CONTINUOUS MEASUREMENT OF DRAINAGE DISCHARGE

R. Schoneman, J. E. Ayars

ABSTRACT. *The west side of the San Joaquin Valley of California has had drainage disposal problems since irrigation was introduced in the early 1900s. Selenium toxicity problems associated with the Kesterson Reservoir caused closure of the existing agricultural drainage system in 16 194 Ha (40,000 acres) in 1986. The continuing need for drainage of irrigated agricultural lands has prompted several water management studies by the Water Management Research Laboratory of the USDA. One of the essential data requirements in these studies is the quantification of drain flows. A measurement station was constructed for this purpose employing a manhole with a 90° V-notch weir and datalogging electronics to provide hourly water flow data. Power was supplied by solar and conventional sources. Construction details, costs (for a solar-powered station), and resulting data are shown. As configured, the measurement station has provided seasonal data streams for analysis during three years of operation.*
Keywords. *Drainage discharge, Datalogging, 90° V-notch weir, Construction costs, Manhole.*

The Water Management Research Laboratory (WMRL) has conducted several integrated irrigation and water management studies on the west side of the San Joaquin Valley of California since 1983. Results of field studies have demonstrated that upward flow from the groundwater, also described as Et usage by crops, occurred in both surface and subsurface drip irrigated plots (Ayars and Schoneman, 1984). Crop extraction and groundwater quality were shown to impact drain spacing design in an adjusted design technique (Ayars and McWhorter 1985). A multi-year study showed that irrigation timing and climatic parameters could affect upward flow in the groundwater (Ayars and Schoneman 1986). On a water district scale, reductions in deep percolation were recommended as a control for toxic trace elements in shallow groundwater (Ayars et al., 1990).

In each of the above studies, measurements were required to characterize the groundwater table response as part of water balance calculations. Observation wells were installed to determine the level and shape of the water surface and manhole measuring stations monitored drain water flow exiting the study site. The manhole stations were developed in two configurations.

The first configuration was an installation of concrete rings stacked on a poured-in-place concrete floor with drainpipe adapters inserted through holes chipped in the bottom concrete ring. A tapered section was stacked on top to reduce access to 91.44 cm (36 in.). The drain pipe adapters were plumbed to provide a full pipe for operation of residential-sized municipal water meters. Heavy equipment was required to deliver and set manhole pieces in place. Sealing problems between the concrete rings and the nature of the shallow groundwater in the study field caused the manholes to fill with groundwater on a regular basis. The flooding prevented access for data collection from the manual readout on the meters. Residential meters of brass construction with plastic internal measurement parts were used initially. Meters with plastic cases were then substituted in an attempt to address corrosion problems that caused freezing of the measurement components. The limited range of measurement for these meters caused ponding of groundwater upstream of the manholes as confirmed by measurements in adjacent observation wells.

The second design was an installation of a galvanized steel culvert with a poured, reinforced concrete floor and welded drainpipe adapters. These manhole measuring stations have also served as water table depth adjustment devices. A series of boards are stacked in slots inside the manhole to provide water head for measurement by a weir and restrict the flow passing through. When the flow is restricted, the water table upstream of the station rises. The 1984 and 1986 studies by WMRL have shown that deep-rooted, salt-tolerant crops can use this resource.

Flow data generated by these stations have assisted in calibrating load-flow relationships in areas with elemental chemical toxicity problems. Data have also suggested regional migration of ground water. Moreover, regulatory compliance can be shown to have occurred where disposal requirements must be met.

SYSTEM DESCRIPTION

Each flow-monitoring station consists of a vertical manhole 1.22 m (4 ft) in diameter containing a 90° V-notch weir for measuring flow. At least one board must be inserted under the weir to provide a calm reservoir of water

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flowing over the measuring device. Weirs or orifices can measure flow, but the 90° V-notch weir was chosen for its wide flow range capabilities. Water depth passing through the weir is measured by an ultrasonic transceiver, processed to indicate flow, and logged over time using a Campbell Scientific CR10 or CR500 (brand name use does not imply USDA endorsement). The ultrasonic transceiver was mounted to the weir board in order to allow adjustment of weir height in the manhole. Power is supplied by photovoltaic cells recharging deep-cycle batteries, or by connection to adjacent pump power panels. Data are downloaded to a notebook computer and returned to the laboratory for processing.

