PAP-781

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Water Measurement Device Design, Recommendations, Data Recording and Communications Equipment for the Nambe, Pojoaque, and San Ildefonso Pueblos and the Pojoaque Valley Irrigation District (PVID)

by

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Introduction

The Pojoaque Valley Irrigation District (PVID) and the Indian pueblos of Nambe, Pojoaque, and San Ildefonso receive supplemental irrigation water from Reclamation's San Juan-Chama Project from Nambe Falls Dam and reservoir completed in 1976. Most of the permanent river diversion structures, concrete-lined irrigation canals, and measurement structures were constructed by Reclamation. The Native American Affairs Office has allotted funding for the improvement of water measurement and recording devices for the three pueblos served by PVID. The Albuquerque Area Office (AAO) will be providing technical support to the district and pueblos for this program. The Water Resources Research Laboratory (WRRL) was contacted to assist by providing a review of existing facilities; to recommend possible improvements including designing water measurement structures and specifying recording devices and communications equipment.

The pueblos are interested in adding additional measurement sites to define Indian and non-Indian use of the water and to upgrade the system to include state-of-the-art recording and communication systems. In addition, the top priority site for the pueblos is upstream from Nambe Falls Dam to measure the year-round base flow from the Nambe River. This is now computed from dam releases (measured at the stream gaging station downstream from the dam) and the reservoir elevation. The pueblos would like direct measurement. The other potential new sites are on the Llano, Nueva, and Community ditches. These are currently unlined canal sections with a capacity range of about 1 to 6 ft^3/s. In addition to installing more measurement stations, the district, pueblos, and the AAO would like real-time data to better manage water in the system. The district has only part-time employees, and remote data gathering would be of assistance particularly where access to sites is difficult. The AAO would like accurate data for their computer program to assist with water management of the Upper Rio Grande River.

Purpose

The project involves two separate, but closely tied issues; the measurement device, and the method by which the data is gathered, recorded, and transmitted from that device. <u>The important point is that discharge data from improperly operating measurement devices are not worth recording or transmitting.</u> First, the measurement device must be properly designed, installed, and maintained, then the methods by which the data is gathered, recorded, and transmitted can be determined and installed.

The purpose of the study was to:

- review and evaluate the conveyance and measurement facilities of the PVID,
- recommend possible improvements to the existing water measurement sites,
- design new water measurement structures to replace existing structures, if necessary,
- design water measurement devices for four new sites; one on the Nambe River upstream of the dam and three in unlined ditches within the conveyance system, and
- design and specify new water level measurement devices, data loggers, and communication system for real-time remote data gathering and transmission.

The pueblos will procure the equipment and/or materials from the list provided in this report. The PVID will perform or make arrangements for the installation.

Review of Facilities

The system facilities were toured twice with the assistance of personnel from the AAO, David Vigil from PVID, and Herbert Yates from the Nambe Pueblo. Their input was extremely helpful during our review by providing information about the water delivery system and operations, and their visions for the future of the system.

The irrigation system is very old and, prior to construction of Nambe Falls Dam, had very limited storage capability. District water for irrigation is now supplemented by storage water from Nambe Falls Dam. Reclamation, in addition to constructing the dam at the headwater of the conveyance system, provided improvements to the existing conveyance systems and measurement devices in many locations throughout the district. These improvements also included some new permanent diversion structures in the River downstream from the dam at many canal headings with turnouts leading to concrete-lined canals (figure 1). Other turnouts in the River require an earthen berm be formed in the River to channel flow toward the turnout. The two largest conveyance canals, Highline and Consolidated, have effective sand traps and sluices that return sediment to the River. These keep the sediment in the canals to a minimum, providing much less canal maintenance and better measurement accuracy. In some locations, the concrete canal or pipe lining runs throughout the entire conveyance canal. In other locations, there are unlined canal sections downstream from a lined section immediately downstream from the turnouts.

Figure 1. - River diversion for the Highline canal from the Nambe River downstream from the dam. Note the turnout in the far right, downstream from the gabion structure. Not all turnouts have permanent diversion dams.

There are 14 existing measurement sites throughout the district monitored by PVID. The measurement sites all have Parshall flumes, either 1-, 1.5-, 2-, or 3-ft wide constructed in unlined earth, or concrete-lined trapezoidal canals. Each measurement site has upstream and downstream staff gages that are used to manually record the upstream head, h_a, and downstream head, h_b, in the flume. A pressure tap leads from the upstream head measurement location to a stilling well with a Stevens chart recorder. The printout from the chart recorder is gathered about once every month.

A typical Parshall flume installation is shown on figure 2 with a stilling well and strip chart recorder housing. These sites were all installed by Reclamation with typical capacity in the range of 1-7 ft^3/s except for the Highline and Consolidated canals which typically convey about 15 ft^3/s with a maximum capacity of 20 ft^3/s.

Existing Measurement Site Evaluation - The district must ensure accuracy of the existing Parshall flume measurement installations prior to installing more modern equipment to gather, record, and transmit the data. Many of the sites visited were in a poorly maintained state. The ability of these sites to produce good measurements is hampered by sediment buildup, overgrowth of vegetation (i.e. watercress, moss, grass, etc.) and excessive submergence of the flume in some cases. In general, PVID reported good data at the sites where the canals were well maintained, i.e. sediment traps and free of vegetation. Sediment and debris in the Parshall flume sections were often clogging the head taps and/or causing severe downstream submergence of the flume. Several Parshall flumes were reported to be routinely operating under submerged flow conditions (above 95 percent). Reclamation's Water Measurement Manual [1] offers corrections to the free flow discharge for submergence levels up to 96 percent for a 1- to 8-ft-wide flume, however; operation in this range is not recommended.

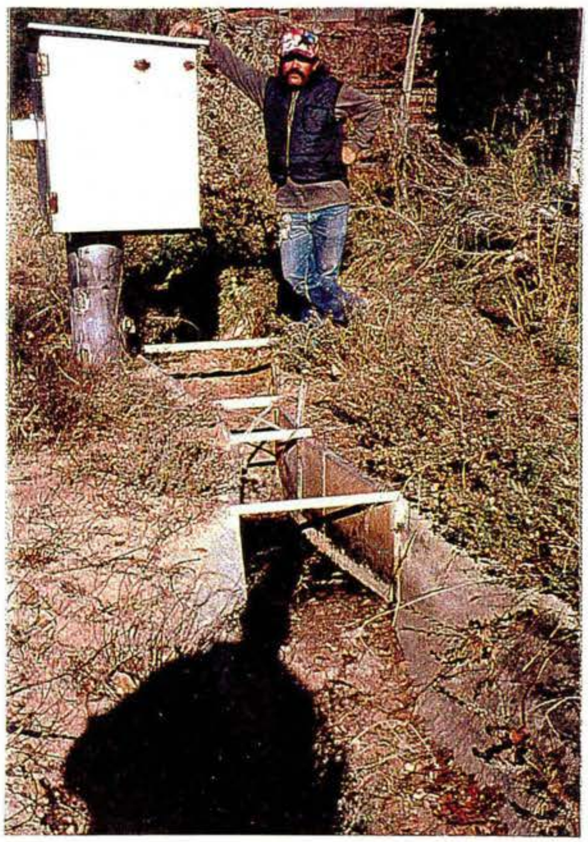

Figure 2. - Typical Parshall flume installation monitored by PVID. The 1-ft-wide flume is located on the Rincon Canal.

Current and ongoing research efforts [2] have shown that wide variations in discharge are reported with high submergence levels. Other authors [3] do not recommend the use of a Parshall flume as a measurement device when the submergence ratio, h_b/h_a, exceeds the practical limit of 0.90.

Parshall flumes should be installed, operated, and maintained such that submergence is limited to 70 percent and recording of only the upstream head is required to determine the discharge. This will significantly reduce the cost of purchasing equipment for monitoring at existing Parshall flume sites.

The accuracy of the existing Parshall flume measurement sites must be evaluated by performing on-site investigations including a survey of the sites with and without flow. Also important is historical operation and inspection of existing records to determine if the flumes have ever operated at less than 70 percent submergence. If these measures are taken, and the submergence ratio will exceed 70 percent with well-maintained installations, then the device should be abandoned.

Under the existing maintenance conditions in the system, most of the data from the Parshall flumes are not accurate enough to consider recording or transmitting for water management use.

Selection of Measurement Structures for New or Replaced Existing Sites - Obviously, there are any number of water measurement devices [1,3] that could be considered at each site. Not all devices are appropriate for each site, and the device selection should be based upon its expected performance in relation to the design constraints that will be encountered.

The potential lack of available head, coupled with weed and debris problems and requirements to keep costs low, indicate that long-throated flumes should be used wherever possible in the system. These flumes, also referred to as ramp or Replogle flumes depending upon the variation of the components, are very easy to install, accurate, and easily modified to fit the site situation.

- Flume Design: Flume design is based upon the work by the Agricultural Research Service (ARS) and the U.S. Bureau of Reclamation [4,5]. The flumes are critical flow devices, meaning that when critical flow occurs in the throat section of the flume, a unique relationship is established between the upstream head and the discharge. The long-throated flume consists of an approach channel, upstream transition, horizontal throat, downstream transition, and tailwater channel as shown on figure 3. Any of the flume components may be customized for an individual site. Normally, a rating curve or table can be computed with an error of less than 2 percent.

A computer program, FLUME, developed by ARS, is being used to design flumes [4]. The FLUME program is used to determine the dimensions of the water measurement structure for a given canal geometry with estimates of the water surfaces. Setting the sill height is critical to preventing excessive submergence of the flume and maintaining accuracy.

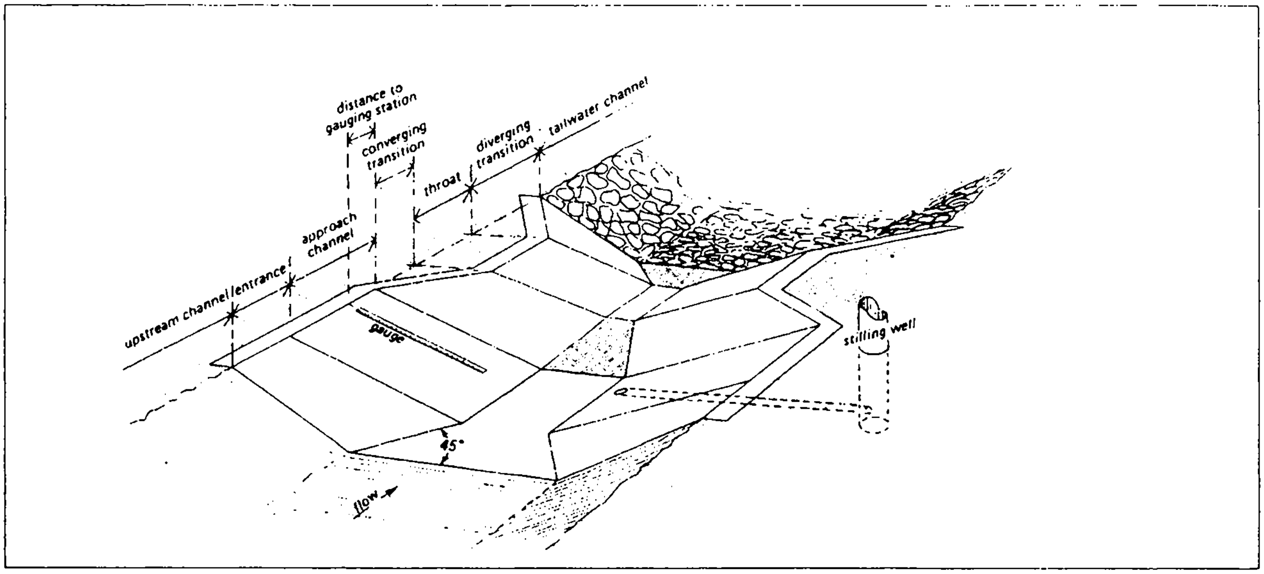

Figure 3. - Components of a general long-throated or Replogle flume. A ramp flume is a simplified version with the control sill dropping vertically at the downstream end back to the downstream channel invert.

Measurement Structure Requirements

Evaluation of existing or design of new measurement structures requires information about the site location including average cross section, invert and water surface elevations, discharge, freeboard, and operations. This information is generally obtained by a field survey of the sites including both upstream and downstream reaches for at least 100 ft. The conditions of the sites must also be determined with special notes regarding turnouts, checks, sediment or debris problems, vandalism, and operations.

Figure 4 is a schematic of the general location of each site with respect to the Nambe River, Nambe Falls Dam, U.S. Hwy 285, and the Rio Grande River. General orientation and scope of the project may be obtained from this layout.

Historical records of the discharge measured through the existing measurement sites were obtained from the AAO beginning in 1983, when the improved system was put into operation. These data were reviewed with the discharges in the following table noted. Typical deliveries may be more than listed because of inaccuracies in the existing measurement devices.

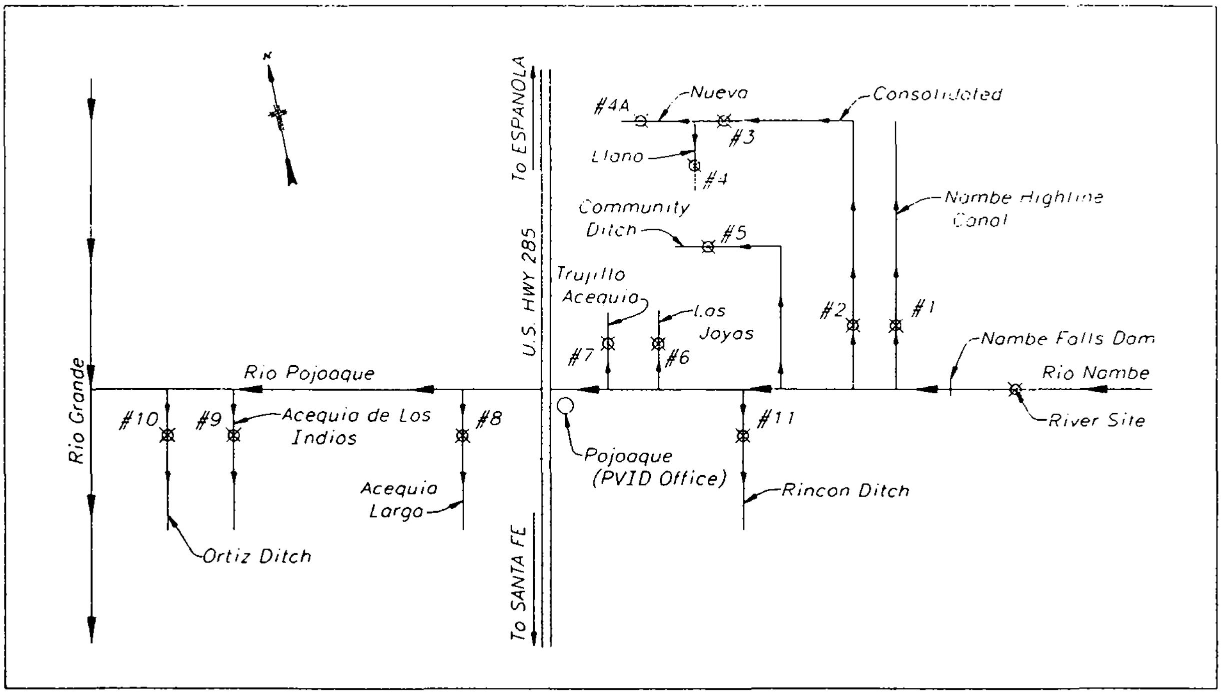

Figure 4. - Schematic of the layout of the sites for the study. It is approximately 13 miles from Nambe Falls Dam to the Rio Grande River.

Measurement Site	Maximum	Minimum	Typical
Consolidated	16	0.30	6.61
Highland	19	0.5	2.86
Rincon	7.7	0.1	1.51
Las Joyas	7.8	0.1	2.32
Trujillo	4.5	0	0.27
(Ortiz S.I.)	8.3	0.2	1.61
Los Indios	3.5	0	0.25
Larga	6.5	0	0.50

These data indicate that the flumes are generally not used to their full free flow capacity on any of the canals.

Existing and New Conveyance System Site Information - The three sites for the new measurement devices in the conveyance system were selected by the Nambe Pueblo, PVID, and AAO representatives. These sites were all in unlined ditches that are small and fairly heavily vegetated above the normal water surface. The normal conveyance capacity is about 1 to 6 ft^3/s.

Invert and hydraulic grade line information were obtained from survey information, both in the dry and with flow in the canals. The flow during the field visits was not always typical, but provided water surface information. Flow data were also obtained from David Vigil of PVID for the new sites that are currently not measured and the existing sites based upon his experience with operations.

