Vocational Heavy Construction Technology
Program Analysis and Description
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Background:
The Vocational Heavy Construction Technology (VHCT) program exists in the Colorado Department of Corrections (CDOC) to provide student inmates with education and training that will equip them with basic life and work skills necessary to obtain employment with a construction company once they have completed their sentences. The Colorado Division of Wildlife (CDOW) has been the major customer of the program in South Park where natural river processes and aquatic habitats have been restored in nearly ten miles of the South Platte River. The VHCT program formed in 1997 when Warren Diesslin, former Warden of the Buena Vista Correctional Facility, Eddie Kochman, former Colorado Division of Wildlife (CDOW) Aquatic Section Manager, and Tom Bowen, Colorado Department of Corrections (CDOC) vocational educational instructor, met and discussed a joint venture to rehabilitate degraded stream habitats while providing heavy construction training for inmates sincere about changing the direction of their lives. To date, 9.4 miles of degraded aquatic stream habitats have been rehabilitated on CDOW properties located along the South Platte River in South Park. South Park was identified as an ideal location to implement the program because CDOW owns or leases over 25 miles of public fishing waters in the Upper South Platte River drainage and its close proximity to the Buena Vista Correctional Facility. Much of the South Platte River in South Park is degraded due to excessive livestock grazing and mining. Over 20 different habitat treatments have been implemented in South Park that fall within three functional categories: restoring river natural processes, reducing bank erosion, and enhancing aquatic habitat for sport fish (Table 1). Treatments include the use of rock, stumps, logs and riparian plants for bank revegetation. Through FY 2010-2011, CDOW river restoration projects in South Park utilizing the VHCT program cost on average $23/linear foot with a range of $6.92-$92.66/linear foot (Table 2 & 3). A survey of six recent river restoration projects in Colorado conducted by private companies range in cost from $61-$390/linear foot (Table 2). The most likely reasons for lower project costs using the DOC VHCT program can be traced to using rental construction equipment and using inmate trainees as heavy equipment operators (Table 4). Added benefits of using the VHCT program over private industry are that a CDOW biologist, technician or engineer oversees the day-to-day operation of the project and make in-the-field decisions about project changes or adjustments (design build). Usually private industry imposes additional charges and requires negotiations when change orders occur, which can lead to conflict. Cost of CDOW/CDOC projects in South Park range from $47,000-$148,000/year, with an average cost of $83,548/year. The total cost to CDOW for thirteen years (1998-2008) of construction was $1,256,173 (Table 3).

CDOW/CDOC river restoration projects completed using VHCT program:
Table 3 includes a list of major CDOW river restoration projects completed through the VHCT program including project year, stream project name, location, county, length of stream restored, cost, and primary funding sources.

Table 1. Benefits assigned to river channel and aquatic/trout habitat treatments used in restoration projects.

Treatments to Improve Natural River Processes			
River Channel Treatment	Benefits		
	River processes	Reduces bank erosion	Aquatic habitats
Reduce river channel width	Primary	Secondary	Primary
Pool excavation	"	"	"
Elevate riffle substrate	"	Limited	"
Improve woody overhead trout cover	"	Secondary	"
Riparian vegetation	"	Primary	Secondary
Riparian bench	"	"	"
Woody Material Treatments Used to Reduce River Bank Erosion			
River Bank Treatments	Benefits		
	Natural processes	Reduces Bank Erosion	Aquatic habitats
Log spur	Secondary	Primary	Secondary
Log vane	"	"	"
Horizontal log	"	"	Primary
River bank root wad	"	"	"
Channel edge log/root wad	"	"	"
Boulder Treatments Used to Reduce River Bank Erosion			
River Channel Treatments	Benefits		
	Natural processes	Reduces bank erosion	Aquatic habitats
Cross vane	Secondary	Primary	Primary
Single boulder deflector	"	"	Secondary
Hard point	"	"	Limited
Boulder J hook	"	"	Primary
Boulder vane	"	"	Secondary
Treatments to Enhance Mid-Channel Aquatic and Trout Habitats			
Aquatic Habitat Treatments	Benefits		
	Natural processes	Reduces bank erosion	Aquatic habitats
Random boulders	Limited	Limited	Primary
Boulder clusters	"	"	"
Rock garden	"	Limited	"
Stumps	"	"	"
Mid-channel Root wads	"	"	"
Off bank root wads	"	Secondary	"

Table 2. Cost comparison of six major river restoration projects from Colorado with river restoration costs using the VHCT program including stream name, river restoration collaborators, miles of river restored, restoration cost, and reasons for restoration.

Stream name	River restoration company/ organization	Miles restored	Cost per linear foot	Reason for restoration
Blue River	Northwest Colorado Council of Governments (NWCCOG), Town of Silverthorne, T.U., National Forest Foundation, CDOW, and Denver Water	0.6	$61	Enhance aquatic habitats and channel reconstruction
Little Snake River	Dave Rosgen, Wildland Hydrology	10.5	$90	Enhance aquatic habitats, channel reconstruction, and riparian revegetation
San Miguel River (Phase I)	Town of Telluride (Public Works)	0.7	$200	Restoration included: creation of an instream sedimentation basin, implementing bank stabilization treatments, creating and improving wetlands, developing riparian habitats, enhancing aquatic habitat, and placing instream hydraulic structures.
Eagle River (Edwards Eagle River restoration)	Eagle River Watershed Council	1.6	$236	Enhance aquatic habitats, channel reconstruction, and riparian revegetation
Lefthand Creek	CDOW, City of Longmont (Public Works), Parks and Open Space, CDOT, Longmont Power and Communications, Carter & Burgess, Duran Excavating, Aquatic and Wetlands Company, and Property Owners	0.9	$333	Channel reconstruction, floodplain reconnection, and riparian revegetation
West Ten-mile Creek		0.4	$390	Channel reconstruction and riparian revegetation
South Platte River	**CDOW/CDOC (VHCT program)**	**10.2**	**$23**	**Restore natural river processes, reduce bank erosion, enhance aquatic habitats**

Table 3. CDOW stream restoration projects complete through the VHCT program including project year, stream project name, location (UTM, NAD 83, Zone 13T), county, length of stream restored, cost (*estimates italicized*), and primary funding sources.

