ANNUAL MONITORING REPORT
2007

MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT

Underground Storage Facility Permit No. 71-563876.0005 (PCFCD)
Water Storage Permit No. 73-563876.0100 (CMID)
Recovery Well Permit No. 74-568133 (CMID)
Water Storage Permit No. 73-563876.0200 (PCRWRD)

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1.0 INTRODUCTION

The Marana High Plains Effluent Recharge Project (MHPERP) is a demonstration recharge project developed by the Pima County Regional Flood Control District (PCRFCD) in cooperation with the Bureau of Reclamation (BOR), Arizona Water Protection Fund (AWPF), Cortaro-Marana Irrigation District (CMID), and the Town of Marana. The project is located in Section 33 of Township 11 South, Range 11 East in the Avra Valley sub-basin of the Tucson Active Management Area (**Figure 1**). It is one component of a regional water resource, flood control, environmental protection and enhancement, and recreation program (the Northwest TAMA Replenishment Program) that is sponsored by more than a dozen local, state, and federal entities.

MHPERP is designed to investigate the feasibility of recharging treated effluent into the local groundwater aquifer, while simultaneously investigating wildlife habitat opportunities associated with recharge facilities. The overall objectives for the project, as identified in the final Environmental Assessment (BOR, 1998), include the following:

- To recharge approximately 600 acre-feet of water per year while determining what infiltration rates can be maintained in basins having side slopes vegetated with emergent plants and riparian trees, and in basins fully vegetated with native grasses tolerant of periodic inundation;

- To provide trails, descriptive literature, and interpretive signs describing the pilot project operation. Trails at the effluent pilot project site may eventually be linked to a longer river trail network that is scheduled to be built along the Santa Cruz River;

- To revegetate the area outside the recharge basins with plants that will improve wildlife habitat value and, once established, could survive if the recharge activities cease;

- To characterize wildlife, aquatic macroinvertebrates, and vegetative resources associated with an important effluent-dominated stream; and

- To identify and monitor any biological effects that may result from establishing other habitat types that are now rare to the area (e.g., marsh, grassland), and increase the aerial extent of riparian vegetation.

The MHPERP facility is comprised of one settling basin (equalization basin) and four spreading basins (recharge cells), totaling 3.88 acres of recharge area (**Figure 2**). A comprehensive description of the MHPERP and the related monitoring plan was provided to the Arizona Department of Water Resources (ADWR) in support of the Constructed Underground Storage Facility (USF) Permit Application for the project filed in October 1999. In addition to the USF Permit (No. 71-563876), the facility has an Aquifer Protection Permit (No. P-103195) from the Arizona Department of Environmental Quality (ADEQ) that authorizes the discharge of treated effluent into the aquifer.

Operations began in February 2003 and, in accordance with Sections 2 and 3 of the USF Permit, this is the fifth annual report for the MHPERP. This report includes all of the data that was collected during the 2007 Calendar Year.

2.0 PROJECT OPERATIONS

2.1 Water Delivery

Water is delivered to the MHPERP via the "oxbow" channel, a remnant channel of the Santa Cruz River from when the riverbed was less incised and the channel meandered back and forth across the floodplain. A berm consisting of streambed materials is used to divert some of the effluent flowing down the main channel of the Santa Cruz River into the oxbow channel. Sources of the effluent discharges are the Roger Road Wastewater Treatment Plant and the Ina Road Wastewater Treatment Plant, which are located approximately 15 miles and 10 miles upstream of the diversion structure respectively. The effluent flows down the oxbow channel for about one mile before reaching the MHPERP.

A constructed wet well collects the oxbow channel flows and two non-clogging, submersible pumps convey the effluent through an 8-inch line into an equalization basin. The equalization basin is used to provide a more constant source of available effluent for recharge, and to help serve as a settling basin for removing particulate materials that could clog the recharge cells. A level sensor is installed in this basin to automatically turn the pumps on and off based on levels within the oxbow channel and the equalization basin. From the equalization basin, the effluent passes through a 16-inch isolation valve into the main distribution line, which feeds into each of the four recharge cells through motorized butterfly valves. A level sensor is installed at each cell to automatically open and close the valves based on pre-set water levels. The valves are closed manually, using an electronic switch, by the daily operator when the cells are scheduled for a drying cycle.

Deliveries to MHPERP are based on the daily cycle of discharges from the treatment plants to the Santa Cruz River. Peaks in water levels at this site normally occur in the late morning and early evening hours. Deliveries to the facility are impacted by storm water events in the Santa Cruz River that demolish the earthen diversion structure used to divert flows into the oxbow channel. Malfunctioning pumps, faulty valve controls and flow meters, and basin maintenance can also disrupt deliveries to the recharge cells. Details of all the delivery interruptions for Calendar Year 2007 are provided in Section 6.0 (Facility Inspections and Maintenance) of this report.

2.2 Inflow Volumes

Water deliveries into the MHPERP facility are measured using a Magnetflow® Mag Meter installed within the main line that runs from the pumps to the equalization basin.[1] Deliveries into each of the recharge cells are measured using an American Sigma 950 Flow Meter equipped with an area/velocity sensor installed within the outlet pipe feeding into each cell. The meters measure flows on a continuing basis, record the data every minute, and compile the data into daily totals. The daily totals are read on-site by the facility operator, who compiles the data onto a daily log sheet. The daily log sheets are transmitted to PCRFCD staff on a weekly basis.

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[1] Flows from the start of operations through September 30, 2007 were measured using an American Sigma 950 Flow Meter equipped with an area/velocity probe. This flow meter was replaced because the probe malfunctioned and it was difficult to maintain and calibrate. **Appendix E** gives the specifications of the new meter.

Appendix A contains the monthly recharge accounting reports for Calendar Year 2007. Column 2 of the Monthly Accounting Report (**Appendix A**) indicates the daily delivered volume to the equalization basin, which is used for temporary storage of the water before it is directed into the recharge cells. Columns 3-6 show daily volumes delivered to each of the recharge cells. Column 7 shows the total daily volume delivered to the project, which is simply the sum of the inflows into each of the recharge cells. The difference between Column 2 and Column 7 indicates an approximate amount of effluent lost through infiltration and evaporation within the equalization basin.

The total water volume delivered to MHPERP for Calendar Year 2007 is 368.90 acre-feet, of which 329.70 acre-feet was delivered to the recharge cells. Water volumes stored for recharge by month are as follows: January – 59.08 AF, February -23.74 AF, March -22.56 AF, April – 18.86 AF, May – 16.95 AF, June 44.22 AF, July – 25.36 AF, August - 0.00 AF, September – 5.31 AF, October – 41.56 AF, November 38.38 AF, and December – 33.68 AF. A total of 141.19 AF of the water delivered during this Calendar Year was stored for and recovered by CMID, who has both a Water Storage Permit (No. 73-563876.0100) and a Recovery Well Permit (No. 74-568133) for this facility. The remaining water, which totaled 188.51 AF, was stored for the Pima County Regional Wastewater Reclamation Department (formerly Pima County Wastewater Management), who has a Water Storage Permit (No. 73-563876.0200) for the facility.

2.3 Evaporation/Evapotranspiration

Column 8 of the Monthly Accounting Report displays the calculated evaporation volumes for Recharge Cells 1-3. These calculations are based on the Cooley Method (1970) using the "Maximum Curve", as approved by ADWR (**Appendix B**).

Column 9 shows the daily evapotranspiration volumes for Recharge Cell 4. These volumes are calculated using the daily reference evapotranspiration values determined by the Arizona Meteorological Network (AZMET) at their Marana weather station (**Figure 3**). AZMET determines reference evapotranspiration (ETo) using a modification to the Penman Equation developed for the California Irrigation Management Information System (CIMIS). An explanation of the procedures used in this computation is provided in **Appendix C**. No multiplication factor was used in the calculation of reference evapotranspiration (ETo) for the MHPERP because there are no available crop coefficients for the native vegetation in this region.[2]

2.4 Recharge Volumes

Column 10 in the Monthly Accounting Report displays the adjusted net recharge volume for the facility, which is the sum of the daily volumes delivered to the recharge cells less the evaporation/evapotranspiration losses. Net recharge for the facility during the 2007 Calendar Year is 319.46 AF. Monthly and cumulative recharge volumes for each recharge cell and for the total project are displayed in **Figures 5** though **9**.

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[2] The reference evapotranspiration values are determined for tall (8-15 inches), cool season grasses. Much of the vegetation within Recharge Cell 4 consists mostly of grasses that are approximately 8-15 inches in height. Since no information is available for the species established at MHPERP, it is assumed that the evapotranspiration losses at this facility are the same as those calculated at the AZMET station.

3.0 HYDROLOGIC MONITORING

Hydrologic monitoring of the facility includes measurement of on-site and off-site groundwater levels and direct observation of basin water levels. The on-site monitoring network consists of one monitor well and one piezometer, both measured monthly using a depth sounder (**Figure 4**). Off-site monitoring consists of monthly water level measurements for three monitor wells: SC-09, SC-10 and AVMW-1 (**Figure 4**).

3.1 Basin Water Levels

Water levels within the equalization basin are expected to fluctuate from one to five feet above the bottom elevation of 1,984 feet above mean sea level. Water depths in each of the recharge cells are expected to fluctuate from three to twelve inches during the wet cycles. Water levels sensors within the basins are programmed to automatically open and close the motorized butterfly valves to maintain these ranges. Basin water levels are observed visually on a daily basis to insure that the sensors are working properly.

3.2 Regional Groundwater Levels

Groundwater levels are measured for four monitoring wells, one on-site (HP-1) and three off-site (SC-09, SC-10 and AVMW-1). HP-1 is measured monthly by PCRFCD personnel using an electric sounder. Wells SC-09 and SC-10 are also monitored on a monthly basis by PCRFCD staff using an electric sounder. Well AVMW-1 is measured monthly by the Central Arizona Water Conservation District (CAWCD) using both an automatic datalogger and a manually operated electric sounder. PCRFCD has an agreement with CAWCD to obtain the data collected from the AVMW-1 well.

Table 1 contains the water level data collected for the on-site and off-site monitor wells. All of the monitor wells have alert levels of 20 feet below land surface. Alert levels for the monitoring wells were not exceeded during the 2007 Calendar Year. The water level in the on-site monitoring well, HP-1, rose almost five feet in 2007 (from 186.3 feet below land surface to 181.4 feet below land surface). This rise is mainly attributed to large sources of upgradient, Central Arizona Project water recharged at the Lower Santa Cruz Recharge Project.

3.3 Perched Groundwater Occurrence

Table 2 contains the monitoring data for the one piezometer (HP-2) used to assess perched water conditions. This eighty-foot deep well was dry during the entire 2007 Calendar Year. The alert levels for this well are set at 20 feet below land surface.

4.0 INFILTRATION RATE ASSESSMENT

The average daily and monthly infiltration rates for each of the recharge cells during the 2007 Calendar Year are displayed in **Appendix D**. Infiltration rates were estimated using the "volumetric" method, which is simply the total daily inflow divided by the wetted acreage.

The total wetted acreage used to calculate the infiltration rate is determined using the level sensor on the area/velocity flow meter combined with known topography of the recharge cell bottom. Data

downloaded from the flow meter is used to determine average daily water levels in the recharge cells. Rating curves, calculated using topography of the site, are used to estimate the percentage of wetted area in each recharge cell. The percent wetted area is then multiplied by the total basin acreage to calculate the wetted acreage. Daily visual estimates are also provided by the facility operator as a check.

The average monthly infiltration rates for the annual reporting period ranged from 0.11 feet/day (Cell 3, March) to 3.4 feet/day (Cell 2, December). A graph of the average monthly rates is displayed in **Figure 10**. Infiltration rates were fairly high in January, as a continued result of the basin cleaning/disking that occurred in November 2006. Infiltration gradually reduced over the next six months, as more and more fine grained sediment and organic material settled to the bottom of the recharge cells. After six weeks of downtime from washout of the diversion berm, the recharge cells were cleaned and ripped in September. Recharge Cells 1 and 2 experienced higher infiltration rates through December as a result of the deep ripping. Infiltration rates in Recharge Cells 3 and 4 did not increase as sharply nor last as long as in Cells 1 and 2.

5.0 WATER QUALITY MONITORING

5.1 Water Quality Sampling Activities

The Aquifer Protection Permit requires water quality samples to be collected and analyzed on a monthly basis for nutrients (Nitrogen constituents), and on a quarterly basin for total metals and Volatile Organic Compounds (VOCs). Samples are collected from the source water inflow and from monitor well HP-1. Nitrogen forms are monitored more frequently because of the high nitrogen content in effluent water, and the potential for recharge to increase the nitrogen content in the local aquifer through leaching of nearby agricultural soils. Water quality sampling at the MHPERP also serves as a tool for studying nitrogen transformations in riparian and aquatic ecosystems, to determine if nitrogen levels can be reduced through the wetland recharge process.

5.2 Chemical Analyses Results

Table 3 summarizes the results from sampling taken during the 2007 Calendar Year. Samples were taken at the oxbow channel, when flowing, and at monitoring well HP-1.[3] Sampling for nitrogen constituents was performed on a monthly basis, while sampling for Total Metals and VOCs was performed quarterly. There were no analytes reported above the alert levels set by the Aquifer Protection Permit for this facility.

6.0 FACILITY INSPECTIONS

Inspections of the facility equipment and functions are required by the Aquifer Protection Permit on a weekly basis. The facility operator at MHPERP performs inspections on a daily basis while collecting data for PCRFCD, transmitting any problems or required maintenance through the daily logs delivered on a weekly basis to PCRFCD. PCRFCD staff is contacted immediately for any

[3] The oxbow channel was not sampled in July, August and September due to no flow or the combination of effluent with storm water. Well HP-1 was not sampled in July, August and September due to the pump breaking down and the pipe rusted out.

alarms or serious problems concerning the facility equipment. PCRFCD performs weekly investigations of the facility to insure quality of the data collected and note any general maintenance needs.

Table 4 lists the problems that occurred throughout the 2007 Calendar Year and the solutions performed to resolve them. Facility downtime in 2007 was mostly attributed to the storm water events from July 25th through August 27th. Minor disturbances to water deliveries occurred from inoperable pumps and motorized control valves, along with maintenance to the main flow meter (FMeq).

7.0 CONCLUSIONS

The volume of water stored at the MHPERP for Calendar Year 2007 is 319.46 AF. This is almost double the total from last year, and is approximately 50 AF higher than the previous high observed in 2003. However, it is still about 280 AF short of the yearly permitted total for the recharge facility (600 AF).

Monitoring of operations has shown no exceedences of water quality standards or water alert levels at the project site. Off-site monitoring showed no negative impacts to surrounding operation from a water level perspective. Recharge at MHPERP increased significantly with regular maintenance performed on the recharge cell bottoms. Although there were a few interruptions to water deliveries throughout the year, the presence of fine grained materials in the cell bottoms is believed to be the most likely reason for the lower-than-expected recharge at this site.

The current USF permit expired on September 26, 2007. In June 2007, PCRFCD staff submitted an application to extend the USF permit for MHPERP by twenty years and to modify the recharge cells in order to enhance the facility's recharge capacity. This permit application is still under review as of the date of this report, with PCRFCD in the process of responding to questions provided by ADWR staff. PCRFCD continues to operate the recharge facility under the old permit conditions while the new permit application is being processed.

FIGURES

FIGURE 1
Location Map

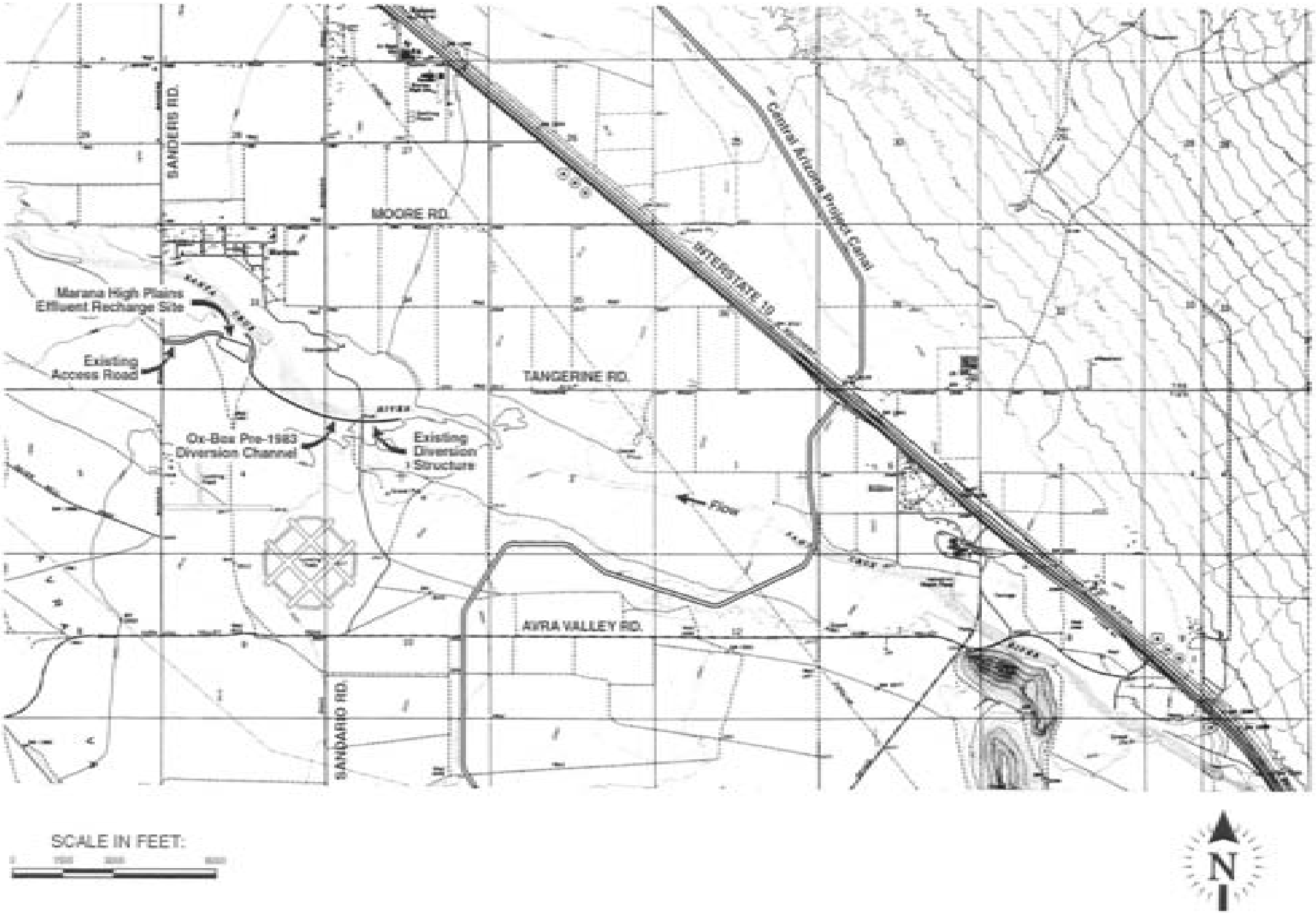
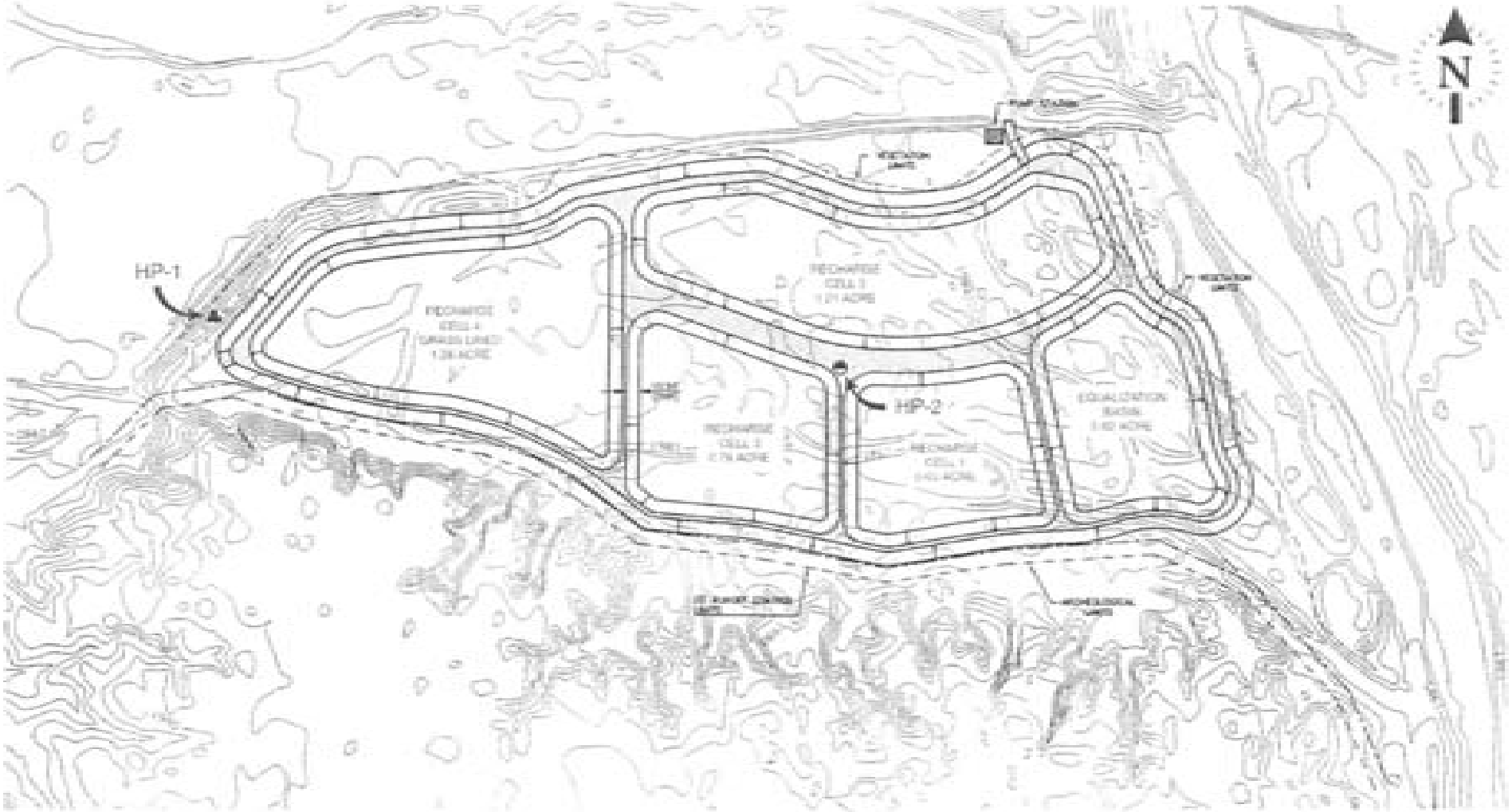


FIGURE 2
Facility Map



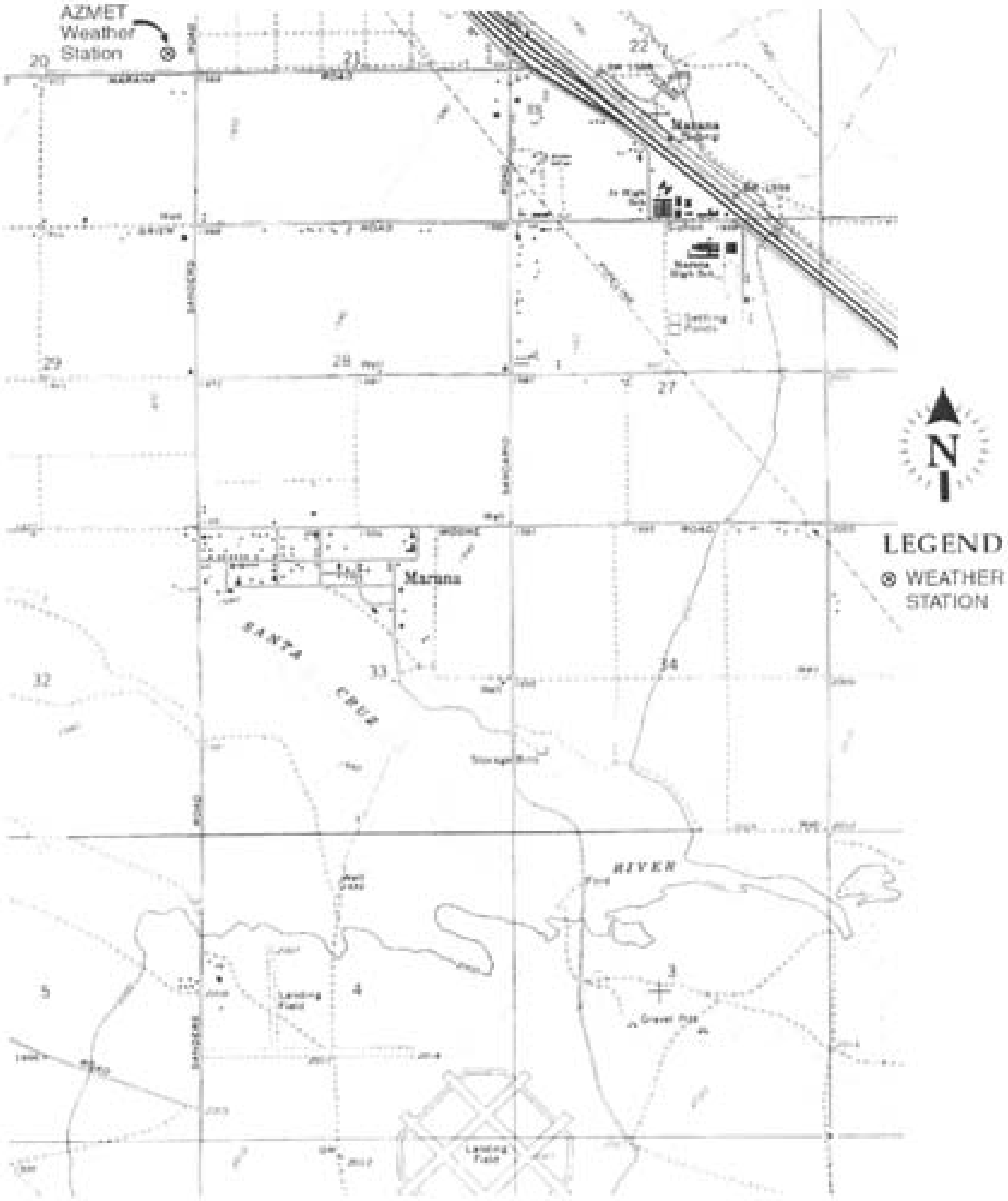
SCALE IN FEET:

TOTAL RECHARGE AREA = 3.88 ACRES
ESTIMATED RECHARGE VOLUME = 290 ACRE-FT/YR

LEGEND

▲ MONITOR WELL

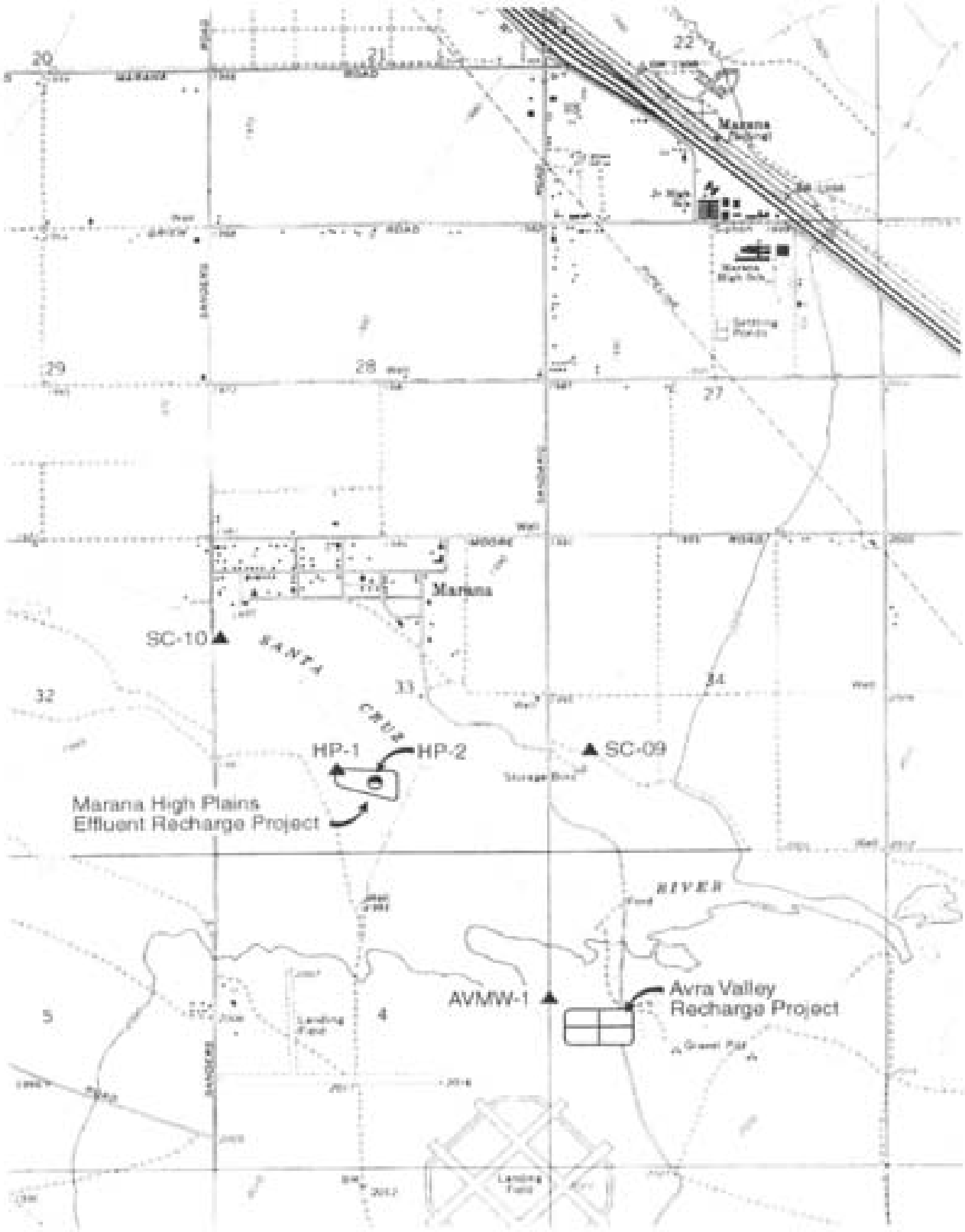
● PIEZOMETER



Date on line: Sep 1 1987 (Julian Day 244)
Location: 1.6 km (1 mile) west of I-10 on Trico-Marana Rd.
Elevation: 601 meters (1972 ft)
Coordinates: Latitude = 32° 27' 40" N; Longitude = 111° 14' 00" W
Cooperator: Marana Agricultural Center College of Agri., Univ. of Arizona

FIGURE 3
Marana High Plains Effluent Recharge Project :
AZMET Weather Station Location Map

Miles .5 1 2
SCALE:



LEGEND

▲ MONITOR WELL

● PIEZOMETER

N

FIGURE 4
Marana High Plains Effluent Recharge Project : Offsite Monitor Well Location Map

Miles .5 1 2

SCALE:

FIGURE 5
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
Cell 1 - 2007 Monthly and Cumulative Recharge

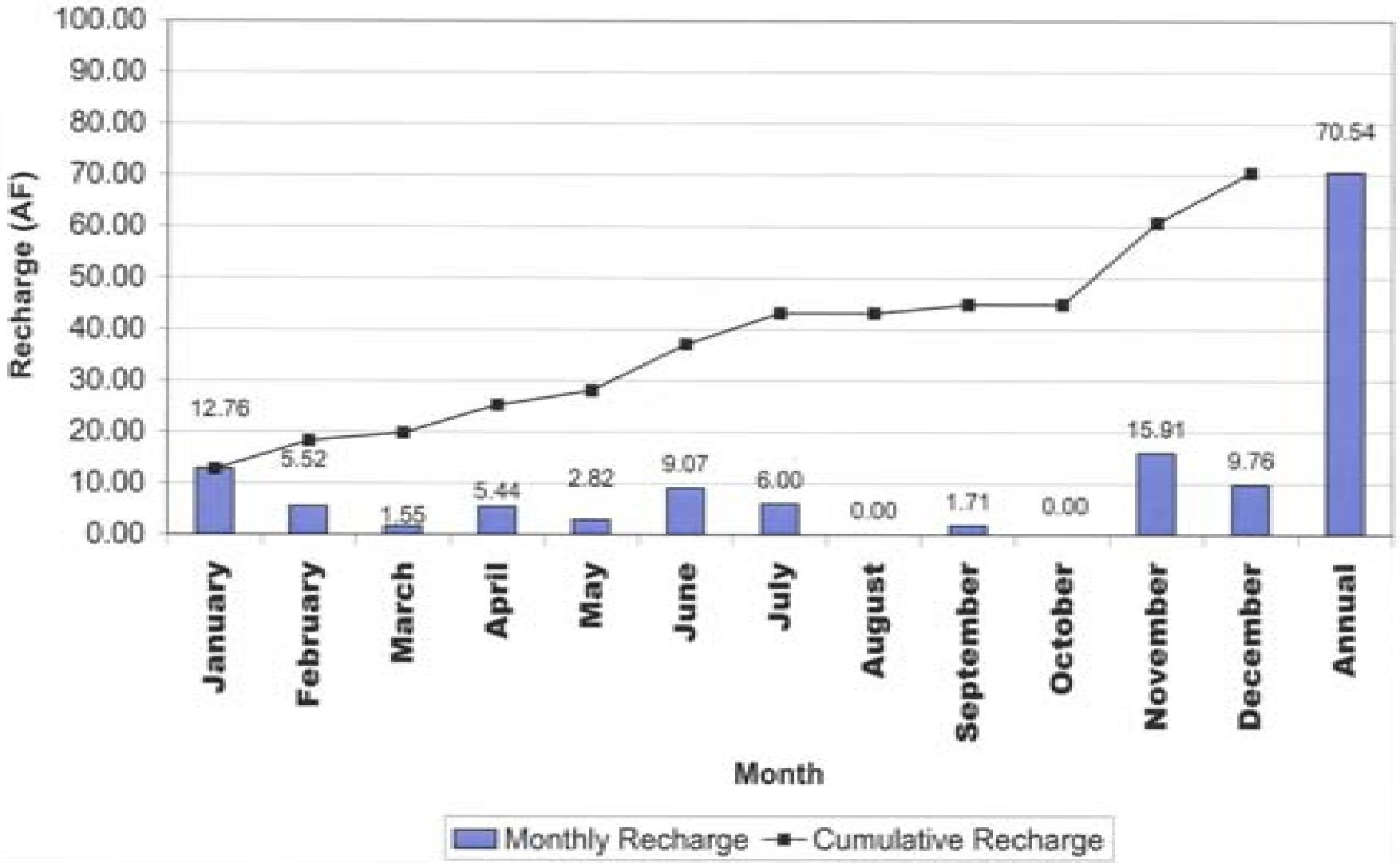


FIGURE 6
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
Cell 2 - 2007 Monthly and Cumulative Recharge

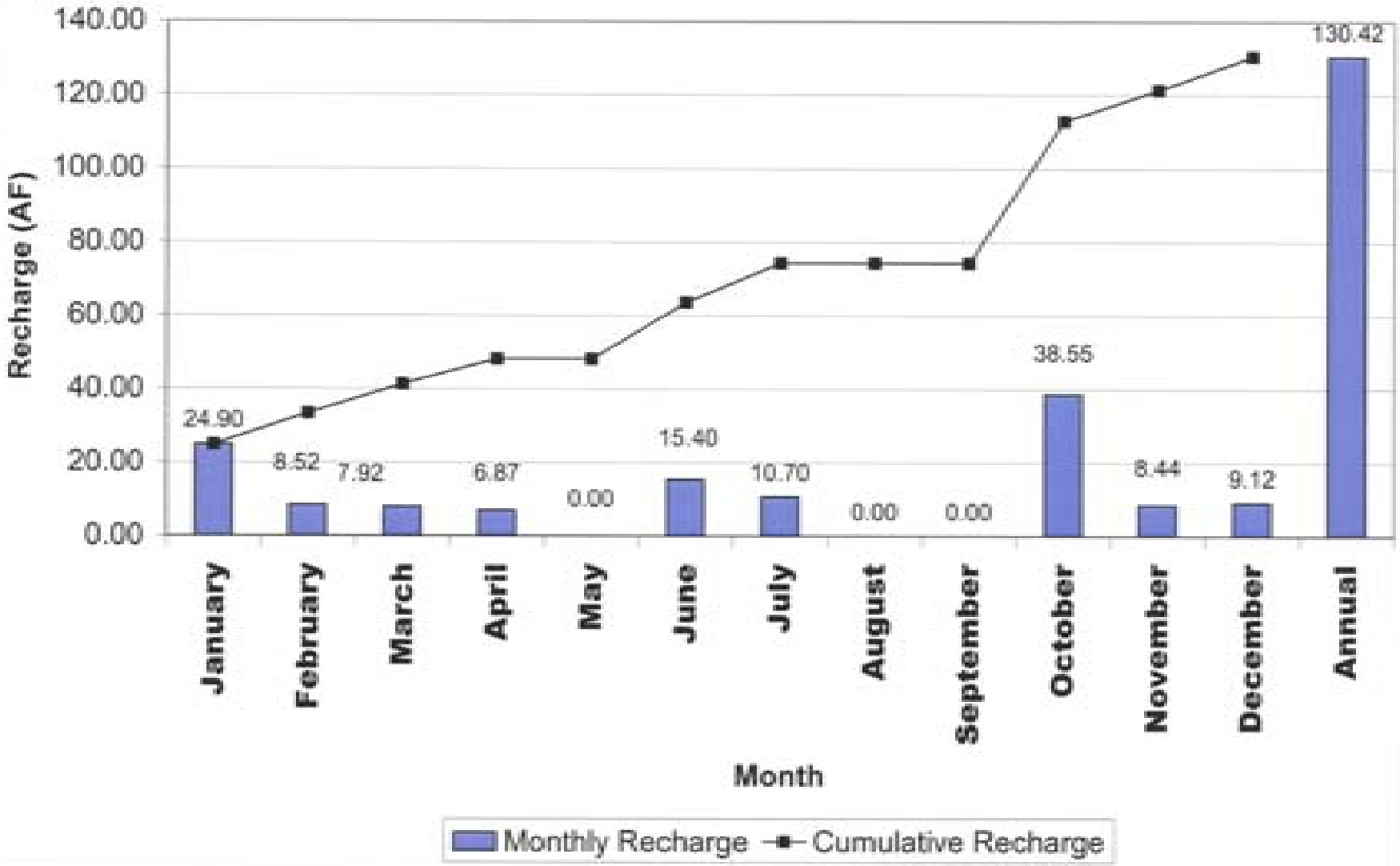


FIGURE 7
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
Cell 3 - 2007 Monthly and Cumulative Recharge

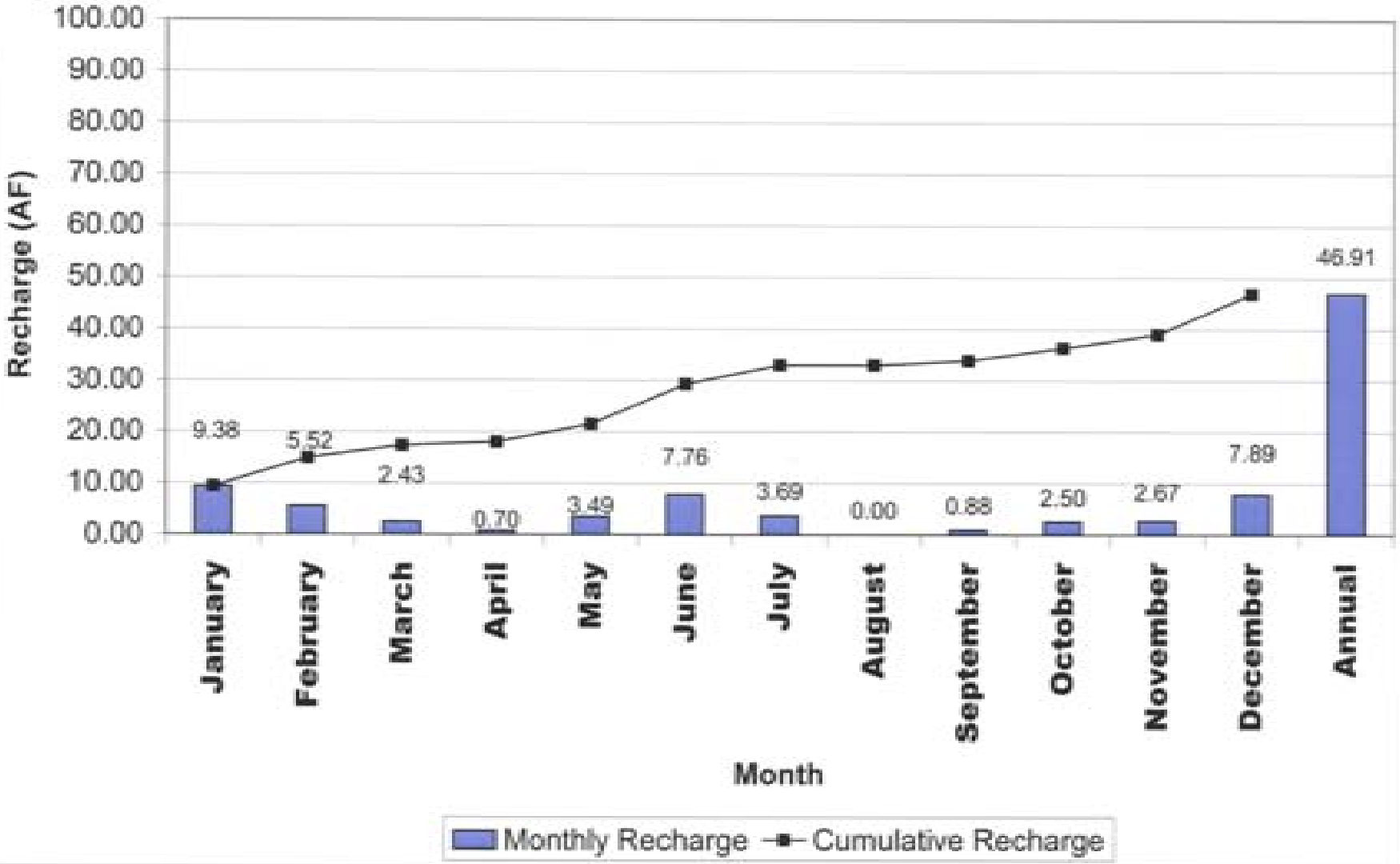


FIGURE 8
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
Cell 4 - 2007 Monthly and Cumulative Recharge

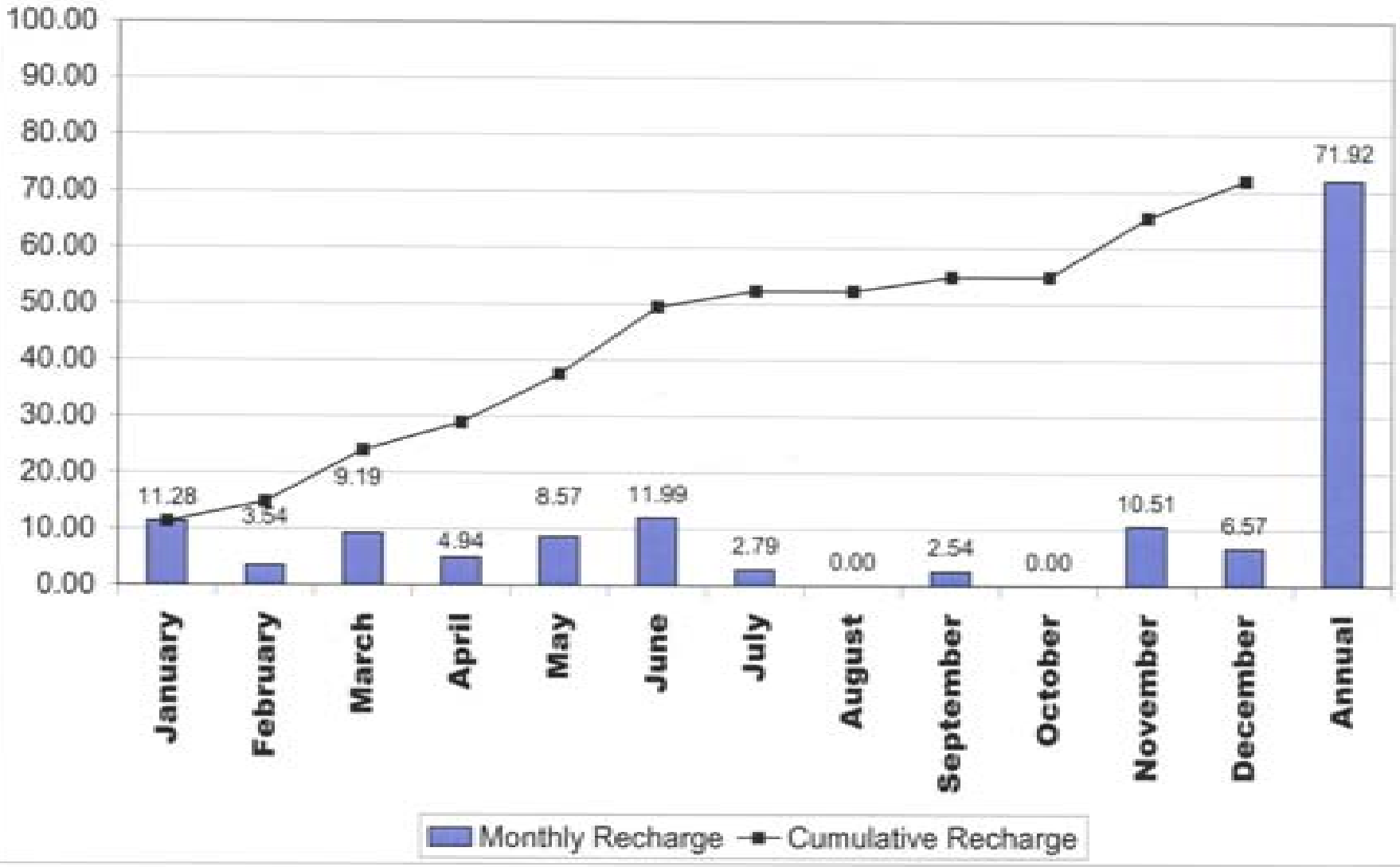


FIGURE 9
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
Total Project - 2007 Monthly and Cumulative Recharge