The following table summarizes the flow and geometry criteria that were used for the flow measurement device evaluations and designs for the conveyance system sites. It includes assumptions regarding flows where information was unavailable or unsubstantiated.

Site No.	Site Name	Existing Device			Lined?	Submerged	Minimum Flow (ft^3/s)	Average Flow (ft^3/s)	Maximum Capacity (ft^3/s)	Invert Slope	H. G. L.	Comments
		Yes	No	Size (ft)								
1	Highline	X		2.5	yes	NO	0.5	5	10			Sediment sluice, flume bent through throat.
2	Consolidated	X		2	yes	YES	5	12-18	20	0.0029	0.003	Sediment sluice, good shape, 79% sub. during visit.
3	Consolidated	X		3	u/s yes	YES	5	12-15	20	0.0022	0.0033	End of line, modified, wave upstream from flume. Move measurement location upstream.
4	Llano		X		no		1	3-5	5	0.0018	0.0038	Site must be moved downstream about 135 yds to measure all non-Indian use. Heavily vegetated ditch.
4a	Nueva		X		no		1	1-5	6	0.0032	0.004	Somewhat curving section, site OK.
5	Community		X		no		1	1-5	6	0.002	0.0013	No water during visit, straight section for site.
6	Acequia de las Joyas	X		1.5	no	NO	1			0.002	0.0005	No water during visit, but water line indicated acceptable drop.
7	Trujillo	X		1	yes	YES	0.75	1-1.5	2.75	0.004		No water during visit, but large cottonwood growing in ditch downstream from flume is most likely the cause of submergence.
8	Acequia Larga	X		1.5	no	YES	1	1-3	7	0.01	0.0138	No water during visit, sediment problem, no drop visible from water line. Sediment sluice.
9	Acequia de los Indios	X		1	yes	YES	1	1-3	7	0.0018	0.0025	No water during visit, sediment problem.
10	Ortiz SI	X		1	yes	YES	?	?	?			Spring water overflowing ditch about 65 yds upstream from flume, heavy vegetation growing in lined ditch, sediment.
11	El Rincon	X		1	no	NO	1	1-3	7			Good site.

Nambe River Measurement Structure Information - The river measurement device has special requirements that are not pertinent to the conveyance system. The river has widely varied flow rates between seasons and also has the potential for needing fish passage. Discussions during the first site visit indicated that the stream is very stable and not sediment-laden or filled with woody debris because the upstream watershed is well vegetated and quite rocky. During peak spring runoff, transport of small rocky material does occur, but this does not appear to be a major concern. Vandalism is not an issue. The Nambe Pueblo was quite interested in constructing a stable measurement device that would pass small rock and debris during the spring runoff while providing accurate measurement of the critical base (low) flow condition. The discharge range for measurement was discussed and set to be from 3 to 100 ft^3/s. The maximum to be passed by the river is 500 ft^3/s.

Two potential sites for measurement were visited. One, upstream from a rock drop created in the river about 1000 ft upstream from the reservoir to prevent upstream migration of the fish in the reservoir to the natural river. The second, at the rectangular box culverts forming the road crossing about 625 ft upstream from the reservoir. Both sites appear viable from a measurement standpoint. There is significantly better construction access at the box culverts.

Although initial designs called for locating the water measurement structure in the box culvert about 625 ft upstream from the reservoir, later information indicated that fish spawning requirements might impact the structure design by possibly requiring fish passage. The State of New Mexico sent a letter to the AAO outlining acceptable velocities and depths for a fishway structure with instructions on how to determine the design flow rate for a fishway structure. The letter quoted a velocity of 3.94 ft/s and a minimum flow depth of 0.656 ft for effective fish passage. The pueblo was informed of the additional requirements in the design to accommodate fish passage requirements. The simplest course of action would be to move the water measurement structure upstream to the rock drop/fish barrier already constructed in the river to avoid controversy over the issue. The Pueblo still wanted to pursue the structure at the box culvert. As a result, water measurement structure designs were investigated that would hopefully also meet fish passage requirements.

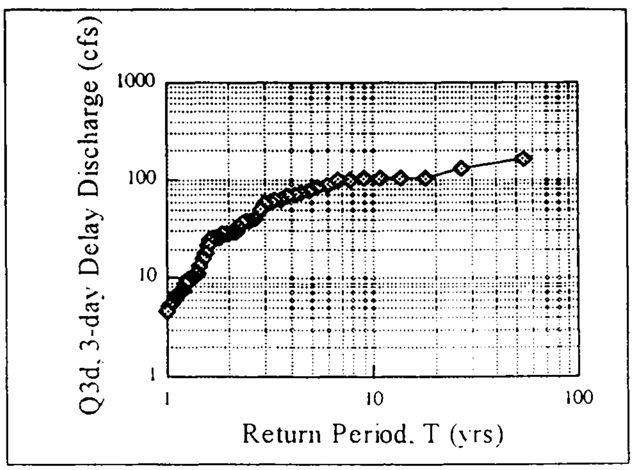

Figure 5. - Fishway design discharge for the Nambe River.

The fishway design flow was determined for the Nambe River from daily hydrologic data obtained from the AAO for 1932-1996. Data were missing from 1952-1963, but this still provided excellent data for 54 years of record. John Pittenger from the State of New Mexico Department of Fish and Game was contacted regarding the normal spawning period of the reservoir trout. He replied that the spawning period began in late April and continued until early June. The hydrologic data was then reduced to include only these spawning months and the 3-day delay discharge frequency curve, figure 5, was developed using a spreadsheet. A delay period of less than 3 days in annual spawning migrations is usually acceptable for most freshwater species. From this curve, the 3-day delay discharge, Q_{3d}, was determined to be 104 ft^3/s (the discharge associated with a delay longer than 3 days with a 1:10-year frequency). Interestingly, this fishway design discharge that will be used as the design discharge for the combined water measurement/fishway structure is the discharge that the pueblo noted as the maximum discharge they wanted measured for their records.

Water Measurement Structure Designs

Thirteen sites, including the Nambe River site, have been evaluated for upgrading of existing measurement structures and/or new structure design. Each design includes a description of the site including a photograph or plan view of the survey drawing showing the locations of new, existing, or replacement flumes, when specified. Recommendations are made for each site. At existing Parshall flume sites, recommendations are made whether to use the existing Parshall flume as is, rehabilitate it, or replace it with a new long-throated flume. When a new flume is recommended, the new flume design is discussed and shown on schematics with dimensions of the approach channel, flume section, and downstream channel. The discharge rating curve for each site is also given for use in programming the new data loggers. The 13 water measurement sites are discussed in the following sections beginning with the Nambe River site, then the new previously unmeasured sites, and, finally, the existing sites.

Nambe River or Box Culvert Measurement Site - The river channel has an average slope of 0.0254 upstream and downstream from the four 10-ft-wide by 8-ft-high box cells. The total width of the river channel at the box culvert is about 45 ft, figure 6. The fishway discharge of 104 ft^3/s was used as the maximum flow with 2 ft^3/s as the minimum flow. A flow rate of 500 ft^3/s was rather arbitrarily determined to be the total flow rate that must be passed by the river, but not necessarily accurately measured. Sediment

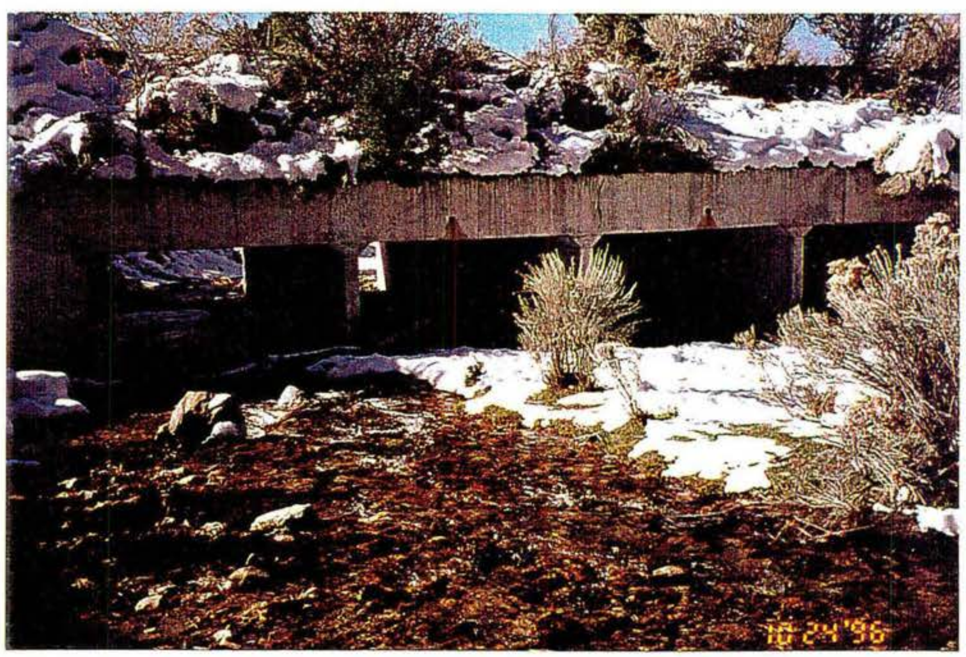

Figure 6. - Box culverts about 625 ft upstream from Nambe Falls reservoir, looking downstream.

accumulated in and near the box culvert will need to be removed for construction of the flume and weir walls.

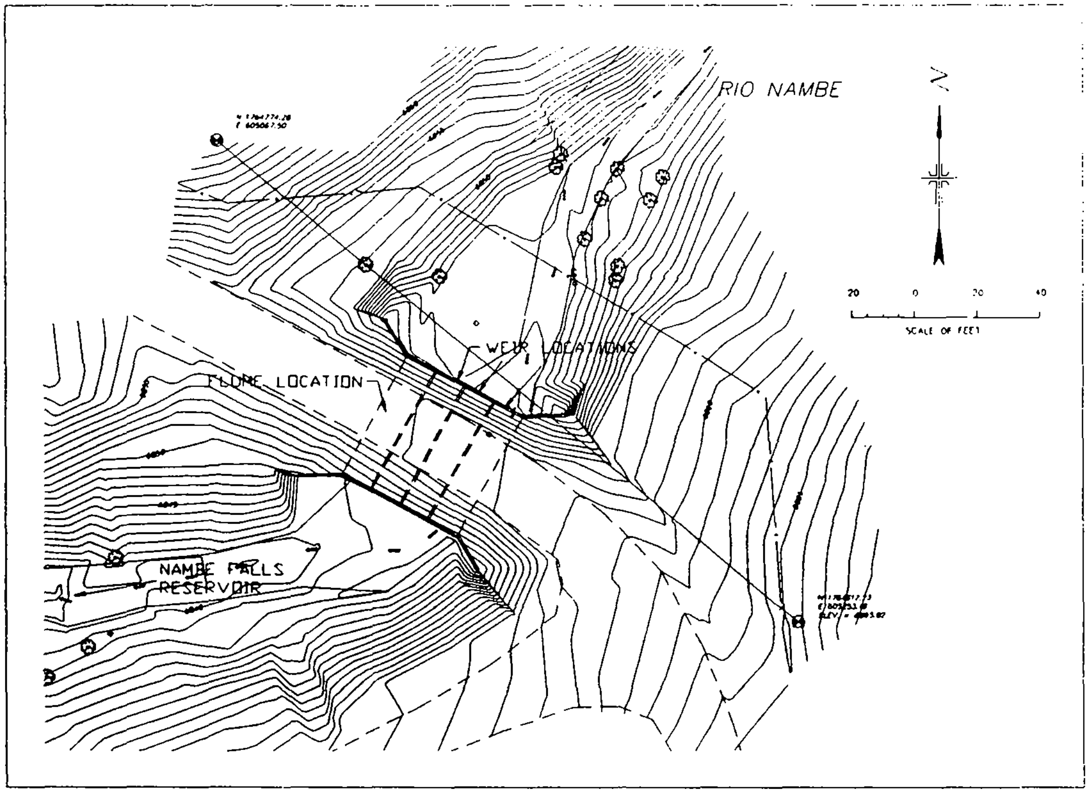

Figure 7. - Location of the flume/weir combination for the Nambe River site.

Recommendation: The small base flow to be measured required the use of only one of the culvert boxes for measurement. The others will be blocked off with a weir set at the level of the water surface of the fishway flow, figure 7. When 104 ft^3/s is exceeded, the weirs will overflow and contribute to passing the flood flow that will only be approximated by the measurement.

The box culvert dimensions were used as the approach and exit channel geometry and a rectangular control section chosen for the flume. The height of the sill and side contractions were varied until flow criteria were met. The height of the box culvert opening also limits the ability to pass flow because the weir across the other three box culverts must be high enough to prevent flow around the flume for flows less than 104 ft^3/s, yet the culverts must be capable of passing the higher flows up to 500 ft^3/s.

The design flume, figure 8, is 2-ft high and 5.69-ft wide at the control section, with a 6-ft-long converging section. In the 6-ft-long converging section, the side walls converge from the 10-ft width of the culvert box to the 5.69-ft width of the control section and the floor ramps up to the 2-ft-high sill. The flume should be installed in the far right culvert to best follow the river contour. This should allow accurate measurement of low base flows and the normal spring runoff discharge over the ramp flume with additional flows over the weir. The head measurement should be taken 6 ft upstream from the beginning of the converging section inside the culvert. Instrumentation should be added as specified later in the report.

The discharge rating for the Nambe River flume is given by:

$$Q=16.873H^{1.536}$$

where H is equal to the measured upstream head above the control sill elevation.

The combined flume/weir discharge may be approximated by:

$$Q=16.873H^{1.536}+84H_w^{1.5}$$

where H_w is equal to the upstream head above the weir height of 5.33 ft. If H_w is less than zero, then only the flume is being used and this must be accounted for when programming the data logger.

The flow goes through critical depth in the throat of the flume, where the highest velocities and lowest depths will occur. The critical depth and velocity and the brink depth and velocity were computed and used to evaluate the feasibility of the structure design to meet fish passage requirements. The velocities at Q_{3d}=104 ft^3/s exceed the criteria set forth by the State for the trout during the migration period, however, flow depth criteria are met.

Further investigation of trout swimming speeds was performed using Bell's Fisheries Handbook [6]. Brown and cutthroat trout were listed with cruising speeds of about 2.5 ft/s, sustained swimming speeds of about 3 to 7 ft/s, and darting speeds from about 12.8 to 13.8 ft/s. Perhaps you could expect the criteria for rainbow trout to be similar. If so, the flume throat length of 4.5 ft could probably be traveled by the fish under darting speed.

The Nambe Pueblo was contacted with these results and determined that they would still like the flume with weirs constructed in the box culvert. The construction summary is given in the appendix of this report.