Construction Details

The manhole (see fig. 1) was constructed of corrugated galvanized steel culvert 1.22 m (4 ft) in diameter and 3.05 m (10 ft) long. Steel channel 7.62 cm × 3.81 cm (3 in. × 1 1/2 in.) was welded to the inside surface parallel to the length to provide a slot for boards. Welds were applied at the locations where channel steel touched the culvert. The channel steel ran the length of the culvert beginning 91.44 cm (36 in.) from one end to the point where the crosspiece fit at the other end. The channel crosspiece was welded into position such that the edges of the channel flanges were 10.16 cm (4 in.) from the end of the culvert. Strap steel 3.81 cm × 3.18 mm (1 1/2 in. × 1/8 in.) was welded to the downstream flange edge of the channel. The strap steel provided an extra support for the weir and any adjustment boards. It should be noted that the weld must be continuous to minimize leakage around the weir and boards. Two circular openings were cut for connection to the underground drainpipe 90° away from the channel steel, one on each side. The invert of each opening was 30.48 cm (12 in.) from the end of the culvert where the channel crosspiece was located. A mesh of 1.27-cm (1/2-in.)-diameter, reinforcing steel rod 30.48 cm (12 in.) on center was welded into the sides of the culvert at the bottom underneath the steel channel. The mesh was welded into position 5.08 cm (2 in.) from the end of the culvert.

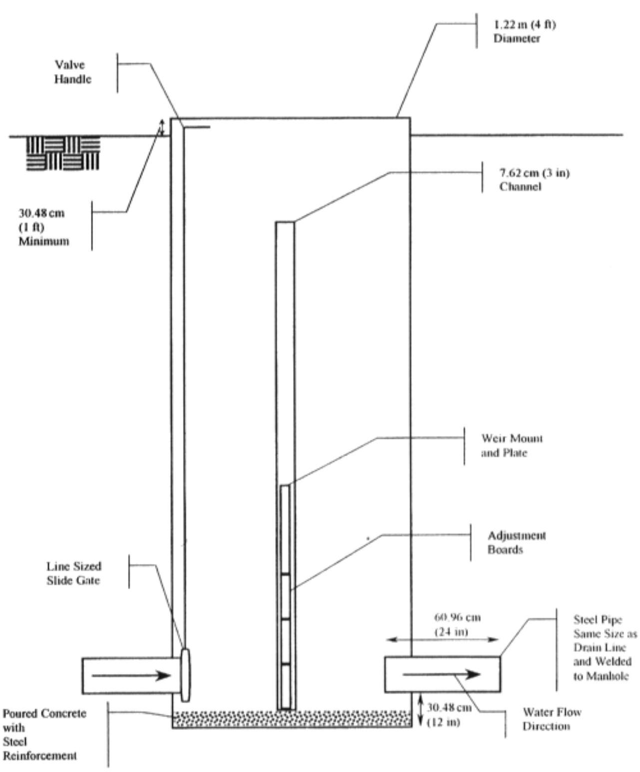

Figure 1–Manhole construction, side view.

The culvert was lifted upright on an asphalt-paved surface and concrete shoveled into the bottom through the side openings. Enough concrete was placed so that its surface was flush with the top edges of the channel steel crosspiece. Standard equipment and techniques were used to finish and smooth the concrete surface. When the concrete had cured, a pipe stub was welded to one of the circular openings and a slide gate with an extended handle and pipe stub was welded in the other. Gaps between the culvert corrugations and the welded channel were filled with sprayed expansion foam in hand-held spray cans. A gate hinge available at a hardware store was welded to the culvert to provide mounting for a plywood cover. The cover was a 1.22 m × 1.22 m (4 ft × 4 ft), 0.64-cm (0.25-in.)-thick plywood section with the corners cut to a rounded shape. The corners were cut such that the plywood piece rested on the culvert top. Subsequent installations have made use of expanded metal covers fabricated by the owners.

Boards for use in the manhole were cut from 5.08 cm × 30.48 cm (2 in. × 12 in.) rough-sawn redwood lumber. The rise desired in the upstream water table determined the number of boards. One board was chosen for the bottom of the manhole and modified to prevent undercutting by water. A strip of 0.635-cm (1/4-in.) closed-cell foam was cut to wrap the bottom edge of the board. The foam strip also extended up the sides and ends of the board 5.08 cm (2 in.). The foam was treated with a special adhesive recommended by the product vendor, then fastened in place with a staple gun. When multiple boards are installed, leakage at the board edges occurs. This problem has been addressed by the attachment of tarp material to the upstream side of the installation. The plastic tarp material was attached to the weir board with furniture tacks. A section was cut from the middle to expose the weir plate. The bottom was weighted with sandbags. The sandbags were partially filled and formed into cigar shapes. Electrical tape was wrapped around the sandbags to make the cigar shape stable.