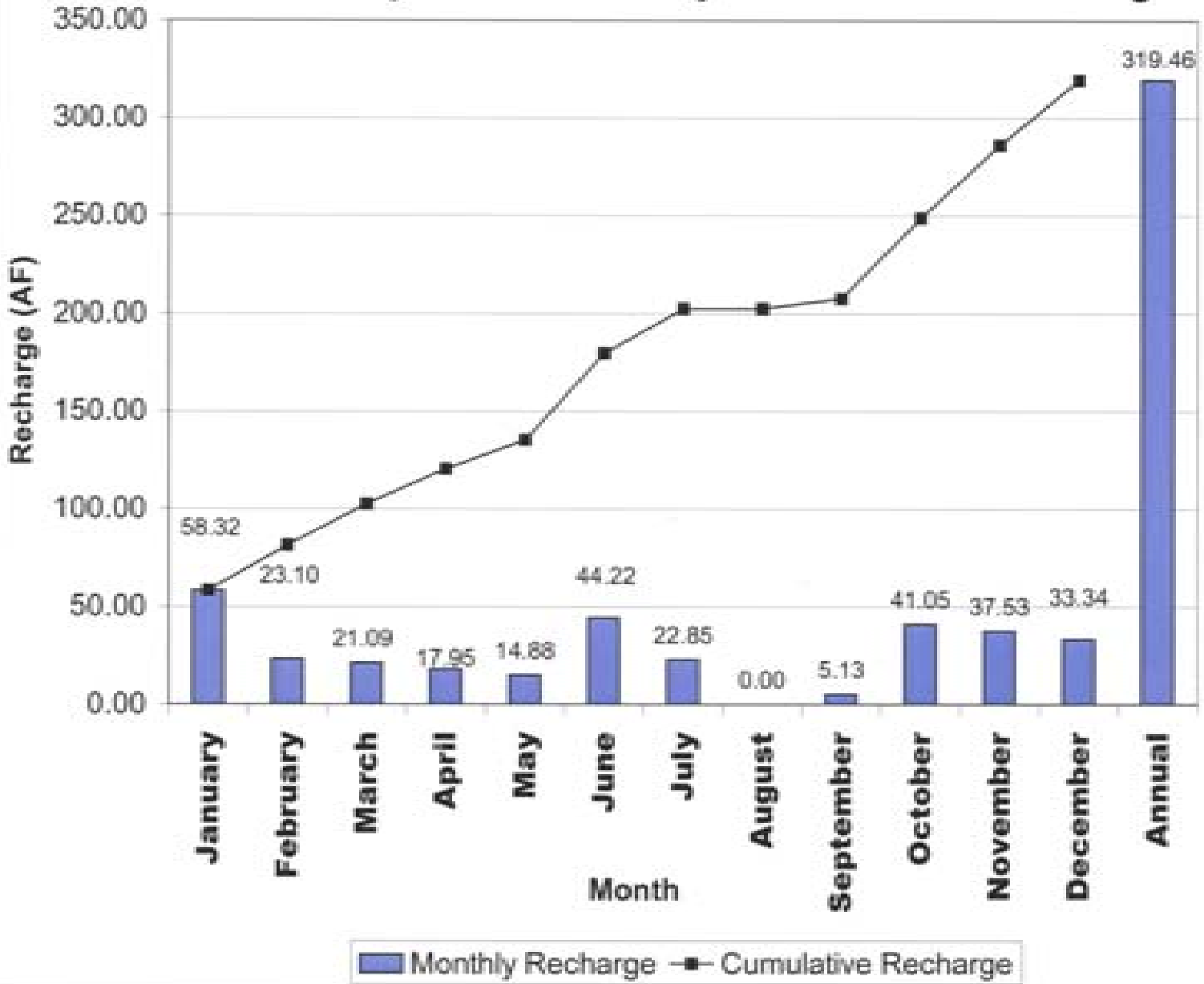
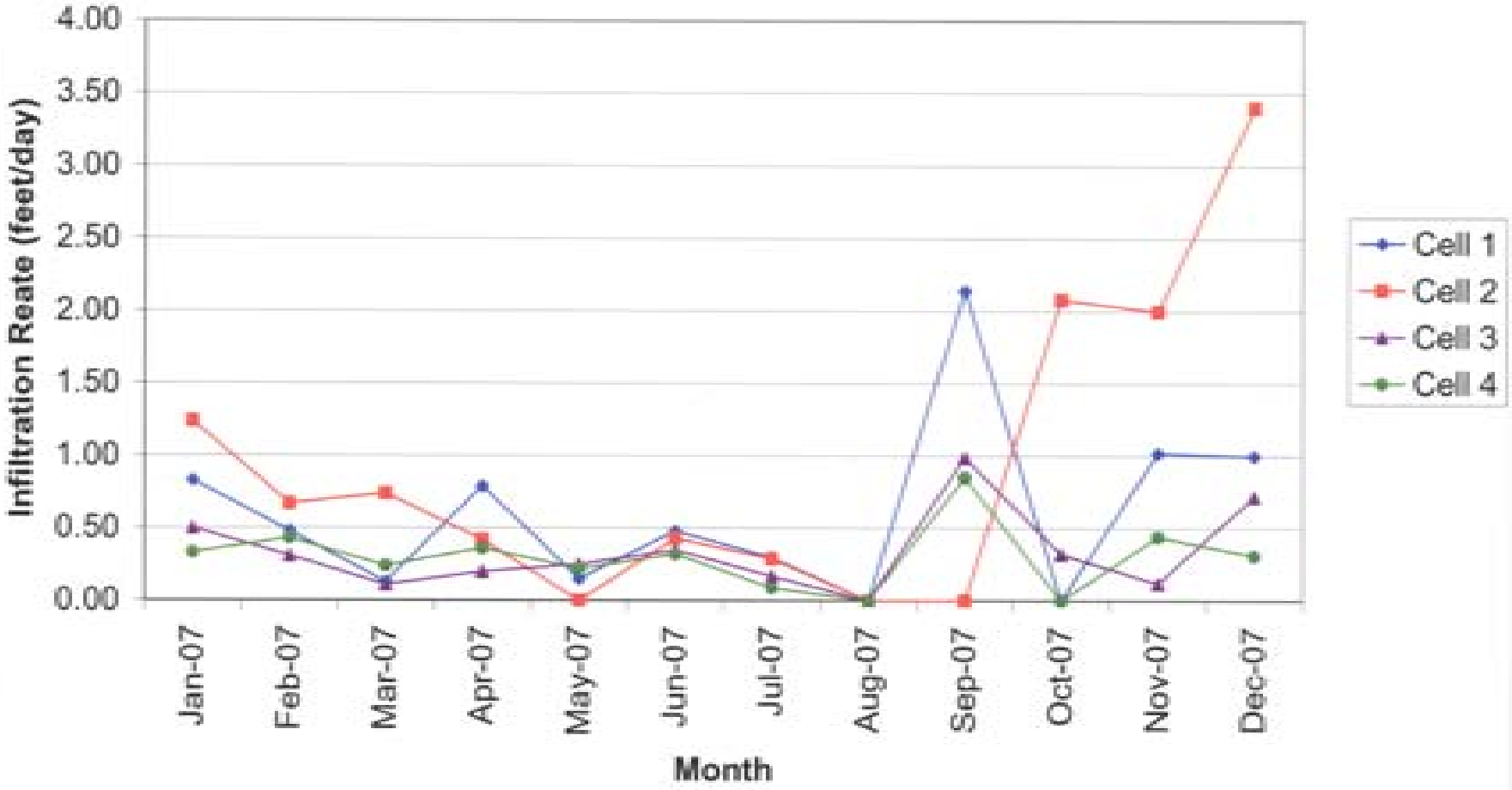


Figure 10
Marana High Plains Effluent Recharge Project
Average Monthly Infiltration Rates: CY 2007



TABLES

TABLE 1
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
ON-SITE AND OFF-SITE MONITOR WELL LEVELS
CALENDAR YEAR 2007

Offsite Wells

Monitoring Well ID:	SC-09		Monitoring Well ID:	SC-10		Monitoring Well ID:	AVMW-1	
Cadastral Location:	D(11-11) 34cbc		Cadastral Location:	D(11-11) 33bcb		Cadastral Location:	D(12-11) 3cbb	
Reference Point Elev.:	1991.41		Reference Point Elev.:	1977.89		Reference Point Elev.:	2014.7	
Date	Depth to water	Water Level Elevation	Date	Depth to water	Water Level Elevation	Date	Depth to water	Water Level Elevation
1/19/2007	193.00	1798.41	1/19/2007	186.22	1791.67	1/24/2007	193.90	1820.80
1/30/2007	194.43	1796.98	1/30/2007	187.63	1790.26	2/22/2007	181.10	1833.60
4/12/2007	195.41	1796.00	4/19/2007	190.58	1787.31	4/16/2007	179.50	1835.20
5/25/2007	194.21	1797.20	5/9/2007	188.94	1788.95	5/15/2007	179.80	1834.90
8/9/2007	193.28	1798.13	5/25/2007	188.88	1789.01	6/18/2007	180.30	1834.40
8/17/2007	193.67	1797.74	8/17/2007	187.25	1790.64	7/16/2007	177.90	1836.80
9/28/2007	191.17	1800.24	9/28/2007	185.08	1792.81	8/23/2007	174.80	1839.90
10/22/2007	190.17	1801.24	10/22/2007	183.58	1794.31	9/17/2007	173.60	1841.10
11/29/2007	188.42	1802.99	11/29/2007	181.67	1796.22	10/18/2007	173.60	1841.10
12/21/2007	187.17	1804.24	12/21/2007	180.38	1797.51	11/21/2007	182.70	1832.00
						12/19/2007	197.30	1817.40

Onsite Well

Monitoring Well ID:	HP-1	
Cadastral Location:	D(11-11) 33cac	
Reference Point Elev.:	1985.17	
Date	Depth to water	Water Level Elevation
1/11/2007	186.30	1798.87
2/26/2007	185.80	1799.37
3/14/2007	186.04	1799.13
4/9/2007	189.25	1795.92
5/9/2007	188.20	1796.97
6/12/2007	188.83	1796.34
7/10/2007	188.00	1797.17
8/17/2007	185.83	1799.34
9/28/2007	183.92	1801.25
10/16/2007	181.75	1803.42
11/20/2007	182.22	1802.95
12/20/2007	181.40	1803.77

Note: All depths to water are measured in feet; all water level elevations are measured in feet above sea level.

TABLE 2
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
ON-SITE PIEZOMETER WATER LEVELS
CALENDAR YEAR 2007

Date Measured	Depth to Water	Mound Height	Elevation* (feet)
1/11/2007	DRY @ 80'	None	N/A
2/26/2007	DRY @ 80'	None	N/A
3/14/2007	DRY @ 80'	None	N/A
4/9/2007	DRY @ 80'	None	N/A
5/9/2007	DRY @ 80'	None	N/A
6/12/2007	DRY @ 80'	None	N/A
7/10/2007	DRY @ 80'	None	N/A
8/17/2007	DRY @ 80'	None	N/A
9/28/2007	DRY @ 80'	None	N/A
10/16/2007	DRY @ 80'	None	N/A
11/20/2007	DRY @ 80'	None	N/A
12/20/2007	DRY @ 80'	None	N/A

* Reference elevation for well port is 1986.75 feet (above sea level).
N/A = Not applicable

TABLE 3
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
WATER QUALITY SUMMARY: CALENDAR YEAR 2007

Constituent	Unit	Sample Date and Location											
		Source Water											
		Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
Nutrients													
Total Nitrogen[1]	mg/l	31.0	35.0	26.0	27.0	36.0	27.0	27.0	No Event	No Event	27.3	6.5	34.0
Nitrate-Nitrite as N	mg/l	5.8	3.7	4.0	3.6	5.9	7.8	7.6	No Event	No Event	7.3	6.5	< 2.0
Total Kjeldahl Nitrogen (TKN)	mg/l	25.0	31.0	22.0	23.0	30.0	19.0	19.0	No Event	No Event	20.0	< 1.3	34.0
Metals (Total)													
Arsenic	mg/l	No Event	No Event	0.0047	No Event	No Event	0.0043	No Event	No Event	No Event	0.0041	No Event	No Event
Barium	mg/l	No Event	No Event	0.062	No Event	No Event	0.058	No Event	No Event	No Event	0.077	No Event	No Event
Cadmium	mg/l	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Chromium	mg/l	No Event	No Event	0.0011	No Event	No Event	0.001	No Event	No Event	No Event	0.0014	No Event	No Event
Lead	mg/l	No Event	No Event	0.0019	No Event	No Event	0.0023	No Event	No Event	No Event	0.0027	No Event	No Event
Antimony	mg/l	No Event	No Event	< 0.003	No Event	No Event	< 0.003	No Event	No Event	No Event	< 0.003	No Event	No Event
Beryllium	mg/l	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Nickel	mg/l	No Event	No Event	0.004	No Event	No Event	0.0034	No Event	No Event	No Event	0.0043	No Event	No Event
Mercury	mg/l	No Event	No Event	< 0.0002	No Event	No Event	< 0.0002	No Event	No Event	No Event	< 0.0002	No Event	No Event
Selenium	mg/l	No Event	No Event	< 0.002	No Event	No Event	< 0.002	No Event	No Event	No Event	< 0.002	No Event	No Event
Thallium	mg/l	No Event	No Event	No Event	No Event	No Event	< 0.001	No Event	No Event	No Event	No Event	No Event	No Event
Volatile Organic Compounds (VOCs)													
Benzene	mg/l	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Carbon tetrachloride	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
o-Dichlorobenzene	mg/l	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
para-Dichlorobenzene	mg/l	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
1,2-Dichloroethane	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,1-Dichloroethylene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
cis--1,2-Dichloroethylene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
trans-1,2-Dichloroethylene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,2-Dichloropropane	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Ethylbenzene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Monochlorobenzene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Styrene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Tetrachloroethylene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Toluene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,1,1-Trichloroethane	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,1,2-Trichloroethane	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Trichloroethylene	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Trihalomethanes (total THMs)	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Vinyl Chloride	ug/l	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Xylenes (Total)	ug/l	No Event	No Event	< 2.0	No Event	No Event	< 2.0	No Event	No Event	No Event	< 2.0	No Event	No Event

No Event = No sample was taken (No flow at Source Water or Monitor Well HP-1 pump is not operable)

[1] Total Nitrogen is equal to Nitrate-Nitrite-N plus TKN (Aquifer Protection Permit No. P-103195)

TABLE 3
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
WATER QUALITY SUMMARY: CALENDAR YEAR 2007

Constituent	Sample Date and Location											
	Monitor Well HP-1											
	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07
Nutrients												
Total Nitrogen[1]	2.8	4.0	2.4	3.6	5.0	6.0	6.0	No Event	No Event	3.8	3.5	3.6
Nitrate-Nitrite as N	2.8	2.1	2.4	3.6	3.6	6.0	3.7	No Event	No Event	3.8	3.5	3.6
Total Kjeldahl Nitrogen (TKN)	< 1.3	1.9	< 1.3	< 1.3	1.4	< 1.3	2.3	No Event	No Event	< 1.3	< 1.3	< 1.3
Metals (Total)												
Arsenic	No Event	No Event	0.0074	No Event	No Event	0.0022	No Event	No Event	No Event	0.0012	No Event	No Event
Barium	No Event	No Event	0.16	No Event	No Event	0.15	No Event	No Event	No Event	0.13	No Event	No Event
Cadmium	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Chromium	No Event	No Event	0.0011	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Lead	No Event	No Event	0.0055	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Antimony	No Event	No Event	< 0.003	No Event	No Event	< 0.003	No Event	No Event	No Event	< 0.003	No Event	No Event
Beryllium	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Nickel	No Event	No Event	0.0045	No Event	No Event	0.0031	No Event	No Event	No Event	0.0033	No Event	No Event
Mercury	No Event	No Event	< 0.0002	No Event	No Event	< 0.0002	No Event	No Event	No Event	< 0.0002	No Event	No Event
Selenium	No Event	No Event	< 0.002	No Event	No Event	< 0.002	No Event	No Event	No Event	< 0.002	No Event	No Event
Thallium	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Volatile Organic Compounds (VOCs)												
Benzene	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
Carbon tetrachloride	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
o-Dichlorobenzene	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
para-Dichlorobenzene	No Event	No Event	< 0.001	No Event	No Event	< 0.001	No Event	No Event	No Event	< 0.001	No Event	No Event
1,2-Dichloroethane	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,1-Dichloroethylene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
cis-1,2-Dichloroethylene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
trans-1,2-Dichloroethylene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,2-Dichloropropane	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Ethylbenzene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Monochlorobenzene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Styrene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Tetrachloroethylene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Toluene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,1,1-Trichloroethane	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
1,1,2-Trichloroethane	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Trichloroethylene	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Trihalomethanes (total THMs)	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Vinyl Chloride	No Event	No Event	< 1.0	No Event	No Event	< 1.0	No Event	No Event	No Event	< 1.0	No Event	No Event
Xylenes (Total)	No Event	No Event	< 2.0	No Event	No Event	< 2.0	No Event	No Event	No Event	< 2.0	No Event	No Event

No Event = No sample was taken (No flow at S

[1] Total Nitrogen is equal to Nitrate-Nitrite-N pl.

TABLE 4
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
FACILITY INSPECTIONS: PROBLEMS AND RELATED SOLUTIONS
CALENDAR YEAR 2007

Date	Problem	Solution
January 2007	Well HP-1 pump rate is down from 10 gallons per minute to 4 gallons per minute	Well pump was inspected and the wiring rearranged to bring pump rate back up to 8 gallons per minute, which is still low. Gilbert Pump (contractor) replaced ball valve for pump, which is now running at 25 gallons per minute (March 6, 2007)
January 2007	Motorized valve control switch will only open and close the valve; valve will not automatically open and close with the level sensor based on water levels in the basin.	Valve was opened and closed by the daily operator based on water levels in the basin through the month of January. The valve control switch was repaired in February 2007.
February 2007	Pump #2 will not run in "auto" mode; Pump #1 turns off at high water level in Equalization Basin, but neither pump will turn back on at the low level.	Electrician found a loose jumper connection in the wiring, so pumps will now run in "auto" mode (February 21, 2007)
February 2007	Flow meters were pushed out of the pipes in Recharge Cells 2, 3 and 4.	Flow meters were set back into the pipes and bonded to the pipes with silicon cement.
February 2007	Water level sensors in Recharge Cells 2 and 3 will not close the valve at the high water levels.	Valves were opened and closed by the Daily operator through the month of April. The water level sensors were replaced in May 2007; wiring for the sensor in Recharge Cell 3 was reconfigured to allow for proper operation.
March 2007	Recharge cells are getting very weedy	Recharge cell maintenance was performed by Pima County Operations Division in April 2007.
May 2007	Pumps will not operate together in "auto" mode	Relay switch for pumps was replaced in May 2007 to allow for automatic operation of the pumps.
June 2007	Valve controls in Recharge Cell 3 are not functioning; level sensor did not close the valve at the high level, so there was overflow into Recharge Cell 2 on June 1.	Valve controls were repaired on June 27; the valve was opened and closed by the daily operator prior to the repair work.
June 2007	Electrical panels and maintenance road are being inundated with tumbleweeds and quail bush.	Youth crews utilized to clear weeds to allow for better access along the roadway and to the electrical panels.
July 2007	Diversion berm washed out by storm water on July 25, 2007	Diversion berm repaired the week of August 27
July 2007	Flow meter at Influent Lift Station (FMeq) is not operating properly (velocity meter is stuck at 1.5 feet per second)	A new flow meter (Magnetflow® Mag Meter) was installed in October 2007; flows in September and early October were

TABLE 4
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
FACILITY INSPECTIONS: PROBLEMS AND RELATED SOLUTIONS
CALENDAR YEAR 2007

Date	Problem	Solution
		estimated using pump capacity (420 gallons per minute) and the pump running time (read on the attached meter)[1]
August 2007	Well HP-1 pump is not pumping	Pump repaired and new well pipes installed on October 1, 2007
August 2007	Recharge cells are very weedy	Recharge cells were cleaned of vegetation and ripped with tiller on the week of September 17, 2007.
December 2007	Valve controls in Recharge Cell 3 are not functioning; level sensor did not close the valve at the high level, so there was overflow into Recharge Cell 2 on December 1.	The valve for Recharge Cell 3 has been closed for December 2007. The valve can be opened and closed manually if needed. Staff will look into making repairs to the valve sensor in Calendar Year 2008.
December 2007	Pump #2 will not run in "auto" mode; Pump #1 turns off at high water level in Equalization Basin, but neither pump will turn back on at the low level.	The pumps are being operated manually

[1] The pump capacity was confirmed by the new flow meter after its installation. Pumps are pumping at a rate of approximately 420 gallons per minute when run separately.

APPENDIX A

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
JANUARY 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	3.09	0.54	0.56	0.36	1.09	2.55	0.01	0.01	2.53
2	3.09	0.61	0.75	0.23	0.48	2.07	0.01	0.01	2.05
3	3.09	0.62	1.76	0.00	0.01	2.39	0.02	0.00	2.37
4	3.09	0.85	0.17	0.13	0.00	1.15	0.02	0.00	1.13
5	3.09	0.50	1.08	0.51	1.41	3.50	0.02	0.00	3.48
6	2.29	0.45	1.12	0.38	0.27	2.22	0.02	0.01	2.19
7	1.86	0.43	1.00	0.37	0.00	1.80	0.02	0.01	1.77
8	2.60	0.45	0.91	0.21	0.76	2.33	0.02	0.01	2.30
9	3.09	0.62	1.35	0.00	0.82	2.79	0.02	0.02	2.75
10	3.09	0.55	1.13	0.85	0.32	2.85	0.02	0.02	2.81
11	3.09	0.76	1.61	0.65	0.00	3.02	0.02	0.01	2.98
12	2.51	0.60	1.11	0.39	1.01	3.11	0.02	0.01	3.07
13	1.86	0.44	0.94	0.00	0.47	1.85	0.02	0.01	1.82
14	1.86	0.42	0.92	0.00	0.49	1.83	0.02	0.01	1.81
15	1.86	0.42	0.93	0.00	0.49	1.84	0.01	0.01	1.81
16	2.67	0.46	0.94	0.78	0.26	2.44	0.02	0.01	2.41
17	3.09	0.66	1.72	0.71	0.00	3.09	0.02	0.01	3.06
18	3.09	0.55	0.72	0.37	1.08	2.72	0.02	0.01	2.69
19	1.62	0.48	0.57	0.00	0.00	1.05	0.02	0.00	1.03
20	0.00	0.21	0.00	0.00	0.28	0.49	0.02	0.01	0.46
21	1.31	0.49	0.00	0.00	0.53	1.02	0.01	0.00	1.01
22	2.63	0.38	0.59	0.84	0.27	2.08	0.01	0.00	2.07
23	3.09	0.00	2.14	0.78	0.00	2.92	0.02	0.01	2.89
24	2.26	0.00	0.62	0.35	0.00	0.97	0.02	0.00	0.95
25	1.86	0.00	0.01	0.00	0.00	0.01	0.02	0.00	-0.01
26	1.86	0.43	0.00	0.00	0.52	0.95	0.01	0.01	0.93
27	0.00	0.34	0.00	0.00	0.25	0.59	0.01	0.01	0.57
28	0.00	0.03	0.00	0.00	0.02	0.05	0.01	0.01	0.03
29	2.03	0.29	0.11	0.69	0.43	1.52	0.01	0.01	1.50
30	3.09	0.31	1.67	0.59	0.26	2.83	0.02	0.00	2.81
31	2.29	0.00	0.70	0.35	0.00	1.05	0.02	0.00	1.03
Total	70.48	12.89	25.13	9.54	11.52	59.08	0.53	0.24	58.32

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET data (Marana Station)

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
FEBRUARY 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	1.86	0.00	0.03	0.03	0.00	0.06	0.0198	0.0000	0.04
2	0.73	0.57	0.03	0.18	0.75	1.53	0.0249	0.0102	1.49
3	1.31	0.36	0.00	0.00	0.18	0.54	0.0128	0.0133	0.51
4	0.58	0.27	0.00	0.00	0.05	0.32	0.0065	0.0116	0.30
5	0.00	0.00	0.65	0.31	0.00	0.96	0.0254	0.0127	0.92
6	0.00	0.00	0.61	0.77	0.00	1.38	0.0270	0.0000	1.35
7	0.00	0.00	0.02	0.27	0.00	0.29	0.0227	0.0000	0.27
8	0.00	0.00	0.00	0.02	0.00	0.02	0.0081	0.0000	0.01
9	0.00	0.00	0.00	0.00	0.00	0.00	0.0077	0.0000	-0.01
10	0.00	0.00	0.00	0.00	0.00	0.00	0.0042	0.0000	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.00
13	1.13	0.83	0.00	0.00	0.00	0.83	0.0034	0.0000	0.83
14	1.86	0.49	0.70	0.67	0.00	1.86	0.0138	0.0000	1.85
15	1.86	0.34	1.42	0.31	0.00	2.07	0.0251	0.0000	2.04
16	1.86	0.33	1.04	0.54	0.00	1.91	0.0270	0.0000	1.88
17	0.49	0.23	0.55	0.25	0.00	1.03	0.0274	0.0000	1.00
18	0.00	0.10	0.09	0.06	0.00	0.25	0.0268	0.0000	0.22
19	1.23	0.38	0.49	0.36	0.00	1.23	0.0252	0.0000	1.20
20	1.86	0.34	0.97	0.47	0.00	1.78	0.0266	0.0000	1.75
21	1.69	0.21	1.47	0.21	0.00	1.89	0.0276	0.0000	1.86
22	1.47	0.18	0.66	0.00	0.00	0.84	0.0276	0.0000	0.81
23	0.40	0.15	0.00	0.00	0.00	0.15	0.0273	0.0000	0.12
24	0.00	0.13	0.00	0.00	0.00	0.13	0.0271	0.0000	0.10
25	0.40	0.12	0.00	0.00	0.00	0.12	0.0226	0.0000	0.10
26	1.86	0.27	0.00	0.48	1.72	2.47	0.0252	0.0193	2.43
27	1.86	0.23	0.00	0.00	0.35	0.58	0.0155	0.0246	0.54
28	1.86	0.13	0.00	0.77	0.60	1.50	0.0149	0.0215	1.46
Total	24.28	5.66	8.73	5.70	3.65	23.74	0.5222	0.1132	23.10

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET data (Marana Station)