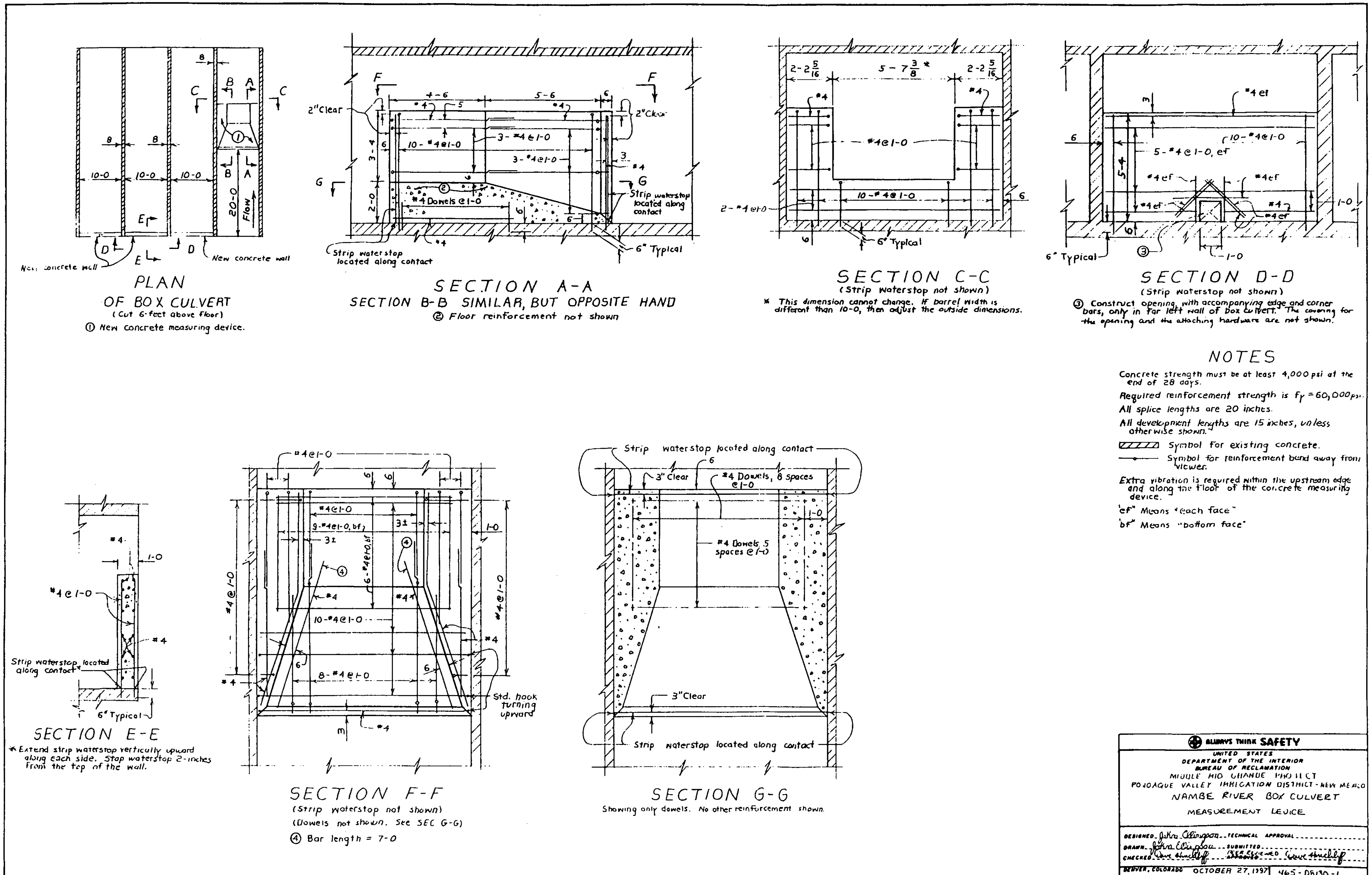

Figure 8. - Dimensions of flume for water measurement of the Nambe River. The flume was designed for the necessary discharge without considering the fishway velocity criteria.

Flume Designs for Previously Unmeasured Conveyance Sites - New water measurement sites are needed on the Llano (#4), Nueva (#4a), and Community (#5) ditches. These sites are all unlined ditches of various size. The flow and geometry data for the designs were determined from PVID's experience and the survey data, respectively. A flume design was needed that would be simple to construct, would retain accuracy at the low flow range, and would pass fines and floating debris. As a result, ramp or long-throated flumes were selected for use. Measurement of the upstream head is the only requirement for computing discharge.

The flumes are rectangular throughout their dimension with only the floor ramp converging upward to the control sill. The water level sensing device will be placed within the confines of the new structure which will assist with the installation, maintenance, and accuracy of the equipment. Therefore, the flume entrance shape was designed to match that of the control section. The head measurement location for each flume is a distance equal to the total flow depth at the maximum discharge upstream from the toe of the ramp. This design has a square upstream entrance to the flume with the loss occurring outside the boundary of where the program is computing losses. A curved sheet metal guide wall (radius equal to one-half the rectangular throat width) should be attached to each side of the square concrete entrance to guide the flow into the approach section.

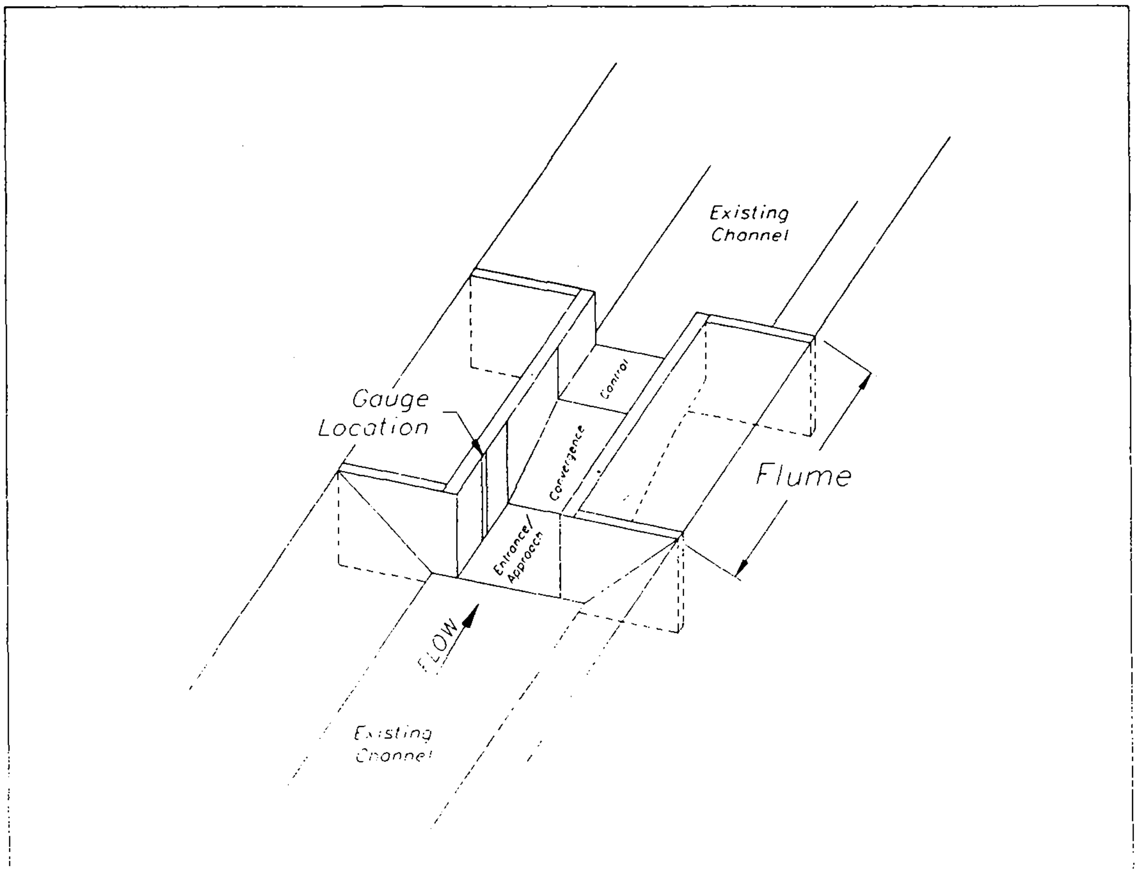

Figure 9. - Three dimensional view of the typical flumes to be constructed at the new measurement sites #4, 4a, and 5.

The three new water measurement sites are discussed in the following paragraphs. Drawings detailing the components of the typical flume design are shown on figures 9 and 10 and with the corresponding dimensions given in the table immediately following figure 10. The dimensions vary according to the geometry and flow requirements of each of the sites. The design of each flume is discussed separately. The flumes will be installed within the limits of the existing ditches, requiring only minimal disruption to the extent of the existing ditch boundary.

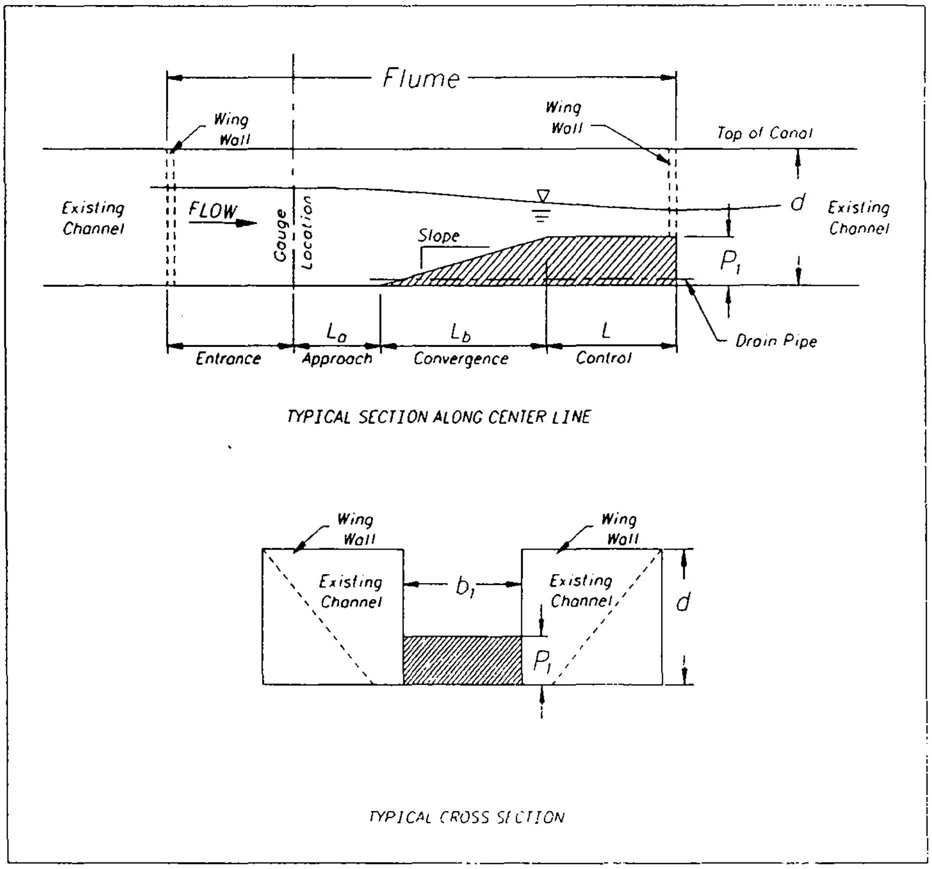

Figure 10. - Typical sections of the flumes to be constructed for sites #4, 4a, and 5.

Flume dimensions for the three new measurement sites.									
Site Name	**Site Number**	**b_1 (ft)**	**Entrance (ft)**	**L (ft)**	**L_a (ft)**	**L_b (ft)**	**P_1 (ft)**	**d (ft)**	**Slope**
Llano	4	1.70	1.5	1.5	1.25	1.11	0.37	1.4	3:1
Nueva	4A	1.70	1.5	1.75	1.75	0.75	.25	1.4	3:1
Community	5	1.70	2	1.75	1.5	2.79	0.93	2.7	3:1

- Site #4: Llano Ditch

This is a new measurement site in an unlined ditch. During the field visit, the discharge through the generally trapezoidal-shaped section was about 2.4 ft^3/s. During the field visit it was also noted that the selected site will not measure flow remaining in the canal after all turnouts to the irrigated land. If it is desired to include all the turnouts, then the site should be moved downstream about 135 yds past the last farm turnout. This has been discussed and the chosen site was deemed appropriate by all parties. The ditch is currently not well maintained, but is quite straight. There is heavy vegetation growing along the banks including trees. The typical section has an invert slope of 0.0018 and is trapezoidal shaped with a 2-ft-wide bottom, 1.25:1 side slopes and a depth of 1.4 ft.

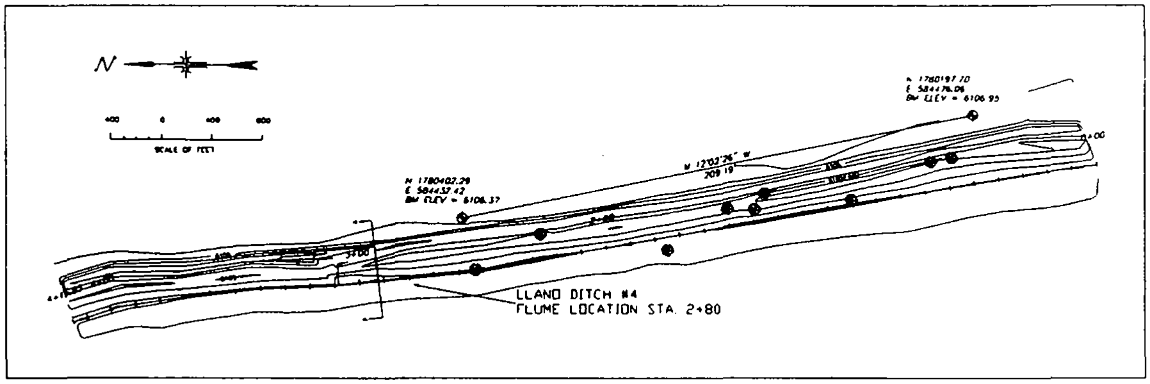

Figure 11. - Location of the new flume for the Llano ditch #4 at station 2+80.

Recommendation: Construct a new long-throated flume with a 0.37-ft-high control sill at about station 2+80, figure 11. The flume was designed for a discharge range of 1-5 ft^3/s. Construct the flume in a section free of trees for some distance both upstream and downstream from the flume. The rectangular-shaped flume will be a self-contained structure within the unlined ditch. See figures 9 and 10 and the table of flume dimensions for this and sites 4a and 5. Consideration should be given to removing many of the trees and shrubs along the ditch.

The rating curve for the new flume at the Llano ditch #4 is:

$$Q=5.998H^{1.582}$$

Add instrumentation and housing as specified.

- Site #4A: Nueva Ditch

This is a new measurement site in an unlined ditch. The ditch is quite windy through the section; however, the chosen site at about station 1+70 seemed to be in the straightest section of the ditch. During the field visit the discharge through the generally rectangular section was about 4.5 ft^3/s. The typical section is trapezoidal with an invert slope of 0.0032, a 2.67-ft bottom width, 1.5:1 side slopes and a depth of 1.4 ft.

Recommendation: Construct a new long-throated rectangular-shaped flume with a 0.25-ft-high control sill in the unlined ditch section at about station 1+70, figure 12. The

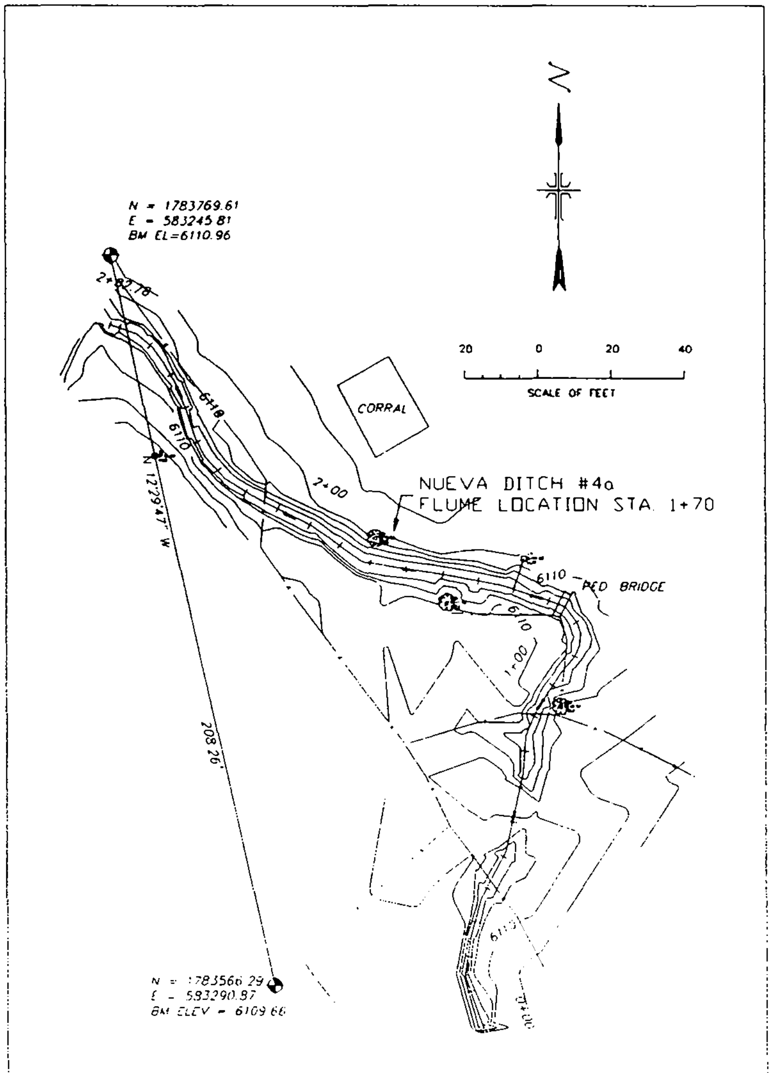

Figure 12. - Location of the new flume for the Nueva #4a ditch at station 1+70.

flume was designed for a discharge range from 1-6 ft^3/s. See figures 9 and 10 and the table of flume dimensions for this site and sites 4 and 5.

The discharge rating curve for site #4a is given by the following equation:

$$Q=6.274H^{1.6}$$

Add instrumentation and housing as specified.

