APPENDIX A

Photographs of Pueblo Indian Irrigation Infrastructure

Appendix A shows photos of some of the irrigation infrastructure in New Mexico Pueblos in need of repair or replacement. The focus is on diversion structures and conveyance facilities.

Diversion structures are constructed in rivers or creeks. They divert water from the river and into the main conveyance, which is either a pipeline or open ditch. Diversion structures act as grade control structures in the river, and should maintain the water surface at the minimum level sufficient for diverting water to the irrigation ditch. Design of engineered diversion structures includes several considerations: stream flow, diversion flow, debris, sedimentation, and specifics of a given site. The structure itself typically includes a headworks gate, an overflow weir or river gates, and sluice gates. The headworks gate is used to control the amount of flow going into the ditch.

The existing diversion structures in these eighteen Pueblos raise the water level by less than 1 foot to over 10 feet. Most of them are constructed of concrete walls and slabs embedded into the creek bed and channel banks. Other structure types include rock gabions with a concrete cap, steel sheet pile, and rock-and-brush. Except for the rock-and-brush diversions, these structures are constructed of material designed for durability, reliability, and control of flows into the ditches.

1.0 NON-ENGINEERED DIVERSION STRUCTURES.

Non-engineered diversion structures are either rock-and-brush structures or simple berms or ditches built across a river or creek. These structures are typically inefficient and unreliable.

The rock-and-brush type diversion has existed for hundreds of years, and is the most common type present in Taos Pueblo. It is constructed of tree branches and 6-inch to 18-inch size rocks placed across the full width of creek bed, usually at an angle to the flow. Sandbags, plywood boards, or plastic sheets are used to fill or plug gaps between larger rocks. These diversions are highly unstable and easily wash out after every spring runoff or thunderstorm event. Reconstruction is necessary after each washout. Frequent minor repairs are also necessary during low flow periods. Lower flows wash out the smaller gravel and cobbles and the tree branches. These non-engineered structures do not have gates and there is no control of flow into the ditches. High flows cause excessive diversion into ditches, which overflow and flood farm lands. During low flows, these inefficient rock-and-brush structures often do not divert any water at all into the irrigation system.

Another type of non-engineered diversion structure is constructed by excavating a trench across the river bed, such as the diversion for the Navajo ditch in the Rio Tesuque.

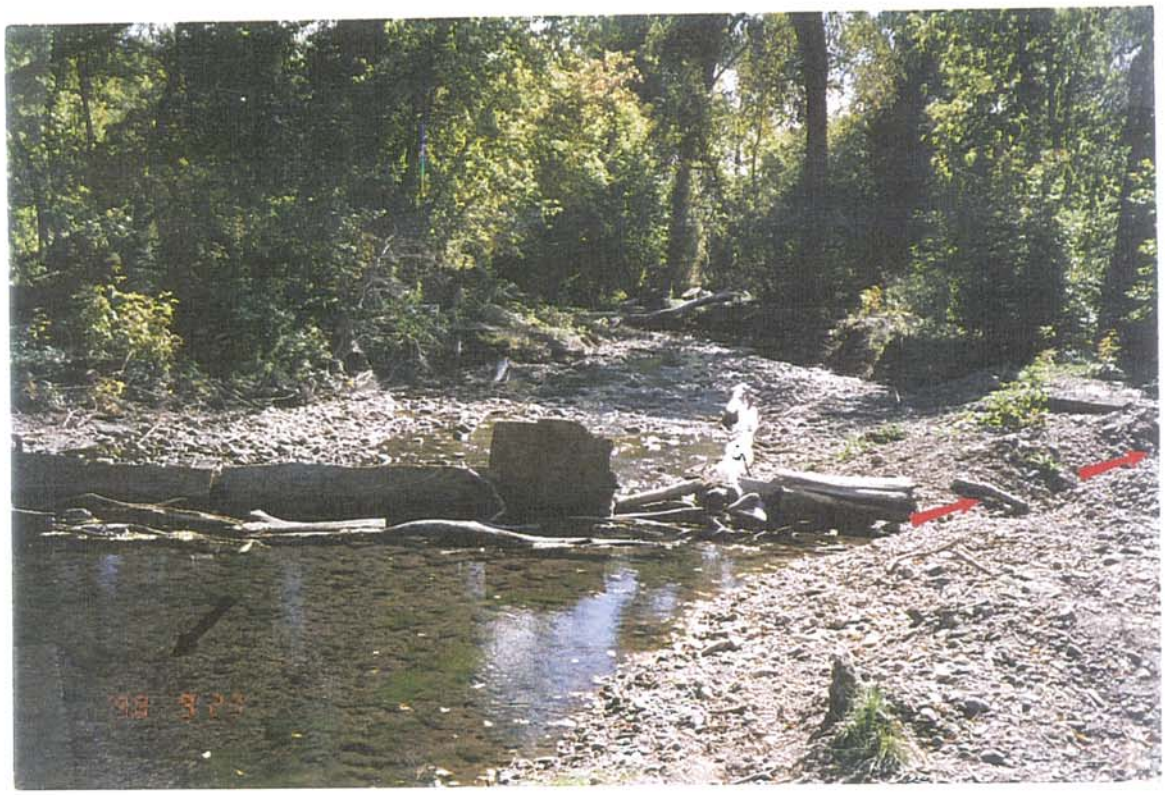

Photo No. 1 – Mirabal Acequia (Taos Pueblo) - Looking downstream at a 150-year-old rock-and-brush diversion structure on the Rio Pueblo de Taos. Ditch inlet is shown by red arrows. The structure washes out after every spring runoff or summer thunderstorm.