Year	Stream project name	Location (UTMs) Upstream	Location (UTMs) Downstream	County	Length (miles)	Cost (total/per linear ft)	Funding
1991	Dream Stream (Phase 1)	436205E 4317880N	436644E 4317668N	Park	.4	$68,700 / $35.74	CDOW/Federal Aid
1993	Buckley Ranch	446523E 4313949N	446817E 4313806N	Park	.4	*$58,000 / $27.46* [2] (estimated)	CDOW/Cap. Const.
1998	Dream Stream (Phase 2),	446817E 4313806N	446897E 4313763N	Park	.2	$97,850 / $92.66	CDOW/Cap. Const.
1999	Antero Project, South Fork of	423008E 4316108N	423513E 4316072N	Park	.7	$139,610 / $37.77	DWD/CDOW Cap. Const.
2000	Threemile Creek Creek Project, Tributary to	447474E 4313277N	447592E 4313211N	Park	.5	$138,000 / $52.27	CDOW/Cap Const.
200l	Dream Stream (Phase 3),	446897E 4313763N	447885E 4313638N	Park	.9	$148,000 / $31.14	CDOW/Cap Const.
2002	Knight-Imler Project, South Fork of	415892E 4324356N	416521E 4322089N	Park	1.2	*$76,643 / $12.57* [1] (estimated)	CDOW/Cap. Const.
2002	Hartsel Project, South Fork of	429621E 4319613N	430562E 4319239N	Park	1.0	*$66,370 / $12.57* [1] (estimated)	CDOW/Cap. Const.
2003	Aurora Project,	440995E 4316473N	441837E 4316347N	Park	1.0	$128,725 / $24.38	CDOW/Cap. Const.
2004	Dream Stream (Phase 4),	447885E 4313638N	448492E 4313429N	Park	.3	$47,000 / $29.67	CDOW/Cap. Const.
2005	South Fork Project, South Fork of	446897E 4313763N	435955E 4318057N	Park	1.7	*$62,114 / $6.92* [1] (estimated)	CDOW/Cap. Const.
2005	Tarryall Project, Tarryall Creek	443144E 4344384N	443602E 4344888N	Park	.6	*$21,922 / $6.92* [1] (estimated)	CDOW/Cap. Const.
2006	Middle Fork side-channel Project, Middle Fork of South Platte River	435539E 4318654N	435904E 4318299N	Park	.6	$50,600 / $15.97	CDOW/Cap. Const.
2007	Middle Fork of South Platte River (Phase 1)	435539E 4318654N	435811E 4318497N	Park	.5	$77,996.40 / $28.89	CDOW/Cap. Const.
2008	Middle Fork of South Platte River (Phase 1 continued)	435811E 4318497N	435918E 4318290N	Park	.2	$50,808.00 / $50.81	CDOW/Cap. Const.
2009	Middle Fork of South Platte River (Phase 2)	435415E 4318627N	436015E 4318251N	Park	.2	$82,779.01/ $78.39	CDOW/Cap. Const.
2010	Middle Fork of South Platte River (Phase 3)	435246E 4318865N	435415E 4318627N	Park	.3	$64,805.40/ $40.91	CDOW/Cap. Const.
2011	Middle Fork of South Platte River (Phase 4)	N/A	N/A	Park	.3	$99,780.41/$62.99	CDOW/Cap. Const.
2013	Dream Stream (Phase 5)	448492E 4313429N	448761E 4313392N	Park	.5	$86,946.33/$32.48	Park County
2014	Dream Stream (Phase 5)	448761E 4313392N	449579E 4313398N	Park	1.0	$117,144.00/$22.19	Park County
Total	**VHCT**	**-**	**-**	**Park**	**12.5**	**$1,683,793.54/$35.14**	**-**

[1] Project costs were estimated because total costs for individual projects were not available, only total cost for both projects within the same year. The cost per linear foot for individual projects was determined by dividing the total cost for that year (both projects) by the total length of the restored reaches for both project areas. The computed cost per linear foot for both projects was multiplied by the total length restored for each individual project to estimate the cost per project.

Table 4. Cost comparison of heavy equipment operators salaries and heavy construction equipment between the VHCT program and private industry (Tom Bowen, DOC; personal communication).

Cost description	VHCT program	Private industry
Heavy equipment operator salary	$.09/hr	$18.00/hr
Cost of one excavator plus operator for one month	$3,500/mo	$32,000/mo
Cost of one front end loader plus operator for one month	$3,500/mo	$32,000/mo
Total heavy equipment plus operator for one month*	$7,000/mo	$64,000/mo

* Most CDOW river restoration projects require both a front end loader and an excavator for one month.

Project Summaries: VHCT

1998: Dream Stream (Phase 2), South Platte River- This area was selected as a candidate for restoration since it is one of the most intensively fished river segments in Colorado. The South Platte River downstream of Spinney Reservoir functions as a popular tail water fishery, has good public access, and it is near Denver and Colorado Springs. The project area is owned and managed by Colorado State Parks. As a tail water fishery, this stream segment has the potential of producing very large, healthy rainbow, cutthroat, and brown trout. Treatments were prescribed to restore natural river processes, reduce river bank erosion, and enhance fish habitat. Specifically, the following habitat limitations and impairments were identified: over width channel, shallow water depths, lack of adult fish cover (vegetative cover and deep pools), actively eroding banks, and a lack of instream habitat complexity. The following habitat treatments were applied in response to the limitations listed above: horizontal logs, root wads, stumps, log vanes, log spurs, boulder vanes, boulder J hooks, single boulder deflectors, vortex structures, boulder clusters, point bar development, pool excavation, riffle enhancement, and revegetation (willow planting). The total length of stream restored was 0.2 miles long and had a total cost of $97,850 or $92.66/linear foot. In 1999, one year following restoration, the biomass of brown trout in the Dream Stream segment (downstream of Spinney including phase 1 and 2 segments) was estimated to be 175 lbs/acre, a 5-fold increase in brown trout biomass from the previous year (1998). See Appendix A, Table 2.

