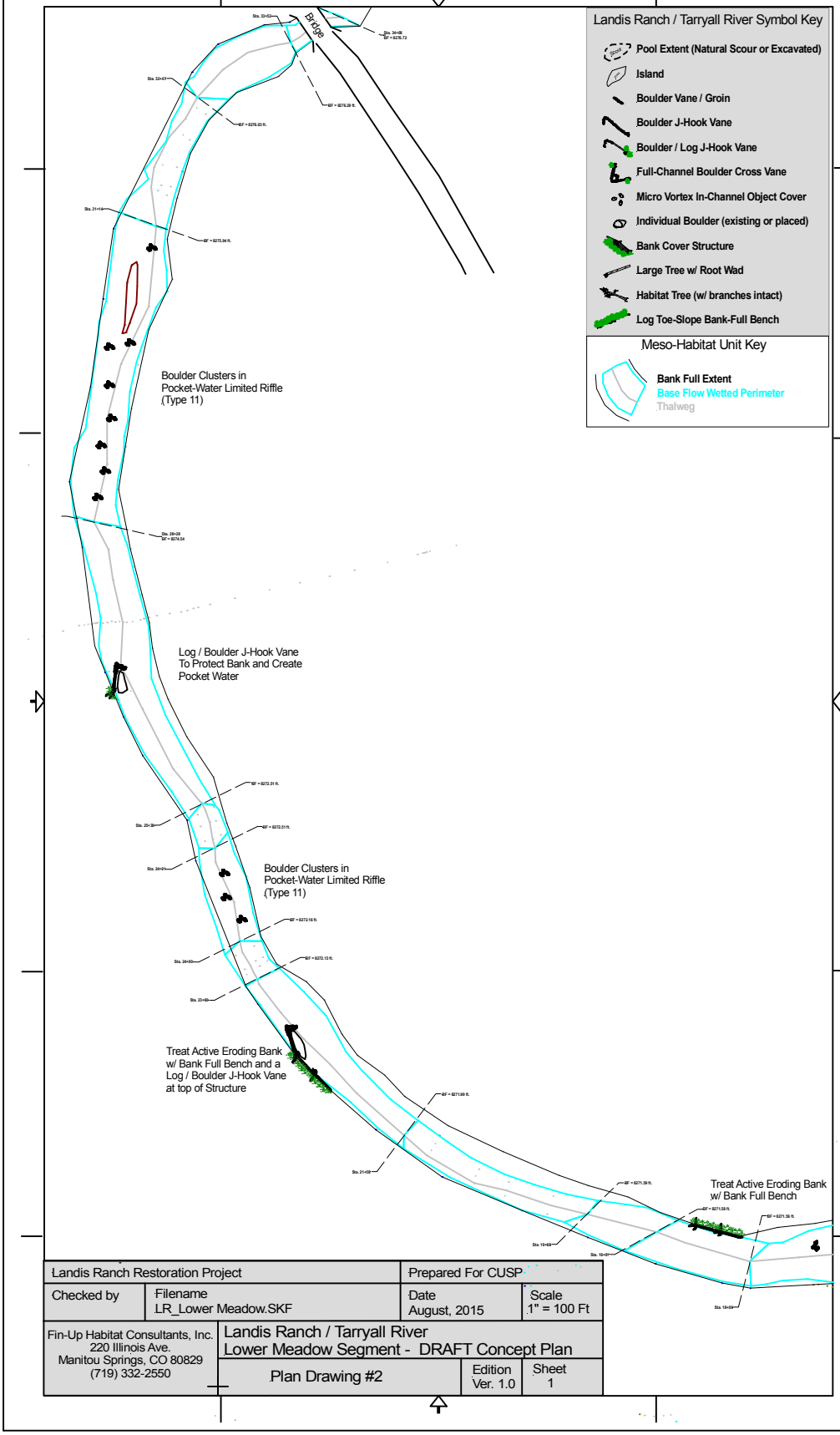
Priority #5: Additional Habitat Features and Enhancements.
The 5th priority project will address the remaining actively eroding and unstable river banks and additional habitat features in the segments of Tarryall Creek that were not addressed in the priority #1 through #4 projects. These segments include the lower end of the study reach, from the 1st bridge upstream to Riffle 3, the segment upstream from the lower diversion structure (priority #1) to the 2nd bridge, and upstream of the upper diversion structure to the Landis Ranch / USFS property boundary.

In the lowest segment, downstream of the lower diversion, approximately 100 feet of actively eroding river bank will be treated utilizing log bank full benching (Drawing #1). The bank full bench will be tied into the upstream end of a small island in this segment to create a backwater pool downstream, effectively creating young-of-the-year refugia in this limited segment. A large boulder J-Hook vane will be installed on the north bank of Riffle 2 to redirect the thalweg and reduce shear along the river bank. The J-Hook vane, and up to four additional boulder clusters, will improve pocket water in-channel object cover in this somewhat limited riffle.

