William P. Ruzzo, PE, LLC
6641 West Hamilton Drive,
Lakewood, Colorado 80227
(303) 985-1091
bill.ruzzo@comcast.net

Memorandum

To: Rick Goncalves, CCBWQA TAC Chairman

CC: Chuck Reid, CCBWQA Manager

From: William P. Ruzzo, P.E.

Date: November 11, 2013

Re: Shoreline PRF Design Approach at Cherry Creek Reservoir

Presented in this memorandum is a summary of the design approach for shoreline pollutant reduction facilities (PRF), discussion of ice related damage and causes, and resulting design changes to minimize damages to shoreline facilities.

Background

The Authority began constructing shoreline stabilization PRFs in 1996 with the East Shade Shelter and East Boat Ramp projects, which were followed by the Tower Loop and Dixon Grove projects in 1999 (see Figure 1 *PRF Location Map*). The most recent project at Mountain and Lake Loop was completed in 2013. To date, the total cost of shoreline PRF's exceeds $1,214,000.

Shoreline stabilization projects qualify as PRF because they minimize the quantity of soil, with attached phosphorus and other pollutants, eroded along the edge of the reservoir that become deposited directly into the lake. In many cases, shoreline erosion and pollutant discharges to the reservoir are aggravated by parking lots that discharge pollutants directly to the reservoir. Erosion is primarily the result of wave and ice forces acting on the shoreline soils, but also from pedestrian and domestic animal uses that destroy vegetation exposing bare soils that are more readily eroded. Examples of shoreline erosion at Cherry Creek are shown on the Photos 1 and 2.

The dominant shoreline stabilization method is to use riprap and large boulders supplemented with willow, bushes, trees, and other suitable vegetation plantings. See Photos 3, 4, 5 and 6. Runoff from parking lots is addressed by creating wetland retention areas (see Photo 3) or infiltration areas that filter pollutants in the runoff minimizing the discharge into the reservoir. More recently at the Mountain and Lake Loop project, jetties were also used which, when properly sized and located, allow sand to become deposited on the leeward side of the jetty creating sand beaches, thereby reducing the length of hardened shoreline required. See Photo 7.

The earlier shoreline PRF's placed large boulders, typically 36" or larger, along the water's edge with the top of the boulder about 18" above the normal maximum water surface (i.e.: 5550 feet) in the Reservoir. For the Tower Loop project, boulders were stacked two and three high creating a wall that raised the fishing platforms constructed along the steep shoreline slope.

The boulder sizes exceed rock sizes needed to protect the shoreline from wave erosion. However, it was observed during some winter and early spring periods that ice forces were able to move and displace some large boulders at the east shoreline projects and, for Tower Loop, resulted in failure of the boulder wall (see Photos 9 through 13). In other areas, the boulders were shifted around leaving gaps in the shoreline protection. Investigation into the causes identified two scenarios where ice forces were likely to cause damage to the shoreline:

- Long, cold winter periods that allowed thick continuous ice cover over the Reservoir which then expanded or shifted due to wind shear creating large horizontal forces at the shoreline.

- Melting of ice cover in the spring that begins along the shallow edge of the reservoir and leaves large, thicker, free floating sheets of ice in the main part of the reservoir. These sheets of ice are readily moved about the reservoir during high wind, spring storm events in almost any direction and impact shoreline facilities including the PRFs and the Marina docks[1].

Design Modifications and PRF Repairs.

It was observed that when smaller rock – d_{50} of 18" and smaller – was placed in front of the large boulders and sloped (i.e.: ~2.5:1 or flatter) away from large boulders, that the ice forces did not result in significant damage to the shoreline protection measures. This design approach is illustrated in the restoration plan for Tower Loop on Figure 2. It is believed that the smaller rock "buttress" caused the ice sheets to be forced upward reducing the forces and minimizing displacement of the large boulders.