1999: Antero Project, South Fork of South Platte River- This project involved designing and excavating a new river channel designed to accommodate a bankfull flow of 25 cfs. The project area is owned by the Denver Water Department and open to public fishing. The purpose of constructing a new channel was to create additional recreational angling opportunities adjacent to an existing tail water fishery (downstream of Antero Reservoir). Restoration treatments associated with the new channel included: excavating a new sinuous channel that would be maintained through natural river processes, placing boulder structures for maintaining pools and increasing habitat complexity, placing logs to create overhead cover and lining the entire channel with the appropriate-sized cobble and gravel substrate. This project is unique in that it involved excavating an entirely new channel where no river channel previously existed, thereby creating 0.7 miles of additional fishing opportunity. A diversion structure was designed and constructed in order to regulate the flow into the channel so that flows through the new channel would not exceed the design discharge for the new channel. The length of the new stream channel was 0.7 miles long and had a total cost of $139,610 or $37.77/linear foot. Following construction of the new channel, a prolonged drought delayed sending water down the new channel from Antero Reservoir for many years.

2000: Three-mile Creek Project, tributary to South Platte River- During the summers of 1997 and 1998, severe thunderstorms occurred in the headwaters of Three-mile Creek and produced sudden flooding in this normally intermittent stream that transported and deposited many tons of fine sediment downstream to the South Platte River. This sediment caused the main channel of the South Platte to over-widen and the river substrate downstream of Three-mile Creek confluence to become embedded with fine sediment, which clogs spawning gravels, limits juvenile fish habitat, and is detrimental to freshwater invertebrate biomass. In order to address this problem, a 0.5 mile stretch of new channel was constructed upstream of the confluence with the South Platte River. This new channel connected to a newly constructed retention basin that was designed to trap and confine fine sediment prior to water flowing into the South Platte River from Three-mile Creek. While the goal of this project was not to directly enhance fish habitat, without addressing the sediment problems associated with Three-mile Creek, any river restoration activities planned downstream of the confluence of Three-mile Creek with the South Platte River could have been destroyed by filling in with fine sediment from this source. This project involved construction of a

0.5 mile channel in Three-mile Creek, construction of a dam, and construction of a retention basin/pond. The project had a total cost of $138,000 or $52.27 per linear foot.

2001: Dream Stream (Phase 3), South Platte River- This area was selected as a candidate for restoration since it is one of the most intensively fished river segments in Colorado. The South Platte River downstream of Spinney Reservoir functions as a popular tail water fishery, has good public access, and it is near Denver and Colorado Springs. This project area is managed by CDOW and is part of the Lower Spinney SWA. As a tail water fishery, this stream segment has the potential of producing very large, healthy rainbow, cutthroat, and brown trout. Treatments were prescribed to restore natural river processes, reduce river bank erosion and enhance fish habitat. Specifically, the following habitat limitations and impairments were identified: over width channel, shallow water depths, lack of adult fish cover (vegetative cover and deep pools), channel straightening (due to railroad grade and irrigation canal diversion), actively eroding vertical banks, and a lack of instream habitat complexity. The following habitat treatments were applied in response to the limitations listed above: sod mats (reduce channel width) by creating riparian benches, imported gravel materials to narrow channel, point bar development, horizontal logs, root wads, stumps, log vanes, log spurs, boulder vanes, boulder J hooks, single boulder deflectors, vortex structures, random boulders, rock gardens, boulder clusters, pool excavation, riffle enhancement, and revegetation (willow planting). The total length of stream restored was 0.9 miles long and had a total cost of $148,000 or $31.14/linear foot. No biomass estimates covering before and after treatments are available.

2002: Knight-Imler Project, South Fork of South Platte River- This stretch of stream is located upstream of Antero Reservoir, located on the CDOW Knight-Imler SWA. This site was selected as a candidate for restoration because it has good public access, good riparian grazing management, adequate stream flows, and a few well-established willow stands good for serving as overhead vegetative cover. The condition of the river banks showed signs of improvement following elimination of intensive cattle grazing; however the stream remained highly over-width with no pool habitat, actively eroding banks, a lack of instream habitat complexity/diversity, and many stretches that lacked deep rooted riparian vegetation, primarily willows. The following habitat treatments were applied in response to the limitations and impairments listed above: sod mats (reduce channel width) by creating riparian benches, imported gravel materials to narrow channel, creating a new low-flow channel (defining a thalweg), stone-toe protection to limit stream bank erosion, point bar development, log vane/boulder J hook combinations, boulder J hooks, root wads, log vanes, horizontal logs, boulder vanes, single-boulder deflectors, random boulders, boulder clusters, pool excavation, riffle enhancement, and revegetation (willow planting). The total length of stream restored was 1.2 miles long and had a total cost of approximately $79,643 or $12.57/linear foot. No biomass estimates covering before and after treatments are available.

2002: Hartsel Project, South Fork of South Platte River- This stretch of stream is located on the CDOW Badger Basin SWA. This site was selected as a candidate for restoration because it has good public access, good riparian grazing management, and adequate stream flows. The condition of the river banks showed signs of improvement following elimination of intensive cattle and buffalo grazing, however the stream remained highly over-width with no pool habitat, formation of mid-channel bars (braiding), actively eroding banks, a lack of instream habitat complexity/diversity, and no deep rooted riparian vegetation (willows). The following habitat treatments were applied in response to the limitations listed above: sod mats (reduce channel width) by creating riparian benches, imported gravel materials to narrow channel, creating a new low-flow channel (defining a thalweg), stone-toe protection to limit stream bank erosion, point bar development, log vane/boulder J hook combinations, root wads, log vanes, rock vanes, vortex structures, boulder J hooks, single boulder deflectors, random boulders, boulder clusters, pool excavation, riffle enhancement, and revegetation (willow

planting). The total length of stream restored was 1.0 miles long and had a total cost of approximately $66,370 or $12.57/linear foot. No biomass estimates covering before and after treatments are available.