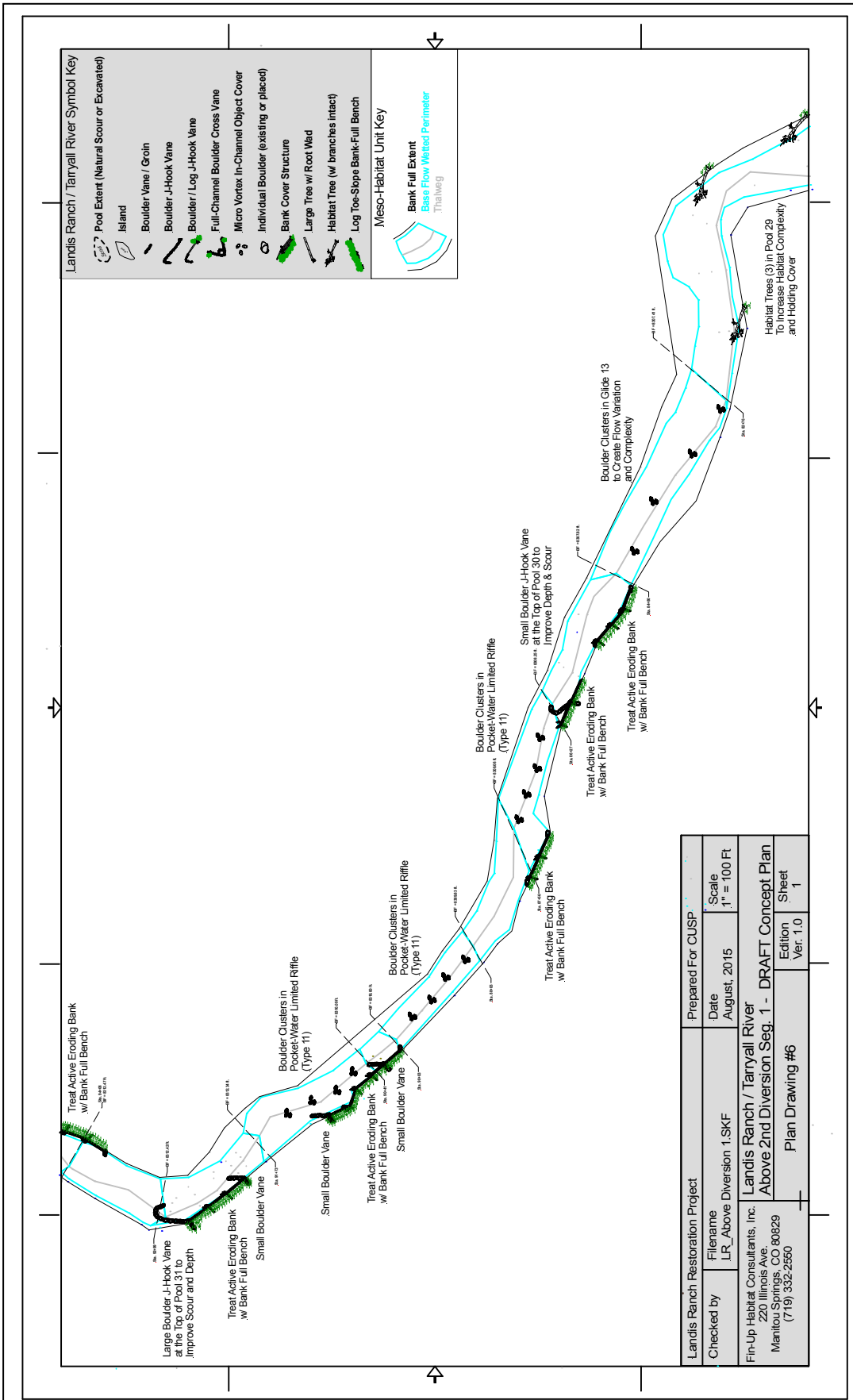
Only limited work will be necessary in the middle segment beginning upstream of the lower diversion structure and extending to the 1st bridge (Drawing #2). Two short (<60ft) actively eroding river banks will be treated by constructing log bank full benches, and up to eleven boulder clusters will be added to the pocket water limited Riffles #10 and #12. Two log/boulder J-Hook vanes will also be installed to create additional pocket water and protect at-risk river banks in Riffle 9 and Riffle 11.