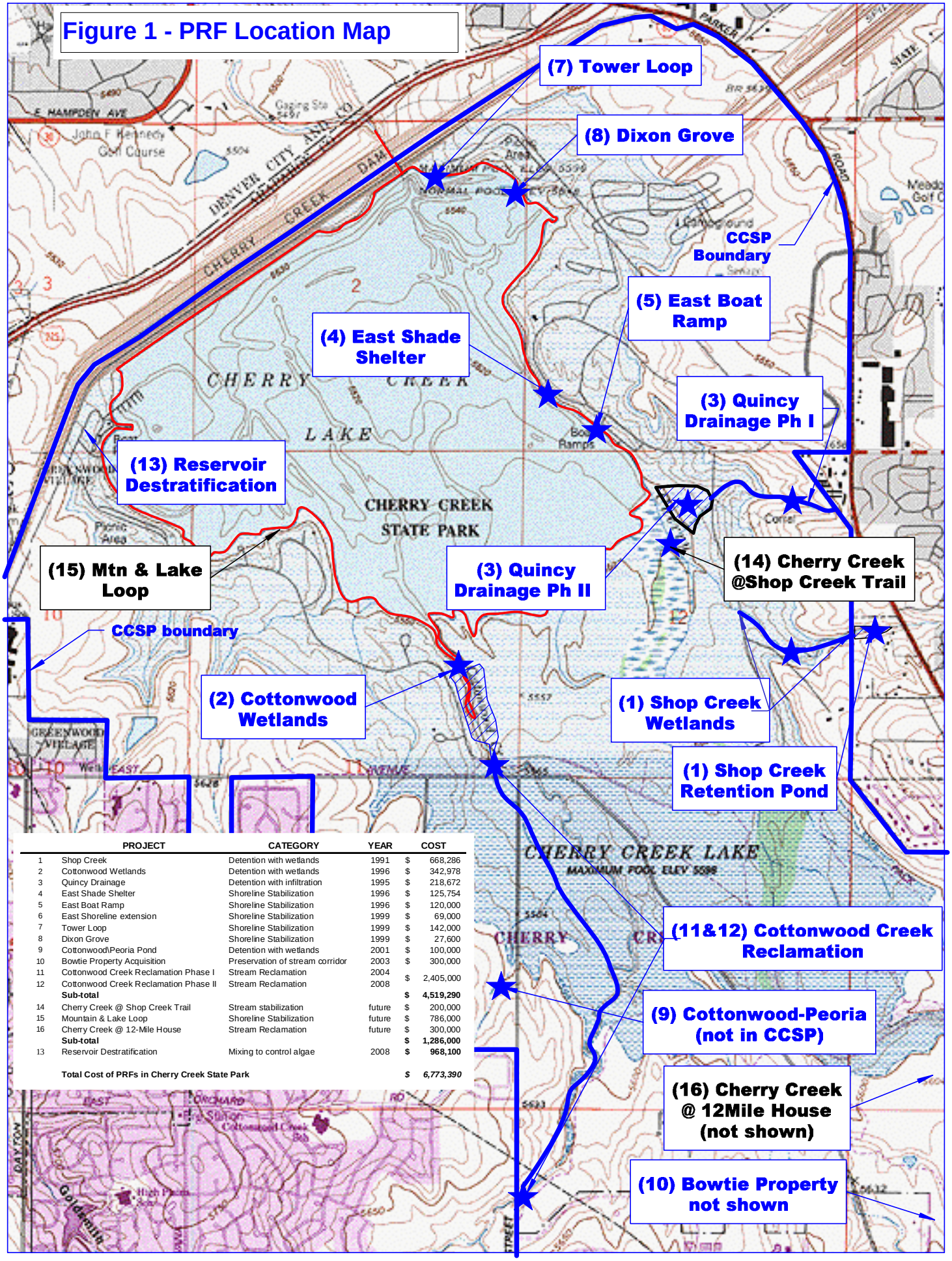
Beginning in 2008, the Authority began a rehabilitation program for the East Boat Ramp, East Shade Shelter, Dixon Grove, and Tower Loop shoreline PRFs that added the rock buttress in front of the large boulders at a cost of around $134,000. Examples of the buttress can be seen in Photo 4, Tower Loop. This design approach was incorporated into the Mountain and Lake Loop project. See Photo 7.