2003: Aurora Project, South Platte River- The project area is owned by the City of Aurora and Colorado State Parks and is open to public fishing. This site was selected as a candidate for restoration because it has good public access, good riparian grazing management, and adequate stream flows. The condition of the river banks showed signs of improvement following elimination of intensive cattle grazing, however the stream channel remained highly over-width with little to no pool habitat, formation of mid-channel bars (braiding), actively eroding vertical banks (old railroad grade), a lack of instream habitat complexity/diversity, and very little deep-rooted riparian vegetation (willows). The following habitat treatments were applied in response to the limitations listed above: riparian benches using sod mats (reduce channel width), imported cobble materials to enhance riffles, stone-toe protection to limit stream bank erosion, point bar development, root wads, log vanes, boulder vanes, boulder J hooks, single boulder deflectors, random boulders, boulder clusters, boulder cross vanes, pool excavation, riffle enhancement, and revegetation (willow planting). Riparian sod was removed from areas adjacent to the active channel which created 0.16 acres of off-channel shallow pool habitat for a variety of wildlife and wetland species. The total length of stream restored was 1.0 miles long and had a total cost of $128,725 or $24.38/linear foot. No biomass estimates covering before and after treatments are available.

2004: Dream Stream (Phase 4), South Platte River- This area was selected as a candidate for restoration since it is one of the most intensively fished river segments in Colorado. The South Platte River downstream of Spinney Reservoir functions as a popular tail water fishery, has good public access, and it is near Denver and Colorado Springs. The project area is managed by CDOW and is part of the Lower Spinney SWA. As a tail water fishery, this stream segment has the potential of producing very large, healthy rainbow, cutthroat, and brown trout. Treatments were prescribed to restore natural river processes, reduce bank erosion and enhance fish habitat. Specifically, the following habitat limitations were identified: over width channel, shallow water depths, lack of adult fish instream and overhead cover (vegetative cover and deep pools), actively eroding vertical banks, and a lack of instream habitat complexity. The following habitat treatments were applied in response to the limitations listed above: imported gravel materials to narrow channel, pool excavation, point bar development, horizontal logs, root wads, log vanes, cross vanes, single boulder deflectors, hard points, random boulders, boulder clusters, and revegetation (riparian grasses and willow plantings). The total length of stream restored was 0.3 miles long and had a total cost of $47,000 or $29.67/linear foot. No biomass estimates covering before and after treatments are available.

2005: South Fork Project, South Fork of South Platte River- This project was selected for restoration because it is open to public fishing, has good access, good riparian grazing management, and it had potential for creating almost two miles of new habitat with relatively little design work. The project area is managed by CDOW and is part of the Upper Spinney SWA. The existing channel was operating as an intermittent channel with flowing water in the active channel only part of the year. Most of the water flow bypassed the intermittent channel and continued to flow back to the Middle Fork of the South Platte just downstream of the Hartsel Ranch headquarters. A streamflow structure was installed to allow more flow to move down the channel under low or base flow conditions and thus create fish habitat year-round. Because this project already had an existing intermittent stream channel, treatments were mainly used to enhance existing instream habitat. The following treatments were applied: excavate pools, excavate the channel to accommodate new design flow, boulder cross vanes, horizontal logs, boulder clusters, random boulders, point bar development, and revegetation using willow plantings. A total of 1.7 miles of new stream habitat was created by restoring this river reach to accommodate trout year-round. Cost was approximately $62,114 or $6.92/linear foot.

2005: Tarryall Project, Tarryall Creek- This project was selected as a candidate for restoration because it is conveniently accessible to public fishing, has good riparian grazing management, and adequate stream flows. The project area is managed by CDOW and is part of the Tarryall SWA. The condition of the river banks showed signs of improvement following elimination of intensive cattle grazing, however the stream channel remained highly over-width with little pool habitat, formation of mid-channel bars (braiding), lack of instream habitat complexity/diversity, actively eroding banks, and very little deep-rooted riparian vegetation (willows). The following habitat treatments were applied in response to the limitations listed above: riparian benches using sod mats (reduce channel width), horizontal logs, log spurs, log vanes, point bar development, single boulder deflectors, boulder clusters, random boulders, pool excavation, boulder cross vanes, rock gardens, revegetation (willow and sedge planting), imported cobble materials to enhance riffles, stone-toe protection to limit stream bank erosion, root wads, and boulder vanes. The total length of stream restored was 0.6 miles long and had a total cost of $21,922 or $6.92/linear foot. Within two years after habitat improvements were completed, trout biomass estimates had tripled in the restored reach compared to before-treatment conditions. Also, no trout > 14 inches were sampled in the project area prior to habitat improvements. Two years after habitat treatments were completed, approximately 3% of the total trout catch sampled were > 14 inches in length. See Appendix A, Table 3.

2006: Middle Fork side-channel project, Middle Fork of South Platte River- The project area is managed by CDOW and it is part of the Badger Basin SWA. This site was selected as a candidate for restoration because it has good public fishing access, good riparian grazing management, and it had potential for creating 0.6 miles of new habitat with relatively little design work. The existing channel was operating as an intermittent channel with flowing water in the active channel only part of the year. Under base flow and low flow conditions, most of the water flow bypassed the intermittent channel and the side-channel would contain no flowing water. The configuration of the side-channel inlet was reconstructed in order to move the inlet further downstream away from the inside radius of a meander bend. The diversion structure was installed to allow more flow to move down the side-channel under low or base flow conditions and thus create fish habitat year-round. Because this project already had an existing intermittent stream channel, treatments were mainly used to enhance existing instream habitat. The following treatments were applied: excavate pools, excavate the channel to accommodate the new design flow, boulder cross vanes, horizontal logs, boulder clusters, random boulders, point bar development, and revegetation using willow plantings. A total of 0.6 miles of new stream habitat was created by restoring this side-channel river reach to accommodate trout year-round. Cost was approximately $50,600 or $15.97/linear foot.