Photo No. 2 – Mirabal Acequia (Taos Pueblo) - Looking upstream from ditch inlet. Ditch alignment is shown by arrows and is often plugged by sediment after moderate runoffs. A permanent diversion structure is recommended.

Photo No. 3 -- Mexican Ditch (Taos Pueblo) - Looking downstream, Rio Pueblo de Taos. Diversion structure is at bottom of photo and is constructed of plastic, logs, rocks, and sandbags. Ditch headwork with slide gate is on the lower left corner of photo. Sediment and debris deposit is evident downstream, making this a maintenance intensive site. Construction of a permanent diversion is recommended.

Photo No. 4 -- Phia No (Taos Pueblo) - Looking downstream at rock-and-brush diversion in Rio Pueblo de Taos. Phia No ditch runs parallel to the river, behind trees on the left side of photo. Ditch gets flooded and plugged with sediment and debris after every large runoff.

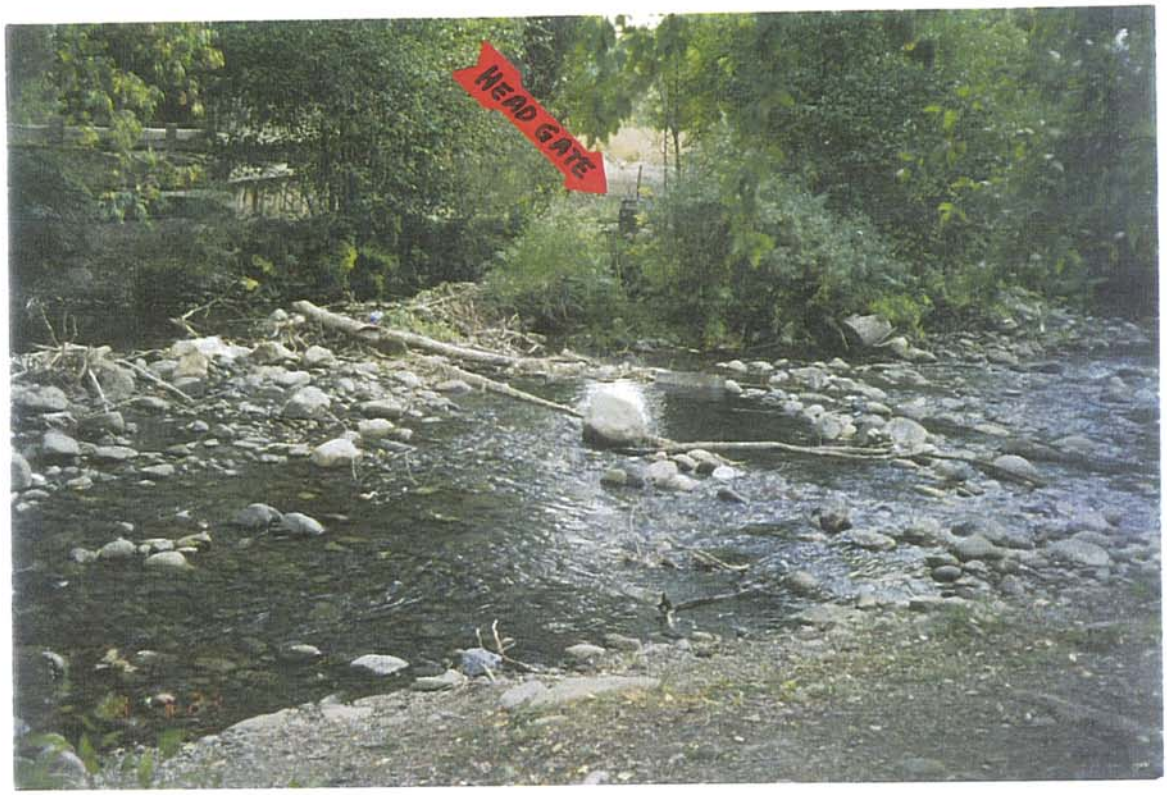

Photo No. 5 -- Phia No (Taos Pueblo) - Looking across Rio Pueblo de Taos channel, flowing left to right, at ditch intake. The rock and brush dam at left has been washed out. A permanent diversion structure is recommended for this site.

Photo No. 6 -- "B" Ditch (Taos Pueblo) - Looking upstream at a rock and brush diversion structure on Rio Pueblo de Taos. Side channel to "B" ditch is shown by arrow. Structure frequently washes out and must be rebuilt each time.