- Site #5: Community Ditch

This is a new measurement site in an unlined ditch with a very straight reach. During the field visit, the discharge through the generally trapezoidal section was about 4 ft^3/s and appeared to be reasonably well maintained except for weed growth along the banks above the water line. The typical unlined earth section is trapezoidal with an invert slope of 0.0043, a 2.67-ft bottom width, 1.5:1 side slopes and a 2.7 ft depth.

Recommendation: Construct a new rectangular-shaped long-throated flume with a 0.93-ft-high control sill in the unlined generally trapezoidal-shaped ditch at about station 1+80, figure 13. The flume was designed for a discharge range from 1-6 ft^3/s. This is a quite

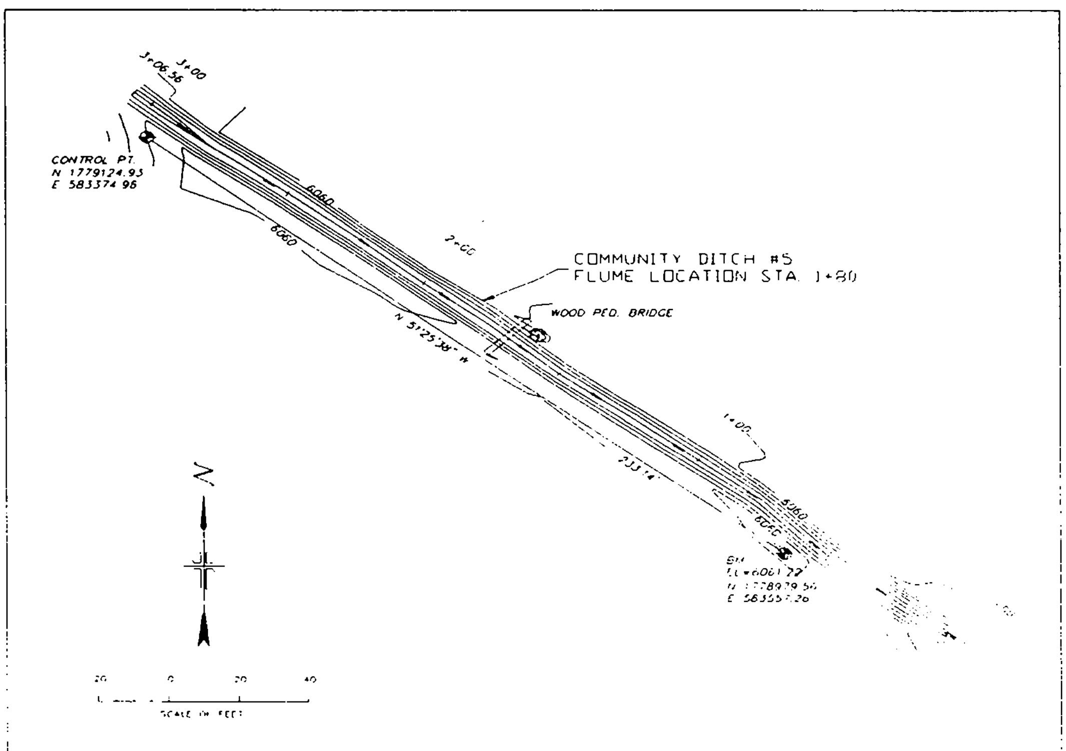

Figure 13. - Location of the new flume for the Community ditch #5 at station 1+80.

large unlined ditch where again a rectangular-shaped flume will be constructed according to the dimensions in the table with reference to figures 9 and 10.

The discharge rating curve for site #5 is given by:

$$Q=5.517H^{1.551}$$

Add instrumentation and housing as specified.

Replacement Flume Designs for Existing Sites - Each existing measurement site has a Parshall flume of some throat width with staff gauges, a stilling well with a float, and a Steven's recorder for recording head measurements. Each stilling well and housing will be reused at the existing sites for the new equipment. A new flume designed to replace an existing Parshall flume will be installed within the limits of the existing ditches whether lined or unlined. Each existing measurement site is evaluated in the following sections.

- Site #1: Highline Canal

This site currently has a 2.5-ft-wide Parshall flume installed in a concrete-lined canal just downstream from the first diversion from the Rio Nambe, figure 14. The canal section upstream from the flume is rectangular shaped and the downstream section is trapezoidal shaped. The discharge passed through the Highline canal is usually about 5 ft^3/s with a maximum of 10 ft^3/s. The flume is installed with earthfill surrounding it and the flume throat is currently bent because of movement of the fill. The site has a sediment sluice located upstream and the site is generally well maintained. The flume was 83 percent submerged during the field visit, but records and PVID both indicated that it is usually less than 70 percent submerged.

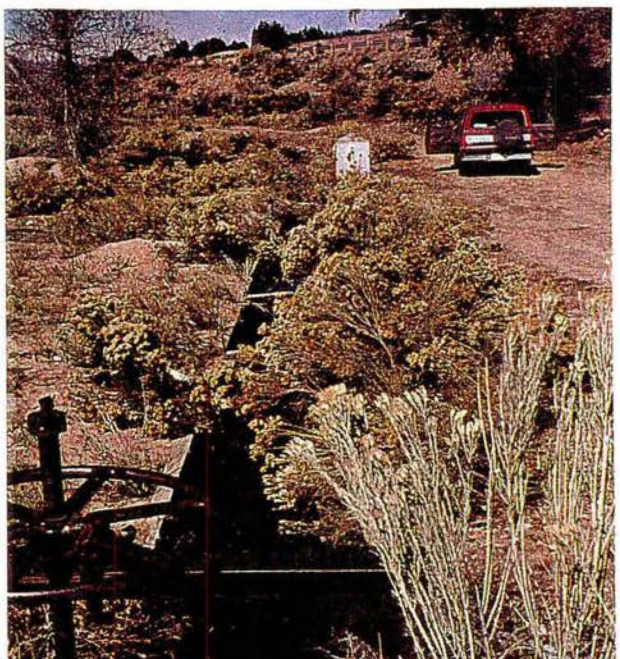

Figure 14. - Existing Parshall flume site at the head of the Highline canal, site #1.

Recommendation: Fix the bent throat section of the existing Parshall flume and continue to use this existing device. The fill should be removed, the flume walls reshaped to be vertical, keeping the throat level, and the fill recompacted or replaced with concrete as many of the other installations have been constructed. Keep the canal sections upstream and downstream of the flume and the flume throat free of sediment to ensure proper measurement of head, thus discharge. It would also be helpful to lay back and clear the slopes adjacent to the canal to prevent rocks, etc., from falling into the canal. Ensure submergence is less than 70 percent at all times, thus ensuring accurate flow measurement while recording only the upstream head measurement, h_a. The discharge rating curve for the Parshall flume at this site is:

$$Q=10.00h_a^{1.559}$$

where h_a is the measured upstream head in the Parshall flume.

Add instrumentation as specified.

- Site #2: Consolidated Ditch

The 2-ft-wide Parshall flume is imbedded in concrete in a lined canal with rectangular upstream and trapezoidal downstream shapes. The flume installation and lining are in good shape, however, flow records indicate submergence is a problem. The flume was about 79 percent submerged during the field visit which would require measurement of the upstream and downstream water levels. The discharge during the field visit was about 13 ft^3/s. The average and maximum discharge ranges are 12-18 and 20 ft^3/s, respectively. The typical section has an invert slope of 0.0029 and is trapezoidal with a 1.75-ft bottom width, 1.15:1 side slopes, and a 2-ft depth.

Recommendation: Construct a long-throated flume in the existing concrete-lined trapezoidal downstream channel about 30 ft downstream from the existing flume at about station 1+80, figure 15. Leave the existing Parshall flume in place.

The new flume should be constructed with a ramp and sill only. The flume has a 3.222-ft-wide flat control sill with a 3:1 sloping upstream ramp from the invert of the existing canal to the sill at a height of 0.64 ft. The control sill is 2 ft long in the direction of flow. The head measurement device should be placed 2.5 ft upstream from the toe of the ramp. Figure 16 shows the side profile and sectional views of the flume.

The rating equation for the new flume at Consolidated #2 is:

$$Q=13.587[H+0.025]^{1.819}$$

Add instrumentation as specified.

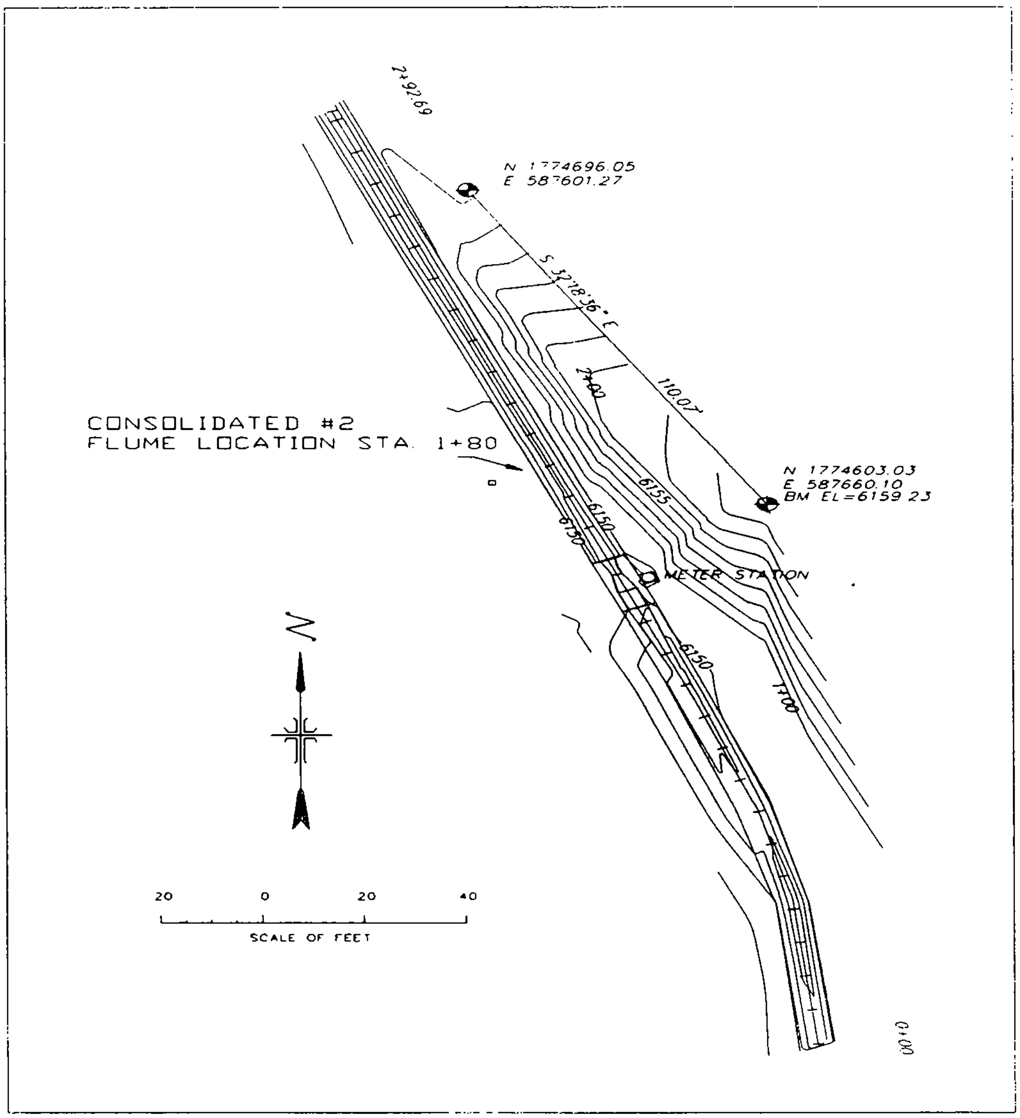

Figure 15. - Location of the new flume for the Consolidated #2 ditch at station 1+80.

- Site #3: Consolidated Ditch (end of line)

This site has an existing 3-ft-wide Parshall flume supported with earthfill and is at the end of the Consolidated ditch. A complicated splitting of the flow into the Llano and Nueva ditches occurs immediately downstream from the flume. The existing flume has a divider wall placed in it from the downstream end up into the throat. A standing wave occurs in the expanding

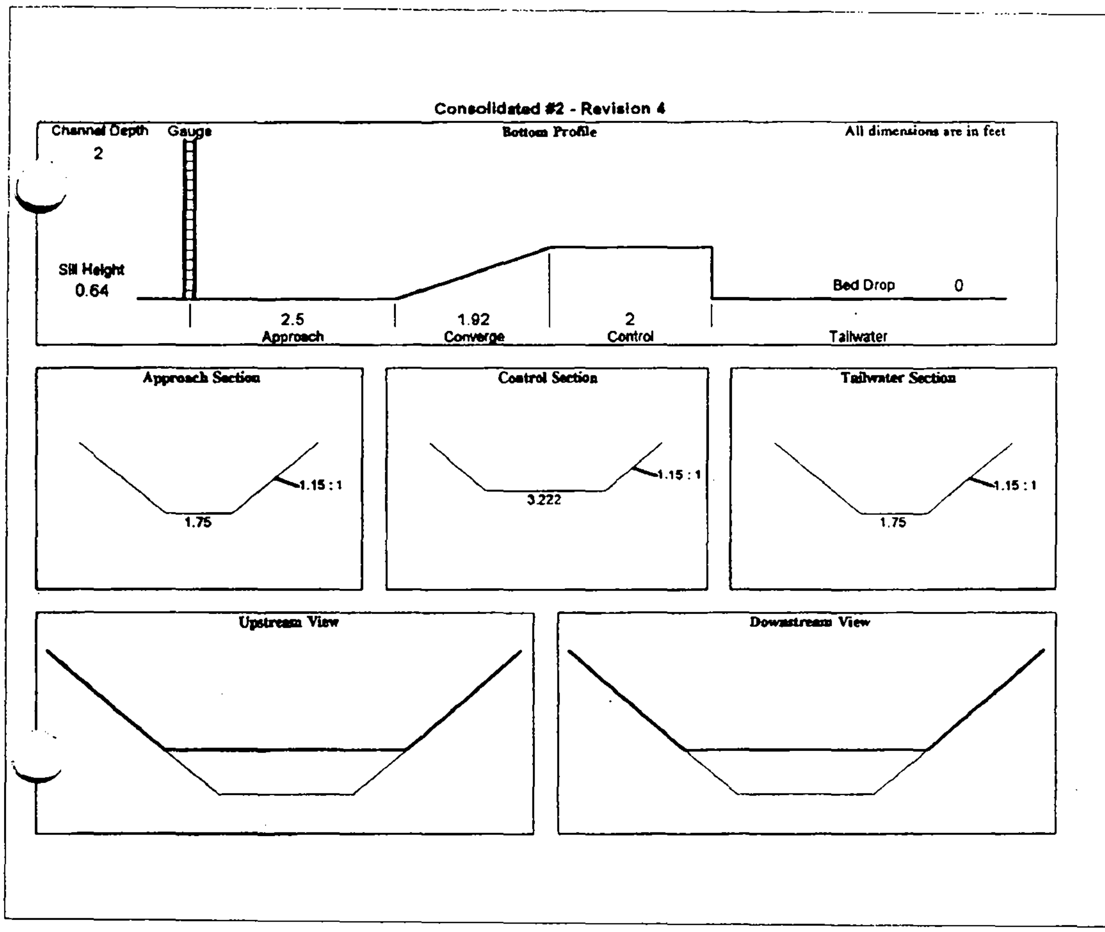

Figure 16. - Schematic with dimensions for construction of the new flume at the Consolidated site #2.

section from the trapezoidal concrete-lined approach canal to the flume. The concrete lining is in good shape upstream from the flume and has an invert slope of about 0.0022. During the field visit about 9 ft^3/s were flowing through the ditch. The typical section is trapezoidal with a 1.84-ft-wide bottom with 1.5:1 side slopes and a depth of 1.84 ft.

Recommendation: Construct a new long-throated flume placed upstream from the existing Parshall flume site in the lined, trapezoidal section. This avoids the downstream change in section and devices used by the irrigaters to split the flow into the turnouts. Construct the new flume about 25 ft upstream from the existing flume at about station 1+40 in a clean section of the canal, leaving the existing flume intact, figure 17.

The flume should be constructed with a ramp and sill only. The 3.342-ft-wide sill is 0.5 ft high with a 3:1 sloping upstream ramp. The sill is 2.5 ft long in the flow direction. The head measurement should be taken 3 ft upstream from the toe of the ramp, figure 18. The height of the lining is somewhat irregular upstream from the existing flume installation. The lining must be raised to at least 2 ft deep upstream from the flume installation for at least 100 ft.

The rating equation for the new flume at the end of the Consolidated #3 canal is:

$$Q=14.752[H+0.043]^{1.931}$$

Add instrumentation and housing as specified.