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
MARCH 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	0.89	0.12	0.00	0.00	0.61	0.73	0.0215	0.0185	0.69
2	0.49	0.09	0.00	0.00	0.00	0.09	0.0212	0.0205	0.05
3	0.98	0.10	0.00	0.00	0.67	0.77	0.0206	0.0267	0.72
4	0.00	0.10	0.00	0.00	0.00	0.10	0.0186	0.0226	0.06
5	0.80	0.11	0.00	0.00	0.59	0.70	0.0186	0.0236	0.66
6	1.11	0.08	0.00	0.63	0.06	0.77	0.0212	0.0244	0.72
7	0.93	0.09	0.00	0.00	0.58	0.67	0.0215	0.0256	0.62
8	0.64	0.09	0.00	0.00	0.70	0.79	0.0212	0.0246	0.74
9	0.28	0.11	0.00	0.00	0.21	0.32	0.0206	0.0246	0.27
10	0.93	0.10	0.00	0.00	0.67	0.77	0.0206	0.0256	0.72
11	0.00	0.08	0.00	0.00	0.16	0.24	0.0186	0.0277	0.19
12	1.51	0.10	0.00	0.72	0.63	1.45	0.0212	0.0267	1.40
13	0.40	0.08	0.89	0.00	0.04	1.01	0.0309	0.0285	0.95
14	1.01	0.10	0.00	0.00	0.60	0.70	0.0258	0.0287	0.65
15	1.07	0.09	0.00	0.00	0.35	0.44	0.0203	0.0315	0.39
16	0.40	0.08	0.00	0.00	0.00	0.08	0.0200	0.0297	0.03
17	1.13	0.07	0.00	0.00	0.83	0.90	0.0178	0.0308	0.85
18	0.00	0.00	0.00	0.00	0.00	0.00	0.0148	0.0318	-0.05
19	1.86	0.11	1.46	0.47	0.02	2.06	0.0275	0.0305	2.00
20	1.86	0.03	0.60	0.23	0.96	1.82	0.0329	0.0277	1.76
21	1.86	0.00	0.27	0.12	0.24	0.63	0.0290	0.0179	0.58
22	1.86	0.00	2.39	0.03	0.00	2.42	0.0296	0.0128	2.38
23	1.13	0.00	0.64	0.00	0.00	0.64	0.0301	0.0097	0.60
24	0.89	0.00	0.00	0.00	0.63	0.63	0.0296	0.0203	0.58
25	0.00	0.00	0.00	0.00	0.00	0.00	0.0289	0.0213	-0.05
26	0.98	0.00	0.00	0.00	0.76	0.76	0.0264	0.0216	0.71
27	0.00	0.00	0.00	0.00	0.00	0.00	0.0217	0.0368	-0.06
28	0.00	0.00	0.00	0.00	0.00	0.00	0.0049	0.0224	-0.03
29	1.86	0.00	1.03	0.44	0.65	2.12	0.0135	0.0236	2.08
30	1.86	0.00	0.84	0.11	0.00	0.95	0.0290	0.0236	0.90
31	0.28	0.00	0.00	0.00	0.00	0.00	0.0280	0.0275	-0.06
Total	26.99	1.73	8.12	2.75	9.96	22.56	0.7064	0.7672	21.09

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET data (Marana Station)

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
APRIL 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	1.30	0.00	1.18	0.00	0.00	1.18	0.03	0.00	1.15
2	1.24	0.00	0.98	0.00	0.00	0.98	0.03	0.00	0.95
3	0.93	0.00	0.57	0.00	0.00	0.57	0.03	0.00	0.54
4	0.00	0.00	0.21	0.00	0.00	0.21	0.03	0.00	0.18
5	0.73	0.00	0.36	0.00	0.00	0.36	0.02	0.00	0.34
6	0.77	0.00	0.98	0.00	0.00	0.98	0.03	0.00	0.95
7	0.00	0.00	0.26	0.00	0.00	0.26	0.03	0.00	0.23
8	0.00	0.00	0.11	0.00	0.00	0.11	0.02	0.00	0.09
9	0.00	0.00	0.05	0.00	0.00	0.05	0.02	0.00	0.03
10	0.85	0.00	0.58	0.00	0.00	0.58	0.02	0.00	0.56
11	1.45	0.00	1.18	0.00	0.00	1.18	0.03	0.00	1.15
12	1.18	0.00	0.75	0.00	0.00	0.75	0.03	0.00	0.72
13	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	-0.02
14	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	-0.01
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1.86	0.41	0.00	0.00	1.37	1.79	0.01	0.03	1.74
21	1.39	0.33	0.00	0.00	0.64	0.97	0.01	0.02	0.93
22	0.62	0.11	0.00	0.00	0.04	0.14	0.01	0.03	0.10
23	1.08	0.13	0.00	0.00	1.07	1.20	0.01	0.03	1.16
24	0.00	0.09	0.00	0.00	0.05	0.14	0.01	0.03	0.10
25	0.93	0.10	0.00	0.19	0.20	0.49	0.02	0.03	0.44
26	1.24	0.11	0.00	0.26	1.14	1.52	0.03	0.03	1.45
27	0.62	0.62	0.00	0.26	0.01	0.89	0.03	0.04	0.82
28	1.86	1.72	0.00	0.03	0.50	2.25	0.03	0.02	2.19
29	0.62	1.47	0.00	0.02	0.06	1.56	0.03	0.03	1.49
30	0.00	0.50	0.00	0.01	0.19	0.71	0.02	0.03	0.65
Total	19.14	5.60	7.21	0.77	5.28	18.86	0.58	0.33	17.95

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET data (Marana Station)

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
MAY 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	0.00	0.00	0.00	0.03	0.91	0.94	0.03	0.03	0.87
2	0.00	0.00	0.00	0.02	0.01	0.02	0.02	0.03	-0.03
3	0.31	0.00	0.00	0.00	0.02	0.02	0.02	0.04	-0.04
4	1.08	0.00	0.00	0.00	0.84	0.84	0.02	0.04	0.79
5	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.04	-0.03
6	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.03	-0.03
7	1.51	0.18	0.00	0.00	0.74	0.92	0.02	0.03	0.87
8	1.66	0.06	0.00	0.00	0.01	0.08	0.02	0.03	0.03
9	1.86	0.08	0.00	0.00	0.04	0.11	0.02	0.04	0.06
10	0.48	0.10	0.00	0.00	0.80	0.90	0.02	0.04	0.84
11	1.25	0.13	0.00	0.00	0.02	0.14	0.02	0.04	0.09
12	0.53	0.09	0.00	0.00	0.04	0.13	0.02	0.04	0.07
13	0.00	0.10	0.00	0.00	0.98	1.07	0.02	0.04	1.02
14	1.28	0.27	0.00	0.38	0.05	0.70	0.03	0.04	0.62
15	0.93	0.11	0.00	0.07	0.06	0.24	0.03	0.04	0.17
16	0.46	0.09	0.00	0.06	0.08	0.22	0.03	0.03	0.16
17	0.64	0.11	0.00	0.06	0.73	0.90	0.03	0.04	0.83
18	0.52	0.08	0.00	0.07	0.02	0.17	0.03	0.04	0.10
19	0.00	0.10	0.00	0.07	0.10	0.27	0.04	0.04	0.20
20	0.00	0.22	0.00	0.19	0.85	1.25	0.03	0.04	1.18
21	1.16	0.31	0.00	0.24	0.49	1.04	0.04	0.04	0.97
22	1.86	0.21	0.00	1.06	0.43	1.71	0.04	0.04	1.63
23	0.00	0.14	0.00	0.01	0.08	0.23	0.04	0.03	0.15
24	1.24	0.13	0.00	0.01	0.09	0.22	0.04	0.04	0.14
25	0.46	0.11	0.00	0.02	1.03	1.15	0.04	0.04	1.07
26	0.00	0.08	0.00	0.07	0.00	0.16	0.04	0.04	0.08
27	0.00	0.09	0.00	0.05	0.01	0.15	0.04	0.04	0.07
28	0.00	0.10	0.00	0.14	0.07	0.32	0.04	0.04	0.24
29	1.24	0.15	0.00	0.09	0.22	0.46	0.03	0.04	0.38
30	0.46	0.14	0.00	0.09	0.76	0.99	0.04	0.04	0.91
31	1.52	0.20	0.00	1.14	0.22	1.56	0.04	0.04	1.48
Total	20.46	3.37	0.00	3.86	9.72	16.95	0.91	1.15	14.88

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970)

4 Calculated for Recharge Cell 4 using AZMET data (Marana Station)

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
JUNE 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated EV Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	1.86	0.21	0.00	2.00	0.26	2.47	0.05	0.04	2.38
2	1.86	0.21	0.16	1.41	0.93	2.71	0.07	0.02	2.62
3	1.86	0.21	0.32	0.86	0.29	1.68	0.07	0.04	1.57
4	1.86	0.24	1.81	0.00	0.36	2.41	0.08	0.04	2.29
5	1.86	0.34	0.55	0.00	0.95	1.83	0.08	0.05	1.71
6	1.62	0.37	0.99	0.00	0.26	1.62	0.08	0.05	1.50
7	0.98	0.27	0.04	0.00	0.34	0.65	0.08	0.04	0.54
8	1.86	0.24	1.24	0.02	0.29	1.78	0.08	0.04	1.66
9	1.31	0.26	0.04	0.22	1.20	1.72	0.08	0.04	1.60
10	1.86	0.30	1.22	0.24	0.18	1.94	0.08	0.04	1.82
11	0.98	0.20	0.08	0.18	0.21	0.67	0.08	0.03	0.57
12	1.31	0.28	1.00	0.16	0.36	1.80	0.08	0.04	1.69
13	1.24	0.32	0.15	0.21	0.36	1.03	0.08	0.04	0.92
14	1.31	0.34	1.12	0.17	0.86	2.50	0.08	0.04	2.38
15	1.08	0.36	0.10	0.17	0.30	0.93	0.08	0.04	0.81
16	1.86	0.40	0.65	0.16	0.36	1.57	0.08	0.04	1.46
17	1.86	0.40	0.67	0.15	0.33	1.55	0.08	0.04	1.43
18	1.86	0.35	0.22	0.15	1.15	1.88	0.08	0.05	1.75
19	1.86	0.36	1.14	0.14	0.30	1.94	0.08	0.04	1.82
20	1.08	0.38	0.17	0.19	0.35	1.10	0.08	0.04	0.98
21	0.98	0.37	0.45	0.21	0.28	1.31	0.08	0.04	1.19
22	1.86	0.42	0.95	0.18	0.20	1.74	0.08	0.04	1.62
23	1.86	0.42	0.20	0.17	0.96	1.75	0.08	0.04	1.63
24	0.98	0.40	0.51	0.20	0.24	1.36	0.08	0.04	1.24
25	1.86	0.41	0.90	0.22	0.23	1.76	0.08	0.04	1.64
26	1.08	0.31	0.14	0.21	0.29	0.94	0.08	0.04	0.83
27	0.98	0.31	0.29	0.26	0.22	1.09	0.07	0.04	0.98
28	1.86	0.31	1.00	0.18	0.90	2.40	0.07	0.04	2.28
29	1.86	0.29	0.10	0.17	0.12	0.69	0.08	0.04	0.57
30	1.86	0.35	0.21	0.17	0.10	0.84	0.08	0.04	0.72
Total	46.50	9.64	16.43	8.42	13.17	47.66	2.26	1.18	44.22

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970)

4 Calculated for Recharge Cell 4 using AZMET (Marana Station) data

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
JULY 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	1.86	0.38	1.15	0.15	0.17	1.85	0.07	0.04	1.74
2	1.86	0.33	0.43	0.17	1.01	1.93	0.07	0.04	1.82
3	1.86	0.40	0.42	0.17	0.03	1.02	0.07	0.04	0.92
4	1.08	0.39	0.34	0.17	0.00	0.91	0.06	0.04	0.80
5	0.77	0.41	0.39	0.15	0.15	1.10	0.06	0.04	0.99
6	1.86	0.41	1.05	0.14	0.24	1.84	0.07	0.03	1.74
7	1.86	0.35	0.32	0.17	1.03	1.86	0.07	0.04	1.75
8	0.77	0.29	0.34	0.14	0.03	0.79	0.07	0.04	0.69
9	1.86	0.29	0.99	0.14	0.00	1.41	0.07	0.04	1.31
10	1.08	0.11	0.17	0.12	0.06	0.46	0.07	0.03	0.36
11	0.62	0.16	0.00	0.14	0.18	0.49	0.07	0.04	0.38
12	0.00	0.28	0.00	0.13	0.17	0.58	0.07	0.04	0.48
13	0.77	0.29	0.15	0.17	0.14	0.75	0.07	0.03	0.64
14	1.08	0.27	0.49	0.22	0.09	1.07	0.07	0.03	0.97
15	1.86	0.25	1.00	0.20	0.00	1.45	0.07	0.00	1.38
16	0.54	0.21	0.32	0.21	0.00	0.75	0.07	0.00	0.67
17	0.62	0.20	0.18	0.20	0.00	0.57	0.07	0.00	0.50
18	1.86	0.25	1.02	0.25	0.00	1.53	0.07	0.00	1.46
19	1.86	0.25	0.39	0.21	0.00	0.85	0.07	0.00	0.78
20	1.39	0.24	0.53	0.21	0.00	0.99	0.07	0.00	0.91
21	1.08	0.22	0.85	0.17	0.00	1.25	0.07	0.00	1.18
22	0.77	0.16	0.32	0.17	0.00	0.64	0.07	0.00	0.57
23	0.54	0.16	0.46	0.21	0.00	0.83	0.07	0.00	0.76
24	0.00	0.12	0.18	0.15	0.00	0.45	0.07	0.00	0.38
25	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	-0.07
26	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	-0.07
27	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	-0.06
28	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	-0.04
29	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	-0.04
30	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	-0.03
31	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	-0.02
Total	27.84	6.43	11.48	4.15	3.31	25.36	1.99	0.52	22.85

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970)

4 Calculated for Recharge Cell 4 using AZMET data (Marana Station)

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
AUGUST 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET (Marana Station) data

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
SEPTEMBER 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow (AF)	Calculated Evaporation Volume (AF)	Calculated ET Volume (AF)	Net Recharge (AF)
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	1.33	0.09	0.00	0.17	0.11	0.37	0.00	0.00	0.37
8	1.86	0.31	0.00	0.46	0.48	1.26	0.01	0.01	1.23
9	1.86	0.63	0.00	0.10	0.83	1.57	0.02	0.02	1.53
10	1.86	0.55	0.00	0.07	0.96	1.58	0.03	0.03	1.53
11	0.61	0.16	0.00	0.12	0.25	0.53	0.02	0.03	0.49
12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-0.01
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	7.50	1.74	0.00	0.93	2.64	5.31	0.08	0.09	5.14

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET (Marana Station) data

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
OCTOBER 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated EV Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	1.86	0.00	0.95	0.00	0.00	0.95	0.00	0.00	0.94
2	1.86	0.00	1.31	0.00	0.00	1.31	0.00	0.00	1.31
3	1.86	0.00	1.29	0.00	0.00	1.29	0.00	0.00	1.29
4	1.86	0.00	1.25	0.00	0.00	1.25	0.00	0.00	1.24
5	1.86	0.00	1.28	0.00	0.00	1.28	0.00	0.00	1.27
6	1.86	0.00	1.88	0.00	0.00	1.88	0.01	0.00	1.87
7	0.62	0.00	0.94	0.00	0.00	0.94	0.00	0.00	0.93
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.77	0.00	0.41	0.00	0.00	0.41	0.00	0.00	0.40
13	1.86	0.00	1.57	0.00	0.00	1.57	0.01	0.00	1.56
14	1.86	0.00	2.26	0.00	0.00	2.26	0.02	0.00	2.24
15	1.86	0.00	1.99	0.00	0.00	1.99	0.02	0.00	1.97
16	1.86	0.00	1.89	0.00	0.00	1.89	0.02	0.00	1.87
17	1.79	0.00	0.98	0.00	0.00	0.98	0.02	0.00	0.96
18	1.79	0.00	1.46	0.08	0.00	1.54	0.02	0.00	1.52
19	1.79	0.00	1.91	0.37	0.00	2.28	0.03	0.00	2.25
20	1.79	0.00	2.03	0.41	0.00	2.43	0.03	0.00	2.40
21	1.79	0.00	1.67	0.46	0.00	2.12	0.03	0.00	2.09
22	1.82	0.00	1.74	0.28	0.00	2.02	0.03	0.00	1.99
23	1.85	0.00	1.87	0.01	0.00	1.88	0.02	0.00	1.85
24	1.85	0.00	1.14	0.00	0.00	1.14	0.02	0.00	1.12
25	1.85	0.00	1.51	0.46	0.00	1.97	0.03	0.00	1.94
26	1.85	0.00	1.37	0.16	0.00	1.53	0.03	0.00	1.50
27	1.85	0.00	1.37	0.10	0.00	1.47	0.03	0.00	1.44
28	1.85	0.00	1.35	0.09	0.00	1.44	0.03	0.00	1.41
29	1.85	0.00	1.24	0.08	0.00	1.33	0.03	0.00	1.30
30	1.85	0.00	1.24	0.09	0.00	1.33	0.03	0.00	1.30
31	1.86	0.00	1.07	0.05	0.00	1.12	0.03	0.00	1.09
Total	47.36	0.00	38.92	2.64	0.00	41.56	0.51	0.00	41.05

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET data from the Tucson Station, modified for the Marana area.

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
NOVEMBER 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated EV Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	1.78	0.00	1.08	0.10	0.00	1.17	0.02	0.00	1.15
2	1.87	1.06	1.08	0.12	0.75	3.01	0.02	0.00	2.98
3	1.94	0.55	0.46	0.13	0.69	1.82	0.01	0.02	1.79
4	1.94	0.70	0.52	0.17	0.65	2.05	0.01	0.02	2.01
5	1.89	0.95	0.81	0.15	0.23	2.14	0.02	0.02	2.10
6	1.95	0.94	0.93	0.19	0.00	2.06	0.02	0.00	2.04
7	1.96	0.74	1.59	0.19	0.00	2.52	0.02	0.00	2.50
8	1.92	0.73	1.42	0.20	0.00	2.36	0.03	0.00	2.33
9	1.90	0.52	0.61	0.17	0.39	1.70	0.03	0.00	1.67
10	1.91	0.61	0.00	0.17	0.95	1.73	0.01	0.01	1.70
11	1.91	0.59	0.00	0.17	0.43	1.18	0.01	0.02	1.15
12	1.91	0.45	0.00	0.09	0.65	1.19	0.01	0.01	1.17
13	1.38	0.44	0.00	0.07	0.00	0.52	0.01	0.02	0.49
14	1.81	0.45	0.00	0.08	0.79	1.33	0.01	0.02	1.29
15	1.37	0.44	0.00	0.08	0.01	0.52	0.01	0.02	0.49
16	0.00	0.44	0.00	0.08	0.73	1.25	0.01	0.02	1.22
17	1.86	0.45	0.00	0.10	0.02	0.57	0.01	0.02	0.54
18	1.86	0.45	0.00	0.10	0.68	1.24	0.01	0.02	1.21
19	0.15	0.44	0.00	0.06	0.03	0.54	0.01	0.02	0.50
20	1.78	0.46	0.00	0.07	0.64	1.18	0.01	0.02	1.14
21	0.32	0.44	0.00	0.06	0.01	0.51	0.01	0.02	0.48
22	0.00	0.47	0.00	0.03	0.56	1.06	0.01	0.02	1.03
23	0.68	0.49	0.00	0.12	0.01	0.61	0.01	0.01	0.59
24	1.83	0.46	0.00	0.08	0.53	1.06	0.01	0.01	1.04
25	1.83	0.45	0.00	0.00	0.00	0.45	0.01	0.01	0.43
26	1.82	0.45	0.00	0.00	0.55	1.00	0.01	0.01	0.98
27	0.91	0.48	0.00	0.00	0.00	0.48	0.01	0.01	0.46
28	1.70	0.47	0.00	0.00	0.78	1.25	0.01	0.01	1.22
29	0.79	0.47	0.00	0.07	0.78	1.31	0.02	0.01	1.29
30	0.15	0.50	0.00	0.06	0.00	0.56	0.02	0.00	0.54
Total	43.13	16.10	8.51	2.91	10.86	38.38	0.50	0.35	37.53

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET (Marana Station) data

APPENDIX A
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
MONTHLY ACCOUNTING REPORT
DECEMBER 2007

1	2	3	4	5	6	7	8	9	10
Day	Project Inflow[1] (AF)	Cell 1 Inflow (AF)	Cell 2 Inflow (AF)	Cell 3 Inflow (AF)	Cell 4 Inflow (AF)	Total Recharge Inflow[2] (AF)	Calculated Evaporation Volume[3] (AF)	Calculated ET Volume[4] (AF)	Net Recharge (AF)
1	3.07	0.09	0.00	2.19	0.20	2.47	0.01	0.01	2.46
2	2.97	0.67	0.00	2.15	0.42	3.23	0.01	0.01	3.21
3	1.47	0.00	0.00	0.86	0.00	0.87	0.01	0.01	0.84
4	1.59	0.50	0.00	0.77	0.82	2.10	0.01	0.01	2.08
5	0.30	0.16	0.00	0.04	0.10	0.30	0.01	0.01	0.28
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	1.45	0.08	0.00	0.15	0.08	0.31	0.00	0.00	0.31
18	2.12	0.52	0.00	0.56	0.35	1.44	0.01	0.00	1.43
19	2.31	0.95	0.00	0.31	0.70	1.96	0.01	0.01	1.95
20	1.85	1.03	0.00	0.35	0.59	1.96	0.01	0.01	1.94
21	1.90	1.01	0.95	0.35	0.59	2.90	0.01	0.01	2.89
22	1.93	0.60	1.20	0.24	0.27	2.30	0.01	0.01	2.28
23	1.93	0.48	1.08	0.00	0.26	1.82	0.01	0.01	1.80
24	1.93	0.42	0.83	0.00	0.32	1.57	0.01	0.01	1.55
25	1.93	0.31	0.50	0.00	0.22	1.04	0.01	0.01	1.02
26	1.69	0.58	0.77	0.00	0.24	1.59	0.01	0.01	1.57
27	1.42	0.32	0.91	0.00	0.37	1.60	0.01	0.01	1.58
28	1.34	0.27	1.01	0.00	0.35	1.62	0.01	0.01	1.61
29	1.34	0.72	0.72	0.00	0.29	1.74	0.01	0.01	1.72
30	1.34	0.65	0.58	0.00	0.25	1.48	0.01	0.01	1.47
31	1.31	0.48	0.60	0.00	0.29	1.38	0.01	0.01	1.36
Total	35.22	9.84	9.15	7.96	6.73	33.68	0.18	0.16	33.34

1 Total inflow into the equalization basin

2 Total inflow into the recharge cells (1-4)

3 Calculated for the equalization basin and Recharge Cells 1-3 using the Cooley Method with "Maximum Curve" (1970).

4 Calculated for Recharge Cell 4 using AZMET (Marana Station) data

APPENDIX B

ARIZONA DEPARTMENT OF WATER RESOURCES
HYDROLOGY DIVISION

TECHNICAL BULLETIN

Justification for using the Cooley Method Maximum Curve as the standard method for calculating evaporation losses at open-air underground storage facilities.

The Hydrology Division recommends using the Cooley Method with the Maximum Curve when calculating evaporative losses for spreading basins. This recommendation was derived for the following reasons:

- The Cooley Method is very consistent, in that, the daily evaporation rates and adjustment factors are fixed and do not change over time. This allows for a very simplified calculation method that is identical from year to year.

- The Cooley method is easy to use and can be adopted by a wide range of permittees and facilities. Especially as it relates to the collecting, reporting, and reviewing of the data and calculations. This has proven to be a benefit for new facility operators and changes in personnel at the Department. This is an important factor to consider when taking into account a duration of twenty years or longer for some facilities.

- The consistency of the Cooley Method makes it easy for the Department to review and verify calculation parameters when reviewing a new application and/or determining long term storage credits.

- The Cooley Method can be used without the Department demanding extraneous monitoring cost. The information required such as, wet/dry status of the basin(s) and the volume of water discharged are currently required in the USF permit for credit calculations and infiltration calculations.

- The Cooley Method unlike other empirical methods was designed specifically for Arizona.

- Other methods of determining evaporation can be very accurate, however, they are relatively expensive, requiring intensive measurements and calculation efforts to obtain evaporation values. In Hydrology's experience the difference between these methods and Cooley is negligible. This is especially true given the relatively small ratio of evaporation to the total amount of water recharged.

- The daily evaporation rates and adjustment factors, determined by Cooley, are used by the Arizona Department of Environmental Quality (ADEQ Engineering Bulletin No. 12). Thus having consistency between state agencies.

Justification for Using the Maximum Curve of the Cooley Method

- Using the maximum evaporation rate calculates evaporative loss less than the Class A pan evaporation data and greater than the normal evaporation curve. This produces a value that assures that all losses have been accounted for when calculating annual storage credits but is not over conservative.

- Class A pan data was one of the three sources used in preparing the Cooley Method. The corrections used in Class A pan calculations were calibrated to open water surfaces, considerably deeper than the average spreading basin. These deep open water bodies contain cooler water upwelling toward the surface causing a decrease in the evaporation rate. The spreading basins used in current recharge operations typically contain very shallow water (2 to 3 feet) that heats up fairly rapidly, thus increasing evaporative losses. Therefore, using the evaporation values calibrated for open water conditions would underestimate the evaporative losses in a spreading basin. The maximum evaporation rate more accurately estimates the evaporative losses for the conditions present at shallow recharge basins.

- Evaporation caused by the "wicking effect" may continue during dry cycles even when the basin does not contain standing water. The "wicking effect" process consists of water moving upward toward the surface due to the drying and heating of the ground above. This factor is not taken into account when using the normal values of evaporation, but is compensated for when using the maximum evaporation rate in calculations.