Photo No. 7 -- South Trash Pile Ditch (Taos Pueblo) - Headgate to ditch shown on left bank just upstream of rock-and-brush diversion structure on Rio Pueblo de Taos. Debris accumulation and heavy vegetation growth near headgate hinders diversion. A permanent diversion structure is needed at this site.

Photo No. 8 -- North Trash Pile ditch (Taos Pueblo) - Looking downstream, from end of rock and brush structure. Note the rocks that had washed downstream from this structure. Replacement of rock and brush structure with concrete diversion is recommended.

Photo No. 9 -- Pottery Ditch (Taos Pueblo) - Looking at rock and brush diversion that diverts flow to Pottery Ditch, on the lower left corner of photo. Reconstruction is required after every moderate spring runoff and thunderstorm. A permanent concrete diversion is recommended.

Photo No. 10 -- Pottery Ditch (Taos Pueblo) - Another view of the rock and brush diversion, partially deteriorated from erosion.

Photo No. 11 – Navajo Ditch Diversion (Tesuque Pueblo) - This ditch is on the river bed of the Rio Tesuque and diverts surface water during low flow periods. It washes out after every spring runoff and thunderstorm.

Photo No. 12 -- Navajo Ditch Diversion Structure (Tesuque Pueblo) - Continuation of ditch in Photo No. 11, conveying water to an existing storage pond.

2.0 ENGINEERED DIVERSION STRUCTURES

Engineered diversion structures are typically made of concrete, gabions, sheet piles, or some combination thereof. Most Pueblo engineered diversion structures show considerable deterioration and many are structurally deficient. Some no longer divert water efficiently or dependably.

Older concrete diversion structures that are 30 to 65 years old show considerable corrosion and wear. At many diversion structures, the radial gates show typical long-term degradation, such as worn out seals and pitted, abraded concrete. Slide gates show severe corrosion or damaged stems, and have become inoperable.

Several structures are maintenance intensive due to lack of sluicing capability. They are frequently plugged by debris and sediment. Often, debris and sediment are much worse than anticipated when designed. Sometimes the needed sluice gates or other features were deleted due to lack of adequate construction funding.

Photo No. 13 – Rio Lucero Diversion (Taos Pueblo) -- Typical radial gate with deteriorated seals and severely abraded concrete crest. Note the severe leakage.

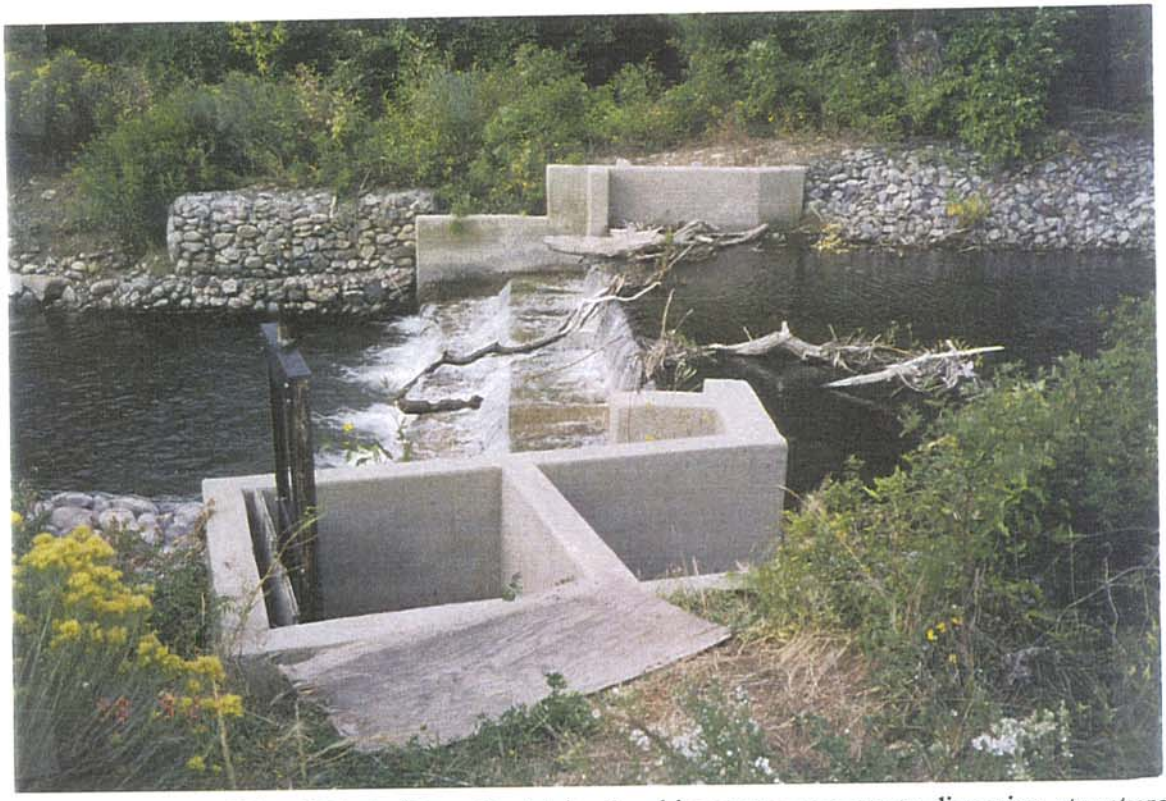

Photo No. 14 -- Pull Leaf Ditch (Taos Pueblo) - Looking across concrete diversion structure. Upstream bank was eroded, requiring riprap placement. Diversion headworks box has no cover, which is a safety hazard, and the slide gate is inoperable and needs replacement.