Much more extensive work will be necessary in the segment from the upstream diversion to the property boundary. Approximately 850 feet of actively eroding river banks will be treated with bank full benching. Two boulder J-Hook vanes and three smaller boulder vanes will be used to further protect these river banks and create additional in-channel cover for resident trout. A full channel cross vane will be installed immediately upstream of the 3rd bridge to direct the thalweg through the center of the bridge, and to provide fish viewing opportunity from the bridge itself. Eight Type 11 riffles will be enhanced for improved pocket water cover with the installation of up to 36 boulder clusters in this segment. Five additional habitat trees will also be anchored into the pool upstream of the diversion structure, and in the uppermost glide to create additional habitat complexity and velocity shelter. Details of these improvements are shown in Drawings #6 and #7.

We expect we can obtain necessary materials on site for this work, and we estimate that it would take up to 14 days to complete at a cost of $60,000.00. Timeline for construction would likely be late 2017 or beyond.



Drawing 2: Restoration Site Plan for river bank stabilization & other habitat enhancements in the lower segment of the study reach (Priority #5).



Drawing 6: Restoration Site Plan for river bank stabilization & other habitat enhancements in the upper segment of the study reach (Priority #5).

Enhancement Projects Summary & Budget.

We have designed the restoration plan to be implemented over a period of three or more years. The table below outlines the estimated costs to implement all priorities described in this aquatic enhancement plan. These estimates are based on current costs for equipment and materials, and may change over time, and should not be considered an formal offer or bid for the project. Costs are based on implementing each priority as a separate project, and assume that necessary materials such as boulders and large trees will be available on-site, except as noted in the restoration plan. Significant savings may be realized by combining priority phases as opportunity allows. For example, if all five priorities were implemented at the same time, a savings of over $15,000.00 in equipment mobilization fees alone could be realized. We would also expect some savings in the cost of equipment due to improved economies of scale from combining projects.

Tarryall River / Landis Ranch River Restoration Project			
Preliminary Budget Estimate and Timeline			
Task	Time To Complete	Completion Date	Total
Pre Project Design & Planning			
Tree Harvest and Transport to the worksite	2 Weeks	Done	$ 7,000.00
Pre-Project Data Collection	1 Week	Done	$ 3,750.00
Data Analysis / Project Design / Permitting	2 weeks	Partial	$ 2,250.00
Pre Project Site Visits w/ Agencies	4 days	Aug. 2015	$ 2,700.00
Materials Acquisition and Contracting	1 week	Oct. 2015	$ 750.00
CUSP Grant Writing and Fundraising		ongoing	$ 3,000.00
Project Construction			
Priority #1 - Lower Diversion and Channel Realignment	2 weeks	fall 2015	$59,000.00
Priority #2 - Upper Diversion Structure Replacement	1 week	fall 2016	$40,250.00
Priority #3 - Middle Segment (hay meadows) River Bank Stabilization & other improvements	2 weeks	fall 2016/2017	$58,250.00
Priority #4 - Existing Drop Structure replacment / realignment / restoration.	1 week	2016/2017	$28,000.00
Priority #5 - Additional Habitat Features & Enhancments	2 weeks	2017 and beyond	$60,000.00
Post Project Reporting			
CUSP Oversight and Grant Reporting		ongoing	$ 1,200.00
Post Project Reporting / Permit Requirements		upon completion	$ 4,000.00
Project total			$270,150.00

Table 3: Preliminary Budget Estimate for the Landis Ranch (2015 dollars).

Glossary of Terms:

Benthic Zone - The benthic zone is the lowest level of a body of water. It is inhabited mostly by organisms that tolerate cool temperatures and low oxygen levels, called benthos or benthic organisms.

Cascade - A meso-habitat type. Cascades are the steepest riffle habitat types, in terms of gradient, in streams. These riffles consist of alternating small waterfalls and shallow pools. These habitats may appear to have the characteristics of a Step-pool system. Cascades are characterized by swift current flows and often have exposed rocks and boulders above the water surface, which creates considerable turbulence and surface agitation. The substrate normally found in cascades is bedrock or accumulations of boulders.

Cover - Locations where fish prefer to rest, hide and feed are called cover. Cover serves to visually isolate fish, which increases the number of territories in the same space. Additionally, cover can create areas of reduced velocities providing critical resting and feeding stations for fish. The amount of cover available in a stream can influence the production of a number of fish and invertebrate species.

Cross-Vane - A structure spanning the entire width of the channel, constructed of large boulders and/or large wood, that provides vertical stability, increased scour, increased stage upstream, and reduced stream power. This structure type is commonly used as a diversion structure for irrigation ditches, as well as for treating active down cutting and head cuts in the stream channel.

Embeddedness - The degree to which the interstitial spaces between larger substrate particles are filled with finer sediments. Embeddedness tends to armor the substrate, thus limiting available habitat for benthic dwelling macroinvertebrates and spawning habitat for salmonids.