Exterior A-C plywood 2.54 cm (1 in.) thick × 60.96 cm (2 ft) × 121.92 cm (4 ft) was cut to provide a mount for the V-notch weir. A V-notch was centered and cut in one side 5.08 cm (2 in.) wider than the V-notch measurement opening in the stainless steel weir plate. The downstream side of the plywood was beveled to prevent interference with the flow passing over the weir.

The weir itself was cut from a plate of 3.18 mm (1/8 in.) 316 stainless steel. The plate was sized to overlap the notch cut in the plywood, providing room for fasteners. A 90° V-notch was cut in one side (see fig. 2). The downstream side of the plate was beveled to allow the flow nappe to leap free. It is important to pay attention to this beveling process to ensure that the edge is sharp, otherwise, the flow nappe will attach itself to the downstream side of the weir plate. The resulting flow rate will be higher than that predicted by the governing equation for this device. With a

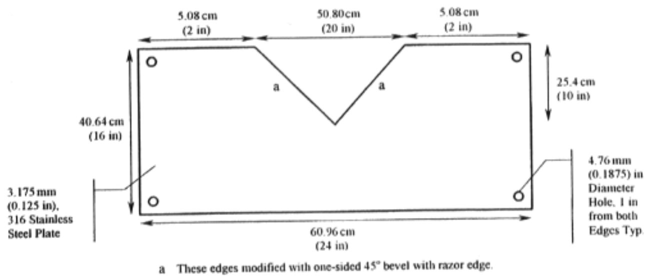

Figure 2–90° V-notch weir plate and mount.

V-notch depth of 25.4 cm (10 in.), the flow ranges from 0 to 160 m^3-h^{-1} (0-705 gal-min^{-1}). The flow rates anticipated are of an intermittent nature and vary widely according to rainfall, irrigation schedules, or groundwater migration.

A bracket was fabricated to provide a mount for the ultrasonic transceiver (see fig. 3). Constructed of angle iron and steel plate, it provided a clamping surface for the transceiver and a flat, horizontal plate for reflection of the sonic signal. The bracket was bolted through the weir mount such that the horizontal plate aligned with the point of the V-notch in the stainless steel plate (see fig. 4). Sections of 3.81 cm × 3.81 cm × 4.76 mm (1 1/2 in. ×

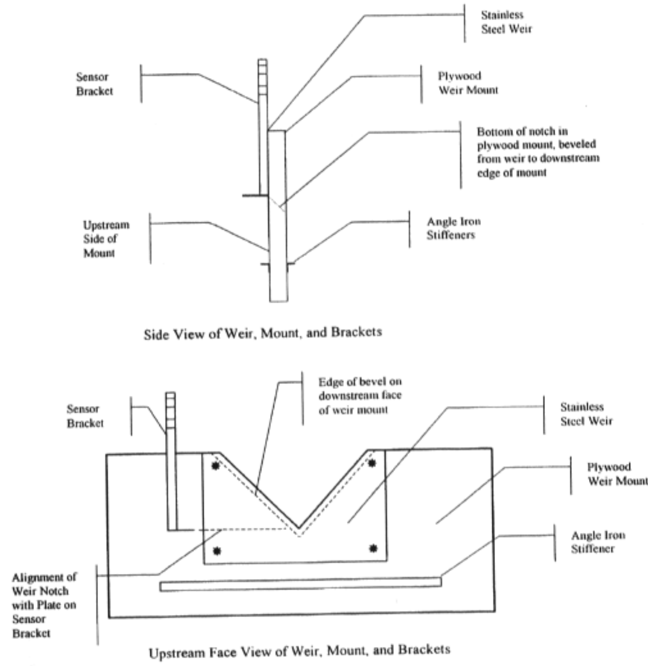

Figure 4–Views of weir, mount, and bracket.