Photo No. 15 -- Cicada Nose Acequia and Elk Horn Ditch (Taos Pueblo) - Looking at stepped concrete diversion structure. Note concrete spalling and deterioration of concrete floor edges and abutment. Rehabilitation is required to prevent concrete degradation from becoming severe.

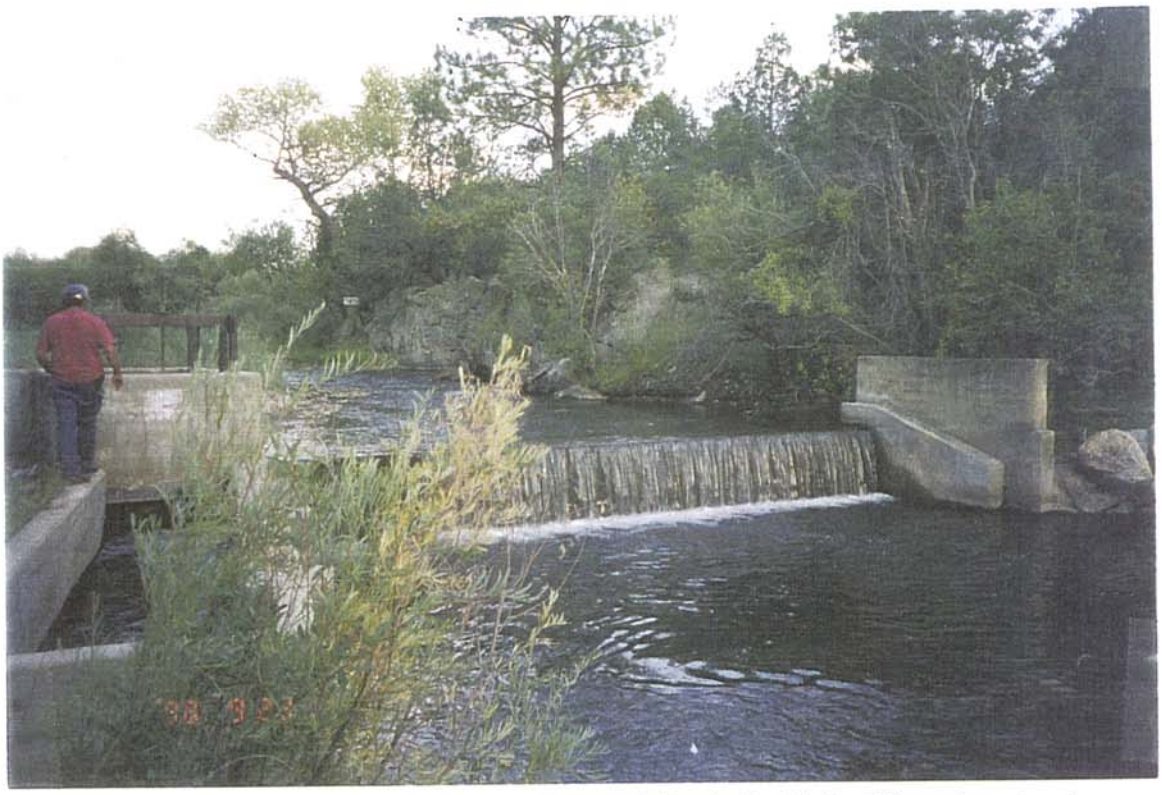

Photo No. 16 -- Highline Ditch Diversion Structure (Picuris Pueblo) - Diversion structure headworks is on lower left side of photo. Erosion has undermined this headworks box structure (close-up is shown in Photo No. 16).

Photo No. 17 -- Highline Ditch Diversion Structure (Picuris Pueblo) - The concrete headworks box structure has been severely eroded, undermining the box structure. Repair is required to repair the concrete and prevent the box structure from collapsing.

Photo No. 18 -- West Side Ditch Headworks and Diversion Box at End of Highline Ditch (Picuris Pueblo) - Slide gate on the left is the headworks to a 24-inch steel pipe flume that crosses the Rio Pueblo and connects to the West Side Ditch. The two slide gates leak and should be replaced.

Photo No. 19 -- Santa Clara Main Canal Diversion Structure (Santa Clara Pueblo) - View at end of an L-shaped diversion in the Rio Grande, showing two slide gates. The left gate is a sluice gate which is too small to pass most debris. The debris piles on the right side of the photo have been manually removed from the area in front of the two gates. The debris piles then have to be trucked from the site.