Conclusions

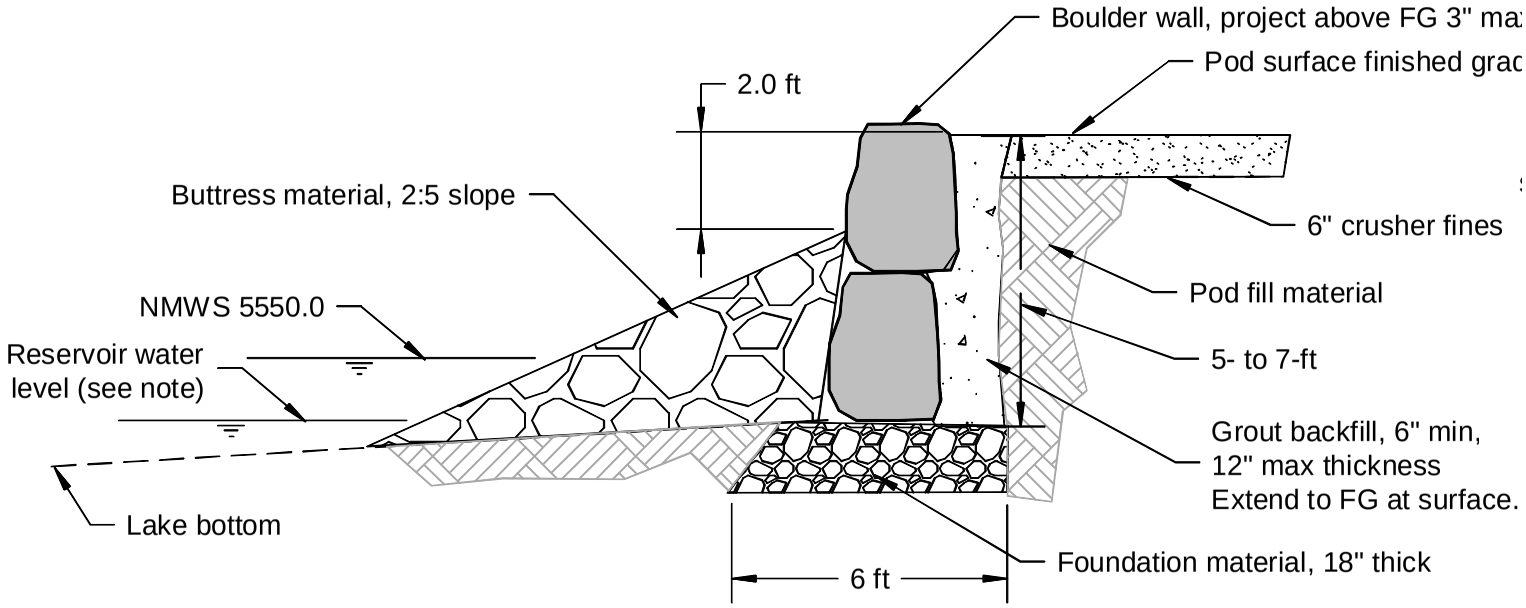
The Authority has modified its design approach for stabilization of shorelines by including sloping rock buttresses waterside of any large boulders used to protect the shoreline that deflect ice forces upward and minimize damages. This approach has appeared to significantly reduce ice related damages to shoreline PRFs.

[1] The Destratification system has been started up in the spring with some ice cover to break up the ice sheets using the warmer air bubbles to reduce the ice thickness.

Figure 1 - PRF Location Map



	PROJECT	CATEGORY	YEAR	COST
1	Shop Creek	Detention with wetlands	1991	$ 668,286
2	Cottonwood Wetlands	Detention with wetlands	1996	$ 342,978
3	Quincy Drainage	Detention with infiltration	1995	$ 218,672
4	East Shade Shelter	Shoreline Stabilization	1996	$ 125,754
5	East Boat Ramp	Shoreline Stabilization	1996	$ 120,000
6	East Shoreline extension	Shoreline Stabilization	1999	$ 69,000
7	Tower Loop	Shoreline Stabilization	1999	$ 142,000
8	Dixon Grove	Shoreline Stabilization	1999	$ 27,600
9	Cottonwood\Peoria Pond	Detention with wetlands	2001	$ 100,000
10	Bowtie Property Acquisition	Preservation of stream corridor	2003	$ 300,000
11	Cottonwood Creek Reclamation Phase I	Stream Reclamation	2004	
12	Cottonwood Creek Reclamation Phase II	Stream Reclamation	2008	$ 2,405,000
	Sub-total			**$ 4,519,290**
14	Cherry Creek @ Shop Creek Trail	Stream stabilization	future	$ 200,000
15	Mountain & Lake Loop	Shoreline Stabilization	future	$ 786,000
16	Cherry Creek @ 12-Mile House	Stream Reclamation	future	$ 300,000
	Sub-total			**$ 1,286,000**
13	Reservoir Destratification	Mixing to control algae	2008	**$ 968,100**
	Total Cost of PRFs in Cherry Creek State Park			***$ 6,773,390***



TYPICAL SECTION BOULDER WALL REPAIRS

Figure 2 Tower Loop Repair Plan

Photo 1 - Lake Loop Shoreline prior to stabilization

Photo 2 - Lake Loop Shoreline prior to stabilization

Photo 3 East Boat Ramp.
Boulder edging with loose rock backfill. NMWS is shown by the change in color along the boulder. Open areas left between boulder areas to create small, localized beaches. Willow growth behind rock wall is runoff treatment for the parking lot.

Photo 4 - Tower Loop Fishing Pod.
Smaller rock buttress can be seen on the lake side of the taller rock wall.

Photo 5 East Boat Ramp.
Boulder edging with loose rock backfill. NMWS is shown by the change in color along the boulder. Open areas left between boulder areas to create small, localized beaches.