Attachments:

Evaporation from Open Water Surfaces in Arizona, K.R. Cooley, 1970

EVAPORATION FROM OPEN WATER SURFACES IN ARIZONA

Keith R. Cooley
Research Hydrologist
U. S. Water Conservation Laboratory, Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture.

Most people know that a considerable amount of water is lost by evaporation from open water surfaces in Arizona. However, they are amazed that, from a stock tank containing water 7 feet deep, the loss to evaporation in a year's time could be as much as 6 feet, leaving only one foot for livestock. On the other hand, declines in water level of 3 or 4 inches per day from fish ponds and swimming pools cannot be due entirely to evaporation.

Using the method outlined in this folder, the home owner, farmer, rancher, contractor, or consultant can estimate the amount of evaporation expected from an open, unbroken water surface during any part of the year and for any location in Arizona. Results will generally be within 10 percent of actual evaporation on an annual basis.

How to Estimate Evaporation

Estimation of evaporation consists of three steps.

1. Select the average daily or average monthly evaporation for the period in question from Figure 1. For daily evaporation, choose one of the three curves, depending on whether you want maximum, normal, or minimum expected evaporation.

Values of average normal evaporation are shown in the bar graph as inches per month.

Use the curve representing normal evaporation for an estimate of expected evaporation under average conditions. However, for extremely hot windy periods, or cool cloudy periods, the curves representing maximum and minimum evaporation, respectively, will give a better estimate. The curves of maximum and minimum evaporation may also be of value when considering the possible range of seepage losses from water storage facilities.

2. Determine an adjustment factor from Figure 2 for the location in question. Read from the map the factor nearest the location in which you are interested.

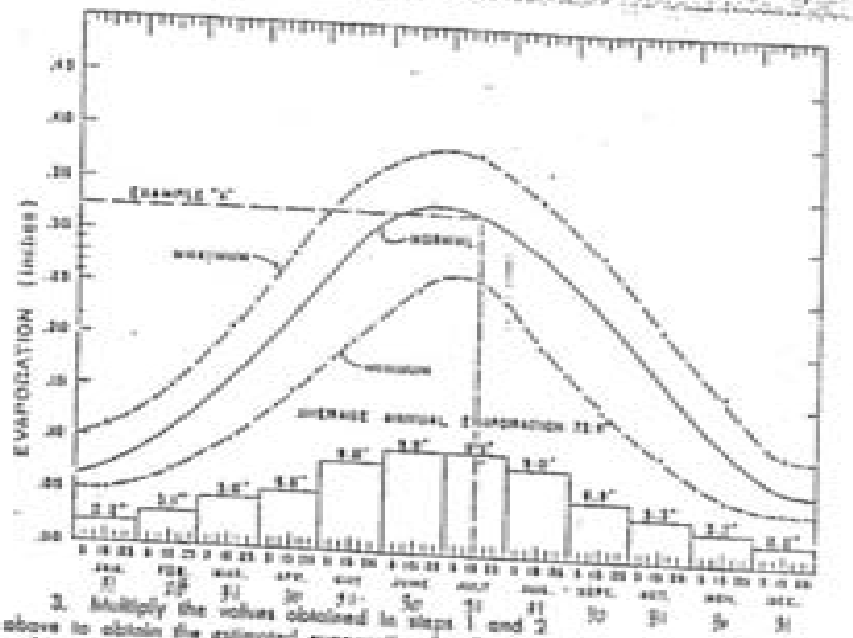


FIGURE 1. Maximum, Normal, and Minimum Daily Evaporation and Average Monthly Evaporation From Open Water Surfaces (Adjustment Factor = 1.00).

3. Multiply the values obtained in steps 1 and 2 above to obtain the estimated evaporation for the time and location in question.

For facilities with exposed walls, such as above-ground stock tanks and exposed-wall swimming pools, multiply the value obtained in step 3 above by 1.25, which is an average coefficient for the entire state for all types of exposed-wall structures.

Examples:

A. Wanted: Average daily normal evaporation from a swimming pool in Tucson during July.
   Step 1. From Figure 1, average evaporation for July = 0.22 inches/day.
   Step 2. From Figure 2, adjustment factor = 0.95.
   Step 3. Multiply values obtained in steps 1 and 2 above: 0.22 x 0.95 = 0.2 inches/day = average daily evaporation during July in Tucson.

B. Wanted: Average normal evaporation from a fish pond in Phoenix during May and June.
   Step 1. From Figure 1, average evaporation for May and June = 9.0 and 9.9 inches, respectively.
   Step 2. Adjustment factor from Figure 2 for Phoenix = 1.0.

(See back)

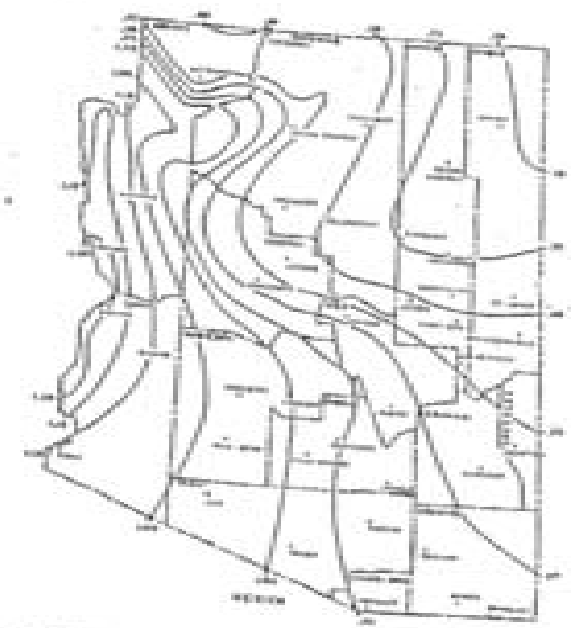


FIGURE 2. Evaporation Adjustment Factors for Arizona

Step 3. Multiply values obtained in steps 1 and 2 above: (9.0 x 1.0) + (9.9 x 1.0) = 18.9 or approximately 19 inches = total average evaporation for May and June.

C. Wanted: Maximum evaporation to be expected from a stock pond near Snowflake during May, June, and July.

Step 1. From the curve of maximum values in Figure 1, values for May, June, and July are: 0.35, 0.38, and 0.38 inches/day, respectively.

Step 2. From Figure 2, adjustment factor for Snowflake = 0.80.

Step 3. Multiply values obtained in steps 1 and 2 above times the number of days in each month.

May: 0.35 x 31 x 0.8 = 8.7
June: 0.38 x 30 x 0.8 = 9.1
July: 0.38 x 31 x 0.8 = 9.4
Totals 27.2 inches

Maximum evaporation expected from a stock pond near Snowflake during May, June, and July is approximately 27 inches.

D. Wanted: Average normal evaporation from an exposed-wall swimming pool near Yuma during June.

Step 1. From Figure 1, average evaporation for June is 9.9 inches.

Step 2. From Figure 2, adjustment factor for Yuma = 1.10.

Step 3. Multiply values obtained in steps 1 and 2 above.
9.9 x 1.10 = 10.9 inches.

Step 4. Multiply by the coefficient for exposed-wall storage facilities, 1.25.
10.9 x 1.25 = 13.6 inches = average evaporation from an exposed-wall swimming pool at Yuma during June.

Acknowledgement

Data used in preparing this paper were obtained from three sources: (1) records of evaporation from sunken insulated evaporation pans at the U. S. Water Conservation Laboratory near Phoenix, Arizona, for the years 1966-1968, (2) records of evaporation from a Class A evaporation pan at the University of Arizona Mesa Experiment Farm for the years 1957-1967, and (3) evaporation maps of the United States based on 1946-1955 data.

Special acknowledgement is made to Mr. Paul C. Kangieser, U. S. Weather Bureau Climatologist, for supplying records of evaporation recorded at the Mesa Experiment Farm.

This publication is issued by the Cooperative Extension Service and the Agricultural Experiment Station of The University of Arizona. See your local County Extension Agent for additional information.

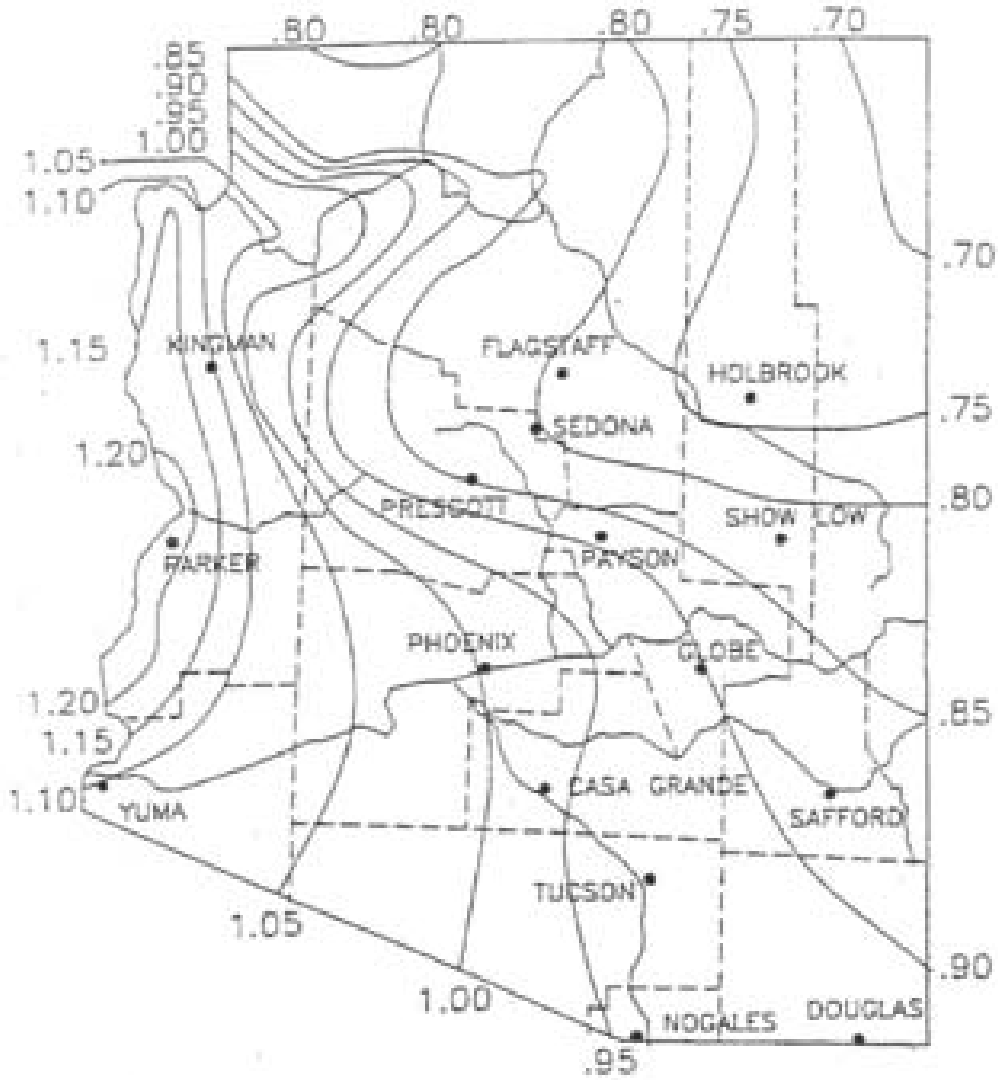
EVAPORATION FROM OPEN WATER SURFACES IN ARIZONA

BULLETIN 153

Agricultural Experiment Station
And
Cooperative Extension Service
The University of Arizona

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, in cooperation with the U. S. Department of Agriculture. George E. Hull, Director of Extension Service, The University of Arizona College of Agriculture, Tucson,

FIGURE 10. EVAPORATION ADJUSTMENT FACTORS FOR ARIZONA



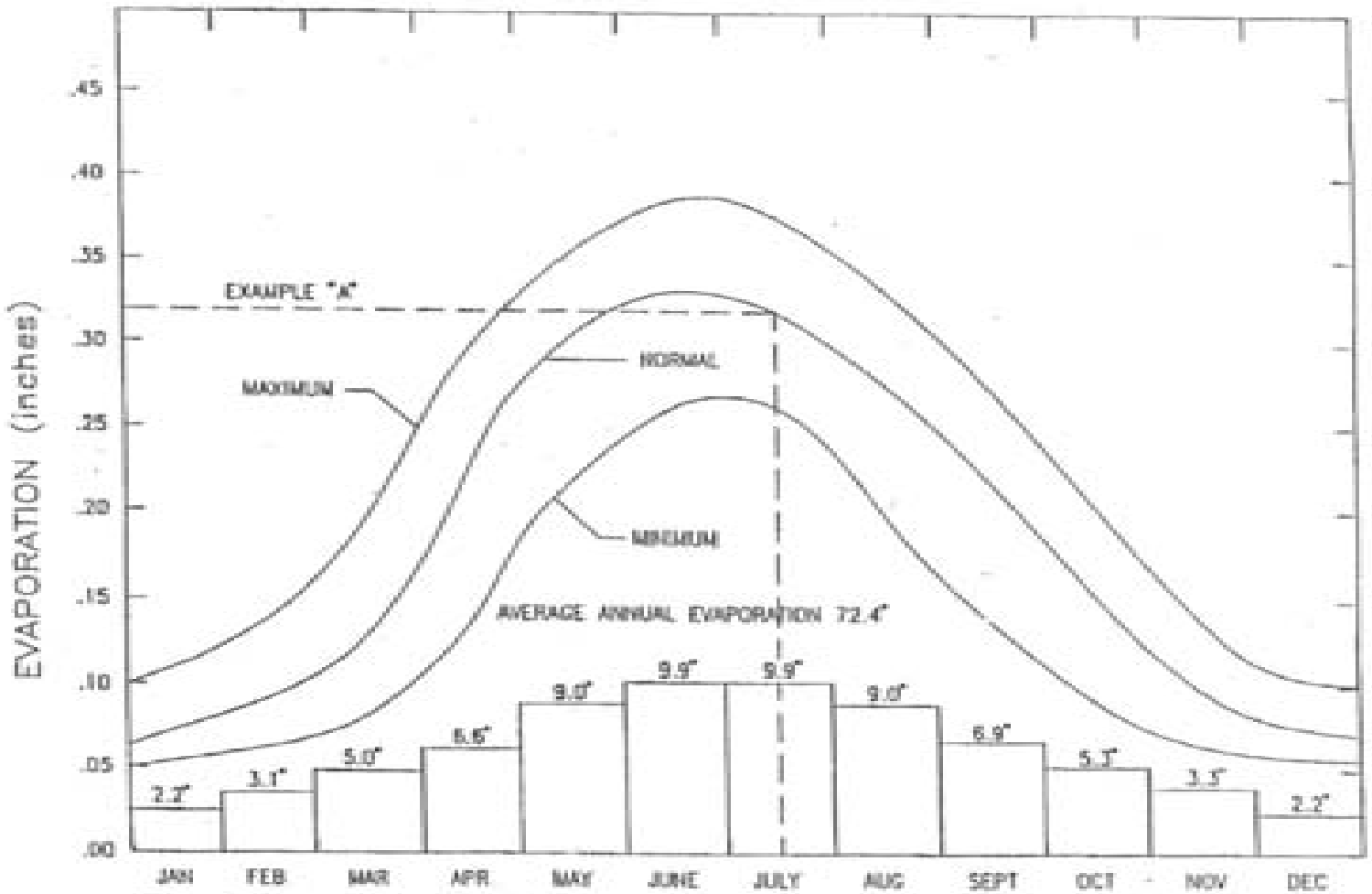


FIGURE 9. MAXIMUM, NORMAL AND MINIMUM DAILY EVAPORATION AND AVERAGE MONTHLY EVAPORATION FROM OPEN WATER SURFACES (Adjustment Factor = 1.00)

TABLE 3.2 MONTHLY MAXIMUM, NORMAL, AND MINIMUM OPEN WATER EVAPORATION AMOUNTS FOR ARIZONA (UNADJUSTED).

	EVAPORATION (IN)		
MONTH	MAXIMUM	NORMAL	MINIMUM
Jan (31 days)	3.6	2.2	1.6
Feb (28)	4.5	3.1	2.3
Mar (31)	6.5	5.0	3.1
April (30)	8.4	6.6	4.5
May (31)	10.9	9.0	6.2
June (30)	11.4	9.9	7.5
July (31)	11.8	9.9	8.1
August (31)	10.5	9.0	6.0
Sept (30)	8.7	6.9	4.1
Oct (31)	7.0	5.3	2.8
Nov (30)	4.8	3.3	1.8
Dec (31)	3.1	2.2	1.6
TOTAL	91.2 (7.6 ft.)	72.4 (6.0 ft.)	49.6 (4.1 ft.)

From: Cooley, 1970

APPENDIX C

THE UNIVERSITY OF ARIZONA®
Cooperative Extension

STANDARDIZED REFERENCE EVAPOTRANSPIRATION

A NEW PROCEDURE FOR ESTIMATING REFERENCE EVAPOTRANSPIRATION IN ARIZONA

Introduction

The Arizona Meteorological Network (AZMET) has provided daily values of reference evapotranspiration (ETo) for a number of southern Arizona locations for more than 15 years. ETo is a computed meteorological parameter that provides an estimate of environmental evaporative demand and serves as a critical input variable for most scientifically based irrigation scheduling systems. ETo is also used to estimate evaporation from water bodies and evapotranspiration (ET) from rain-fed ecosystems.

While there is general agreement among agronomists, irrigation engineers and meteorologists that ETo is a useful environmental parameter, there has been less agreement on how to compute ETo. And all too often the computational procedure for ETo varies from region to region and sometimes within a region. Use of multiple ETo computation procedures within a region can generate biases in ETo that result from the computation process, not any true differences in environmental evaporative demand. Figure 1 provides graphic evidence of this computational bias by presenting the total ETo for Tucson in 1996 as computed using the published ETo procedures for the public weather networks operating in Arizona (Brown, 1998), California (Snyder and Pruitt, 1985), and New Mexico (Sammis, 1996). It is important to note that the same meteorological data were used to generate the ETo data in Figure 1; only the computational procedures differed. These results provide clear evidence that lack of a standardized computational procedure for ETo can lead to confusion and perhaps serious mistakes when one is involved in activities such as irrigation scheduling, estimating consumptive use of vegetation, water rights litigation (especially across state lines), and development of crop coefficients (adjustment factors that convert ETo to crop ET).

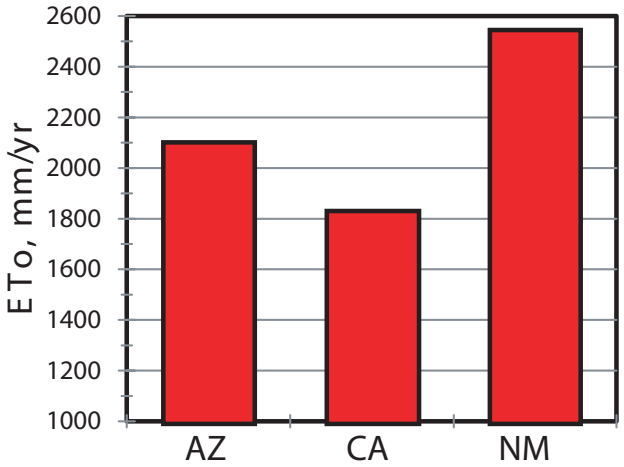


Figure 1. Reference ET (ETo) for Tucson for calendar year 1996 as computed using the published procedures for the public weather networks in Arizona, California, and New Mexico.

Over the past decade, scientists have recognized the problems and frustrations associated with non-standardized ETo computation and have formed national and international committees to address this issue. The American Society of Civil Engineers (ASCE) developed

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a special Task Committee (TC) in 1999 to develop a standardized procedure for computing ETo. The ASCE TC has issued its recommendations (Walter et al., 2004) which are to be published in 2005. AZMET participated in the ASCE TC and began generating ETo values using this ASCE Standardized ETo procedure in 2003. The purpose of this report is to first review the computation procedure recommended by the ASCE TC; second, provide specifics on the computation procedure AZMET will employ; and third, summarize how the new standardized ETo procedure and the original AZMET ETo (EToa) procedure compare across months and locations.

Standardized Reference Evapotranspiration Definition

The ASCE TC defined reference evapotranspiration as "the ET rate from a uniform surface of dense actively growing vegetation having specified height and surface resistance (to transfer of water vapor), not short of soil water, and representing an expanse of at least 100 m of the same or similar vegetation." This definition leaves open the option of having more than one reference surface (differing height and surface resistance) and reflects the view of the TC that standardized computation procedures were necessary for two reference surfaces: 1) a short crop similar to clipped grass and 2) a tall crop similar to full-cover alfalfa. The recommended abbreviations for ETo computed for the short and tall crops using the standardized procedures are ETos and ETrs, respectively (see Table 1 for list of ET abbreviations used in this report).

The need to have procedures for two reference surfaces reflects the history of ET research in the U.S. Two crops — cool-season grass and alfalfa — have been used as reference surfaces for ET estimation for several decades. The TC recommendations allow users with a strong preference for one reference surface or another to continue using their preferred surface. An important reason for recommending two surfaces pertains to crop coefficients (Kcs) — the adjustment factors used to convert ETo to estimates of ET for a specific type of vegetation. Kcs will differ for the two reference surfaces since alfalfa typically uses more water than grass when both are grown under reference conditions. Over the past 30+ years, Kcs have been developed for use with ETo computed for both grass and alfalfa reference surfaces. The TC recommendation to allow for two reference surfaces allows local users to continue using the Kcs and reference surface they are most comfortable with.

ABBREVIATION	EXPLANATION
ET	Evapotranspiration
ETc	Evapotranspiration of a particular crop or vegetation type
ETo	Reference Evapotranspiration in general
ETos	Standardized Reference Evapotranspiration for Short Reference Crop
ETrs	Standardized Reference Evapotranspiration for Tall Reference Crop
ETsz	Standardized Reference Evapotranspiration in general
EToa	Reference Evapotranspiration as computed by AZMET in past years

Table 1. Abbreviations related to evapotranspiration that are contained in this report.

Standardized Reference ET Equation

Generalized Form of Standardized Equation

The ASCE TC standardized procedure for computing reference evapotranspiration is based on the Penman-Monteith Equation and more specifically on simplifying the version of the Penman Monteith Equation recommended by ASCE (Jensen et al., 1990). The recommended general computation procedure is provided below:

$$ETsz = \frac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T+273} u_2(e_s - e_a)}{\Delta + \gamma\,(1 + C_d u_2)} \quad (1)$$

Where:

ETsz = standardized reference crop evapotranspiration (mm d^{-1} or mm h^{-1})

Δ = slope of the saturation vapor pressure-temperature curve (kPa $^{o}C^{-1}$)

R_n = Calculated net radiation at the crop surface (MJ m^{-2} d^{-1} or MJ m^{-2} h^{-1})

G = Soil heat flux density at the soil surface (MJ m^{-2} d^{-1} or MJ m^{-2} h^{-1})

γ = psychrometer constant (kPa $^oC^{-1}$)

C_n = numerator constant that changes with reference type and calculation time step

T = mean daily air temperature measured at 1.5 to 2.5 m above ground level (^oC)

U_2 = mean daily wind speed wind speed measured at 2 m above ground level (m s^{-1})

e_s = saturation vapor pressure measured at 1.5 to 2.5 m above ground level (kPa)

e_a = mean actual vapor pressure measured at 1.5 to 2.5 m above ground level (kPa)

C_d = denominator constant that changes with reference type and calculation time step

Equation 1 represents a generalized equation that can, with appropriate use of constants, handle different reference surfaces; different computational time steps; and slight variation in the measurement height of certain meteorological measurements. Note that standardized reference ET when described in this generalized form is given the abbreviation ETsz.

Standardized Equation To Be Used By AZMET

AZMET will utilize the standardized procedure for a short reference crop computed using a daily computational time step. The appropriate equation for this version of the standardized procedure is provided below:

$$ETos = \frac{0.408\Delta R_n + \gamma \frac{900}{T+273} u_2(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34u_2)} \qquad (2)$$

Where:

ETos = standardized reference crop evapotranspiration for a short crop in mm d^{-1}

Δ = slope of the saturation vapor pressure-temperature curve (kPa $^oC^{-1}$)

R_n = Calculated net radiation at the crop surface in MJ m^{-2} d^{-1}

γ = psychrometer constant (kPa $^oC^{-1}$)

T = mean daily air temperature measured at 1.5 m above ground level (^oC)

u_2 = mean daily wind speed measured at 2 m above ground level (m s^{-1})

e_s = saturation vapor pressure measured at 1.5 m above ground level (kPa)

e_a = mean actual vapor pressure measured at 1.5 m above ground level (kPa)

A comparison of Eqs. 1 and 2 reveal some significant differences. One notable difference is the change in abbreviation for reference ET. The ASCE task force recommended using the abbreviation ETos for short crop standardized reference ET. Another important difference among the two equations is that the numerator and denominator constants in Eq. 1 are set equal to 900 and 0.34, respectively which represent the appropriate constants for the short reference crop and daily computational time step. Finally, one will notice that Eq. 2 no longer contains the soil heat flux variable (G in Eq. 1). Soil heat flux is typically very small over a period of 24 hours (heat that flows into soil in day is lost back to the surface at night) and thus is set equal to zero in the standardized equation when the daily computation time step is used.