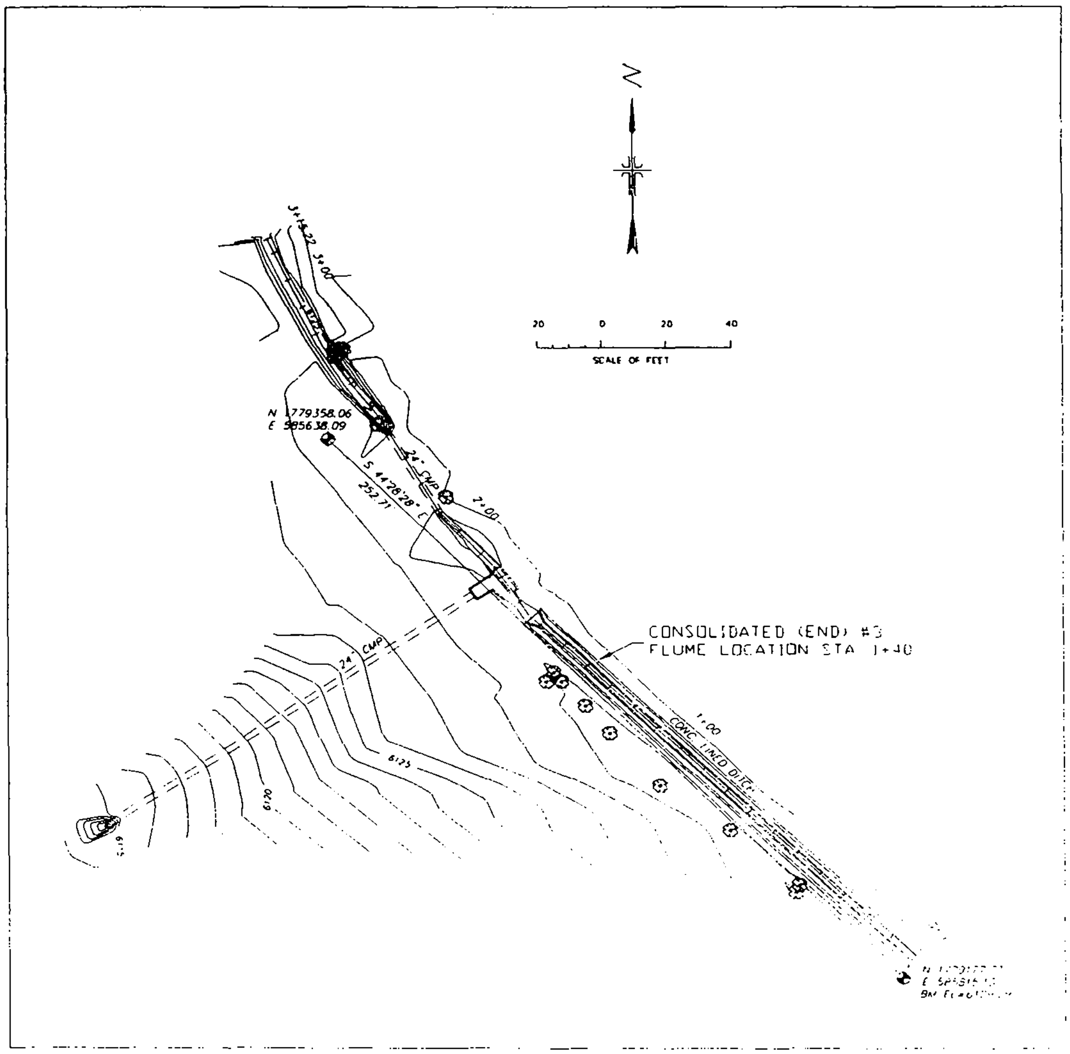

Figure 17. - Location of the new flume for the end of the Consolidated #3 at station 1+40, about 25 ft upstream from the existing Parshall flume.

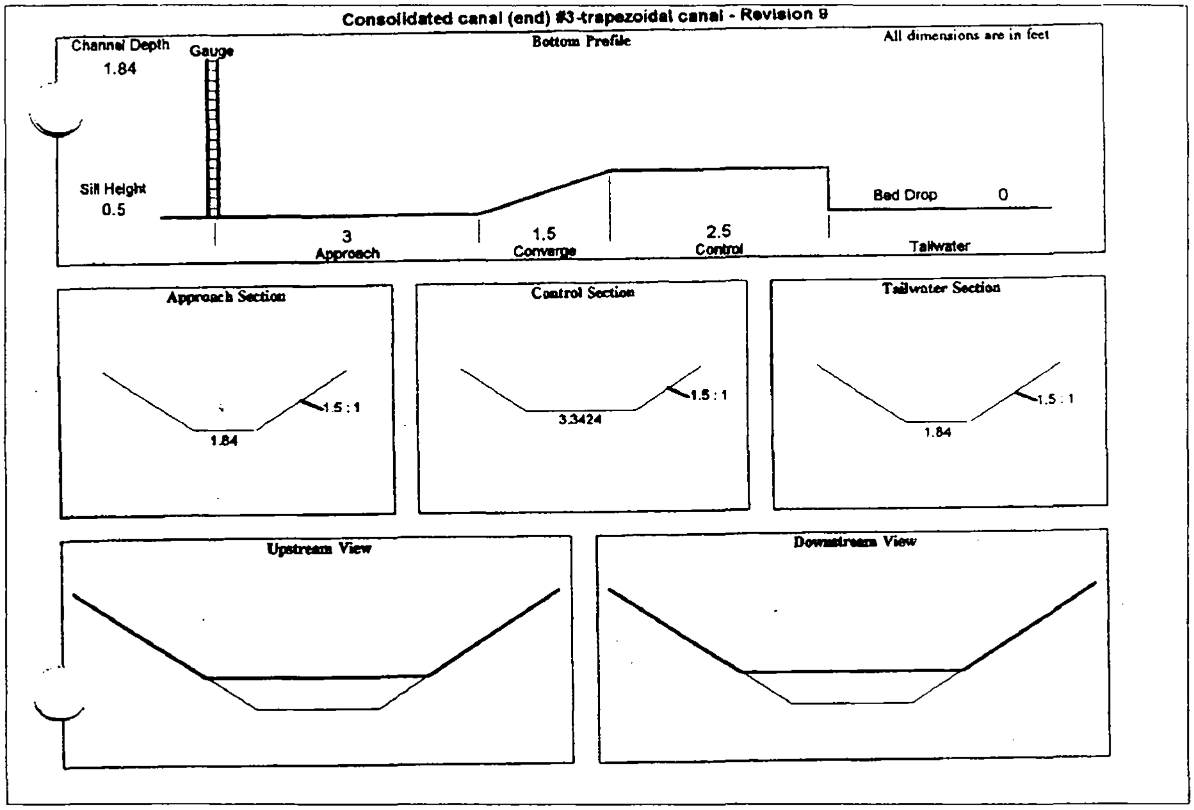

Figure 18. - Schematic with dimensions for the new flume at the Consolidated site #3.

- Site #6: Acequia de las Joyas

The site has an existing 1.5-ft-wide Parshall flume in an unlined ditch with earthfill support. The flume appeared to be in good shape. The ditch is generally trapezoidal shaped and is heavily vegetated above the water line. The discharge measured during the field visit was about 4 ft^3/s. Average flows range from 1-5 ft^3/s. The ditch rider reported generally good performance or no submergence through the flume and the stained water line seemed to indicate adequate head differential through the flume throat. However, the historical discharge measurements indicated submergence was a problem. A typical section has an invert slope of 0.002 with a 2-ft bottom width with 1.25:1 side slopes and a depth of 1.7 ft.

Recommendation: It does appear from the survey drawings that there is enough drop downstream from the existing Parshall flume to expect adequate performance without submergence exceeding 70 percent. The survey drawings indicated a drop of 0.5 ft downstream from the flume, figure 19. Inspect the flume and ditch and clean out the ditch downstream from the flume. Keep the existing site free of sediment to ensure accurate measurements.

Use the existing Parshall flume at site #6 with the rating given by the following equation:

$$Q=6.00h_a^{1.54}$$

If poor performance, with good site maintenance, is noted during the irrigation season, then the existing flume could be removed and a new flume designed and installed.

Add instrumentation as specified.

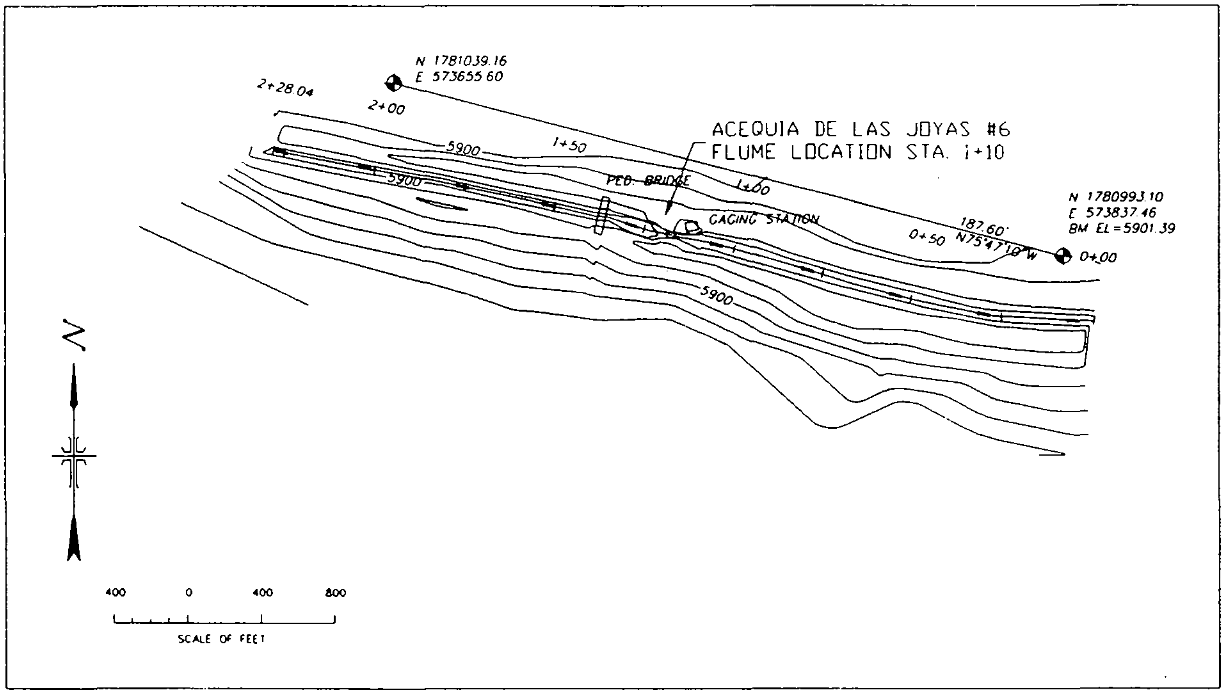

Figure 19. - Location of the new flume for Las Joyas #6 ditch at station 1+10, if necessary.

- Site #7: Trujillo Ditch

This site has an existing 1-ft-wide Parshall flume in a trapezoidal-shaped concrete-lined ditch. The ditch rider and the flow data indicate that this flume is usually submerged. Upon inspection, there is a large cottonwood tree growing into the lined canal downstream from the existing flume. During the field visit, the discharge was measured to be about 0.3 ft^3/s and a substantial drop in the water surface occurred downstream where the tree is choking off a large area of the canal. The average discharge range is 1-1.5 ft^3/s. The flume appears to be in good condition; however, the upstream concrete lining is very cracked and broken up in places. The invert slope is 0.004. The typical section has a bottom width of 1 ft with 1:1 side slopes and a 1-ft depth.

Recommendation: The large cottonwood tree growing in the canal downstream from the flume is most likely backing water up and submerging the flume. This tree should be removed prior to any other modifications being made at this site to improve measurement, figure 20. After removal of the tree the operation of the existing flume should be reevaluated to assure submergence is less than 70 percent.

The discharge rating for the 1-ft-wide Parshall flume at Trujillo ditch #7 is:

$$Q=3.95h_a^{1.55}$$

Add instrumentation as specified assuming that the site will operate properly after removal of the tree.

If these actions do not solve the problem, then a new long-throated flume should be designed and installed at the location of the existing flume, station 1+60, figure 20. The new flume design has a 0.76-ft-wide trapezoidal-shaped control section that is 0.175-ft high. The control sill is 1.5-ft long with a 5:1 upstream ramp within the trapezoidal canal. The head measurement should be taken 1.75 ft upstream from the toe of the ramp. Figure 21 shows the shape and dimension required for the flume. The rating curve for the new flume, if necessary, at site #7 is:

$$Q=4.602[H+0.027]^{1.976}$$

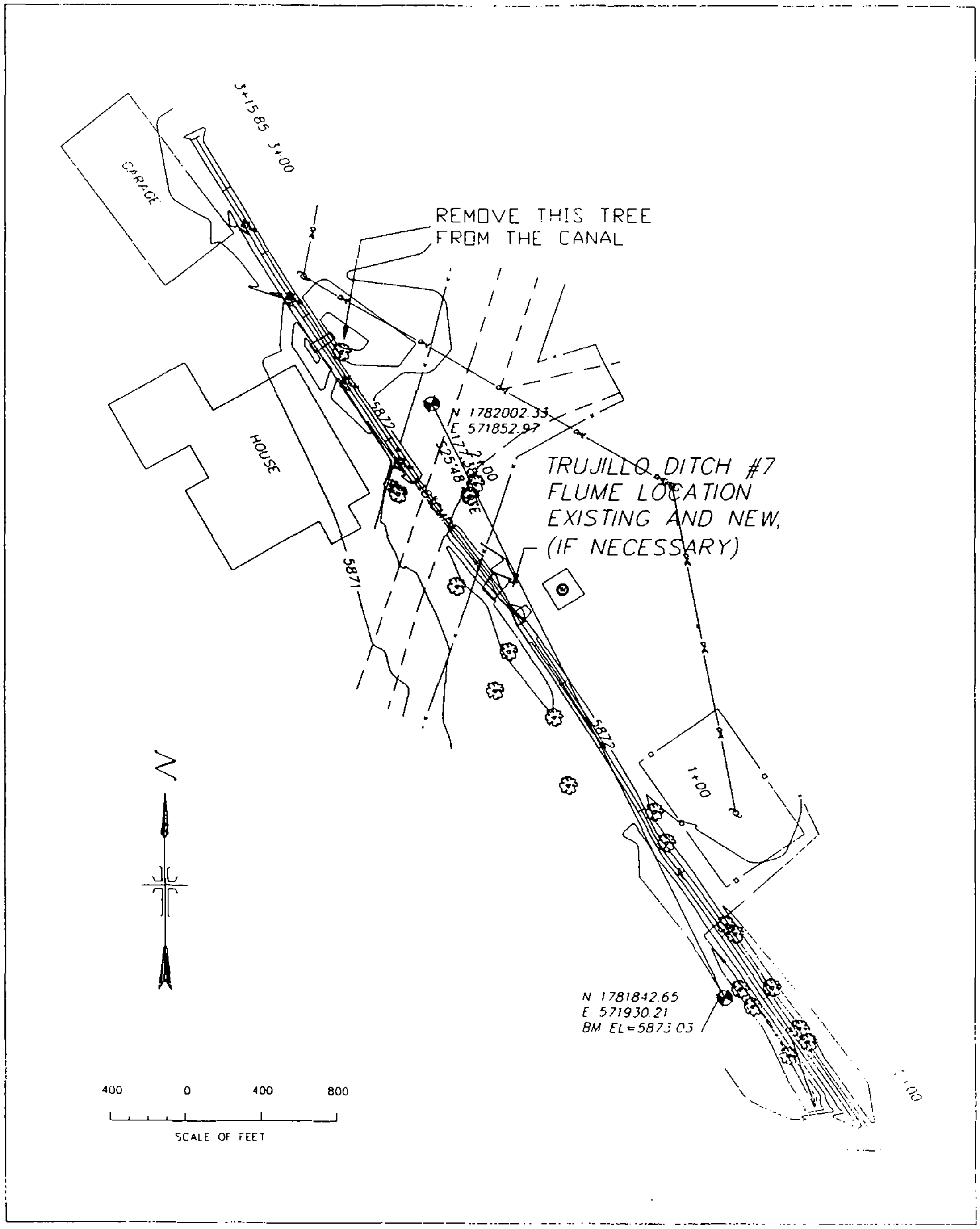

Figure 20. - Location of the tree to be removed and, if necessary, the new flume for the Trujillo ditch #7 at station 1+60.