2007: Middle Fork of South Platte River (Phase 1)- The project area is managed by CDOW and it is part of the Badger Basin SWA. This site was selected as a candidate for restoration because it has good public fishing access, good riparian grazing management, and relatively unregulated stream flows. The condition of the river banks showed some signs of improvement following elimination of intensive cattle grazing, however the stream channel remained highly over-width with little pool habitat, lack of instream habitat complexity/diversity, actively eroding banks, and very little deep-rooted riparian vegetation (willows). The following habitat treatments were applied in response to the limitations listed above: riparian benches using sod mats (reduce channel width), horizontal logs, log vanes, point bar development, single boulder deflectors, boulder clusters, random boulders, pool excavation, J-hooks, boulder cross vanes, revegetation (willow planting), and stone-toe protection to limit stream bank erosion. The total length of stream restored was 0.5 miles long and had a total cost of $77,996.40 or $28.89/linear foot. No biomass estimates covering before and after treatments are available. A total station survey of aquatic habitat was completed for the entire phase 1 river reach prior to construction in order to monitor pre- and post- aquatic habitat conditions.

2008: Middle Fork of South Platte River (Phase 1 continued)- This project is a continuation of work begun in 2007 on the Badger Basin SWA (see "2007: Middle Fork of South Platte River (Phase 1)"). The following habitat treatments were applied: riparian benches using sod mats (reduce channel width), horizontal logs, point bar development, single boulder deflectors, boulder clusters, random boulders, rock garden, pool excavation, J-hooks, boulder cross vanes, and revegetation (willow planting). The total length of stream restored was 0.2 miles long and had a total cost of $50,808 or $50.81/linear foot.

2009: Middle Fork of South Platte River (Phase 2)- This project was completed on the Badger Basin SWA with the primary goals of: 1) addressing moderate-to-high eroding banks that were not adequately treated during phase 1 construction, 2) expanding the project reach by (eventually) doubling the project area completed during phase 1 and 2) experimentation with four new treatments to determine their effectiveness in meeting project goals. New treatments that were applied to the project reach included: 1) toe-wood sod mat treatments applied to three locations (designed to create overhead cover/undercut banks, enhance deep pools and stabilize "tall" eroding banks, 2) (modified) horizontal log treatments applied to 2 locations (designed to create overhead cover, provide bank toe protection and stabilize "low to moderately high" eroding banks), 3) two log vane/J-hook combination treatments (designed to enhance deep pools and protect sensitive/eroding banks), and 4) one constructed riffle treatments (designed to increase pocket water within riffles, create complex depths/velocities within a riffle, and ultimately enhance holding areas for adult fish in riffle locations). The total project area was expanded by 0.2 miles outside of the phase 1 treatment area by excavating pools, constructing point bars, and installing boulder J-hooks (quantity 2). In addition, experimental treatments were applied within the phase 1 project reach to address a total of about 300 linear feet of eroding banks that were left over from phase 1 construction. A total of 10,000 bare-root willows were planted. The total length of steam restored was 0.2 miles long and had a project cost of $82,779.01 or $78.39/linear foot.

2010: Middle Fork of South Platte River (Phase 3)- Completed an additional 1,500 foot section (or 0.3 miles) of Middle Fork South Platte River on Badger Basin SWA that includes approximately 700 linear feet of experimental toe-wood sod mat treatment for enhancing trout holding areas/cover adjacent to deep pools, installing three constructed riffle treatments, and constructing 6 point bar/pool excavation treatments. Over 200 large ponderosa pine root wads (including many beetle-killed trees) with attached main stem/trucks were used to complete the toe-wood sod mat treatments. Over 9,000 bare root willows (bare root) and 2,000 willow cuttings were planted in completed portions of project area. An as-built survey of the entire project reach (up to and including phase 1-3) was completed on the Badger Basin stream restoration reach (approximately 7500 linear feet) including longitudinal profile and 6 cross sections. A long-term fish sampling station was established to monitor fish response in a 1,000 foot reach that includes experimental toe-wood/sod mat treatment and horizontal logs. First year data for brown trout biomass within the toe-wood/sod mat treated reach was 3.5 times greater than in an untreated reach located approximately 1 mile downstream. In addition, the brown trout biomass in the toe-wood/sod mat treated reach was significantly (alpha of 0.05) higher than a Rosgen-designed boulder-type restoration project (Buckley Ranch) for all but two years out of 18. The total length of stream restored was 0.3 miles long and had a project cost of $64,805.40 or $40.91 linear foot.

Table 4. CDOW stream restoration projects completed without the VHCT program (Non-VHCT) including project year, stream project name, location, county, length of stream restored, cost (*estimates italicized*), and primary funding sources.

[2] Project costs were pre-project costs estimated by engineering. Final post-project costs were not available.

Year	Stream project name	Location (UTMs) Upstream	Location (UTMs) Downstream	County	Length (miles)	Cost (total/per linear ft)	Funding
1991	South Platte River	436205E 4317880N	436644E 4317668N	Park	.4	$68,700 / $35.74	CDOW/Federal Aid
1993	South Platte River	446523E 4313949N	446817E 4313806N	Park	.4	*$58,000 / $27.46* [2] (estimated)	CDOW/Cap. Const.
1993	Big Thompson River	459136E 4469374N	459191E 4469221N	Larimer	.1	*$36,126 / $68.42* [2] (estimated)	CDOW/Trout Unlimited
1997	Grape Creek	457217E 4225645N	457649E 4226320N	Fremont	.2	not available	CDOW/SE Region
1997	Big Thompson River	458827E 4469449N	459136E 4469374N	Larimer	.2	*$72,252 / $68.42* [2] (estimated)	CDOW/FIF
1998	Grape Creek	457217E 4225645N	457649E 4226320N	Fremont	.3	not available	CDOW/SE Region
2001	Lefthand Creek	492348E 4444493N	491405E 4443947N	Boulder	.9	$1,582,416/ $333.00	City of Longmont
Total	Non-VHCT			Statewide	2.5	-	-

Non-VHCT CDOW river restoration projects:
Table 4 includes a list of major CDOW river restoration projects completed without the VHCT program including project year, stream project name, location, county, length of stream restored, cost, and primary funding sources.