Photo No. 20 – Santa Clara Main Canal Diversion Structure (Santa Clara Pueblo) - End of diversion structure. Debris is trapped and accumulates in front of the diversion headworks gate and cannot be flushed out through the sluice gate (edge is visible immediately left of the headworks gate). Modification of the flushing system is needed.

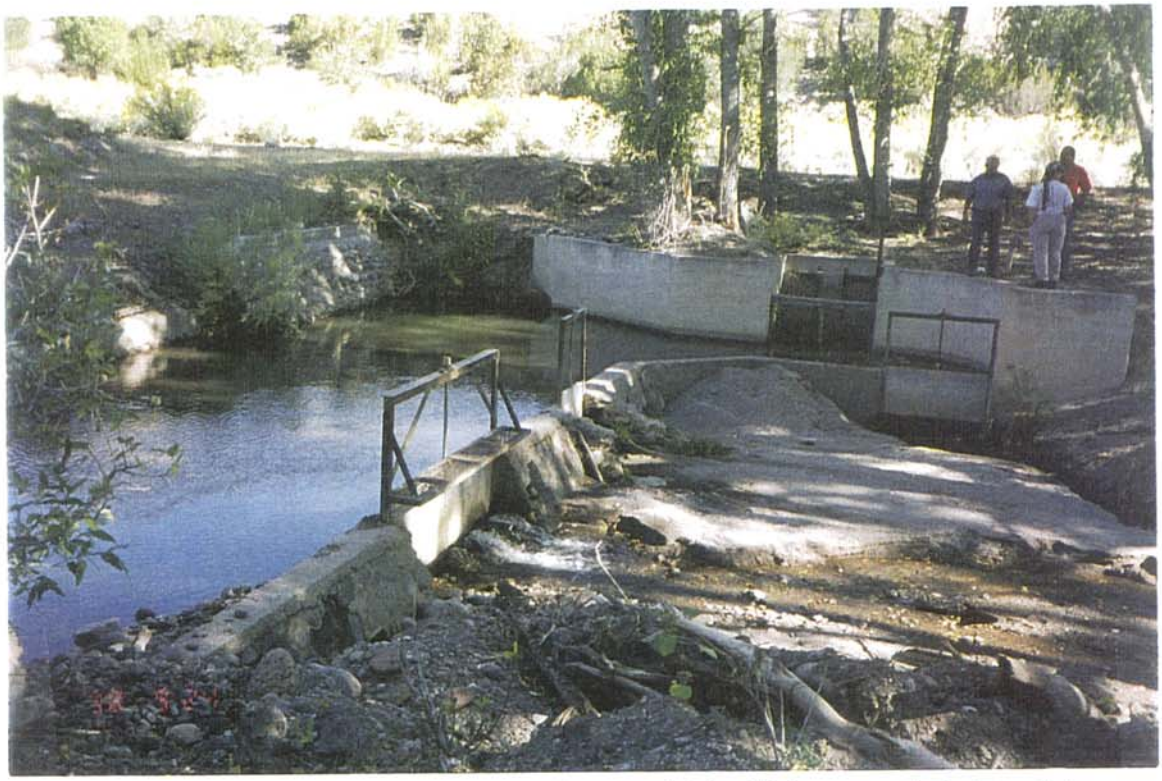

Photo No. 21 -- Santa Clara Diversion (Santa Clara Pueblo) - Sluice gates leak into sluiceway. Overall structural deterioration and accumulation of sediment and debris are evident. New gates and modified sluicing system are needed.

Photo No. 22 -- Rio Pojoaque Main Diversion (San Ildefonso Pueblo) - Looking north along alignment of diversion structure. Crest of concrete diversion structure spans half the river's width. The other half of diversion has washed out, making it incapable of diverting water. Rio Pojoaque flows from right to left.