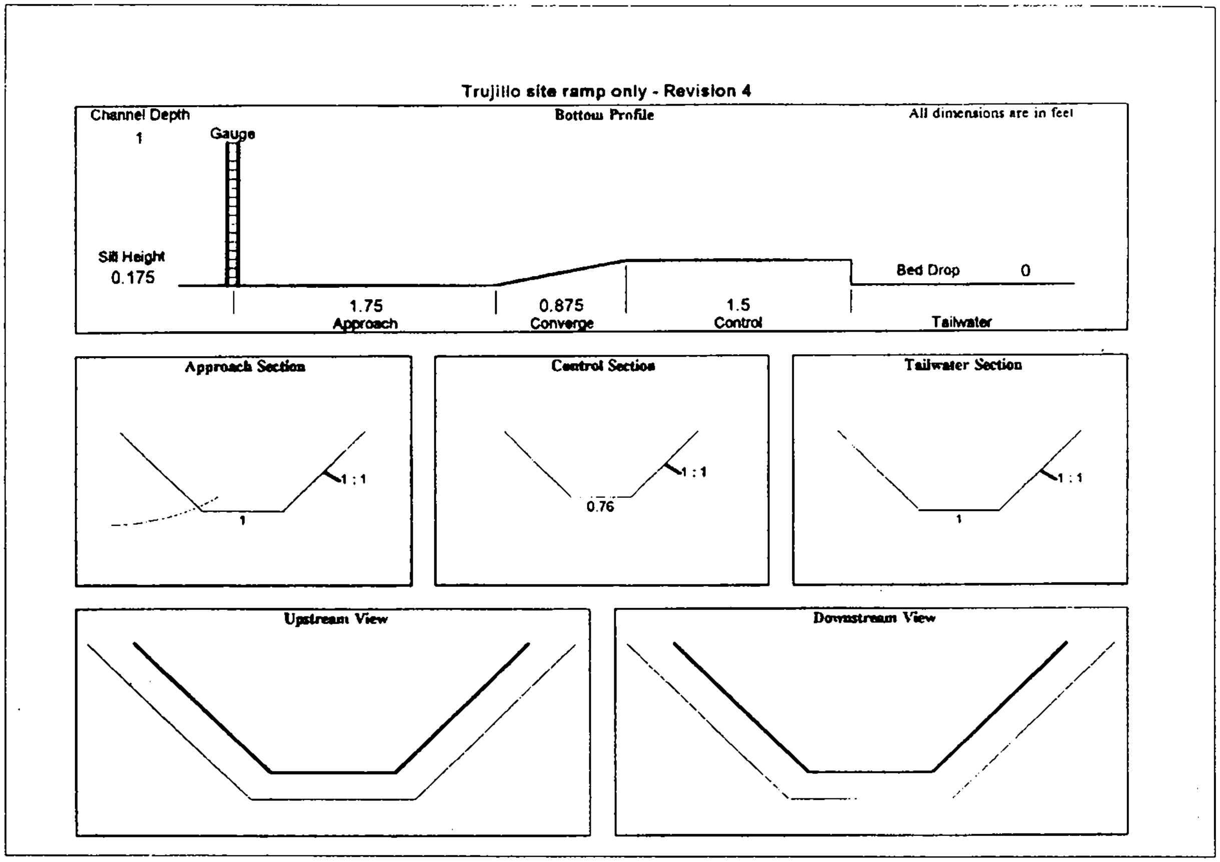

Figure 21. - Schematic and dimensions for a new flume at the Trujillo site, if necessary.

- Site #8: Acequia Larga

This site is close to the PVID office and has a 1.5-ft-wide Parshall flume in an unlined trapezoidal canal section. The sediment sluice upstream is not used. Two field visits were made; one with no water that revealed the flume was heavily silted and water and moss lines indicated that the flume was probably usually submerged. During the second field visit, the discharge was about 2.4 ft^3/s with 71 percent submergence and about 0.8 ft of sediment in the flume. The typical flow range is from 1-3 ft^3/s with a maximum of 7 ft^3/s. The 1996 flow data indicate that the flume operated highly submerged all season. The typical section has an invert slope of 0.01 and a 1-ft bottom width with 1:1 side slopes and is 2 ft deep.

Recommendation: It is possible that this installation will perform adequately if the earth channel downstream from the Parshall flume to the 18-in metal pipe is cleared out and maintained to slope to the elevation of the invert of the pipe, figure 22. In addition, the sediment must be cleared from the flume section and this must be maintained. The steep invert slope also would indicate that the existing flume should perform adequately with these improvements. It is recommended that this be accomplished and the operation of the existing flume reevaluated to assure the submergence ratio is less than 70 percent.

The discharge for the 1.5-ft-wide Parshall flume at site #8 may be computed from:

$$Q=6.00h_a^{1.54}$$

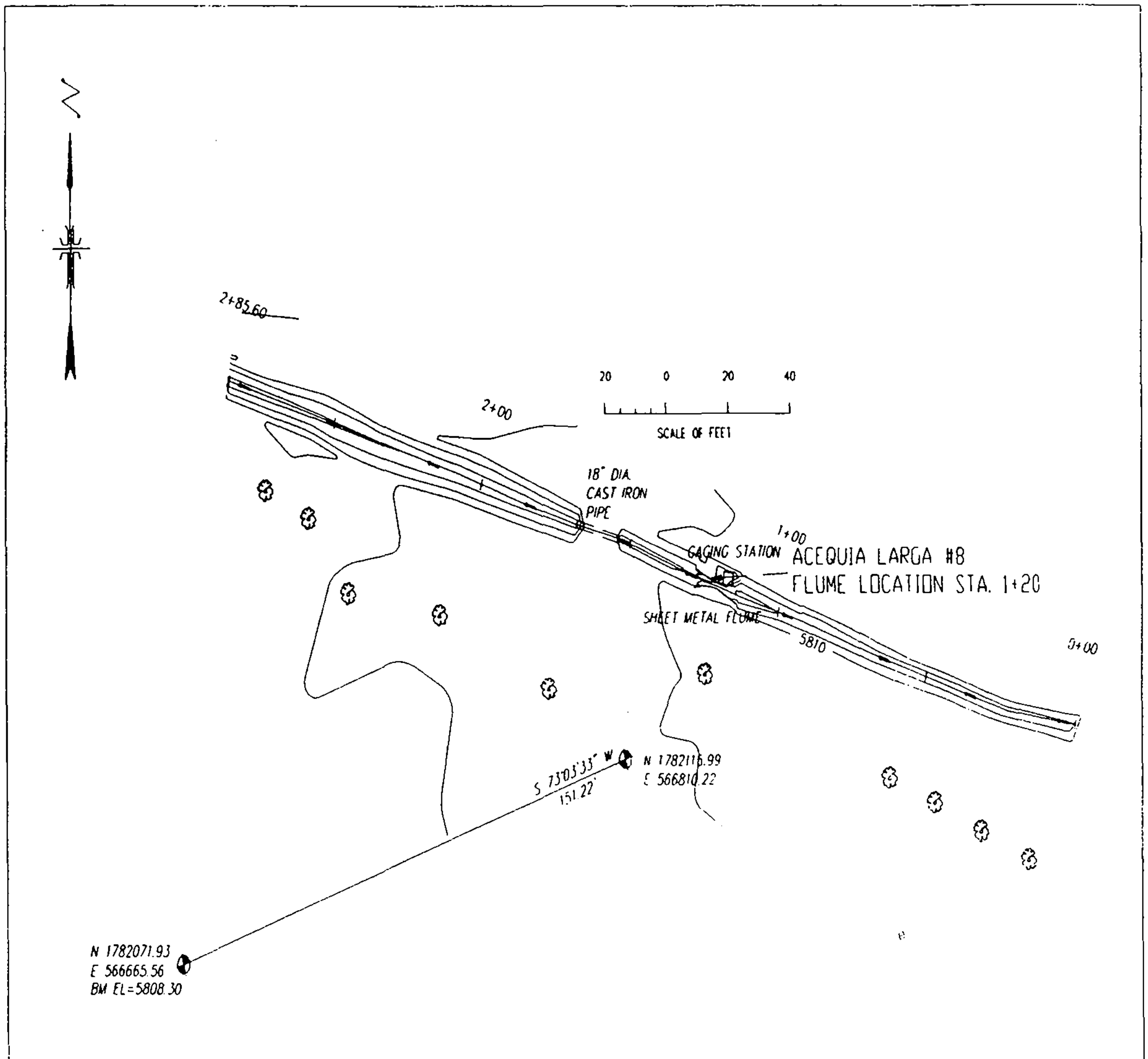

Figure 22. - Location of the existing flume for the Larga ditch #8 at station 1+20.

If operation of the existing flume is submerged after making the suggested improvements, a new long-throated flume should be constructed at the location of the existing flume at about station 1+20. The new flume would be rectangular shaped with a 1.8-ft-wide control sill with a height of 0.6 ft. The upstream ramp has a 5:1 slope to the sill which is 2 ft long in the flow direction. The head measurement should be made 1.5 ft upstream from the toe of the ramp. The existing flume could easily be removed because it is not embedded in concrete and the new flume installed at the same location.

The flow equation for the new flume at the Larga site, if necessary, is:

$$Q=5.722H^{1.534}$$

Add instrumentation as specified.

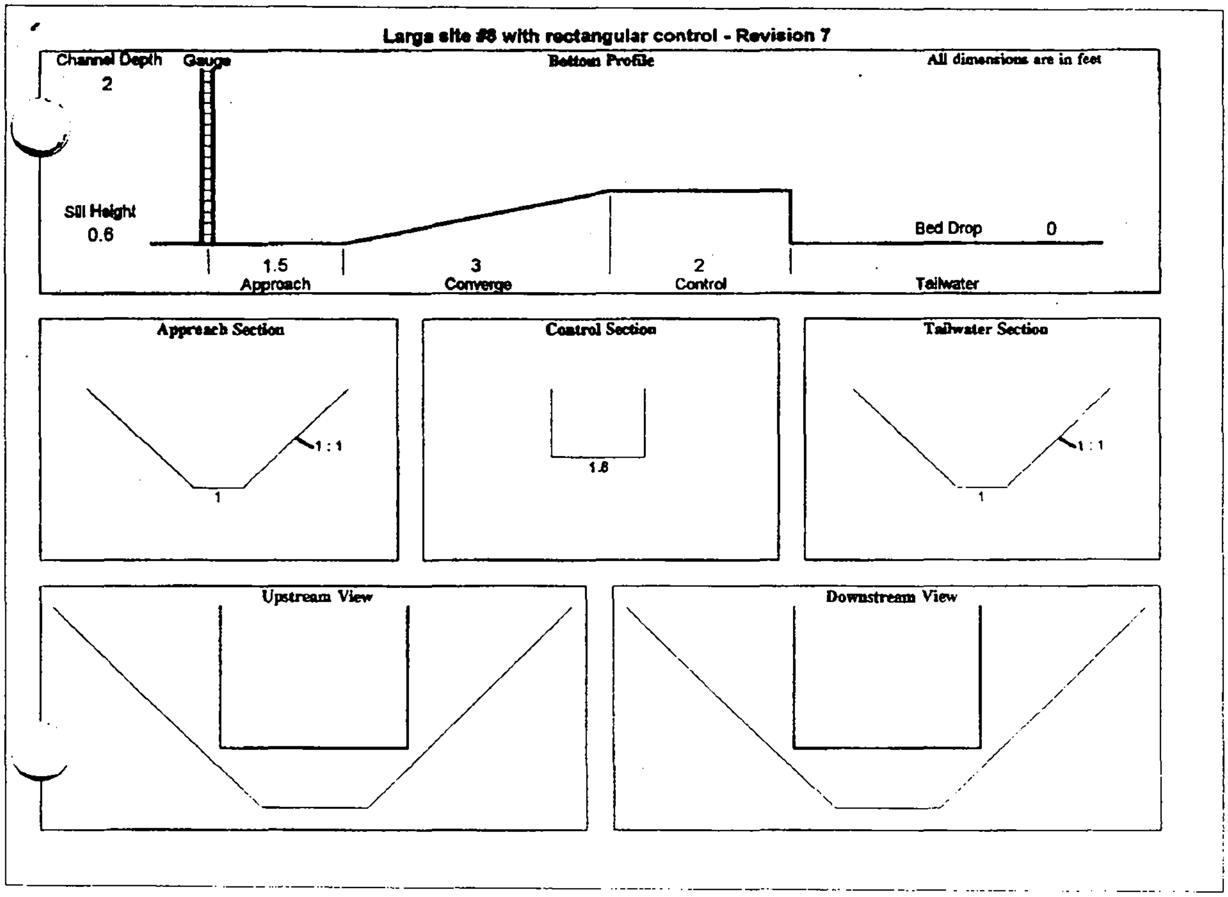

Figure 23. - Schematic and dimensions for a new flume at the Larga #8 site, if necessary.

- Site #9: Acequia de los Indios

This site has a 1-ft-wide Parshall flume in a concrete-lined trapezoidal-shaped canal. The canal is heavily silted. Spring water feeds the ditch, otherwise there was no water during the field visits. The flume was 85 percent submerged with only a spring water flow of about 0.25 ft^3/s. The typical flow range is 1-3 ft^3/s with a maximum flow of 6 ft^3/s. There were no flow data for 1996. A typical section is 1-ft wide on the bottom with 1:1 side slopes with a depth of 1.25 ft.

Recommendation: Construct a new trapezoidal-shaped long-throated flume in the trapezoidal-shaped ditch at about station 1+40 upstream from the existing flume, figure 24. This flume shape includes the side contractions, or is essentially a new trapezoid constructed within the existing trapezoidal-shaped canal. The new flume has a 0.2-ft-high sill that is 1.0 ft wide across the canal and 1.75 ft long in the flow direction, figure 25. The measurement station should be located 1.75 ft upstream from the toe of the 3:1 sloping ramp.

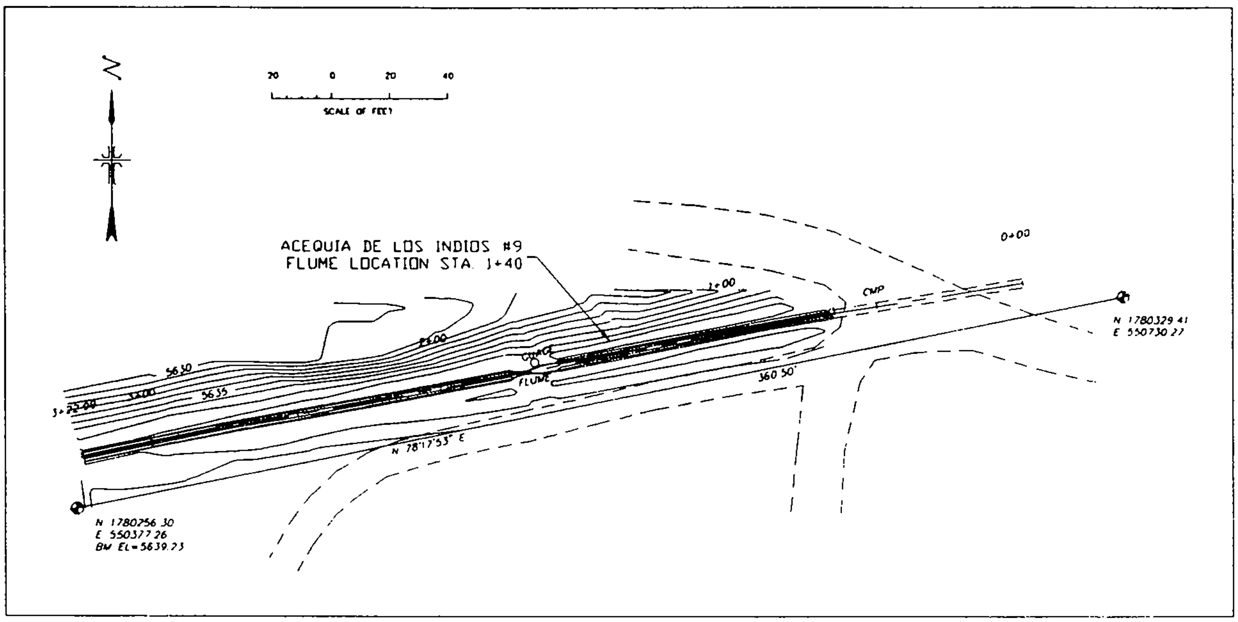

Figure 24. - Location of the new flume for the Los Indios ditch #9 at station 1+40.

The flow equation for the new flume at site #9 is:

$$Q=5.646[H+0.031]^{1.974}$$

Add instrumentation as specified.