Project Summaries: Non-VHCT

1991: Buckley Ranch Project, South Platte River- This project area was selected as a candidate for restoration because it has good public access, riparian grazing management, and adequate stream flows. The project area is managed by CDOW and is part of the Upper Spinney SWA. Treatments were prescribed to restore natural river processes, reduce river bank erosion and enhance fish habitat. Specifically, the following habitat limitations were identified: over width channel, shallow water depths, lack of adult fish instream and overhead cover (vegetative cover and deep pools), actively eroding vertical banks, lack of over-winter trout habitat, and lack of instream habitat complexity. The following habitat treatments were applied in response to the limitations listed above: revegetation (seeding uplands and planting willow stubs), reducing river channel width with sod blocks, imported cobble and small boulders, pool excavation, boulder vortex structures, boulders used to armor outside curves of pool areas, and willow bundles used for bank revetment installed along the outside curves of pool areas. The total length of stream restored was 0.4 miles long and had a total cost of $68,700 and $35.74/linear foot. Pre-project trout biomass data was collected for two years before restoration work began both in the project area and in a control reach located downstream of the project area. After restoration work was completed, trout biomass was monitored for another 6 non-consecutive years following habitat improvement work in both treatment and control reaches. Biomass increased in the treatment area during the years following restoration work, with restored-reach biomass almost tripling compared to pre-treatment biomass 9 years post-construction. A control reach located downstream of the project area showed a decrease in trout biomass over time before finally rebounding closer to pre-restoration biomass levels 9 years post-construction. Generally trout biomass in the control reach was about 3-4 times less than biomass in the restored reach for a given year. It is possible that the changes in biomass in the control/treatment reaches were due to trout emigration from the control reach to the restored reach. However, this possibility was never tested and some salmonid experts offer explanations for these results that do not support this assumption (Dr. Kurt Fausch, personal communication). (See Appendix A, Table 1).

1993: Dream Stream (Phase 1), South Platte River- This area was selected as a candidate for restoration since it is one of the most intensively fished river segments in Colorado. The South Platte River downstream of Spinney Reservoir functions as a popular tail water fishery, has good public access, and it is near Denver and Colorado Springs. The project area is owned by the City of Aurora and Colorado State Parks. As a tail water fishery, this stream segment has the potential of producing very large, healthy rainbow, cutthroat, and brown trout. Treatments were prescribed to restore natural river processes, reduce river bank erosion and enhance fish habitat. Specifically, the following habitat limitations were identified: over width channel, shallow water depths, lack of

adult fish cover (vegetative cover and deep pools), actively eroding banks, and a lack of instream habitat complexity. The following habitat treatments were applied in response to the limitations listed above: vortex structures, boulder clusters, pool excavation, willow bundle revetment along the outside bends of pool areas, revegetation (reseeding riparian grasses in disturbed areas), and decrease in channel width using excavated river substrate, imported cobble, and imported fill material from an upland site. The total length of stream restored was 0.4 miles long. The initial pre-project costs generated by engineering were estimated at $58,000 or $27.46/linear foot.

1993 and 1997: Big Thompson River (Phase 1 and 2) - This area was selected for restoration because it functions as a tail water fishery with tremendous potential for growing large trout, it is open to public fishing, and most of the costs for the project were funded through Trout Unlimited and a Fishing is Fun grant as well as in-kind services provided by the Colorado Department of Transportation, Bureau of Reclamation and Park Service (heavy equipment, operator, and rock materials). The project area is owned by the Bureau of Reclamation. Treatments were prescribed primarily to enhance fish habitat. The following treatments were used in Phase 1 (1993), a 0.1 mile stream segment immediately upstream of the Mall Street Bridge below Olympus Dam in Estes Park: vortex structures, pool excavation, boulder clusters, and a few random boulders. Phase 2 (1997) involved restoring a 0.2 mile segment downstream of the stream gage below Olympus Dam. Treatments used in phase 2 included random boulders, boulder vanes, vortex structures, boulder clusters, root wads, log spurs, horizontal logs, reducing channel width using fill material, pool excavation, installation of a spawning channel, and planting riparian vegetation (willows and river birch). The total length of the project area was 0.3 miles. The initial pre-project costs generated by engineering were estimated at $108,386 or $68.42/linear foot.

1997 and 1998: Grape Creek (Phase 1 and 2)- This area was selected for restoration because it has good access for public fishing and potential for holding more trout based on its impaired state (severely eroding banks for an F type channel). The project area is leased by CDOW and managed primarily for fisheries. Costs for this project were greatly reduced by an estimated $20,000 per year when the Southeast Region was able to use its own CDOW operator and heavy equipment to conduct river restoration work. Treatments prescribed for this area were conducted to reduce bank erosion and enhance fish habitat. The following treatments were used in Phase 1 (1997), a 0.2 mile stream segment upstream of De Weese Reservoir: excavated pools, vortex structures, boulder vanes, random boulders, boulder clusters, single boulder deflectors, horizontal logs, root wads, log spurs, imported cobble (to reduce channel width and protect the toe of eroding river banks), revegetation (willow and grass planting), and spawning gravel bed. Phase 2 (1998) involved restoring a 0.3 mile segment downstream of Phase 1 project area, above De Weese Reservoir. Treatments used in this river reach included log spurs, stumps, root wads, horizontal logs, riffle enhancement, point bar development, channel width reduction, vortex structures, random boulders, boulder vanes, and revegetation (willow planting).

2001: Lefthand Project, Lefthand Creek- The City of Longmont initiated the Lefhand Creek improvement project in order to relocate 0.34 miles of new stream channel into a newly constructed floodplain. Unlike previous restoration projects, the primary goal of this project was not to enhance sport fisheries, but to enhance stream habitat for native Great Plains and Front-Range transition zone fishes. In addition, the City of Longmont desired to recreate a stream channel with aesthetically pleasing natural materials and extensively re-vegetate using native vegetation. The project consisted of designing a new stream channel (similar to the Antero Project) and using native materials such as tree trunks, root wads, salvaged trees, boulders, riffle enhancement, and extensive revegetation work including riparian sod mats and hundreds of varieties of native trees, shrubs, and grasses. A total of 0.9 miles of new stream habitat was created by restoring this river reach. Cost was $1,582,416 or $333/linear foot.