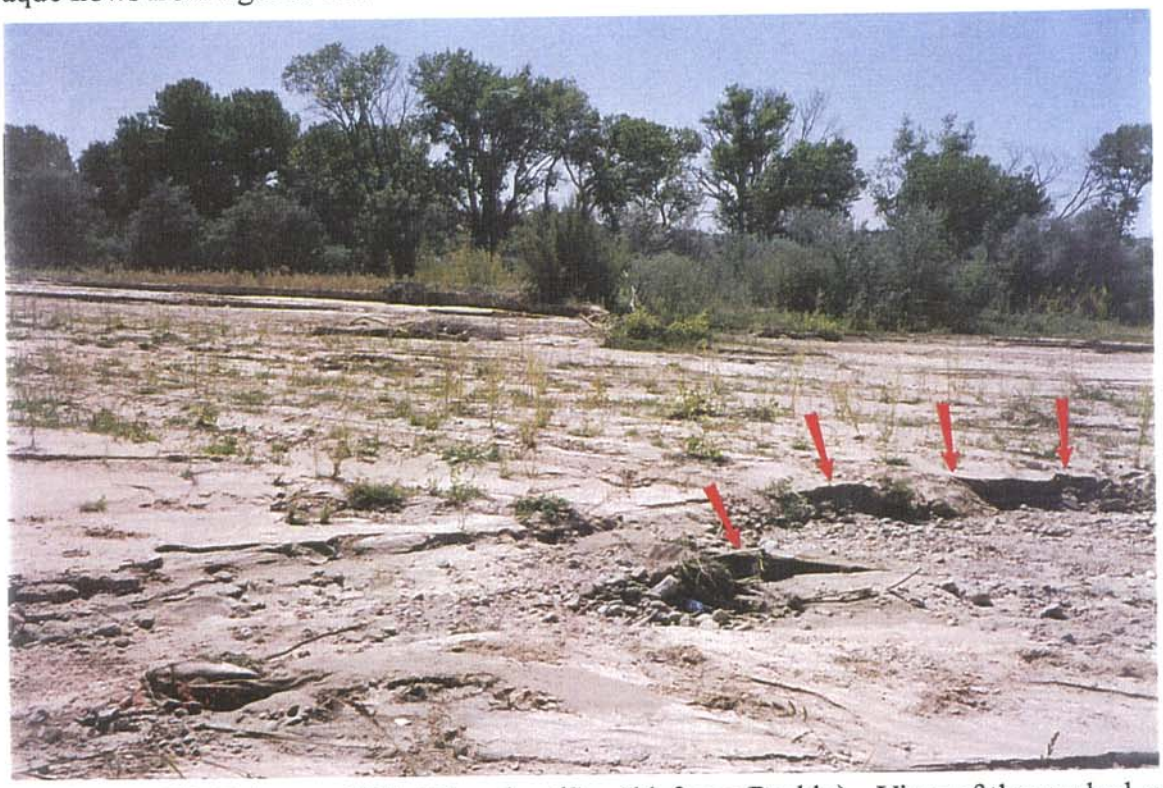

Photo No. 23 -- Rio Pojoaque Main Diversion (San Ildefonso Pueblo) - View of the washed-out half of the diversion structure, with arrows showing remnants of the steel sheet pile structure. Collapse was caused by high flows, which scoured downstream of the structure.

Photo No. 24 – Rio Pojoaque Main Diversion (San Ildefonso Pueblo) - Looking at the headworks on the north river bank, which can no longer divert water. River flows now go to the south side of the river, which is lower because of the structural collapse shown in Photo No. 23.

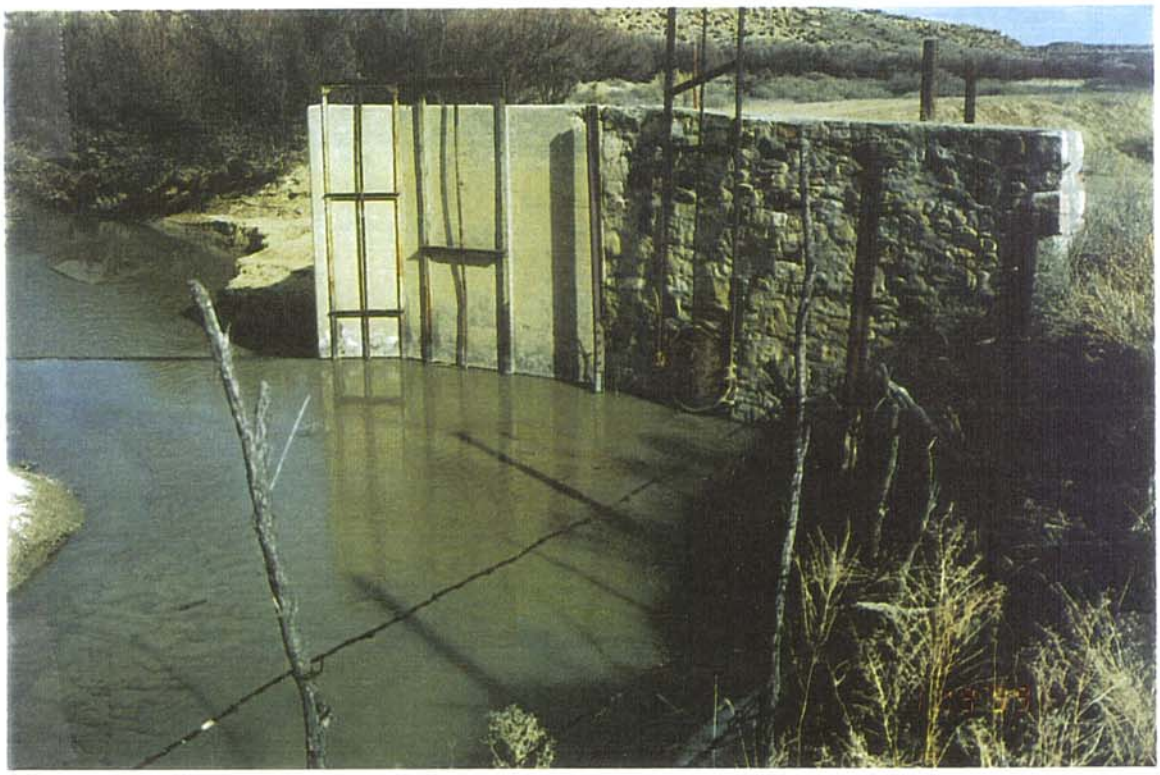

Photo No. 25 – Seama Diversion (Laguna Pueblo). Constructed in 1930's. Irrigation headgate shown at center leaked badly. It was repaired at considerable effort but has not been operated since, because it may not be possible to stop the leak again. Gate should be replaced.