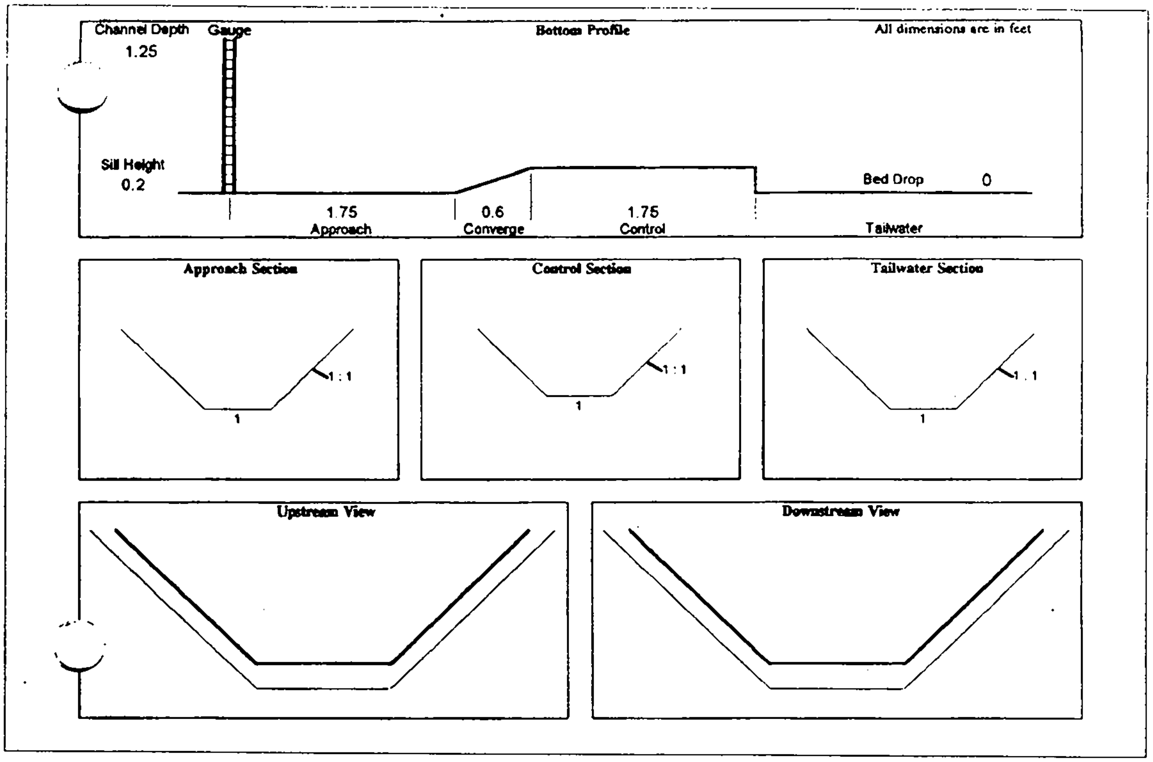

Figure 25. - Schematic and dimensions for the new flume at Los Indios, site #9.

- Site #10: Ortiz SI

This site has a 1-ft-wide Parshall flume in a concrete-lined trapezoidal section. The entire canal reach is choked with heavy water-born vegetation and sediment. Water was overflowing the lined canal banks for 65 ft upstream from the flume during one visit. During the next visit, the vegetation was cleaned out of the canal for about 66 ft upstream and about 200 ft downstream from the flume. The flume was still 94 percent submerged and bank full, figure 26. During both visits the canal was only passing water from a spring and not a normal delivery.

Recommendation: No measurement device will operate properly under the existing conditions in the canal. If this site cannot be better maintained, there is no point in measuring here. It would not be possible to make deliveries under these conditions and nothing should be installed at this site unless a commitment for better maintenance is obtained. If the site will be better maintained then the existing flume should perform adequately and the instrumentation purchased and installed.

- Site #11: El Rincon

This site has a 1-ft-wide Parshall flume in a concrete-lined trapezoidal-shaped canal, figure 2. The flume and canal are in good condition with no submergence of the existing Parshall flume reported. During the field visit, the discharge was measured at 2.9 ft^3/s with no submergence. The typical flow rate is from 1-3 ft^3/s with a maximum of 7 ft^3/s. The typical section has a 1-ft bottom width, 1:1 side slopes and a depth of 1.5 ft.

Recommendation: This site is excellent. No measurement device modifications are needed. Continued maintenance is necessary. The rating curve for the Parshall flume currently installed at El Rincon, site #11, is:

$$Q=3.95h_a^{1.55}$$

Add instrumentation as specified.

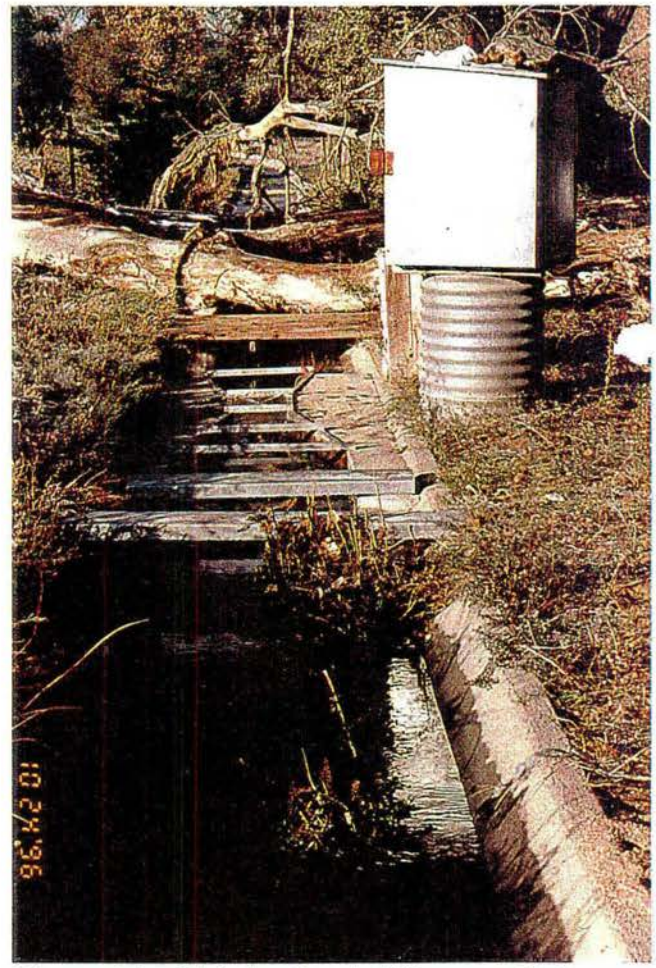

Figure 26. - Existing Parshall flume at Ortiz SI showing the extremely poor operating conditions of the measurement site.

Flume Construction Requirements

Each of the flume designs is based upon the general shape of the canals and ditches from the survey data. The actual channel shape at the flume location may vary from those used in the design. If this is the case, then modifications to the exterior of the flume can be made. The control sill dimensions are the important dimensions to maintain during construction. The sill should be level in all directions and the width and length dimensions given for each flume matched. The exterior can be made to match the canal geometry as best as possible.

Flumes being installed in unlined channels will require rock be placed just downstream from the flume. Rock lining downstream from the flume will prevent erosion at the end of the flume due to the plunging jet from the flow over the control sill.

Installation of the flumes will also cause sediment to collect upstream and only allow the canals to drain to the level of the flumes. To assist with sediment transport through the flumes and provide drainage of the canal sections upstream from the flume when not irrigating, two 1-in PVC pipes should be installed through the flumes on the bottom of the canals. The pipes should be placed at approximate third points across the bottom width of the canal. The pipes will introduce some error in the flow measurement, but has been computed to be less than 1.5 percent in all cases under the normal flow range. Plugs or valves could be placed on the end of the pipes to prevent errors at low flows. However, the plugs must be accessible for the draining.

General Maintenance Recommendations

This construction phase and updating of equipment allows the opportunity to revitalize the system in general. Some simple improvements could be made while out at each of the water measurement sites. First, near the measurement structures where the banks of the ditches are steep and unraveling, it would pay dividends in the future to lay these slopes back and clear weed growth. This would assist with the day-to-day maintenance needed at each site. Second, walk the ditches and clean out the fines and sediment that have deposited upstream, in, and downstream from the existing Parshall flume sites that will continue to be used and the new installations. Third, consider removing trees and woody shrubs from the banks of the ditches and concrete-lined canals to prevent future problems. Finally, consider constructing sand traps and sluices at the river turnouts where possible to help control the amount of sediment that enters the system.

Maintenance of measurement devices and instrumentation is an ongoing job for all irrigation districts. The importance of proper maintenance; however, cannot be overemphasized. The following recommendations are made that pertain particularly to the sites in this project area:

- Before the beginning of every irrigation season, clean out sediment, silt, tumbleweeds, debris, etc., that may have gathered in the ditches and flumes during the winter.

- Inspect the equipment and make sure it is all in working order.

- During the irrigation season, use the sediment sluices where they are installed. This will greatly reduce the amount of sediment entering the ditches from the river.

- Ensure proper maintenance at each measurement site throughout the irrigation season. This includes routinely cleaning out the canals during irrigation season to ensure quality data. Weeds, debris, and sediment must be cleared from the area at the flume and a good distance both upstream and downstream from the flume. Localized efforts at the flume do not ensure accurate measurements due to the possibility of downstream (backwater) effects that can submerge the flume. Keep the flumes free from sediment. Where bubblers or existing chart recorders are being used in the stilling wells, the taps to the stilling wells must be free of sediment.
- While the system is operating, cross check the head measurements using the staff gages and the newly installed instrumentation to ensure that data gathering techniques are acceptable and the flumes and instrumentation are operating properly.

Recommended Flow Monitoring Capabilities

The primary goal of this proposal is to provide flow measurement and monitoring capabilities at 13 sites. At each of these sites, a water level sensor will measure the water level at a flow measurement structure. This water level will be stored and converted into a flow value and these flow values will be accumulated and stored in a data logger at the site. At a specific programmed interval or upon request, flow data will be telemetered from each site to a central location or master station where flows throughout the canal system can be monitored by canal operations personnel. A solar panel and battery must be installed to provide power for the instrumentation at each measurement site because there is no electricity available.

The data communication system will be configured for peer-to-peer communication between individual water measurement sites and finally to the master station. The proximity of the sites to each other makes telemetry of the data between sites to a master station fairly simple (figure 4). Because the sites are all relatively close together, there is no need for a cellular phone system. The radio system alone will be sufficient. This will save the district operation costs. The majority of sites will be able to channel their data directly to the master station. Those sites that cannot will use peer-to-peer communication to send data to the computer at the master station. In other words, data from some sites may need to be relayed through other individual sites until reaching the master station. Because of the flexibility of the data collection equipment, it can be easily programmed to perform peer-to-peer communication.

An office will have to be designated as a master station or central data collection point where another radio and personal computer (PC) will be located. Software is provided by the supplier of the communication system to collect and display the data. The computer at the master station will be programmed to collect data at a specific interval. When the computer at the master station determines that it is time to collect data or if an individual wants to know the present status of the canal system, the computer will call out over the radio system to the all the sites. Once the communication line is open, all of the sites will transmit their data to the master station. The PC at the master station will continue this data collection process until all the needed data has been obtained. All the data that is collected by the central computer can be displayed at the computer in tabular or graphical form. An additional monitoring site may be set up in a truck with an extra notebook computer and radio. This will be explained in the "Future Remote Control Potential" section of this report.

The AAO will need the same communications software to obtain the data from the canal system. The supplier of the communication system should provide this software at no additional cost to the AAO. The AAO will then be able to obtain the desired data simply by calling the master station over the normal phone system. Once the master station is contacted, the stored data from the master station or an inquiry for current canal data can be obtained. The data may also be made available over the Internet, but this may be more difficult to implement. The AAO could also obtain hard copies of the data from PVID as they are currently doing.

Monitoring Site Details, Equipment, and Cost

<u>Sites 1, 2, 6, 7, 8, 9, 10 & 11</u>

These are the flow measurement sites at the Nambe Highline canal, Consolidated ditch, Acequia de las Joyas, Trujillo Ditch, Acequia Larga, Acequia de los Indios, Ortiz SI, and El Rincon. Water level at each of these sites will be measured using a bubbler-type sensor because an enclosure and stilling well exist at each of these sites. The bubbler has an air tube that will be installed in the stilling well to sense the water level in the well. A typical installation for these sites will have the Sutron and bubbler installed in the enclosure with a bubbler tube extending from the instrumentation enclosure down into the stilling well. The water level will still need to be transmitted from the canal to the stilling well as before with the Stevens recorders.

There are a couple of other items specific to the Highline site. The existing enclosure can be utilized as the instrumentation enclosure at the Highline site after repairs are made as necessary. A GOES transmitter may also be added at the Highline site, if desired. The addition of a GOES transmitter would provide additional flexibility in data transmission. This would increase the instrumentation cost for this site by approximately $1000.

Instrumentation components for these site are listed below, with recommended suppliers and estimated cost for each component.

Item	Recommended Supplier	Estimated Cost
bubbler water level sensor	Digital Control Corp.	$800
Sutron 8210	Sutron Corporation	$1,800
radio and modem	Sutron Corporation	$900
radio antenna & mast for Sutron communication system	Sutron Corporation	$300
10-watt solar panel	Photocom	$120
voltage regulator	Photocom	$40
12-volt, 15-amp-hour sealed lead acid battery	Photocom	$70
miscellaneous parts *		$550
Total		$4,580

* Miscellaneous parts include lightning rods and wiring, instrumentation wiring, wiring for the solar panels, and antenna cables. A representative from Sutron has indicated that if the wires have been pulled, Sutron will not charge for hooking up the equipment.

Sites 3, 4, 4a & 5

These are the flow measurement sites at the Consolidated (end), Llano, Nueva, and Community ditches. Water level at each of these sites will be measured using an ultrasonic sensor because there is no existing stilling well or other convenient access for a sensor that must be submerged in the water. The ultrasonic sensor should be mounted above the canal water surface upstream from the flow measurement flume where it will measure the water level required to compute the flow. Figure 1 shows an example installation. Figure 2 shows a detail of an example housing to mount the ultrasonic sensor above the canal water surface. The water level sensor has a 1-ft blanking distance between the device and the water surface. Therefore, the device must be mounted at least 1 ft above the expected maximum water surface.

Instrumentation components for each of these sites are listed below, with recommended suppliers and estimated cost for each component:

Item	Recommended Supplier	Estimated Cost
ultrasonic water level sensor	Milltronics	$850
Sutron 8210	Sutron Corporation	$1,800
radio and modem	Sutron Corporation	$900
radio antenna for Sutron communication system	Sutron Corporation	$300
10-watt solar panel	Photocom	$120
voltage regulator	Photocom	$40
12-volt, 15-amp-hour sealed lead acid battery	Photocom	$70
instrumentation enclosure	Hoffman	$525
miscellaneous parts *		$550
Total		$5,155

* See Site 1 miscellaneous parts description.

The instrumentation enclosure has several components. These components and their costs are shown below:

Item	Part Number	Cost
Hoffman 20"x20"x12" nema 4 enclosure	C-SD202012	$160
enclosure back panel	C-P2020	$25
keylock handle	C-WHK	$25
6" x 6" pedestal	A-66CCOL	$165
24" x 24" base	A-24SBASE	$150
Total Cost for One Unit		$525

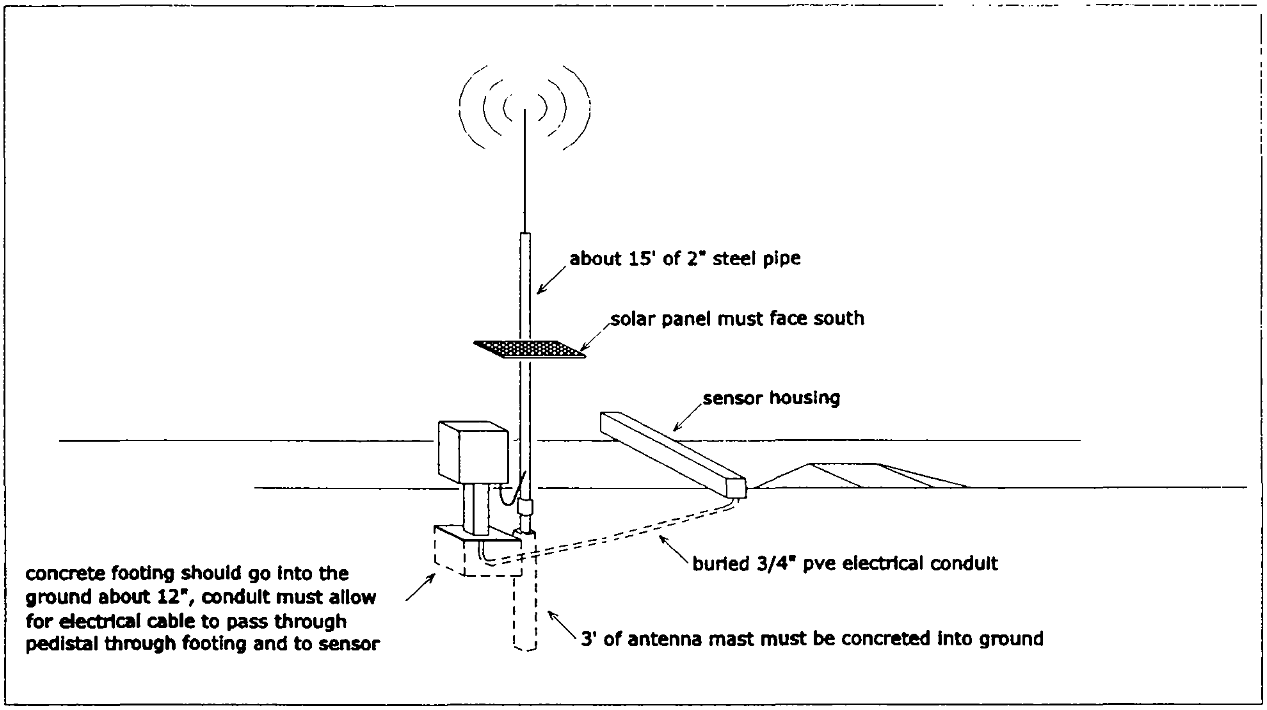

Figure 27. - Diagram of an example instrumentation enclosure and hardware for sites 3, 4, 4a, and 5 (Consolidated (end), Llano, Nueva, and Community ditches).