The reason AZMET chose to use reference ET computed for a short reference crop is to provide continuity with past AZMET ETo data. AZMET has used a 0.08-0.15 m tall cool season grass as its ET reference surface since the inception of the network in 1987.

The time step for ETsz computation was another factor addressed by the ASCE TC. Time step refers to the time interval over which the ETsz computation is made. The TC recommended standardized procedures for two computational time steps — hourly and daily. The daily computational time step has been used for many decades, in part because most older meteorological data sets consisted of daily summaries. The advent of automated weather stations in the late 1970s led to an increase in the number of hourly data sets that could be used to compute ETo. Past research suggests the ETo computation is more accurate when the computation time step is hourly as opposed to daily or longer (Tanner and Pelton, 1960, Van Bavel, 1966), particularly in regions where meteorological conditions vary in an asymmetric manner each day (e.g., coastal locations with fog or sea breeze; certain mountain areas subject to sudden changes in wind or cloudiness each day). One of the objectives of the TC was to recommend a standardized procedure where the computational time step did not greatly impact the resulting ETsz value. The TC did conduct an evaluation of the impact of time step on the resulting ETsz value (Itenfisu et al., 2000). The evaluation found that ETsz computed using the hourly and daily time step was generally within 2% across a large number of locations (including Arizona).

AZMET chose to use the daily time step computation model for the following reasons: 1) meteorological conditions in Arizona do not generally exhibit serious asymmetric tendencies over the course of a day; 2) daily

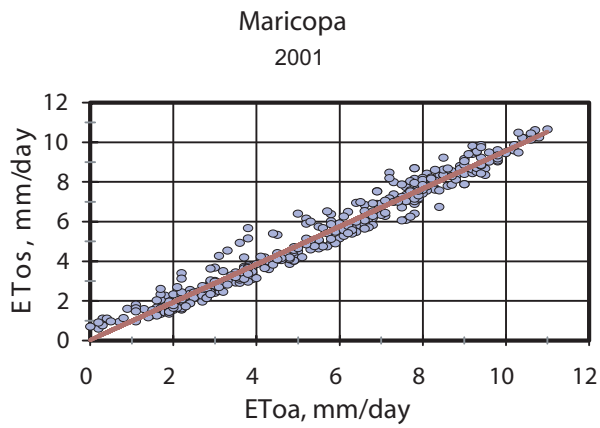

Figure 2. Reference evapotranspiration as computed using the ASCE standardized procedure (ETos) versus reference evapotranspiration computed using procedure employed by AZMET. The line represents the least squares regression line (ETos = 0.03 + 0.95 x EToa; r^2 = 0.96).

meteorological data are easier to estimate than hourly data when data are missing due to instrument failure or station maintenance; and 3) AZMET questions the accuracy of nighttime net radiation (R_n)estimates required to estimate ETos on an hourly timescale.

Data Required To Compute ETos

Both meteorological and non-meteorological data are required for the computation of ETos. The required meteorological data include: 1) daily solar radiation (MJ m^{-2} d^{-1}), 2) mean daily vapor pressure (kPa), 3) mean daily wind speed (m s^{-1}), and 4) maximum and minimum air temperature for the day (^oC). All of the required meteorological data are collected by AZMET weather stations. Required non-meteorological data consist of elevation above sea level and latitude for the locations providing the meteorological data (AZMET weather station locations).

The meteorological data required for computation of ETos must be converted into the specific variables required in Eq. 2. Multiple procedures are available for making these required conversions. The ASCE TC reviewed many of the recommended conversion procedures and made recommendations on the best procedures to use based on the kind and quality of available meteorological data. The specific procedures and/or equations employed by AZMET to generate these required variables are presented in the Appendix to this report

Comparison of Standardized Reference ET with Original AZMET ETo

A logical question for users of ETo data would be how does the new standardized procedure (ETos) compare with the original AZMET ETo (EToa) data. To answer this question, AZMET computed daily ETos for the period 1 January 1998 through 31 December 2001 (4 years), then compared the monthly, seasonal, and annual totals of ETos against similar totals of EToa for locations presently served by AZMET weather stations.

ETos and EToa were highly correlated across all locations served by AZMET. The data presented in Figure 2 are representative of the general relationship between ETos and EToa. While ETos and EToa are highly correlated, values of ETos generally run lower than EToa. This lower bias of ETos is clearly evident in Tables 2 and 3 that present monthly, seasonal, and annual totals of ETos and EToa for all locations presently served by AZMET weather stations. Also included in Tables 2 and 3 are ratios of ETos to EToa for the various time scales.

Annual totals of ETos were 3-17% lower than similar totals of EToa depending on location (Table 3). The lowest ratios of ETos to EToa occur where wind flow is generally low (e.g., Waddell, Phoenix Encanto, and Phoenix Greenway). The highest ratios occur at locations exhibiting fairly high wind speeds (e.g., Marana, Parker).

The monthly and seasonal ratios presented in Tables 2 and 3 reveal that the lower bias of ETos (relative to EToa) is not constant over time. Higher ratios typically occur during windy months and months with higher dew point temperatures (e.g., summer monsoon months). Lower ratios commonly occur when dew point and wind flow are low.

Converting Past EToa to ETos

Long time users of AZMET data may have databases and spreadsheets that contain values of EToa generated in past years. Users interested in converting EToa data into reliable estimates of ETos may use the ratios presented in Tables 2 & 3. The simple conversion process uses the following equation:

$$ETos = Ratio * EToa \quad (3)$$

Table 2. Mean monthly values of reference evapotranspiration for all AZMET station sites for the period 1998-2001 computed using the ASCE standardized (ETos) and original AZMET (EToa) computation procedures. Monthly ratios of ETos to EToa are provided in columns labeled "Ratio."

LOCATION	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE		
	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio
Aguila	72.6	80.5	0.90	77.8	90.1	0.86	125.4	147.2	0.85	171.1	198.5	0.86	241.6	273.0	0.89	261.4	289.3	0.90
Buckeye	74.3	83.8	0.89	84.7	96.1	0.88	134.0	151.7	0.88	180.2	207.0	0.87	240.5	270.0	0.89	251.0	276.2	0.91
Bonita	69.8	79.0	0.88	82.8	94.2	0.88	126.3	146.6	0.86	167.5	197.2	0.85	222.8	256.6	0.87	228.1	247.6	0.92
Coolidge	73.5	78.4	0.94	82.2	90.4	0.91	124.6	140.4	0.89	174.5	197.5	0.88	247.4	269.4	0.92	253.7	271.7	0.93
Eloy	69.4	77.1	0.90	81.1	91.3	0.89	125.7	146.0	0.86	173.5	204.2	0.85	241.6	274.7	0.88	254.0	277.5	0.92
Harquahala	65.7	76.6	0.86	73.9	87.7	0.84	124.5	148.0	0.84	166.8	198.2	0.84	220.9	253.1	0.87	246.7	272.4	0.91
Litchfield Pk.	66.8	75.7	0.88	77.5	88.4	0.88	126.1	144.3	0.87	173.5	202.5	0.86	238.7	270.1	0.88	263.1	287.7	0.91
Maricopa	63.3	72.5	0.87	80.0	89.7	0.89	126.0	143.6	0.88	175.0	199.1	0.88	244.0	267.5	0.91	261.3	280.4	0.93
Marana	90.2	89.5	1.01	98.9	102.2	0.97	144.9	157.5	0.92	184.2	206.2	0.89	251.8	274.1	0.92	264.6	277.3	0.95
Mohave Val.	80.7	87.0	0.93	87.3	94.6	0.92	145.8	164.6	0.89	191.8	214.9	0.89	257.8	278.6	0.93	257.4	275.2	0.94
Paloma	72.9	79.6	0.92	84.8	94.9	0.89	131.1	149.5	0.88	173.5	200.0	0.87	234.4	259.8	0.90	255.8	276.2	0.93
Parker	72.5	78.4	0.93	80.9	90.1	0.90	134.7	153.2	0.88	192.1	211.4	0.91	263.8	280.9	0.94	281.5	288.9	0.97
Phoenix Encanto	54.5	65.6	0.83	67.5	80.7	0.84	111.8	133.6	0.84	153.6	185.3	0.83	209.9	247.0	0.85	228.2	262.3	0.87
Phoenix Greenway	51.1	69.8	0.73	65.4	83.5	0.78	108.6	134.3	0.81	149.7	182.8	0.82	205.3	245.3	0.84	226.0	261.4	0.86
Queen Ck.	61.7	66.0	0.93	74.8	81.9	0.91	117.9	131.0	0.90	159.9	182.3	0.88	214.9	240.3	0.89	227.0	249.1	0.91
Roll	64.5	80.5	0.80	76.9	92.4	0.83	128.4	153.6	0.84	174.8	204.8	0.85	222.5	251.6	0.88	234.2	258.4	0.91
Safford	74.8	80.8	0.93	92.4	100.8	0.92	139.4	156.8	0.89	187.0	211.8	0.88	250.8	274.1	0.92	252.7	264.5	0.96
Tucson	68.6	80.8	0.85	82.4	94.6	0.87	128.0	151.2	0.85	166.3	196.0	0.85	224.3	258.1	0.87	235.4	258.3	0.91
Waddell	54.0	76.2	0.71	67.3	86.2	0.78	111.4	136.8	0.81	156.1	192.3	0.81	217.8	262.6	0.83	236.4	276.2	0.86
Yuma Mesa	69.7	85.2	0.82	80.2	95.8	0.84	129.4	155.0	0.83	168.7	199.6	0.85	217.6	247.7	0.88	238.8	261.8	0.91
Yuma N. Gila	71.6	84.2	0.85	80.2	94.3	0.85	127.5	151.3	0.84	170.2	199.0	0.86	211.8	239.7	0.88	229.0	251.2	0.91
Yuma Valley	83.9	94.5	0.89	90.5	103.3	0.88	135.1	158.7	0.85	181.3	207.9	0.87	230.5	254.1	0.91	259.3	278.5	0.93

Table 2 continued. Mean monthly values of reference evapotranspiration for all AZMET station sites for the period 1998-2001 computed using the ASCE standardized (ETos) and original AZMET (EToa) computation procedures. Monthly ratios of ETos to EToa are provided in columns labeled "Ratio."

LOCATION	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio
Aguila	249.1	259.6	0.96	218.3	222.3	0.98	184.0	199.0	0.92	138.3	153.7	0.90	90.5	100.6	0.90	75.5	82.3	0.92
Buckeye	236.8	245.5	0.96	225.3	226.9	0.99	188.6	200.6	0.94	137.9	153.6	0.90	86.3	97.8	0.88	70.9	79.3	0.89
Bonita	192.3	194.1	0.99	179.3	185.2	0.97	166.7	180.4	0.92	125.9	140.8	0.89	82.3	94.2	0.87	66.3	77.1	0.86
Coolidge	217.7	219.4	0.99	198.3	200.8	0.99	166.0	172.9	0.96	128.0	138.5	0.92	83.5	89.2	0.94	71.9	75.4	0.95
Eloy	236.1	237.6	0.99	219.0	221.7	0.99	177.3	192.1	0.92	130.3	147.1	0.89	78.5	93.6	0.84	65.3	73.0	0.89
Harquahala	249.6	260.8	0.96	231.2	234.9	0.98	182.7	199.1	0.92	127.6	148.5	0.86	77.7	93.4	0.83	68.6	78.6	0.87
Litchfield Pk.	246.8	257.5	0.96	219.2	228.3	0.96	172.5	192.0	0.90	121.4	138.1	0.88	74.7	86.8	0.86	60.9	69.0	0.88
Maricopa	247.6	249.7	0.99	223.6	225.1	0.99	182.8	192.9	0.95	128.1	141.9	0.90	73.6	84.4	0.87	58.9	66.1	0.89
Marana	220.2	216.1	1.02	209.6	204.4	1.03	193.4	194.1	1.00	152.9	155.2	0.99	107.9	107.5	1.00	82.6	83.7	0.99
Mohave Val.	233.5	244.3	0.96	211.0	217.2	0.97	169.0	184.8	0.91	131.0	144.1	0.91	89.0	97.6	0.91	91.8	99.8	0.92
Paloma	241.4	247.8	0.97	213.4	213.9	1.00	174.4	183.4	0.95	129.5	142.7	0.91	81.4	90.8	0.90	69.4	72.9	0.95
Parker	276.1	275.7	1.00	224.0	224.4	1.00	194.2	202.2	0.96	144.8	156.7	0.92	88.4	97.7	0.90	75.3	82.2	0.92
Phoenix Encato	223.8	243.3	0.92	207.0	222.7	0.93	161.3	185.7	0.87	108.7	131.2	0.83	63.3	79.8	0.79	49.9	61.7	0.81
Phoenix Greenway	221.2	240.3	0.92	206.2	222.1	0.93	158.1	185.7	0.85	106.8	137.0	0.78	60.3	85.6	0.70	47.0	66.4	0.71
Queen Ck.	219.7	222.5	0.99	205.8	207.9	0.99	169.2	179.5	0.94	117.9	131.1	0.90	72.5	82.2	0.88	57.3	63.2	0.91
Roll	234.1	246.0	0.95	222.2	230.5	0.96	180.8	193.5	0.93	129.9	143.3	0.91	74.8	84.3	0.89	63.8	77.5	0.82
Safford	205.5	203.4	1.01	178.2	177.7	1.00	161.8	170.0	0.95	125.7	136.0	0.92	80.3	88.5	0.91	68.9	72.4	0.95
Tucson	201.1	205.2	0.98	192.1	197.9	0.97	168.8	183.8	0.92	123.6	143.1	0.86	77.6	92.0	0.84	64.1	77.3	0.83
Waddell	225.6	250.7	0.90	199.0	220.2	0.90	156.2	188.8	0.83	107.5	140.2	0.77	61.9	88.8	0.70	48.8	71.0	0.69
Yuma Mesa	241.0	252.4	0.95	217.6	224.6	0.97	174.9	191.3	0.91	129.3	150.2	0.86	83.4	98.5	0.85	75.1	90.5	0.83
Yuma N. Gila	249.3	254.1	0.98	233.6	233.6	1.00	182.9	193.5	0.95	133.6	148.3	0.90	82.7	92.8	0.89	74.6	85.5	0.87
Yuma Valley	266.8	276.3	0.97	240.2	241.8	0.99	203.7	212.8	0.96	148.8	162.9	0.91	96.1	104.1	0.92	89.0	97.9	0.91

Table 3. Seasonal and annual means of reference evapotranspiration for all active AZMET monitoring sites for the period 1998-2001 as computed using the ASCE standardized (ETos) and original AZMET (EToa) procedures. Ratios of ETos to EToa are provided in columns labeled "Ratio."

LOCATION	WINTER (Dec. - Feb.)			SPRING (Mar. - May)			SUMMER (Jun. - Aug.)			FALL (Sep. - Nov.)			ANNUAL		
	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio	ETos (mm)	EToa (mm)	Ratio
Aguila	225.9	252.9	0.89	538.1	618.7	0.87	728.8	771.2	0.94	412.8	453.3	0.91	1905.7	2095.9	0.91
Buckeye	229.9	259.2	0.89	554.7	628.7	0.88	713.1	748.6	0.95	412.8	452.0	0.91	1910.5	2088.2	0.91
Bonita	218.9	250.3	0.87	516.6	600.4	0.86	599.7	626.9	0.96	374.9	415.4	0.90	1710.2	1892.9	0.90
Coolidge	227.6	244.2	0.93	546.5	607.3	0.90	669.7	691.9	0.97	377.5	400.6	0.94	1821.3	1944.0	0.94
Eloy	215.8	241.4	0.89	540.8	626.4	0.86	709.1	735.3	0.96	386.1	432.8	0.89	1851.9	2035.7	0.91
Harquahala	208.2	242.9	0.86	512.2	599.3	0.85	727.5	768.1	0.95	388.0	441.0	0.88	1835.9	2051.2	0.90
Litchfield Pk.	205.2	233.1	0.88	538.3	616.9	0.87	729.1	773.5	0.94	368.6	416.9	0.88	1841.3	2040.4	0.90
Maricopa	202.2	228.3	0.89	545.0	610.2	0.89	732.5	755.2	0.97	384.5	419.2	0.92	1864.2	2012.8	0.93
Marana	271.7	275.4	0.99	580.9	637.8	0.91	694.4	697.8	1.00	454.2	456.8	0.99	2001.2	2067.6	0.97
Mohave Val.	259.8	281.4	0.92	595.4	658.1	0.90	701.9	736.7	0.95	389.0	426.5	0.91	1946.2	2102.4	0.93
Paloma	227.1	247.4	0.92	539.0	609.3	0.88	710.6	737.9	0.96	385.3	416.9	0.92	1862.0	2011.3	0.93
Parker	228.7	250.7	0.91	590.6	645.5	0.91	781.6	789.0	0.99	427.4	456.6	0.94	2028.4	2141.6	0.95
Phoenix Encanto	171.9	208.0	0.83	475.3	565.9	0.84	659.0	728.3	0.90	333.3	396.7	0.84	1639.6	1898.7	0.86
Phoenix Greenway	163.5	219.7	0.74	463.6	562.4	0.82	653.4	723.8	0.90	325.2	408.3	0.80	1605.6	1914.1	0.84
Queen Ck.	193.8	211.1	0.92	492.7	553.6	0.89	652.5	679.5	0.96	359.6	392.8	0.92	1698.5	1836.7	0.92
Roll	205.2	250.4	0.82	525.7	610.0	0.86	690.5	734.9	0.94	385.5	421.1	0.92	1806.9	2016.3	0.90
Safford	236.1	254.0	0.93	577.2	642.7	0.90	636.4	645.6	0.99	367.8	394.5	0.93	1817.6	1936.6	0.94
Tucson	215.1	252.7	0.85	518.6	605.3	0.86	628.6	661.4	0.95	370.0	418.9	0.88	1732.2	1938.2	0.89
Waddell	170.1	233.4	0.73	485.3	591.7	0.82	661.0	747.1	0.88	325.6	417.8	0.78	1642.0	1989.7	0.83
Yuma Mesa	225.0	271.5	0.83	515.7	602.3	0.86	697.4	738.8	0.94	387.6	440.0	0.88	1825.7	2052.4	0.89
Yuma N. Gila	226.4	264.0	0.86	509.5	590.0	0.86	711.9	738.9	0.96	399.2	434.6	0.92	1847.0	2027.4	0.91
Yuma Valley	263.4	295.7	0.89	546.9	620.7	0.88	766.3	796.6	0.96	448.6	479.8	0.93	2025.2	2192.5	0.92

where **Ratio** represents the appropriate annual, seasonal or monthly ratio from Tables 2 and 3. Annual ratios should be used only to adjust annual totals of EToa. Monthly ratios provide the best means of converting short term data sets (e.g., daily, weekly or monthly totals of EToa). *Users wishing to obtain actual computed values of ETos for past years should contact AZMET. As part of the move to adopt ETos, AZMET will generate ETos for its entire database which extends back to 1987 at some locations.*

Crop Coefficients and ETos

Crop coefficients (Kcs) are used to convert ETo data into estimates of crop evapotranspiration (ETc). The simple conversion procedure is as follows:

$$ETc = Kc * ETo \quad (4)$$

It is important to note that Kcs need to be matched to the ETo procedure in order to obtain reliable estimates of ETc from Eq. 4. To help clarify this point, suppose one has a turf Kc of 0.75 that is appropriate for use with AZMET ETo (EToa). To obtain an estimate of turf water use in Tucson for May one would multiply the Kc (0.75) times the May EToa value for Tucson (258.1 mm from Table 2):

$$ETc = Kc * EToa$$

$$ETc = 0.75 * 258.1 \text{ mm}$$

$$ETc = 193.6 \text{ mm } (7.62'')$$

If, however, this same Kc is erroneously applied to values of ETos, the same May turf water use estimate in Tucson would be:

$$ETc = Kc * ETos$$

$$ETc = 0.75 * 224.3 \text{ mm}$$

$$ETc = 168.2 \text{ mm } (6.62'')$$

or 25.4 mm (1.0") less than the correct value. It is clear from this example that failure to match Kcs with ETo procedure can lead to significant errors when estimating water use from vegetation.

Very few Kcs have been validated for use with ETos in Arizona with the notable exception of turfgrass (Brown and Kopec, 2000). While a number of research studies are presently underway (University of Arizona and USDA-ARS) that should provide validated Kcs for a number of Arizona crops in the near future, individuals interested in applying Kcs to ETos must either use published Kcs developed in another location, or adjust existing AZMET Kcs. A good place to locate Kcs for use with ETos is the publication entitled *Crop Evapotranspiration: Guidelines for computing crop water requirements* which is listed in the Reference section of this report.

Adjusting AZMET Kcs is a simple process that requires the use of the ratio data in Tables 2 and 3:

$$Kc_{os} = Kc_{az} / \text{Ratio} \quad (5)$$

where Kc_{os} and Kc_{az} are the crop coefficient values appropriate for use with ETos and EToa, respectively; and **Ratio** is the ratio of ETos to EToa provided in Tables 2 and 3. In the previous example pertaining to turfgrass water use for Tucson in May, one would correct the Kc_{az} value of 0.75 by dividing by the May ratio presented in Table 2 (0.87):

$$Kc_{os} = 0.75 / 0.87 = 0.86$$

Seasonal ratios of ETos to EToa are provided in Table 3 to assist with adjusting Kc_{az} for row crops. For example, AZMET has recommended using a Kc of 1.12 for full cover cotton when using EToa. The process of adjusting this Kc for use with ETos at Maricopa would proceed as follows:

$$Kc_{os} = 1.12 / 0.97 = 1.15$$

The value of 0.97 is the summer ratio for Maricopa (see Table 3).

On a practical note it is important to recognize that existing Kc_{az} values will require only minor adjustments (if any) when used during the summer months. Larger adjustments will be required in winter where the ratios of ETos to EToa are generally much less than 1.0.

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Appendix

The procedures and equations used to compute the variables presented in Equation 2 are described in this Appendix. The variables are presented in the order they are encountered in Eq. 2.

Δ: Slope of Saturation Vapor Pressure vs. Temperature Relationship

The slope of the saturation vapor pressure versus temperature relationship, Δ (kPa $^{o}C^{-1}$), is computed using:

$$\Delta = 2503 \exp((17.27T)/(T + 237.3))/(T + 237.3)^2 \quad (A1)$$

where T is the mean temperature for the day (^{o}C).

Rn: Net Radiation

Net radiation is the net amount of radiant energy available at the surface for evaporating water. Rn includes both short and long wave radiation and is computed using:

$$Rn = Rns - Rnl \quad (A2)$$

where Rns = net shortwave radiation (MJ m^{-2} d^{-1}) defined as positive in the downward direction (toward earth) and Rnl = net longwave radiation (MJ m^{-2} d^{-1}) defined as positive in the upward direction (toward sky).

Net shortwave radiation (Rns) is computed as the difference between incoming and reflected shortwave radiation:

$$Rns = Rs - \alpha Rs = (1 - \alpha)Rs \quad (A3)$$

where α = albedo or canopy reflection coefficient which is fixed at 0.23 and Rs = incoming solar radiation (MJ m^{-2} d^{-1}).

Net longwave radiation (Rnl) is the difference between upward longwave radiation (Rlu) and downward longwave radiation from the sky (Rld):

$$Rnl = Rlu - Rld \quad (A4)$$

The daily value of Rnl is computed using:

$$Rnl=\sigma[(TK^4max+TK^4min)/2]*(0.34-0.14\sqrt{ea})[1.35(Rs/Rso) - 0.35] \quad (A5)$$

where Rnl is net long-wave radiation in MJ m^{-2} d^{-1}, σ is the Stefan-Boltzman constant [= 4.901 x 10^{-9} MJ K^{-4} m^{-2} d^{-1}], TK^4max is the maximum absolute temperature for the day (K), TK^4min is the minimum absolute temperatures for the day (K), ea is the actual vapor pressure (kPa), Rs is solar radiation (MJ m^{-2} d^{-1}), and Rso is calculated clear-sky solar radiation (MJ m^{-2} d^{-1}). The ratio Rs/Rso indicates the relative level of cloudiness must be limited to $0.3 < Rs/Rso < 1.0$. Rs/Rso values <0.30 are set = 0.30; Rs/Rso values > 1.0 are set = 1.0.

Clear sky solar radiation (Rso) is computed using:

$$Rso = (0.75 + 2 * 10^{-5} z)Ra \qquad (A6)$$

where z is the elevation above sea level (m) and Ra is extraterrestrial radiation (MJ m^{-2} d^{-1}).