Photo No. 26 – Casa Blanca Ditch at Philadelphia Diversion (Laguna Pueblo) - Headgate from ditch to river. The concrete has deteriorated and the gate leaks because it cannot seat properly.

Photo No. 27 – Encinal Canyon Ditch (Laguna Pueblo) - Diversion structure has silted in (behind wall), and is not functional. Rehabilitation of this structure is recommended.

Photo No. 28 – Mesita Dam (Laguna Pueblo) - Headgate for Mesita pipeline inside the concrete box leaks because it is poorly seated when closed.

3.0 CONVEYANCE FACILITIES

Conveyance facilities consist of a canal or ditch and its related structures which deliver water from the diversion structure to the irrigated land. The conveyance system normally consists of several components: conveyance structures (canals, siphons to cross arroyos, road crossing culverts, flumes, and drop structures), regulating structures (checks and wasteways), protective structures (cross drains), water measuring structures (weirs and Parshall flumes), and turnouts. Its design typically includes several considerations: design capacity to meet water demand, topography and soil types along the canal, hydrologic factors, operation and maintenance, and other site specific factors.

Conveyance in the eighteen Pueblos is through earthen ditches, concrete lined ditches, or pipelines. Many have been poorly maintained and are severely deteriorated.

In northern Pueblos, the concrete and PVC pipelines have been installed at shallow depths above the frost line, and are subject to frost heave. One common type of pipe deterioration is joint separation caused by foundation settlement or frost heave. Damaged pipes are repaired soon after the pipe break or leakage occurs. No photos were taken of damaged buried pipeline.

Concrete lined ditches in the northern pueblos are also subjected to frost heave. Typical deterioration is caused by heaving of the floors and buckling or collapsing of the sidewalls. Saturated earth pressure on the sidewalls also damages concrete ditches. This is especially evident in ditches traversing along hillsides in Acoma Pueblo. Some concrete ditches are so extensively deteriorated that they no longer have a uniform grade line or slope, and sometimes flow uphill for short reaches. There are also severe flow area constrictions caused by collapsed walls. One damaged section can become a bottleneck that constricts flow and considerably reduces the overall flow capacity. Flow constrictions also cause overtopping of ditches, undermining concrete ditch foundations and flooding fields.

Typical deterioration of earth ditches consists of collapsed or eroded side walls and irregular sections from heavy siltation and vegetation growth. Silt build up in Encinal Canyon ditch has raised ditch invert by twelve to eighteen inches, which considerably reduces its flow capacity. North Acomita Ditch capacity is reduced to almost zero because of bank sloughing, siltation, and a very flat and irregular grade line. Efficient and reliable flow in this ditch is critical to adequately serve two neighboring pueblos in an area which routinely experiences water shortages. Water is diverted into the North Acomita Ditch from Acomita Lake, and flows are usually limited to a few days a month because of the limited water supply in Acomita Lake.

Elevated flumes are commonly used to carry canal water over natural drainage channels. They are used only when the preferred buried siphon alternative becomes too costly. Several flumes leak and have not been in service for the last few years because of excessive water loss. Some have severe safety deficiencies.

Photo No. 29 -- West Side Ditch Flume Crossing (Picuris Pueblo) - Flume structural support. O&M platform is missing.

Photo No. 30 – West Side Ditch Pipe Flume (Picuris Pueblo) - Steel pipe flume crossing Rio Pueblo. Note surface corrosion on the steel pipe and worn-out paint coating. A new protective coating is needed to prevent severe pipe corrosion.

Photo No. 31 -- West Side Ditch Pipe Flume (Picuris Pueblo) - View of steel pipe flume showing the narrow walkway of rotted timber decking that is broken at many locations. Installing a maintenance catwalk with adequate safety features is strongly recommended.

Photo No. 32 – Typical deteriorated concrete ditch, with broken panels from subsurface water pressure, soil pressure, and frost heave.

Photo No. 33 – Typical deteriorated concrete ditch with broken floor and sidewall.

Photo No. 34 – Sandoval Ditch (Acoma Pueblo) - Concrete ditch panels on the hillside (left) buckled, due to subsurface water pressure. In addition, runoff from hillside deposits sediment and debris in the ditch, plugging a 1.5 mile section of ditch.