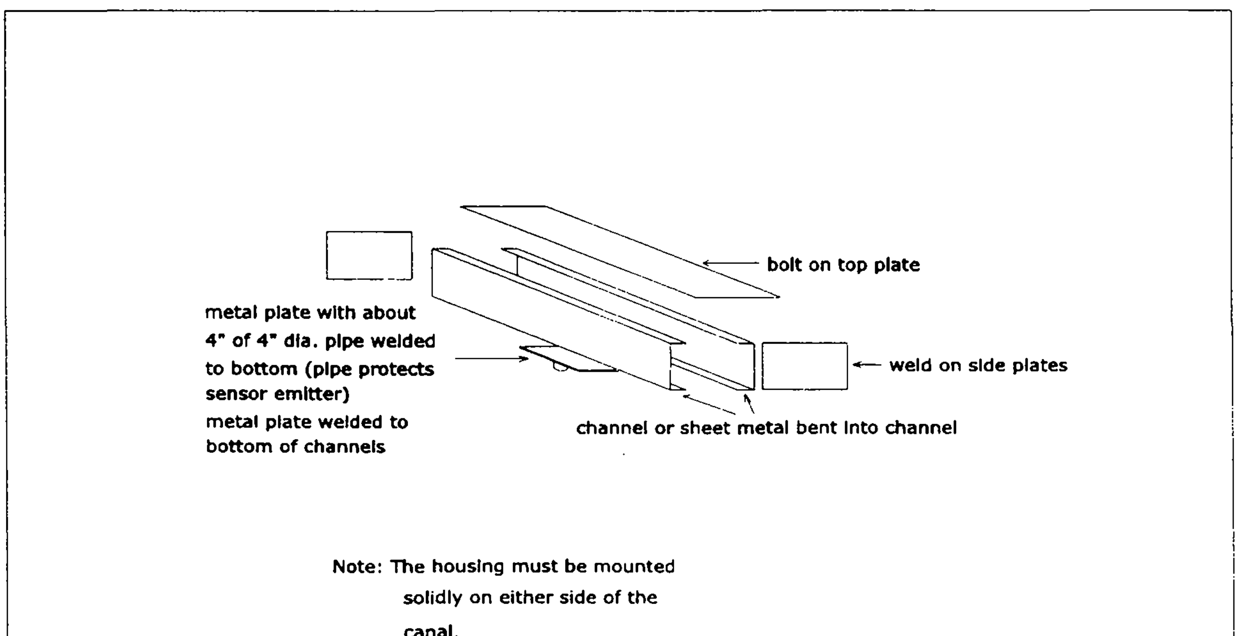

Figure 28. - Example of an ultrasonic sensor housing.

Nambe River Site

This flow measurement site is at the box culvert in the Rio Nambe upstream from Nambe Dam. Because the box culvert is located behind a ridge, two instrumentation enclosures with equipment will have to be installed: one enclosure at the box culvert and the other at the top of the ridge. Instrumentation at the box culvert will collect and record the water level and telemeter these data to the instrumentation on the ridge. The instrumentation enclosure will have to be set up in the same manner as indicated in figure 1 except the bubbler tubes will have to be pulled down the buried conduit to the measurement structure. The end of the tubes can then be fastened at the location specified to measure the water level. A remote data collection system will be required to communicate data between the box culvert and the ridge top. A slave unit at the box culvert will send data to a master unit at the ridge top. The master data collection unit will input data into a Sutron 8210 unit on top of the ridge which will log the water level and flow data and communicate with the other flow measurement sites.

The box culvert site along the river will require the following parts:

Item	Recommended Supplier	Estimated Cost
bubbler water level sensor	Digital Control Corp.	$800
slave unit for remote data collection system	Automata	$500
radio antenna and mast for slave unit	Automata	$200
10-watt solar panel	Photocom	$120
voltage regulator	Photocom	$40
12-volt, 15-amp-hour sealed lead acid battery	Photocom	$70
instrumentation enclosure	Hoffman	$525
miscellaneous parts *		$400
Total		$2,655

List of required parts for unit located on the ridge:

Item	Recommended Supplier	Estimated Cost
Sutron model 8210	Sutron Corporation	$1,800
radio and modem	Sutron Corporation	$900
radio antenna and mast for Sutron Unit	Sutron Corporation	$300
master unit for remote data collection system	Automata	$500

Item	Recommended Supplier	Estimated Cost
radio antenna for master unit	Automata	$150
10-watt solar panel	Photocom	$120
voltage regulator	Photocom	$40
12-volt, 15-amp-hour lead acid sealed battery	Photocom	$70
instrumentation enclosure	Hoffman	$525
miscellaneous parts *		$500
Total		$4,905

* See Site 1 miscellaneous parts description.

<u>Master Station for Data Collection</u>

As mentioned earlier, an office or master station will have to be set up as the central data collection and viewing location. The most appropriate location would be either the PVID office or an office within the Nambe pueblo. The equipment at this site will consist of a computer with system software, modem, and phone. The computer will be programmed to call out at regular intervals to the individual sites to retrieve the desired data. In addition, the immediate status of the monitoring sites can be obtained by manually initiating a data request at the master station. Sutron corporation will set up the software to the required specifications of PVID, the pueblos, and the AAO. This computer should be dedicated to the data collection and monitoring system.

Item	Estimated Cost
personal computer (486 or better)	$2,000
computer modem	$100
uninterruptable power supply (UPS)	$300
radio and radio modem	$900
antenna and mast	$300
miscellaneous parts*	$300
Total	$3,900

* Miscellaneous parts include lightning rods and wiring, and antenna cables.

If a computer is not already available, a computer may be obtained from a supplier such as Gateway, Dell, or any other reputable company. It would be wise to check with Sutron to determine if the chosen computer and modem are compatible with the Sutron equipment (sometimes there are hardware incompatibilities). The UPS can be purchased from a local computer supply store.

Summary of Equipment Needs

Flow measurement and monitoring instrumentation for all 13 sites and the master station is summarized below:

Number	Item	Possible Supplier	Cost	Total Cost
13	Sutron model 8210	Sutron Corporation 2001 Nevada St. Salt Lake City, UT 84108 (801) 446-6495	$1,800	$23,400
14	radios and modems (including master station)	Sutron Corporation	$900	$12,600
14	antennas and masts for Sutron radios (including master station)	Sutron Corporation	$300	$4,200
6	instrumentation enclosures and stands	Hoffman (Local electrical supplier)	$525	$3,150
1	master unit for data collection system	Automata 16216 Brooks Rd Grass Valley, CA 95945 (916) 273-0380	$500	$500
1	radio antenna for master unit	Automata	$150	$150
1	slave unit for data collection system	Automata	$500	$500
1	radio antenna & mast for slave unit	Automata	$200	$200
14	10-watt solar panels	Photocom Box 14670 Scottsdale, AZ 85267-4670 (800) 223-9580 (602) 948-8003	$120	$1,680
14	voltage regulators	Photocom	$40	$560

Number	Item	Possible Supplier	Cost	Total Cost
14	12-volt, 15-amp-hour sealed lead acid battery	Photocom	$70	$980
9	bubbler water level sensor	Digital Control Corp. 10871 75th St. North Largo, FL 33777 (813) 547-1622	$800	$7,200
4	ultrasonic water level sensor (The Probe, two wire loop powered sensor)	Milltronics 736 Kimbark St. Longmont, CO 80501 (303) 678-8678	$850	$3,400
1	PC computer, modem, UPS		$2,400	$2,400
	misc. parts (13 sites plus master)			$7,800
	Total System Cost			**$68,720**

Future Remote Control Potential

The sites at the Highline, Consolidated, and El Rincon canals (and others of which we may not be aware) have the potential for remote manual control at the diversion structure. In addition to monitoring the flow at these sites, operations personnel could control the gates at these sites from the master station. Gate movement commands could be sent from the master station through the radio system to the on-site instrumentation which would automatically reposition the gate. If a pickup truck is set up with a notebook computer, radio, and radio modem, then remote manual control could also be performed from a pickup truck. The pickup truck would essentially have the same capabilities as the master data collection site but should only be used to perform remote control because it may or may not be in the area for data collection.

The Sutron 8210 units have capability to perform this type of remote control, but would require additional software beyond the software included for data collection and monitoring functions. The equipment at the gate structures would need to be replaced or modified. The gates would need to be motorized, control interface equipment and gate position sensors must be installed, and power must be provided for gate motors. Additional instrumentation enclosures would be required at the turnout structures at the Consolidated and El Rincon canal sites.

At all three sites, the Sutron 8210 units would need support hardware including 20-watt solar panels and master/slave data collection units. The slave unit would be located at the water measurement flume similar to the flow measurement site at the Nambe River.

Additional equipment required for remote control of three sites is summarized below:

Number	Item	Recommended Supplier	Est. Cost	Total Cost
3	motorized gates	Hydrogate	$5,500	$16,500
3	100-amp-hour deep cycle batteries	Local Auto parts store	$100	$300
2	master/slave data collection units	Automata	$1,000	$2,000
3	20-watt solar panels**	Photocom	$200	$600
2	instrumentation enclosures	Hoffman	$525	$1,050
3	control interface hardware and miscellaneous parts		$1,000	$3,000
	Total Additional System Cost			$23,450

**The 20-watt solar panels would meet the power requirements of these sites provided that the gate motors draw less than 8 amps and they are operated four or less times per day.

Field Verification

The ratings provided in the report are standard for the existing Parshall flumes that will continue to be used. The equations given for the new long-throated flume installations assume that the flumes are accurately constructed to the given dimensions. These ratings must be verified by checking the as-built dimensions of the flumes. The district with the assistance of the AAO, if necessary, should perform these checks and contact us with the as-built dimensions for adjustment to the rating curves as necessary.

The equations provided will all be entered by the Sutron Corporation representatives into the recording devices. Field measurement of water levels and discharges during use of the new devices must be made to verify that the measurement devices are working properly. Minor modifications to the rating information can then be made if necessary. These steps will ensure accurate interpretation of results obtained by flow over the flumes.

References

[1] "Water Measurement Manual, Revised Third Edition," U.S. Department of the Interior, Bureau of Reclamation, U.S. Government Printing Office, Denver, CO 1997.

[2] Peck, Hilaire, "Submerged Flow in Parshall Flumes," Proceedings of International Symposium, Hydraulics Division of ASCE, Model-Prototype Correlation of Hydraulic Structures, Colorado Springs, CO, August 9-11, 1988

[3] Bos, M.G., "Discharge Measurement Structures, Third Revised Edition," International Institute for Land Reclamation and Improvement/ILRI Publication 20, P.O. Box 45, 6700 AA Wageningen, The Netherlands, 1989.

[4] Clemens, A.J., M.G. Bos, J.A. Replogle, "FLUME Design and Calibration of Long-Throated Measuring Flumes, Version 3," International Institute for Land Reclamation and Improvement/ILRI Publication 54, P.O. Box 45, 6700 AA Wageningen, The Netherlands, 1993.

[5] Dodge, R.A., "Ramp flume Model Study - Progress Summary," GR-82-14, U.S. Bureau of Reclamation, Denver, CO, 1983.

[6] Bell, Milo C., "Fisheries Handbook of Engineering Requirements and Biological Criteria," U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon, 1991.

Appendix

REQUIREMENTS FOR CONSTRUCTION OF NAMBE RIVER BOX CULVERT CONCRETE MEASURING DEVICE AND WALLS

I. Diversion

When constructing the concrete measuring device and two of the concrete walls, water in the stream can be diverted through the other remaining open bay. When this remaining bay is covered by the last concrete wall, stream flows can be diverted through the completed measuring device, though this will require a small cofferdam to account for the 2-foot difference in elevation between the invert of the weir and the bottom of the concrete wall.

II. Sediments

Accumulated sediments and debris must be removed from the barrel in which the concrete measuring device will be constructed. Sediments and debris shall have to be removed from the other three barrels as required to construct the three walls.

III. Concrete

A. Mix

1. Maximum size aggregate shall be 3/4 inch.
2. Slump shall not exceed 2 inches plus or minus 1 inch.
3. Total air content shall be 6 percent plus or minus 1 percent.
4. The design of the reinforced concrete was based on an assumed concrete compressive strength of 4000 lb/in^2 at 28 days.

B. Placement

1. Maximum ambient placement temperature shall be 90°F and the minimum temperature shall be 45°F.
2. Surfaces on which concrete will be placed must be clean, free from any frost, ice, mud, and debris. Also, existing concrete must be solid and free from loose fragments.
3. Immersion-type vibrators shall be used.
4. Extra vibration shall be done at the upstream-most part of the measuring device (along the floor).

C. Tolerances for New Concrete

1. New concrete surfaces must not gradually vary more than 1/120 inches per inch.
2. Maximum allowable abrupt concrete surface irregularity is 1/16 of an inch.

IV. Reinforcement

Reinforcing bars shall be deformed bars conforming to ASTM A 615, grade 60. Spacing of reinforcing bars shall not deviate from the required spacing by more than 1 inch.

V. Strip Waterstop

A. General - The contractor shall furnish and install flexible strip waterstop in the joints between the new concrete and the existing concrete at the upstream and downstream ends of the measuring device and the three concrete walls as shown on the drawing.

B. Materials - The strip waterstop shall be a bentonite waterstop. It shall be approximately 3/4-inch wide by 3/8-inch thick, furnished in lengths not less than 25 feet, and equal to Waterstop-RX as manufactured by American Colloid Company, 5100 Suffield Court, Skokie IL 60077. Adhesive material shall be equal to Volclay WB-Adhesive manufactured by American Colloid Company.

C. Installation - The waterstop shall have the ability to adhere to clean dry concrete, and have a service temperature range of minus 40°F to 212°F.

The surface to receive the adhesive and waterstop shall be thoroughly cleaned for a minimum of 3 inches on each side of the strip waterstop location. This same surface must be in a dry condition immediately prior to installation. The waterstop shall be positioned to the upstream side of the reinforcing steel and have a minimum clear distance of 2 inches between the waterstop and the outside face of the concrete.

Concrete cut nails may be used in addition to the adhesive to help secure the strip waterstop. The adhesive shall only be applied to the area of concrete to be covered by the waterstop. The strip waterstop shall be installed such that it is in contact with the existing concrete at all times and with no bridging or gaps.

VI. Diversion Opening

The far left wall panel (looking downstream) includes a 1-foot by 1-foot opening at the base of the wall for future operations and maintenance. If the measuring device is plugged with debris and needs to be cleaned or future repairs are required, this opening can be used to bypass stream flows. The opening can pass a stream flow of approximately 5 ft^3/s with a head of 1 foot. Therefore, this opening will only be of value during periods of low flow in the river.

The covering for the opening during normal operations was not specified on the drawing. One option for the cover would be a steel plate that would be bolted onto the face of the concrete and removed whenever needed. The details of the materials for the cover and the attaching hardware would be easier to determine by the field personnel involved in the construction and operation of this measuring device.

VII. Quantity Estimates

Concrete volume in measuring device	10.6 cy
Concrete volume of the three walls	5.9 cy
Weight of steel reinforcement (total)	980 lbs
Total length of strip waterstop	165 lf