Extraterrestrial radiation is computed from earth-sun geometry using:

$$Ra = (24/\pi)Gsc\ dr * [\omega s \sin(\varphi) \sin(\delta) + \cos(\varphi) \cos(\delta) \sin(\omega s)] \qquad (A7)$$

where Gsc is the solar constant [= 4.92 MJ m^{-2} h^{-1}], dr is relative distance factor (between the earth and sun), ωs is sunset hour angle (radians), φ is the latitude (radians), and δ solar declination (radians).

The relative distance factor is computed using:

$$dr = 1 + 0.033\cos(2\pi J/365) \qquad (A8)$$

where J is the day of the year (1 = 1 January; 365 = 31 December).

The solar declination angle is computed using:

$$\delta = 0.409\sin((2\pi J/365) - 1.39) \qquad (A9)$$

The sunset angle is computed using:

$$\omega s = \arccos[-\tan(\varphi) \tan(\delta)] \qquad (A10)$$

γ: Psychrometer Constant

The psychrometer constant, γ (kPa $^{o}C^{-1}$), is computed using:

$$\gamma = 0.000665\ P \qquad (A11)$$

where P is the atmospheric pressure at the weather station site. Atmospheric pressure (kPa) is computed from the elevation of the weather station site:

$$P = 101.3\ ((293 - 0.0065\ z)\ /\ 293)^{5.26} \qquad (A12)$$

where z is the elevation of the weather station above mean sea level (m).

T: Mean Air Temperature

Mean air temperature (^{o}C) is calculated as the mean of the daily maximum and daily minimum air temperature:

$$T = (Tmax + Tmin)/2 \qquad (A13)$$

where Tmax and Tmin are the maximum and minimum air temperatures (°C) as obtained from the weather station data logger.

u_2: Wind Speed

The standardized equation requires the mean daily wind speed measured at 2 m above ground level (agl). Because AZMET measures wind speed at 3 m agl, wind speed is adjusted to an equivalent value at 2 m agl using the following:

$$u_2 = u_3 \, (4.87 / \ln(67.8 \, zw - 5.42) \qquad \text{(A14)}$$

where u_3 is the wind speed measured at 3 m agl and zw is the height of the wind speed measurement (3 m).

e_s: Saturation Vapor Pressure

Saturation vapor pressure is computed using:

$$es = (es(Tmax) + es(Tmin)) \; / \; 2 \qquad \text{(A15)}$$

where es(Tmax) and es(Tmin) are the saturation vapor pressures (kPa) computed using the maximum and minimum air temperatures, respectively. Saturation vapor pressure is computed using the following:

$$es = 0.6108 \exp((17.27Tex) \; / \; (Tex + 237.3)) \qquad \text{(A16)}$$

where Tex is either Tmax or Tmin (°C) .

ea: Actual Vapor Pressure

The mean actual vapor pressure for the day is computed by the weather station datalogger using simultaneous measurements of relative humidity (RH; %) and air temperature (Ta; °C) using:

$$ea = (RH/100) \, [0.6108 \exp((17.27Ta)/(Ta + 237.3))] \qquad \text{(A17)}$$

Values of ea are computed by the datalogger every 10 s and averaged for the day.

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APPENDIX D

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
JANUARY 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.53	0.58	0.92	0.56	0.12	4.66	0.35	0.72	0.49	1.08	1.23	0.88
2	0.60	0.59	1.03	0.75	0.30	2.49	0.22	0.73	0.31	0.47	1.22	0.39
3	0.61	0.61	1.01	1.75	1.06	1.65	-0.01	0.76	-0.01	0.01	0.32	0.02
4	0.84	0.61	1.38	0.16	1.14	0.14	0.12	0.78	0.16	0.00	0.00	none
5	0.49	0.61	0.81	1.07	1.14	0.94	0.50	0.78	0.65	1.41	1.16	1.22
6	0.44	0.61	0.73	1.11	1.11	1.00	0.37	0.76	0.49	0.26	1.23	0.21
7	0.42	0.59	0.72	0.99	1.09	0.91	0.36	0.73	0.50	-0.01	0.95	-0.01
8	0.44	0.58	0.77	0.90	1.03	0.87	0.20	0.72	0.28	0.75	0.95	0.79
9	0.61	0.59	1.04	1.34	1.03	1.30	0.00	0.39	-0.01	0.80	1.23	0.65
10	0.54	0.61	0.89	1.12	1.11	1.01	0.84	0.59	1.44	0.30	1.26	0.24
11	0.75	0.61	1.24	1.60	1.14	1.40	0.64	0.78	0.82	-0.01	1.22	-0.01
12	0.59	0.61	0.97	1.10	1.14	0.96	0.38	0.78	0.49	1.00	1.16	0.86
13	0.43	0.58	0.75	0.93	1.06	0.88	-0.01	0.72	-0.01	0.46	1.23	0.37
14	0.41	0.58	0.72	0.91	1.03	0.88	0.00	0.20	-0.01	0.48	1.23	0.39
15	0.41	0.58	0.72	0.92	1.03	0.89	0.00	0.00	none	0.48	1.23	0.39
16	0.45	0.58	0.78	0.93	1.06	0.88	0.77	0.59	1.32	0.25	1.23	0.20
17	0.65	0.61	1.07	1.71	1.14	1.50	0.70	0.78	0.90	-0.01	0.95	-0.01
18	0.54	0.61	0.89	0.71	1.17	0.61	0.36	0.78	0.47	1.07	1.22	0.88
19	0.47	0.61	0.78	0.56	1.15	0.49	-0.01	0.76	-0.01	0.00	1.23	0.00
20	0.20	0.58	0.35	-0.01	1.09	-0.01	-0.01	0.72	-0.01	0.27	1.22	0.23
21	0.49	0.47	1.03	0.00	0.00	none	0.00	0.20	-0.01	0.53	1.11	0.48
22	0.38	0.32	1.20	0.59	0.12	4.91	0.83	0.59	1.43	0.27	1.23	0.22
23	0.00	0.00	none	2.13	1.14	1.87	0.77	0.78	0.99	-0.01	1.16	-0.01
24	0.00	0.00	none	0.61	1.21	0.50	0.34	0.78	0.44	0.00	0.13	-0.01
25	0.00	0.00	none	0.00	1.11	0.00	-0.01	0.76	-0.01	0.00	0.00	none
26	0.42	0.58	0.73	0.00	0.12	-0.01	-0.01	0.72	-0.01	0.51	1.16	0.44
27	0.33	0.61	0.55	0.00	0.00	none	0.00	0.00	none	0.24	1.23	0.19
28	0.02	0.58	0.04	0.00	0.00	none	0.00	0.00	none	0.01	1.22	0.01
29	0.29	0.47	0.61	0.11	0.06	1.82	0.69	0.39	1.76	0.42	1.16	0.36
30	0.31	0.47	0.65	1.66	1.03	1.61	0.58	0.76	0.77	0.26	1.23	0.21
31	0.00	0.00	none	0.69	1.17	0.59	0.34	0.78	0.44	0.00	0.95	0.00
	Average =		0.83	Average =		1.24	Average =		0.50	Average =		0.33

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
FEBRUARY 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.00	0.00	none	0.02	1.09	0.02	0.02	0.76	0.03	0.00	0.00	none
2	0.56	0.58	0.97	0.02	1.03	0.02	0.17	0.72	0.24	0.74	1.11	0.67
3	0.35	0.61	0.58	0.00	0.00	none	-0.01	0.59	-0.01	0.17	1.23	0.14
4	0.26	0.61	0.43	0.00	0.00	none	0.00	0.00	none	0.04	1.16	0.03
5	-0.01	0.63	-0.01	0.64	1.03	0.62	0.30	0.72	0.42	-0.01	0.95	-0.01
6	-0.01	0.58	-0.01	0.60	1.17	0.51	0.76	0.78	0.98	0.00	0.00	none
7	0.00	0.32	-0.01	0.01	1.03	0.01	0.26	0.78	0.34	0.00	0.00	none
8	0.00	0.00	none	0.00	0.00	none	0.01	0.76	0.02	0.00	0.00	none
9	0.00	0.00	none	0.00	0.00	none	-0.01	0.72	-0.01	0.00	0.00	none
10	0.00	0.00	none	0.00	0.00	none	0.00	0.39	-0.01	0.00	0.00	none
11	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
12	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
13	0.83	0.32	2.62	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
14	0.48	0.59	0.82	0.70	0.12	5.82	0.66	0.59	1.13	0.00	0.00	none
15	0.33	0.59	0.57	1.41	1.03	1.37	0.30	0.73	0.41	0.00	0.00	none
16	0.32	0.61	0.53	1.03	1.14	0.90	0.53	0.78	0.68	0.00	0.00	none
17	0.22	0.61	0.37	0.54	1.17	0.46	0.24	0.78	0.31	0.00	0.00	none
18	0.09	0.61	0.15	0.08	1.14	0.07	0.05	0.76	0.07	0.00	0.00	none
19	0.37	0.58	0.64	0.48	1.06	0.45	0.35	0.72	0.49	0.00	0.00	none
20	0.33	0.59	0.57	0.96	1.14	0.84	0.46	0.76	0.61	0.00	0.00	none
21	0.20	0.59	0.35	1.46	1.21	1.20	0.20	0.78	0.26	0.00	0.00	none
22	0.17	0.61	0.28	0.65	1.21	0.53	-0.01	0.76	-0.01	0.00	0.00	none
23	0.14	0.61	0.24	-0.01	1.21	-0.01	-0.01	0.73	-0.01	0.00	0.00	none
24	0.12	0.61	0.20	-0.01	1.21	-0.01	-0.01	0.72	-0.01	0.00	0.00	none
25	0.11	0.61	0.19	-0.01	1.11	-0.01	0.00	0.39	-0.01	0.00	0.00	none
26	0.26	0.61	0.43	-0.01	1.03	-0.01	0.47	0.72	0.66	1.70	1.16	1.47
27	0.22	0.61	0.37	0.00	0.12	-0.01	-0.01	0.72	-0.01	0.33	1.23	0.26
28	0.12	0.61	0.20	0.00	0.00	none	0.76	0.78	0.98	0.58	1.23	0.47
	Average =		0.48	Average =		0.67	Average =		0.31	Average =		0.43

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
MARCH 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.11	0.63	0.18	0.00	0.00	none	-0.01	0.63	-0.02	0.59	1.23	0.48
2	0.08	0.63	0.13	0.00	0.00	none	-0.01	0.63	-0.02	-0.02	1.23	-0.02
3	0.09	0.63	0.14	0.00	0.00	none	-0.01	0.63	-0.02	0.64	1.23	0.52
4	0.09	0.63	0.14	0.00	0.00	none	-0.01	0.63	-0.02	-0.02	1.23	-0.02
5	0.10	0.63	0.16	0.00	0.00	none	-0.01	0.63	-0.02	0.57	1.23	0.46
6	0.07	0.63	0.11	0.00	0.00	none	0.62	0.63	0.81	0.04	1.22	0.03
7	0.08	0.63	0.13	0.00	0.00	none	-0.01	0.63	-0.02	0.55	1.23	0.45
8	0.08	0.63	0.13	0.00	0.00	none	-0.01	0.63	-0.02	0.68	1.23	0.55
9	0.10	0.63	0.16	0.00	0.00	none	-0.01	0.63	-0.02	0.19	1.23	0.15
10	0.09	0.63	0.14	0.00	0.00	none	-0.01	0.63	-0.02	0.64	1.23	0.52
11	0.07	0.63	0.11	0.00	0.00	none	-0.01	0.63	-0.02	0.13	1.23	0.11
12	0.09	0.63	0.14	0.00	0.00	none	0.71	0.63	0.93	0.60	1.23	0.49
13	0.07	0.63	0.11	0.88	0.61	1.44	-0.01	0.63	-0.02	0.01	1.22	0.01
14	0.09	0.63	0.14	0.00	0.30	-0.02	-0.01	0.63	-0.02	0.57	1.23	0.46
15	0.08	0.61	0.13	0.00	0.00	none	-0.01	0.61	-0.02	0.32	1.26	0.25
16	0.07	0.59	0.12	0.00	0.00	none	-0.01	0.59	-0.02	-0.03	1.23	-0.02
17	0.06	0.58	0.11	0.00	0.00	none	-0.01	0.58	-0.02	0.80	1.23	0.65
18	-0.01	0.58	-0.02	0.00	0.00	none	-0.01	0.58	-0.02	-0.03	1.23	-0.03
19	0.10	0.47	0.22	1.45	0.61	2.38	0.46	0.47	0.64	-0.01	1.22	-0.01
20	0.03	0.32	0.08	0.58	1.11	0.53	0.22	0.32	0.30	0.93	1.23	0.76
21	0.00	0.00	none	0.25	1.14	0.22	0.11	0.00	0.14	0.22	1.26	0.18
22	0.00	0.00	none	2.37	1.21	1.96	0.02	0.00	0.03	-0.01	1.18	-0.01
23	0.00	0.00	none	0.62	1.21	0.51	-0.01	0.00	-0.02	-0.01	1.16	-0.01
24	0.00	0.00	none	-0.02	1.21	-0.02	-0.01	0.00	-0.02	0.61	1.22	0.50
25	0.00	0.00	none	-0.02	1.17	-0.02	-0.01	0.00	-0.02	-0.02	1.16	-0.02
26	0.00	0.00	none	-0.02	1.14	-0.02	-0.01	0.00	-0.02	0.74	1.18	0.63
27	0.00	0.00	none	-0.02	1.03	-0.02	-0.01	0.00	-0.02	-0.04	1.26	-0.03
28	0.00	0.00	none	0.00	0.12	-0.02	0.00	0.00	-0.02	-0.02	1.22	-0.02
29	0.00	0.00	none	1.03	0.30	3.42	0.43	0.00	0.74	0.63	1.23	0.51
30	0.00	0.00	none	0.82	1.14	0.72	0.10	0.00	0.13	-0.02	1.23	-0.02
31	0.00	0.00	none	-0.02	1.11	-0.02	-0.01	0.00	-0.02	-0.03	1.22	-0.02
	Average =		0.13	Average =		0.74	Average =		0.11	Average =		0.24

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
APRIL 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.00	0.00	none	1.15	1.21	0.95	0.00	0.00	none	0.00	0.00	none
2	0.00	0.00	none	0.95	1.21	0.79	0.00	0.00	none	0.00	0.00	none
3	0.00	0.00	none	0.54	1.21	0.45	0.00	0.00	none	0.00	0.00	none
4	0.00	0.00	none	0.18	1.19	0.15	0.00	0.00	none	0.00	0.00	none
5	0.00	0.00	none	0.34	0.91	0.37	0.00	0.00	none	0.00	0.00	none
6	0.00	0.00	none	0.95	1.21	0.79	0.00	0.00	none	0.00	0.00	none
7	0.00	0.00	none	0.23	1.17	0.20	0.00	0.00	none	0.00	0.00	none
8	0.00	0.00	none	0.09	1.03	0.09	0.00	0.00	none	0.00	0.00	none
9	0.00	0.00	none	0.03	0.91	0.03	0.00	0.00	none	0.00	0.00	none
10	0.00	0.00	none	0.56	1.03	0.54	0.00	0.00	none	0.00	0.00	none
11	0.00	0.00	none	1.15	1.21	0.95	0.00	0.00	none	0.00	0.00	none
12	0.00	0.00	none	0.72	1.21	0.60	0.00	0.00	none	0.00	0.00	none
13	0.00	0.00	none	-0.02	1.03	-0.02	0.00	0.00	none	0.00	0.00	none
14	0.00	0.00	none	-0.01	0.30	-0.02	0.00	0.00	none	0.00	0.00	none
15	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
16	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
17	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
18	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
19	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
20	0.40	0.61	0.65	0.00	0.00	none	0.00	0.00	none	1.34	1.23	1.09
21	0.31	0.63	0.50	0.00	0.00	none	0.00	0.00	none	0.62	1.23	0.50
22	0.09	0.63	0.15	0.00	0.00	none	0.00	0.00	none	0.01	1.23	0.01
23	0.11	0.63	0.18	0.00	0.00	none	0.00	0.00	none	1.04	1.26	0.83
24	0.08	0.63	0.12	0.00	0.00	none	0.00	0.00	none	0.02	1.23	0.02
25	0.09	0.63	0.14	0.00	0.00	none	0.18	0.39	0.46	0.17	1.23	0.14
26	0.10	0.63	0.16	0.00	0.00	none	0.24	0.72	0.34	1.11	1.26	0.88
27	0.61	0.63	0.96	0.00	0.00	none	0.24	0.76	0.32	-0.03	1.26	-0.02
28	1.71	0.63	2.71	0.00	0.00	none	0.01	0.72	0.02	0.47	1.26	0.38
29	1.45	0.63	2.31	0.00	0.00	none	0.01	0.59	0.02	0.03	1.23	0.03
30	0.49	0.63	0.78	0.00	0.00	none	0.01	0.20	0.04	0.16	1.23	0.13
	Average =		0.79	Average =		0.42	Average =		0.20	Average =		0.36

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
MAY 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	-0.02	0.63	-0.03	0.00	0.00	none	0.01	0.59	0.02	0.88	1.26	0.70
2	-0.02	0.63	-0.03	0.00	0.00	none	0.01	0.20	0.05	-0.02	1.23	-0.02
3	-0.02	0.63	-0.03	0.00	0.00	none	0.00	0.00	none	-0.02	1.23	-0.01
4	-0.02	0.63	-0.03	0.00	0.00	none	0.00	0.00	none	0.81	1.26	0.64
5	-0.02	0.63	-0.03	0.00	0.00	none	0.00	0.00	none	-0.01	1.23	-0.01
6	-0.02	0.61	-0.03	0.00	0.00	none	0.00	0.00	none	-0.02	1.23	-0.01
7	0.16	0.63	0.26	0.00	0.00	none	0.00	0.00	none	0.71	1.26	0.56
8	0.05	0.63	0.07	0.00	0.00	none	0.00	0.00	none	-0.02	1.23	-0.02
9	0.06	0.63	0.09	0.00	0.00	none	0.00	0.00	none	0.00	1.22	0.00
10	0.08	0.63	0.13	0.00	0.00	none	0.00	0.00	none	0.76	1.26	0.60
11	0.11	0.63	0.18	0.00	0.00	none	0.00	0.00	none	-0.02	1.23	-0.02
12	0.07	0.63	0.11	0.00	0.00	none	0.00	0.00	none	0.00	1.23	0.00
13	0.08	0.63	0.12	0.00	0.00	none	0.00	0.00	none	0.94	1.26	0.74
14	0.26	0.63	0.41	0.00	0.00	none	0.36	0.59	0.62	0.01	1.26	0.01
15	0.10	0.63	0.15	0.00	0.00	none	0.05	0.59	0.09	0.02	1.23	0.02
16	0.07	0.63	0.11	0.00	0.00	none	0.04	0.59	0.08	0.04	1.22	0.03
17	0.09	0.63	0.14	0.00	0.00	none	0.04	0.59	0.08	0.69	1.26	0.55
18	0.06	0.63	0.10	0.00	0.00	none	0.05	0.59	0.09	-0.02	1.23	-0.01
19	0.08	0.63	0.13	0.00	0.00	none	0.05	0.59	0.09	0.07	1.23	0.06
20	0.20	0.61	0.33	0.00	0.00	none	0.17	0.59	0.29	0.81	1.23	0.65
21	0.30	0.58	0.51	0.00	0.00	none	0.22	0.72	0.31	0.45	1.23	0.36
22	0.20	0.63	0.31	0.00	0.00	none	1.04	0.78	1.34	0.39	1.26	0.31
23	0.12	0.63	0.19	0.00	0.00	none	-0.02	0.78	-0.02	0.05	1.23	0.04
24	0.11	0.63	0.17	0.00	0.00	none	-0.02	0.78	-0.02	0.05	1.23	0.04
25	0.09	0.63	0.15	0.00	0.00	none	-0.01	0.78	-0.01	0.99	1.26	0.78
26	0.07	0.63	0.10	0.00	0.00	none	0.05	0.78	0.06	-0.03	1.26	-0.03
27	0.07	0.63	0.12	0.00	0.00	none	0.03	0.76	0.04	-0.03	1.26	-0.03
28	0.09	0.63	0.14	0.00	0.00	none	0.12	0.72	0.17	0.03	1.23	0.02
29	0.13	0.63	0.21	0.00	0.00	none	0.07	0.59	0.12	0.18	1.23	0.15
30	0.12	0.63	0.19	0.00	0.00	none	0.07	0.72	0.10	0.72	1.26	0.57
31	0.18	0.63	0.28	0.00	0.00	none	1.12	0.78	1.44	0.18	1.23	0.15
	Average =		**0.15**	**Average =**		**none**	**Average =**		**0.25**	**Average =**		**0.22**

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
JUNE 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.19	0.63	0.31	-0.01	0.30	-0.03	1.98	0.78	2.54	0.22	1.22	0.18
2	0.19	0.63	0.30	0.13	1.03	0.13	1.39	0.78	1.78	0.91	1.26	0.72
3	0.19	0.63	0.30	0.29	1.03	0.28	0.84	0.78	1.08	0.25	1.23	0.20
4	0.22	0.63	0.35	1.77	1.21	1.46	-0.02	0.78	-0.03	0.32	1.23	0.26
5	0.32	0.63	0.51	0.51	1.15	0.45	-0.02	0.78	-0.03	0.90	1.26	0.72
6	0.35	0.63	0.56	0.96	1.17	0.81	-0.02	0.78	-0.03	0.21	1.26	0.17
7	0.25	0.63	0.40	0.01	1.15	0.01	-0.02	0.78	-0.03	0.30	1.23	0.24
8	0.22	0.63	0.34	1.20	1.17	1.03	0.00	0.78	0.00	0.25	1.23	0.20
9	0.24	0.63	0.38	0.01	1.15	0.01	0.19	0.78	0.25	1.15	1.26	0.92
10	0.28	0.63	0.44	1.18	1.21	0.98	0.22	0.76	0.29	0.14	1.26	0.11
11	0.18	0.63	0.28	0.05	1.15	0.04	0.16	0.73	0.22	0.19	1.26	0.15
12	0.26	0.63	0.42	0.96	1.21	0.80	0.13	0.72	0.19	0.33	1.23	0.26
13	0.30	0.63	0.47	0.11	1.15	0.10	0.18	0.72	0.26	0.32	1.23	0.26
14	0.32	0.63	0.52	1.08	1.21	0.90	0.15	0.72	0.21	0.82	1.26	0.65
15	0.34	0.63	0.53	0.06	1.15	0.06	0.15	0.72	0.21	0.26	1.26	0.21
16	0.38	0.63	0.61	0.62	1.17	0.52	0.14	0.72	0.19	0.32	1.23	0.26
17	0.38	0.63	0.61	0.63	1.17	0.54	0.13	0.72	0.18	0.29	1.23	0.23
18	0.33	0.63	0.53	0.19	1.15	0.16	0.13	0.72	0.18	1.10	1.26	0.88
19	0.34	0.63	0.54	1.11	1.21	0.92	0.12	0.72	0.16	0.26	1.26	0.20
20	0.36	0.63	0.58	0.14	1.17	0.12	0.17	0.72	0.24	0.31	1.26	0.25
21	0.36	0.63	0.56	0.42	1.17	0.35	0.18	0.72	0.26	0.24	1.23	0.19
22	0.40	0.63	0.64	0.91	1.21	0.75	0.16	0.72	0.22	0.15	1.23	0.12
23	0.40	0.63	0.64	0.16	1.17	0.14	0.15	0.72	0.21	0.92	1.26	0.73
24	0.38	0.63	0.60	0.48	1.17	0.41	0.18	0.72	0.25	0.20	1.26	0.16
25	0.39	0.63	0.61	0.86	1.21	0.71	0.20	0.72	0.28	0.19	1.26	0.15
26	0.29	0.63	0.47	0.10	1.17	0.08	0.18	0.72	0.26	0.25	1.23	0.20
27	0.29	0.63	0.47	0.26	1.17	0.22	0.24	0.59	0.42	0.18	1.23	0.15
28	0.29	0.63	0.47	0.97	1.21	0.80	0.16	0.59	0.27	0.86	1.26	0.69
29	0.27	0.63	0.43	0.07	1.17	0.06	0.15	0.72	0.21	0.08	1.26	0.06
30	0.33	0.63	0.53	0.18	1.17	0.15	0.15	0.72	0.21	0.06	1.23	0.05
	Average =		0.48	Average =		0.43	Average =		0.35	Average =		0.32