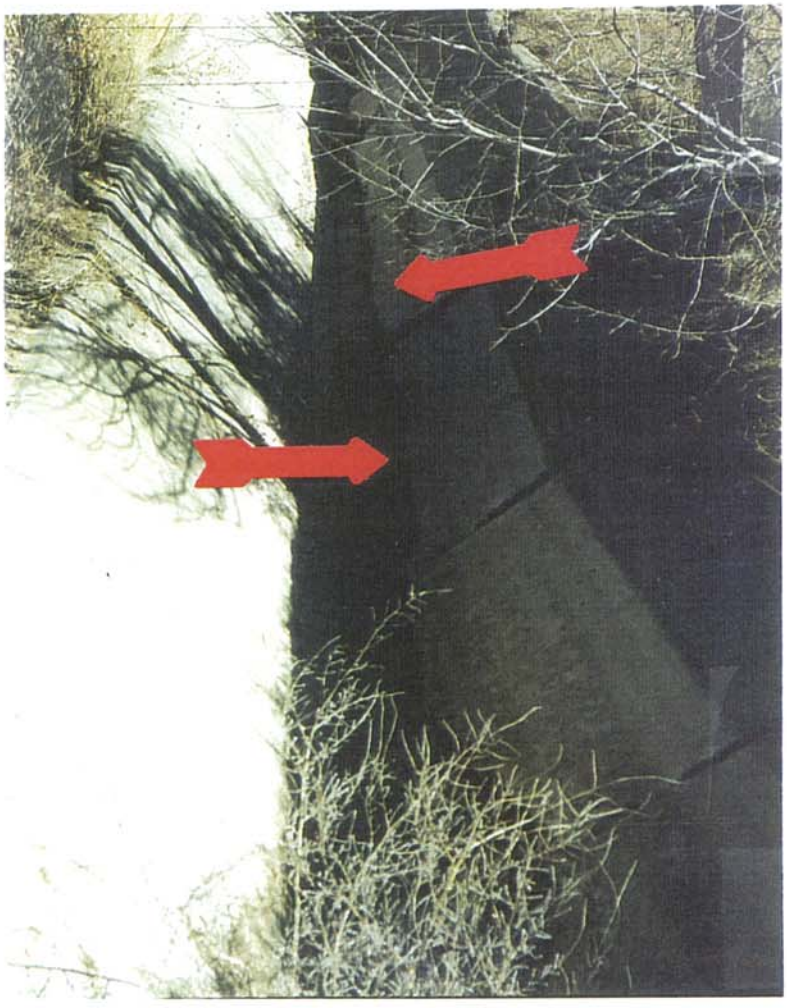

Photo No. 35 – Sandoval Ditch (Acoma Pueblo) - Looking east. Right panels broke at the toe and slipped into ditch bottom. Bottom width of ditch is only half its original width, which is a severe constriction and results in considerable reduction of flow capacity for the full 10 mile length of ditch.

Photo No. 36 – Sandoval Ditch (Acoma Pueblo) - Typical deteriorated concrete ditch.

Photo No. 37 – Sandoval Ditch (Acoma Pueblo). Typical deteriorated ditch turnout that is difficult to operate. Turnout should be replaced.

Photo No. 38 – Sandoval Ditch near Estevan Diversion (Acoma Pueblo) - Approximately 600 feet of ditch frequently plugs up from deposition of hillside runoff debris. This section of ditch should be placed in pipeline.

Photo No. 39 – Sandoval Ditch (Acoma Pueblo) - Left panel completely collapsed and has been removed.

Photo No. 40 – Encinal Canyon Ditch (Laguna Pueblo). This ditch has not been used for several years because it has been filled with silt to half its original depth. Ditch should be cleaned and reshaped.

Photo No. 41 – Encinal Canyon Ditch (Laguna Pueblo). Encinal ditch flume crossing, located about 0.3 mile from Beecher Dam. Flume leaks at several locations.

Photo No. 42 – New Laguna Ditch (Laguna Pueblo). Along east side of New Laguna Rd. Typical earthen ditch with heavy vegetation and poor conveyance capacity.

Photo No. 43 – North Acomita Ditch (from Acoma Pueblo to Laguna Pueblo) - Earthen ditch (shown by arrows) traverses around and along the hillside, to Seama Dam in Laguna Pueblo. The grade of this ditch is very flat. Ditch flow is very inefficient. Sediment deposition is common at various locations along this ditch. This ditch should be concrete lined and sediment laden storm runoffs from the side hills should be properly routed.

Photo No. 44 – Seama Diversion (Laguna Pueblo). Concrete lined ditch downstream of diversion. Further downstream is a 3-mile long, badly deteriorated, earthen ditch that frequently plugs up with debris that falls in from the surrounding hillside.

Photo No. 45 – Sandoval Ditch (Acoma Pueblo). Typical deteriorated road crossing culvert. A 24-inch corrugated metal pipe (CMP) culvert has separated at about mid-pipe, causing leakage into the ground and road settlement. CMP culvert should be replaced.

Photo No. 46 – Seama Ditch (Laguna Pueblo). Stilling basin at the end of a flume and transition to an earthen ditch. Earthen ditch has heavy vegetation growth that retards flow. Ditch should be cleaned and reshaped.

Photo No. 47 – Seama Ditch (Laguna Pueblo). Looking downstream at end of concrete lined ditch from Seama diversion. A turnout (hidden by brush in lower right of photo) has been damaged from ground settlement and erosion. Turnout structure should be rehabilitated.