Photo 6 - Lake Loop Shoreline Stabilization.
Slope flattened and intermittently armored with riprap.

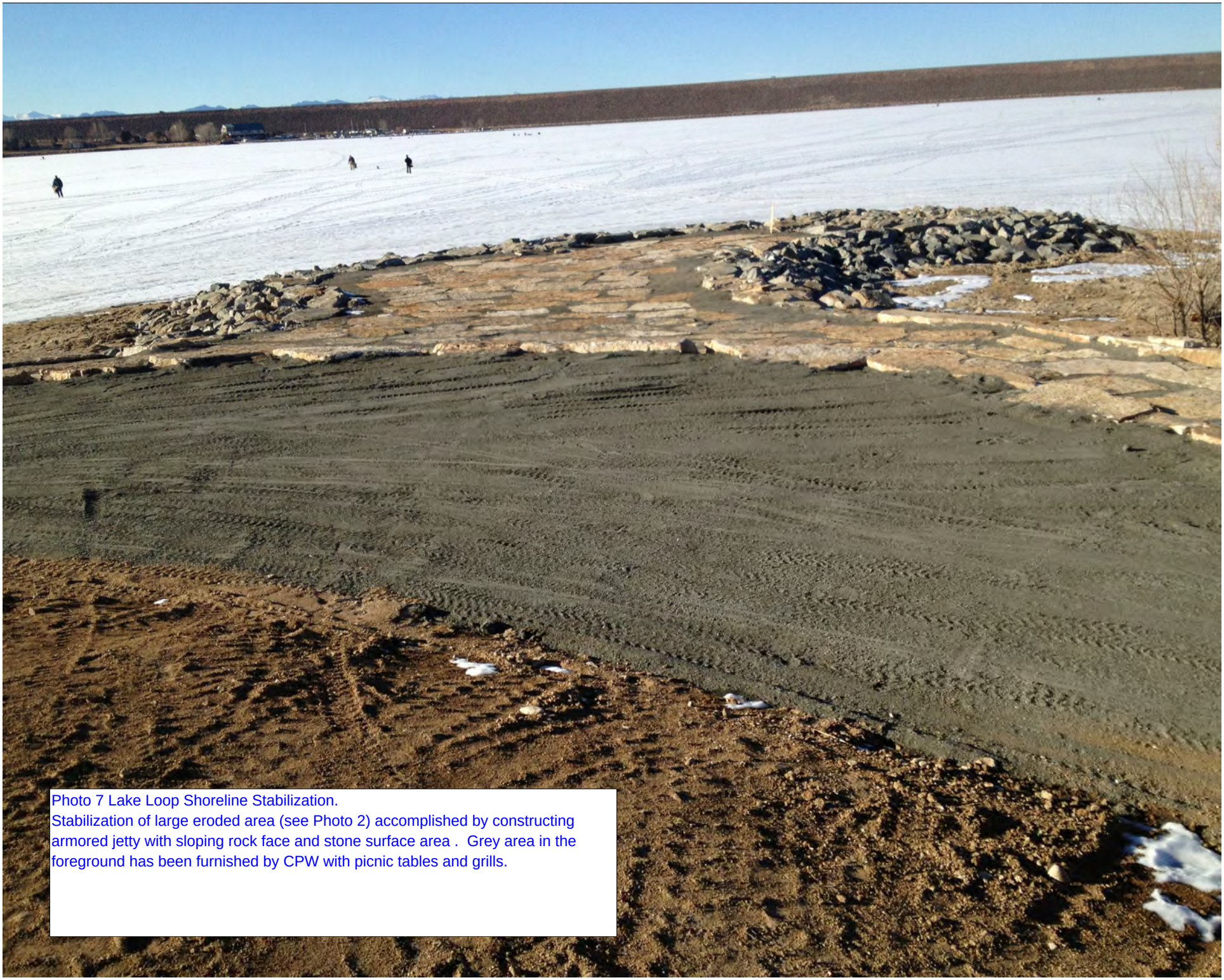


Photo 7 Lake Loop Shoreline Stabilization.
Stabilization of large eroded area (see Photo 2) accomplished by constructing armored jetty with sloping rock face and stone surface area . Grey area in the foreground has been furnished by CPW with picnic tables and grills.

Figure 8 Tower Loop
Ice forces and damages

Figure 9 Tower Loop
Ice forces and damages

Figure 10 Dixon Grove
Ice forces and damages

Figure 11 Tower Loop
Ice forces and damages

Figure 12 Tower Loop
Ice forces and damages

Figure 13 Tower Loop
Ice forces and damages