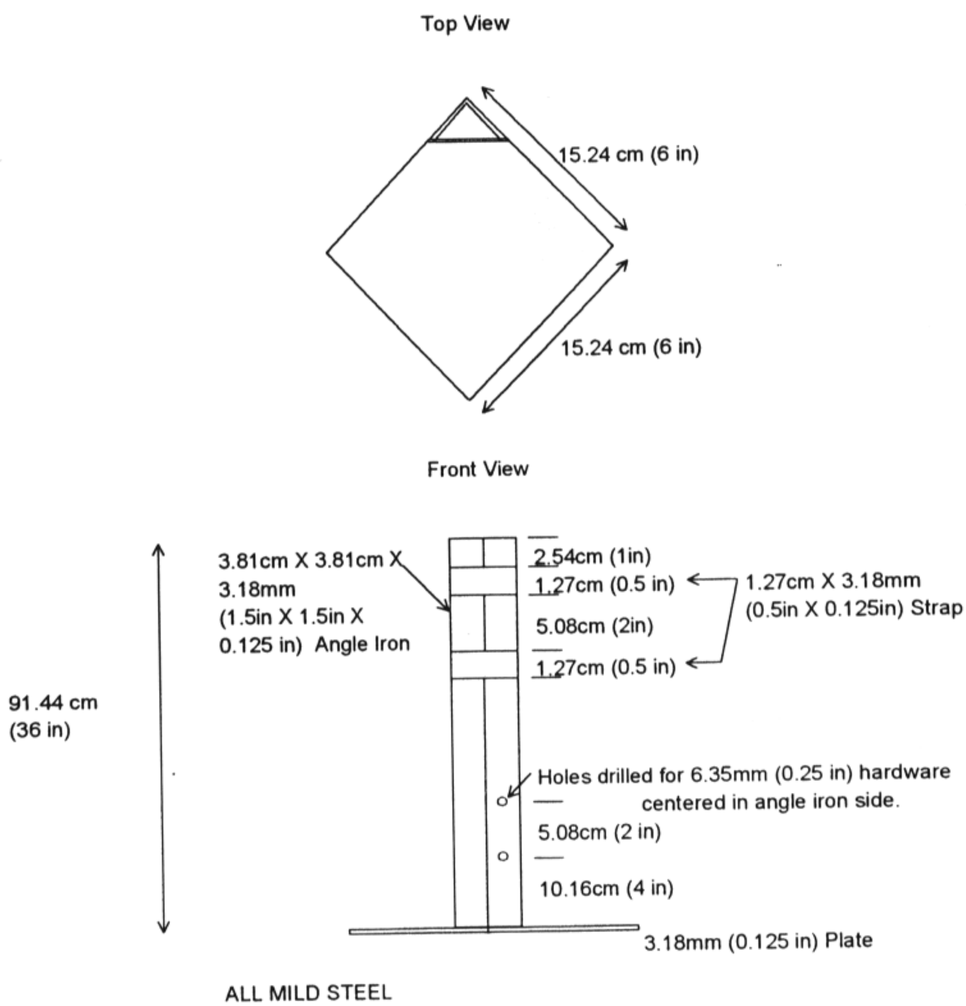

Figure 3–Sensor mounting bracket.

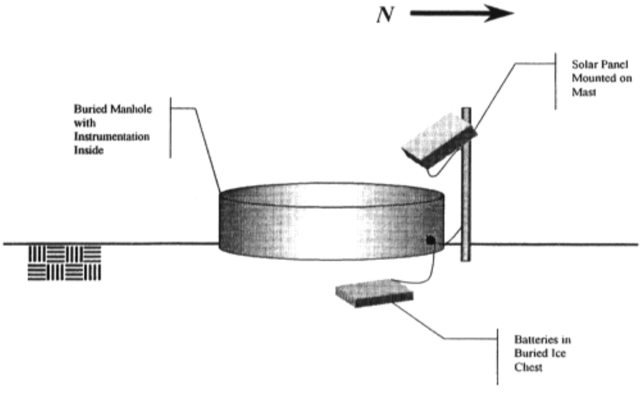

Figure 5–Orientation of solar-powered site components.

1 1/2 in. × 3/16 in.) mild steel angle iron were also attached below the V-notch plate to provide stiffening of the V-notch mount. Two sections were used, one on each side, and bolted through the mount to each other. The bracket and angle iron were fastened with 6.35-mm (1/4-in.) stainless steel bolts, nuts, and washers.

Instrumentation for data collection consisted of an ultrasonic sensor with a signal conditioner capable of interfacing with a variety of measurement devices. When a certain minimum flow passed over the weir, a relay closure was triggered, sending a pulse to the datalogger. The sensor and conditioner (Greyline SLT+) were purchased as a package. The SLT+ was purchased without a datalogger option because dataloggers were already available. Station sites requiring solar power were configured with a 60 W panel and two, 12 V batteries. The solar panel featured a bracket with U-bolts to mount the unit. A 3.05 m (10 ft) long, 3.81 cm (1 1/2 in.) schedule 40 galvanized steel pipe served as a pipe mast mount. When mounted, the solar panel was oriented along an east-west axis, allowing full southern exposure on the solar cell surface (see fig. 5). The bracket mount inclined the solar panel so incoming radiation impinged at right angles to the cell surfaces. Sites requiring solar power were in remote areas and the panels have not been vandalized. The batteries were deep cycle lead-acid, with an 80 amp-h capacity. Solid conductor 10-gauge wire connected the batteries in parallel. The solid conductor wire was deemed easier to attach to the battery terminals than stranded wire. A buried 45.42 L (48 qt) ice chest protected the batteries from weather and theft. Two 1.27 cm (1/2 in.) electrical conduit bulkhead fittings were cut into a corner of the ice chest to provide wiring access for the batteries, solar panel, and instrumentation. At installation, silicone sealant was applied around the fittings to anchor them to the ice chest. When the ice chest was buried, the area around the wiring access holes was cleared to provide ventilation for the batteries.