Glide - A meso-habitat type. Glides are those portions of streams which have relatively wide uniform bottoms, low to moderate velocity flows, lack pronounced turbulence, and have substrates usually consisting of either cobble, gravel or sand. Glides are usually described as stream habitat with characteristics intermediate between those of pools and riffles. These habitats are commonly found in the transition between a pool and the head of a riffle, however they are occasionally found in low gradient stream reaches with stable banks and no major flow obstructions.

Green Line - A narrow band of riparian plant species immediately adjacent to the stream bank in deeply entrenched streams. These are typically streams that have no identifiable flood plains.

Head-Cut - An area of active down-cutting in the channel where a river or stream is eroding down to a new, lower flood plain.

Intermittent - An intermittent stream is one that only flows for part of the year.

Lotic - Of, relating to, or living in moving water such as streams and rivers.

Meso-Habitat - A channel scale habitat form. Typically a pool, riffle, rapid, cascade or glide habitat. A meso-habitat occupies the entire width of the stream channel, and with

few exceptions (most notably plunge pools in high gradient step-pool systems) is at least as long as the channel is wide.

Micro-Habitat - Micro habitats are small, site specific habitats within a meso-habitat form, and may include spawning redds, in-stream or overhead cover, and velocity shelters.

Micro-Vortex - A small rock cluster structure that replicates pocket water habitat in riffles, rapids and cascades.

Over-Wintering Habitat - Areas of a stream or water body exhibiting depths that may sustain a population through the winter months.

Perennial - A perennial stream is one that flows year round.

Pocket Water - A micro-habitat type. Pocket water habitats are typically found in higher gradient riffles, rapids, and cascades with large cobble, boulder, and large woody debris. These pocket water habitats provide small areas for velocity shelter and cover within these fast-water habitat forms.

Pool - A meso-habitat type. Pools are channel segments exhibiting areas of scour and deposition where the water is deeper and slower moving.

Primary Producers - Primary producers are those organisms in an ecosystem that produce biomass from inorganic compounds. In almost all cases these are photosynthetically active organisms.

Rapid - A meso-habitat type. Rapids are riffles associated with high gradients (greater than 4%) with swiftly flowing (greater than 1.5 ft/sec), moderately deep, and highly turbulent waters. These riffles are generally associated with boulder substrates, which protrude through the surface of the water.

Residual Pool Depth (RPD) - Residual pool depth is estimated as the depth of water which would be retained in a pool under highly reduced flows or the stoppage of flows in the stream. This area of pools would be utilized by fish in low flow conditions. Residual pools would also provide habitat for overwintering of fish when ice buildup restricts movement in riffles or glides between pools. Residual pool depth is calculated by locating and measuring the greatest depth of the pool at the riffle crest (deepest point of the downstream boundary cross-section of the pool), and subtracting this value from the greatest measured depth of the pool habitat. The difference in these measurements is described as the RPD. RPD may be difficult to determine in some habitats, particularly dam pools with woody debris structural associations. In many of these habitat units, the RPD may actually be a very low value or zero due to water flowing through these debris dams.

Riffle - A meso-habitat type. Riffles are those areas of the stream in which turbulence in the water column is the major identifying characteristic, as a result of relatively high gradients. These units contain moderately deep to shallow, swift flowing water, and are characterized by boulder or cobble substrates. Riffles are very important for macroinvertebrate production, due to the availability of light and oxygen, and the corresponding vegetative growth on the bottom substrate. The quality of riffles, including low sediment deposition and resulting embeddedness can have a direct impact

on fish populations. The cleaner and healthier the vegetative growth and benthic macroinvertebrate community, the more food there is for the fish population.

Salmonids - Salmonidae is a family of ray-finned fish, the only family of order Salmoniformes. It includes the well-known salmons and trouts; the Atlantic salmons and trouts of genus Salmo give the family and order their names.

Subfamily - Salmoninae
Brachymystax - lenoks
Oncorhynchus - Pacific salmon and trout
Salmo - Atlantic salmon and trout
Salvelinus - Char and trout (Brook trout, Lake trout)

Substrate - Stream substrate (sediment) is the material that rests at the bottom of a stream.

Thermal Refugia - Micro habitats found in streams and lakes that provide thermal protection for cold water species such as trout. These may include shaded areas, cool water springs, and deep water habitats.

Toe-Slope - The foot, or bottom, of the sloping bank of a stream. This is the area of the highest sheer stress and erosion potential on a stream bank, and is typically the point of failure leading to mass wasting and collapse.

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Still Photography by J. Peter Gallagher.

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APPENDIX

Vicinity and Project Reach Maps

2015 BWSHI data sheets and summaries

Longitudinal Profile an Cross Section Analysis

Aquatic Enhancement Plan Drawings

Treatment Plan & Profile Drawings

Photos of Treatment Types

Project Reach Photo-Points and Locations