Summary

Biologists are capable of manipulating fish populations through the following three tools: regulations, stocking, and habitat alteration. If habitat is limiting for a given fish population or fish life stage, habitat restoration can have tremendous advantages over changing regulations or increasing fish stocking. Habitat restoration actually increases the carrying capacity of a stream for a specific stream reach. Stocking fish will have short-term benefits by increasing biomass, but typically will not have the long-term benefits related to improving instream habitats. Changing regulations can improve the fishery if harvest is limiting, but it cannot do anything to increase the long-term potential of the stream to support more or larger fish. Typically, stream habitat restoration and enhancement will have the largest benefit in degraded stream systems that are habitat limited. Since many streams in Colorado are habitat limited due to past human-caused disturbances, habitat improvements can be a very effective tool for increasing trout biomass and for producing larger fish.

Stream restoration costs vary significantly from project to project. The observed range of costs (Table 2, 3, 4, and 5) depend upon the restoration project goals. Some of the factors that influence cost include: amount of re-vegetative work (plantings), accessibility of the project area, length of stream (scale of restoration), width of stream, operator experience, expertise of the project manager, proximity to restoration materials (boulders, imported cobble or gravel, trees), elevation (how many river ice-free days), and type of impairment (e.g. eroding banks from overgrazing versus eroding banks from fluvial mine tailing deposits).

There are a number of factors to consider prior to starting any stream restoration project. These factors form a basis for whether or not stream restoration should be considered an option and as a means to prioritize potential stream restoration projects. Pre-project considerations include the following: Is the water quality good enough to support a self-sustaining population? Is the project area accessible to the public for fishing? Is the project area on public land? Does the CDOW maintain management authority within the project area? Is there evidence that habitat is limiting for at least one specific life-stage? Is the stream type (Rosgen classification system) appropriate for restoration? Is the

project area large enough to justify restoration? Is the project area located in a place such that materials, rental, or labor costs are minimized? Are minimum instream flows secured? Is there local community support for a restoration project? Is there opportunity to collect pre-project data on fish populations for at least 2 years before restoration work begins? Is there commitment to collect post-project data after restoration work is completed? Are there opportunities to address causes leading to impairment prior to conducting restoration work (e.g. change grazing management plan to keep cows out of riparian or improve water quality from mine-contaminated drainages that contribute to poor water quality downstream)? How soon do we wish to see improvement (time scale)? What information do we have about future potentially adverse watershed effects (e.g. are there plans to create new water impoundments or conduct mining operations upstream of a proposed restoration site)?

Stream restoration work conducted by CDOW has not been thoroughly or adequately evaluated to quantify fisheries response to various aquatic/trout habitat treatments. Data included in Appendix A and one study on a treatment segment using PHABSIM (Van Velson Job 1: Final Report) are the only known quantifiable evidence we have related to post-project evaluation of fishery response to stream restoration treatments. Results from the PHABSIM study suggest that the weighted usable area (WUA) had nearly doubled for adult and juvenile brown trout. Weighted usable area is a modeled estimate of the available habitat for a given fish species. Some reasons that post-project evaluations have not been conducted include the following: there is no rigorous methodology developed for conducting evaluations on fisheries response to stream habitat improvement projects, there are a number of confounding variables that increase the complexity of analysis (fisheries response to whirling disease, prolonged drought periods, changes in stocking and/or regulations, changes in angler use), the locations of many proposed restoration sites are not known far enough in advance of when the money is available for restoration so good “before” data can be collected, and studies documenting angler use (creel studies) has been sorely neglected based upon funding constraints.

Table 5. Future proposed stream segments that would benefit from CDOW/DOC river channel and aquatic habitat restoration projects in South Park.

Stream	Project Year/ Estimated Cost	Funding Status	Length (mile)	Primary Treatment	Project Description
South Fork of South Platte River	FY 10-11/ $105,000	Approved FY 09-10	1.0	Reduce channel width, excavate pools, enhance trout habitat	River reach upstream of Badger Basin HQ - Lower end of Badger Basin perpetual easement
South Fork of South Platte River	FY 11-12/ $90,000	Approved FY 10-11	1.0	Reduce channel width, excavate pools, reduce bank erosion, enhance trout habitat	Badger Basin perpetual easement adjacent to Hartsel town site
South Platte River	FY 12-13/ $200,000	Approved FY 08-09	1.0	Reduce channel width, excavate pools, enhance trout habitat	Lower Spinney SWA (Dream Stream)
South Platte River	FY 13-14/ $100,000	Approval Pending[3]	1.0	Reduce channel width, excavate pools , enhance trout habitat	River segment downstream of Park Co. Rd 59
Tarryall Creek (upstream from Tarryall Res.)	FY 13-14/ $55,000	Approval Pending[3]	.5	Design new stream channel & irrigation diversion	Construct new stream channel and irrigation diversion
Tarryall Creek (Upper SWA segment)	FY 14-15/ $35,000	Approval Pending[3]	.2	Design trout passage around an irrigation diversion structure	Construct trout passage structure over irrigation diversion
Total	**6 years/ $540,000**		**4.7**	-	-

[3] – Funding not yet approved but included on FY 08-09 capitol construction planning staging list.

Research study plans

Research plans will be directed toward addressing the following questions related to stream restoration and enhancement projects to improve fisheries: What is the fisheries response to stream aquatic habitat treatments? Within functional classes of aquatic habitat treatments (Table 1), which treatments are most effective? How do stream habitat projects influence angler use? We propose the following plan for addressing these questions.

Study 1:

Background: CDOW has conducted stream restoration and enhancement projects on almost 9 miles of streams in the upper South Platte drainage. There is a need to evaluate how effective stream aquatic habitat treatments are in enhancing the fisheries.

Goal: Evaluate fisheries response to stream aquatic habitat treatments

Objective: Evaluate stream habitat improvements in the upper South Platte River drainage to quantify changes in salmonid biomass (quantity), individual fish size (quality), and fish utilization of habitat treatments (change in carrying capacity) in restored versus un-restored river segments.