Results

A list of costs for the various components in the installation is shown in table 1. Separate lines indicate costs for subunits of the total configuration. Note that prices are for 1996. The datalogger listed represents what was on hand at the WMRL office. Less expensive loggers are available from this company and others. The SLT+ can also be purchased with a datalogger option.

Table 1 Summary of construction costs

Manhole construction (materials)		$2,620.00
Plywood lid, with hardware		15.00
2 weir boards, 2 × 12 redwood		16.85
SLT + sensor, cable, lightning protection, software, manual		1,475.00
12 V dc power input		75.00
Deep cycle batteries, 80 amp-h, 12 V, quantity 2		119.80
Battery storage (ice chest)		30.00
60-W solar panel w/regulator		750.00
Fiberglass enclosure		269.00
V-notch weir plate		175.00
Plywood backing		22.21
Angle iron plywood support		10.00
SLT + sensor mounting bracket		40.00
Data logger CR10X1M		1,202.80
CURS100 shunt resistor		30.00
Miscellaneous conduit, stainless steel hardware		30.00
	1996 Total	$6,880.66

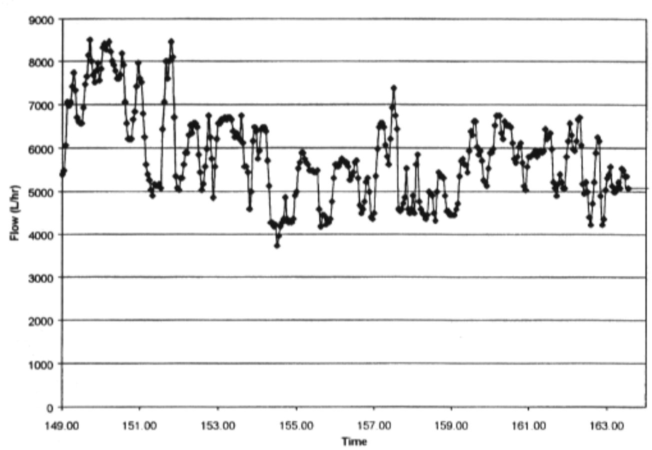

Figure 6–Sample datalogger output.

The field equipment was installed by a minimum of two people using an extension ladder for access. At that time, the signal conditioner and datalogger were programmed. WMRL personnel wrote the datalogger control program. The datalogger monitored the SLT+ every second and totaled the pulses per hour. A volume of 45 L (11.89 gal) was associated with each pulse. When retrieving data, a notebook computer was connected to the datalogger with an RS232 cable. A communications program on the computer interrogated the datalogger and transferred stored data to the notebook computer for later analysis. Data were in the form of hourly flow volumes. Representative data were selected and plotted in figure 6.

Summary

This article has described an installation for monitoring, flow measurement, and control of shallow groundwater. In the regulatory climate that presently exists, there is value in quantifying and controlling groundwater flows from irrigated agricultural lands. This configuration has reliably recorded data for three years and the ultrasonic sensor, as installed, has withstood total immersion. Sensor immersion has been caused by excessive pre-season irrigation. In addition, an intermittent stream located near one site overflowed its channel after an intense rainfall event and flooded the surrounding area and the manhole. Measurements of flow and samples for chemical analysis can be taken. Moreover, different combinations of boards can be stacked in the manhole to retain a desired level of groundwater upstream of such a station. The culvert selected for the manhole allowed access for these adjustments. Additionally, under certain conditions, pumps can be installed to provide recycling capabilities where drain water is pumped to a reentry point in the subsurface drainpipe network. Weirs have the capability of measuring wide fluctuations in water flow, which occurs in subsurface drainage systems as water management changes with crop growth and harvest. Some of the equipment listed in table 1 was on hand which limited configuration options while reducing costs at construction time. Tests of alternative sensors and dataloggers are ongoing and opportunities for their use exist.

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