Approach:

Phase 1: Pre-restoration (2-3 years):

Design a BACT (Before/After/Control/Treatment) study within the 11-mile stream reach proposed for stream restoration in the Upper Arkansas River.

Establish appropriate number of control/treatment study sites (400 m reaches) within the entire un-restored 11-mile segment (Terry Waddle (USGS) and Greg Policky (CDOW fish biologist) will assist).

Determine which study sites will serve as treatments and which will serve as control sites. Randomize study sites if possible.

Sample fish populations within each study site using electrofishing techniques to determine fish species present, fish biomass, length frequency, fish length/weights, fish condition, etc. (Greg Policky (CDOW fish biologist) has years of data already collected to serve as baseline data).

Conduct a snorkel survey at each study site to determine fish locations in relation to habitat features present. Use underwater photography or videography to record fish utilizing existing un-restored fish habitat.

Use GPS survey gear to map instream habitat features in study reaches using River 2D software program (Terry Waddle (USGS) and Tracy Kittell (CDOW engineer) will assist). Maps are critical to modeling changes in fish habitat before and after treatments are constructed.

If time and money permit, use the new CDOW aerial camera system (ES11000) to make detailed maps of the entire 11-mile reach (thermal mapping as well as aerial mapping). Changes in stream channel profile (width to depth ratio) should lead to discernable changes in water temperatures with deeper, narrower channels having cooler temperatures preferable to salmonids.

Phase 2: Post-restoration (3-4 years):

Continue using electrofishing techniques to survey fish populations within each control/treatment study site to determine fish species present, fish biomass, length frequency, fish length/weights, fish condition, etc. (Greg Policky (CDOW fish biologist) will assist).

Conduct a snorkel survey at each study site to determine fish locations in relation to habitat features or treatments present. Use underwater photography or videography to record fish utilizing fish habitat treatments in control and treatment sites.

Use GPS survey gear to map instream habitat including locations of newly constructed habitat treatments in study reaches using River 2D software program (Terry Waddle (USGS) and Tracy Kittell (CDOW engineer) will assist).

If time and money permit, use the new CDOW aerial camera system (ES11000) to make detailed maps of the entire 11-mile reach (thermal mapping as well as aerial mapping).

Study 2:

Background: There are a range of different habitat treatments that can be applied to achieve a desired restoration or enhancement goal. A detailed study of how fish utilize each different habitat treatments is necessary to determine which habitat treatments are most effective at achieving the desired goal at the lowest cost. In addition, physical habitat features identified by biologists as "limiting" to particular life stages of self-sustaining salmonid populations may be evaluated to determine whether habitat treatments imposed to address these limitations lead to the desired response in the fishery.

Goal: Within functional classes of aquatic habitat treatments (Table 1), which treatments are most effective?

Objective: Conduct studies to evaluate the effectiveness of a specific treatments by addressing the following research questions: what is the life expectancy of the treatment, how do fish utilize the treatment, what maintenance is necessary to keep the treatment functioning, what is the initial cost in terms of labor and materials to install the treatment, and how immediate is a given treatment able to provide the desired benefit?

Approach:

Aquatic treatment evaluation (2+ years)
During project construction, installation time will be recorded for individual habitat treatments. Material costs will be assessed (including transportation costs to the site). Specific locations of various treatments will be surveyed and documented appropriately for monitoring purposes. Snorkel surveys will be conducted to observe how fish use different habitat treatments over time (part of Study 1) including how soon fish begin to use the space provided by the specific habitat treatment post-construction. Inspections of specific treatments will occur annually to determine 1) condition and function of individual habitat treatments will be assessed to determine whether it is functioning as originally designed and 2) time and costs required for maintaining individual aquatic treatments will be documented.

Study 3:

Background: There is a need to evaluate changes in angler use once stream habitat improvement projects are completed. Currently, there is very little data to document how stream habitat improvements projects may lead to changes in angler use for restored stream reaches.

Goal #2: How do stream habitat improvement projects influence angler use?

Objective: Conduct a detailed creel study to determine how angler-use has changed in restored post-project stream sites compared to pre-project un-restored stream sites.

Approach: Determine what data (if any) exist in the 11-mile segment to quantify pre-restoration angler use. Conduct additional creel studies to quantify angler use specific to the un-restored 11-mile segment before restoration begins (Greg Policky (CDOW fish biologist). After construction is completed, continue conducting creel studies to quantify angler use specific to the restored 11-mile segment (Greg Policky (CDOW fish biologist) will assist).

Appendix A

Table 1. Buckley Ranch Project brown trout biomass (lbs/acre) results for control and treatment reaches pre-and post-project.

Year	Biomass (lbs/acre)	
	Treatment	Control
1990	26	52
1991	29	31
STREAM RESTORATION		
1992	33	11
1993	36	9
1994	48	11
1995	46	13
1996	64	22
2000	80	29
2004	42	10
2009	41	13

Table 2. Dream stream phase 1 and 2 trout biomass (lbs/acre) for treatments reaches pre- and post-project. Note: One year post- restoration (1999), the biomass of brown trout in the Dream Stream segment was estimated to be 175 lbs/acre, a 4-fold increase from pre-restoration trout biomass estimates.

Year	Biomass (lbs/acre)		
	Brown trout	Rainbow trout	Total
1998	34	12	46
STREAM RESTORATION			
1999	175	0	175
2000	315	84	399
2001	236	116	352
2004	71	72	143
2005	109	81	190
2006	154	100	254
2007	152	102	254
2008	130	35	165

Table 3. Tarryall Project brown and rainbow trout biomass (lbs/acre) results for treatment reaches pre-and post-project.

Year	Biomass (lbs/acre)			Density (#/acre)			
	Brown trout	Rainbow trout	Total	Brown Trout	Rainbow trout	Total	# > 14”
1999	36	2	38	162	27	189	0
2004	48	0	48	110	0	110	0
STREAM RESTORATION							
2006	53	0	53	249	0	249	0
2007	71	2	73	281	8	289	3