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
JULY 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.37	0.63	0.58	1.11	1.17	0.95	0.13	0.59	0.23	0.13	1.23	0.11
2	0.31	0.63	0.50	0.39	1.17	0.34	0.15	0.59	0.26	0.97	1.23	0.78
3	0.38	0.61	0.62	0.39	1.15	0.34	0.15	0.59	0.26	-0.01	1.26	0.00
4	0.38	0.59	0.64	0.31	1.11	0.28	0.16	0.59	0.27	-0.04	1.26	-0.03
5	0.39	0.59	0.66	0.36	1.09	0.33	0.13	0.59	0.23	0.11	1.26	0.09
6	0.40	0.63	0.63	1.01	1.17	0.86	0.12	0.59	0.20	0.21	1.23	0.17
7	0.33	0.63	0.52	0.29	1.17	0.24	0.15	0.72	0.20	0.99	1.23	0.80
8	0.27	0.63	0.42	0.31	1.15	0.27	0.12	0.72	0.17	-0.01	1.26	-0.01
9	0.27	0.63	0.42	0.96	1.17	0.82	0.11	0.72	0.16	-0.04	1.26	-0.03
10	0.09	0.63	0.15	0.13	1.17	0.11	0.10	0.59	0.18	0.03	1.26	0.03
11	0.14	0.63	0.23	-0.03	1.15	-0.03	0.12	0.72	0.17	0.15	1.23	0.12
12	0.26	0.63	0.42	-0.03	1.15	-0.03	0.11	0.59	0.19	0.14	1.22	0.11
13	0.27	0.63	0.43	0.11	1.17	0.10	0.15	0.72	0.21	0.11	1.16	0.09
14	0.26	0.63	0.41	0.46	1.17	0.39	0.20	0.72	0.28	0.06	0.95	0.06
15	0.23	0.63	0.37	0.97	1.17	0.82	0.18	0.72	0.25	0.00	0.95	0.00
16	0.20	0.63	0.31	0.29	1.17	0.25	0.19	0.72	0.26	0.00	0.32	0.00
17	0.18	0.63	0.28	0.15	1.15	0.13	0.18	0.72	0.25	0.00	0.00	none
18	0.23	0.63	0.37	0.99	1.17	0.84	0.23	0.72	0.32	0.00	0.00	none
19	0.24	0.63	0.38	0.35	1.17	0.30	0.19	0.72	0.27	0.00	0.00	none
20	0.22	0.63	0.35	0.50	1.15	0.44	0.19	0.72	0.27	0.00	0.00	none
21	0.20	0.63	0.32	0.82	1.17	0.70	0.15	0.73	0.21	0.00	0.00	none
22	0.14	0.63	0.22	0.28	1.17	0.24	0.15	0.72	0.21	0.00	0.00	none
23	0.14	0.63	0.23	0.43	1.15	0.37	0.19	0.73	0.26	0.00	0.00	none
24	0.10	0.63	0.16	0.15	1.15	0.13	0.13	0.73	0.18	0.00	0.00	none
25	-0.02	0.61	-0.03	-0.03	1.14	-0.03	-0.02	0.72	-0.03	0.00	0.00	none
26	-0.02	0.61	-0.03	-0.03	1.09	-0.03	-0.02	0.72	-0.03	0.00	0.00	none
27	-0.02	0.59	-0.03	-0.03	1.03	-0.03	-0.02	0.59	-0.03	0.00	0.00	none
28	-0.02	0.58	-0.03	-0.01	0.30	-0.03	-0.02	0.59	-0.03	0.00	0.00	none
29	-0.02	0.58	-0.03	0.00	0.12	-0.03	-0.02	0.59	-0.03	0.00	0.00	none
30	-0.02	0.58	-0.03	0.00	0.00	none	-0.02	0.59	-0.03	0.00	0.00	none
31	-0.01	0.47	-0.03	0.00	0.00	none	-0.01	0.39	-0.03	0.00	0.00	none
	Average =		0.30	Average =		0.31	Average =		0.17	Average =		0.14

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
AUGUST 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
2	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
3	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
4	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
5	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
6	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
7	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
8	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
9	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
10	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
11	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
12	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
13	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
14	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
15	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
16	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
17	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
18	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
19	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
20	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
21	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
22	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
23	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
24	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
25	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
26	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
27	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
28	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
29	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
30	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
31	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
	Average =		none	Average =		none	Average =		none	Average =		none

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
SEPTEMBER 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
2	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
3	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
4	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
5	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
6	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
7	0.09	0.03	2.90	0.00	0.00	none	0.17	0.04	4.31	0.11	0.06	1.78
8	0.31	0.06	4.85	0.00	0.00	none	0.45	0.59	0.77	0.48	0.32	1.52
9	0.63	0.16	3.97	0.00	0.00	none	0.09	0.59	0.15	0.81	0.95	0.86
10	0.54	0.60	0.90	0.00	0.00	none	0.06	0.59	0.10	0.93	1.23	0.75
11	0.15	0.57	0.26	0.00	0.00	none	0.12	0.20	0.61	0.22	0.95	0.24
12	0.00	0.16	-0.02	0.00	0.00	none	0.00	0.08	-0.02	-0.01	0.32	-0.03
13	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
14	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
15	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
16	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
17	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
18	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
19	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
20	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
21	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
22	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
23	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
24	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
25	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
26	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
27	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
28	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
29	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
30	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
	Average =		2.14	Average =		none	Average =		0.99	Average =		0.85

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
OCTOBER 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.00	0.00	none	0.94	0.30	3.12	0.00	0.00	none	0.00	0.00	none
2	0.00	0.00	none	1.31	0.30	4.33	0.00	0.00	none	0.00	0.00	none
3	0.00	0.00	none	1.29	0.30	4.25	0.00	0.00	none	0.00	0.00	none
4	0.00	0.00	none	1.24	0.30	4.10	0.00	0.00	none	0.00	0.00	none
5	0.00	0.00	none	1.27	0.30	4.20	0.00	0.00	none	0.00	0.00	none
6	0.00	0.00	none	1.87	0.61	3.08	0.00	0.00	none	0.00	0.00	none
7	0.00	0.00	none	0.93	0.30	3.08	0.00	0.00	none	0.00	0.00	none
8	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
9	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
10	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
11	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
12	0.00	0.00	none	0.40	0.30	1.32	0.00	0.00	none	0.00	0.00	none
13	0.00	0.00	none	1.56	0.61	2.58	0.00	0.00	none	0.00	0.00	none
14	0.00	0.00	none	2.24	1.06	2.10	0.00	0.00	none	0.00	0.00	none
15	0.00	0.00	none	1.97	1.11	1.77	0.00	0.00	none	0.00	0.00	none
16	0.00	0.00	none	1.87	1.14	1.64	0.00	0.00	none	0.00	0.00	none
17	0.00	0.00	none	0.96	1.03	0.93	0.00	0.00	none	0.00	0.00	none
18	0.00	0.00	none	1.45	0.61	2.40	0.07	0.59	0.12	0.00	0.00	none
19	0.00	0.00	none	1.89	1.03	1.84	0.36	0.72	0.50	0.00	0.00	none
20	0.00	0.00	none	2.01	1.03	1.95	0.39	0.72	0.55	0.00	0.00	none
21	0.00	0.00	none	1.65	1.09	1.51	0.45	0.72	0.62	0.00	0.00	none
22	0.00	0.00	none	1.72	1.14	1.51	0.27	0.59	0.46	0.00	0.00	none
23	0.00	0.00	none	1.85	1.17	1.58	0.00	0.20	0.02	0.00	0.00	none
24	0.00	0.00	none	1.12	1.15	0.98	0.00	0.00	none	0.00	0.00	none
25	0.00	0.00	none	1.49	1.15	1.29	0.45	0.72	0.63	0.00	0.00	none
26	0.00	0.00	none	1.35	1.15	1.17	0.15	0.59	0.26	0.00	0.00	none
27	0.00	0.00	none	1.35	1.15	1.17	0.09	0.72	0.12	0.00	0.00	none
28	0.00	0.00	none	1.33	1.15	1.16	0.07	0.72	0.10	0.00	0.00	none
29	0.00	0.00	none	1.22	1.15	1.06	0.07	0.72	0.10	0.00	0.00	none
30	0.00	0.00	none	1.22	1.15	1.06	0.08	0.72	0.11	0.00	0.00	none
31	0.00	0.00	none	1.05	1.15	0.91	0.04	0.72	0.06	0.00	0.00	none
	Average =		none	Average =		2.08	Average =		0.32	Average =		none

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
NOVEMBER 2007

Day	Cell 1			Cell 2			Cell 3			Cell 4		
	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.00	0.00	none	1.06	0.93	none	0.09	0.72	0.12	0.00	0.00	#DIV/0!
2	1.06	0.32	3.35	1.07	0.94	3.35	0.11	0.72	0.15	0.75	0.32	2.37
3	0.54	0.32	1.72	0.46	1.52	1.72	0.12	0.72	0.16	0.67	0.95	0.71
4	0.70	0.32	2.21	0.52	4.30	2.21	0.17	0.72	0.23	0.63	1.16	0.54
5	0.94	0.47	1.99	0.80	2.66	1.99	0.15	0.72	0.20	0.21	1.16	0.18
6	0.93	0.58	1.60	0.93	3.07	1.60	0.18	0.72	0.25	0.00	0.00	none
7	0.73	0.61	1.20	1.58	2.62	1.20	0.18	0.72	0.25	0.00	0.00	none
8	0.73	0.61	1.19	1.41	1.37	1.19	0.19	0.72	0.27	0.00	0.00	none
9	0.52	0.61	0.85	0.60	0.58	0.85	0.16	0.72	0.22	0.39	0.32	1.23
10	0.60	0.61	0.99	0.00	none	0.99	0.16	0.72	0.22	0.94	1.22	0.77
11	0.58	0.63	0.92	0.00	none	0.92	0.16	0.72	0.22	0.41	1.26	0.33
12	0.45	0.63	0.71	0.00	none	0.71	0.08	0.72	0.11	0.64	1.23	0.52
13	0.44	0.63	0.70	0.00	none	0.70	0.07	0.72	0.09	0.00	1.23	0.00
14	0.45	0.63	0.71	0.00	none	0.71	0.07	0.72	0.10	0.78	1.23	0.63
15	0.43	0.63	0.68	0.00	none	0.68	0.07	0.72	0.10	0.00	1.23	-0.01
16	0.43	0.63	0.69	0.00	none	0.69	0.07	0.72	0.10	0.71	1.23	0.58
17	0.44	0.63	0.70	0.00	none	0.70	0.10	0.72	0.13	0.00	1.23	0.00
18	0.44	0.63	0.70	0.00	none	0.70	0.10	0.72	0.13	0.66	1.23	0.54
19	0.44	0.63	0.70	0.00	none	0.70	0.06	0.72	0.08	0.01	1.23	0.01
20	0.46	0.63	0.72	0.00	none	0.72	0.07	0.72	0.09	0.62	1.23	0.50
21	0.43	0.63	0.69	0.00	none	0.69	0.06	0.72	0.08	0.00	1.23	0.00
22	0.46	0.63	0.73	0.00	none	0.73	0.03	0.72	0.04	0.55	1.23	0.44
23	0.48	0.63	0.76	0.00	none	0.76	0.11	0.72	0.15	0.00	1.23	0.00
24	0.45	0.63	0.71	0.00	none	0.71	0.07	0.72	0.10	0.52	1.23	0.42
25	0.45	0.63	0.71	0.00	none	0.71	0.00	0.72	0.00	0.00	1.23	0.00
26	0.44	0.63	0.70	0.00	none	0.70	0.00	0.72	0.00	0.55	1.23	0.44
27	0.48	0.63	0.76	0.00	none	0.76	0.00	0.72	0.00	0.00	1.23	0.00
28	0.46	0.63	0.73	0.00	none	0.73	0.00	0.72	0.00	0.76	1.23	0.62
29	0.46	0.63	0.73	0.00	none	0.73	0.06	0.78	0.08	0.77	1.26	0.61
30	0.49	0.63	0.78	0.00	none	0.78	0.05	0.78	0.06	0.00	1.26	0.00
	Average =		1.02	Average =		2.00	Average =		0.12	Average =		0.44

APPENDIX D
MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT
DAILY INFILTRATION RATES
DECEMBER 2007

		Cell 1			Cell 2			Cell 3			Cell 4	
Day	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)	Recharge Volume (AF)	Wetted Area (acres)	Infiltration Rate (feet/day)
1	0.08	0.61	0.13	0.00	0.00	none	2.18	0.90	2.41	0.20	1.22	0.16
2	0.66	0.58	1.15	0.00	0.00	none	2.14	1.08	1.97	0.41	1.26	0.32
3	0.00	0.59	0.00	0.00	0.00	none	0.85	1.08	0.78	0.00	1.23	0.00
4	0.50	0.47	1.06	0.00	0.00	none	0.77	0.78	0.98	0.81	1.23	0.66
5	0.16	0.47	0.33	0.00	0.00	none	0.04	0.59	0.07	0.09	1.16	0.08
6	0.00	0.00	none	0.00	0.00	none	0.00	0.20	none	0.00	0.32	none
7	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
8	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
9	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
10	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
11	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
12	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
13	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
14	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
15	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
16	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none	0.00	0.00	none
17	0.08	0.16	0.52	0.00	0.00	none	0.15	0.00	none	0.08	0.00	none
18	0.52	0.32	1.64	0.00	0.00	none	0.56	0.39	1.44	0.35	0.32	1.11
19	0.95	0.32	3.00	0.00	0.00	none	0.31	0.72	0.43	0.69	1.16	0.60
20	1.02	0.59	1.73	0.00	0.00	none	0.34	0.73	0.46	0.58	1.23	0.47
21	1.01	0.63	1.60	0.95	0.12	7.88	0.34	0.76	0.45	0.58	1.26	0.46
22	0.59	0.59	1.00	1.19	0.30	3.95	0.23	0.73	0.32	0.26	1.23	0.21
23	0.47	0.59	0.80	1.07	0.30	3.55	0.00	0.59	0.00	0.26	1.23	0.21
24	0.41	0.58	0.71	0.83	0.30	2.74	0.00	0.39	0.00	0.31	1.22	0.25
25	0.31	0.58	0.53	0.50	0.12	4.13	0.00	0.00	none	0.21	1.22	0.17
26	0.58	0.58	1.00	0.77	0.30	2.54	0.00	0.00	none	0.23	1.23	0.18
27	0.32	0.58	0.55	0.90	0.30	2.98	0.00	0.00	none	0.36	1.23	0.29
28	0.26	0.47	0.56	1.00	0.30	3.32	0.00	0.00	none	0.34	1.23	0.28
29	0.71	0.47	1.51	0.72	0.30	2.39	0.00	0.00	none	0.29	1.23	0.23
30	0.64	0.47	1.36	0.58	0.30	1.91	0.00	0.00	none	0.25	1.23	0.20
31	0.48	0.58	0.83	0.60	0.30	1.98	0.00	0.00	none	0.28	1.23	0.23
	Average =		1.00	Average =		3.40	Average =		0.72	Average =		0.31

APPENDIX E

Magnetoflow® Mag Meter	Flanged Meter with Model Primo® 3.1	Installation & Operation Manual

IMPORTANT !!!! This manual contains important warnings and information. READ AND KEEP FOR REFERENCE.

SCOPE OF THIS MANUAL

This manual contains information concerning the installation, operation and maintenance of Badger's Magnetoflow® electromagnetic flow meter models with Primo® Amplifier.

To ensure proper meter performance, the instructions given in this manual should be thoroughly understood. Keep a copy of this manual in a readily accessible location for future reference.

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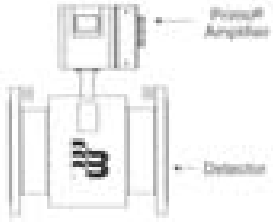
SYSTEM DESCRIPTION

Magnetoflow® electromagnetic flow meters are intended for fluid metering in most industries including water, wastewater, food and beverage, pharmaceutical and chemical.

The basic components of an electromagnetic flow meter are two: 1) The Detector, which includes the flow tube, isolating liner and measuring electrodes, and 2) the Amplifier, which is the electronic device responsible for the signal processing, flow calculation, display and output signals.



The materials of construction of the wetted parts (liner and electrodes) should be appropriate for the specifications on the intended type of service. Review of the compatibilities consistent with the specifications is recommended.

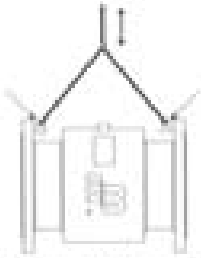
All Badger's Magnetoflow mag flow meters are factory tested and calibrated. A calibration certificate is included in the shipment of each meter.

UNPACKING AND INSPECTION

Magnetoflow mag flowmeters are shipped in special shipping containers. Upon receipt of the meter, perform the following unpacking and inspection procedures. If damage to the shipping container is evident, be present when the meter is unpacked.

A) Carefully open the shipping container following any instructions that may be marked on the exterior. Remove all cushioning material surrounding the meter.

B) Carefully lift the meter from the container. Always use the lifting lugs provided for safety on meter sizes 10" and larger.



C) Retain the shipping box or crate and all packing materials for possible use in reshipment or storage.

D) Visually inspect the meter for any physical damage such as scratches, loose or broken parts, or any other sign of damage that may have occurred during shipment.

NOTE: If damage is found, request an inspection report by the carrier's agent within 48 hours of delivery. Then file a claim with the carrier. A formal claim for equipment damaged in transit is the responsibility of the customer.

E) Verify that the meter received is consistent with the product ordered. The detail on the product labels on the detector and the amplifier should help this verification.

F) All detectors with PTFE liner are shipped from the factory with a liner protector. This protector maintains the proper form of the PTFE material and protects it during shipping and storage. Do not remove this protector until you are ready to install the unit.

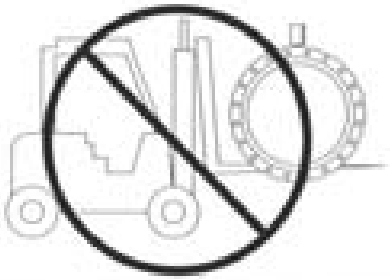
G) Storage: If the meter is not to be immediately installed, store it in its original container in a dry, sheltered location. Storage temperature: -4 to 158 °F (-20 to 70 °C)

TRANSPORTATION AND HANDLING

Do not lift the detector from the amplifier housing, the junction box or the connecting cable. As noted earlier, use lifting lugs for larger sizes.

Very large meter sizes are packed and crated with the meter laying on its side for shipping safety and stability reasons. In order to lift the meter in vertical position, it's recommended to use a sling rigged method as shown below.

If using a forklift, do not lift the detector from its body between the flanges. The housing could be accidentally dented and permanent damage could be caused to the internal coil assemblies.



IMPORTANT:
NEVER introduce the forks of a forklift, chains, wire slings or any other sharp object inside the flow tube for lifting or handling purposes. This could permanently damage the isolating liner and could render the meter inoperable.

METER INSTALLATION

METER LOCATION GUIDELINES

The following are several guidelines for determination of a good location for meter installation:

Temperature Ranges
In order to prevent damage to the meter, the maximum temperature ranges must be observed.

Primo® Amplifier
Ambient temperature: -4 to 140°F (-20 up to +60°C)

Meter with Meter Mount Primo
Fluid temperature: PTFE/PFA, -40 to 212°F (-40 up to +100°C)
Hard/Soft Rubber, 32 to 176°F (0 up to +80°C)

Outdoor Installations - Primo Amplifier
The Primo Amplifier can be installed outdoors but with a few requirements:

1. The ambient environment must not be out of the temperature ratings for the unit. (-4 to 140°F)

2. The Primo must be protected to some degree from the outside elements. At a minimum, a roof or shield of sorts should be fabricated over the unit to protect the LCD display from the sunlight. It will also keep the unit out of the possibility of a hard sustained rain which could cause moisture to get into the unit. An alternative approach would be to simply mount the unit in a "Hoffman style" outdoor enclosure, eliminating the potential of either issue arising.

If an indoor environment is within 250 feet of the Mag meter installation, consideration should be given to increase the cable length and mount the Primo indoors.

Meter with Remote Mount Primo
Fluid temperature: PTFE/PFA, -40 to 302°F (-40 up to +150°C)
Hard/Soft Rubber, 32 to 176°F (0 to +80°C)

Chemical Injection Applications
For water line applications with a chemical injection point, the meter should be installed upstream of the chemical injection point to eliminate any issues with the meter performance. If an upstream location is not possible for the meter, consider moving the injection point downstream of the meter location. If the meter must be installed downstream of the chemical injection point, the distance between these (2) locations must be significant; frequently 50 - 100 feet.

When the solution made up of the water and the injected chemical reach the Mag meter, it must be a complete homogeneous mixture. If too close, the Mag meter will sense (2) different liquids (conductivity different for each) and will be confused as to how to process the information. Many other factors such as the type of injection method, (spaced bursts versus continuous stream of drops), or whether the chemical is injected in a liquid or gas form, can cause a wide variation in the distance required from one application to another.

Due to this wide range of factors, it is difficult to specify a distance that will always work for any application without establishing a value far in excess of what would usually be required. Please contact Badger Meter's Technical Support at 1-800-456-5023 with your application detail and they can assist in determining if the Mag meter should properly perform. As noted, the meter may require 50 - 100 feet from the injection point to assure the complete homogeneous state.

Submersible Option
If the meter is to be installed in a meter vault, it should be ordered with the remote amplifier option to be sure the amplifier is not installed inside the vault. It is also recommended that the remote style meter package be ordered with the submersible option (Nema 6P). This will eliminate any potential problems from occurring should the vault become flooded or from any presence of humidity in the vault.

Other Considerations
Avoid all pipe locations where the flow is pulsating, such as in the outlet side of piston or diaphragm pumps.

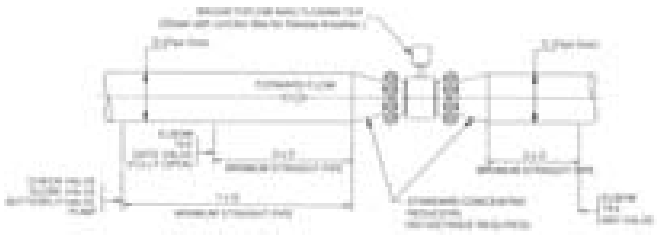
Avoid locations near equipment producing electrical interference such as electric motors, transformers, variable frequency, etc.

Install the meter with enough room for future access for maintenance purposes.

The mag meter isolating liner, whether if it is PTFE or Rubber, is not intended to be used as gasket material. Standard gaskets (not provided) should be installed to ensure a proper hydraulic seal. When installing the gaskets, make sure they are properly centered to avoid flow restriction or turbulence. Do not use graphite or any electrically conductive sealing compound to hold the gaskets in place during installation. This could affect the reading accuracy of the measuring signal.

STRAIGHT PIPE REQUIREMENTS

For optimum accuracy performance, it is required to provide sufficient inlet and outlet straight pipe runs. An equivalent to 3 diameters of straight pipe is required on the inlet side, and 2 diameters on the outlet side. There are no special requirements for standard concentric pipe reducers.



By using pipe reducers, a smaller meter size can be mounted in larger pipeline sizes. This may also increase low flow accuracy performance.

In order to minimize flow disturbances and excessive loss of head, custom fabricated pipe reducers must have a minimum slope angle of 15 degrees. If this is not possible, install the custom pipe reducers as if they were fittings, leaving the minimum straight pipe required.

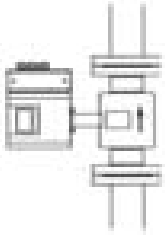
Mounting Location
The detector should never be installed on the suction side of a pump where a vacuum exists to eliminate the possibility of damage to the liner.

If vibration exits on the pipeline, secure the piping before and after the meter. If a strong vibration exists, the amplifier should be mounted remotely.

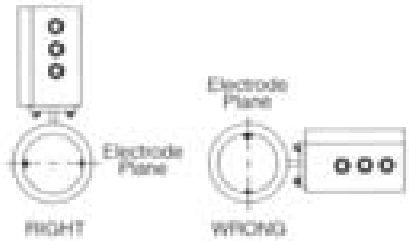
Remote Version
Do not install cables near power cables, electrical machines, etc. Be sure both ends of signal cable are securely fastened. Run power and signal cables in separate conduit.

METER ORIENTATION
Magnetoflow® Mag meters can operate accurately in any pipe orientation and can measure the volumetric flow in the forward and reverse directions (note FORWARD FLOW direction printed on the detector label). The most recommended installation position is vertical piping, with the liquid flowing upward (see figure below).

This installation practice ensures two objectives:
1. The pipe remains completely full of liquid, even at low flow, low pressure applications with a discharge to the atmosphere.
2. Solid build-ups or sediments that could be part of the process fluid will not deposit or accumulate on the liner and/or electrodes.

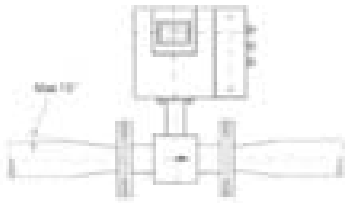


In horizontal piping orientation, the detector should be mounted in a position at which the measuring electrodes axis will remain in a horizontal plane (3 and 9 o'clock position; see figure below)



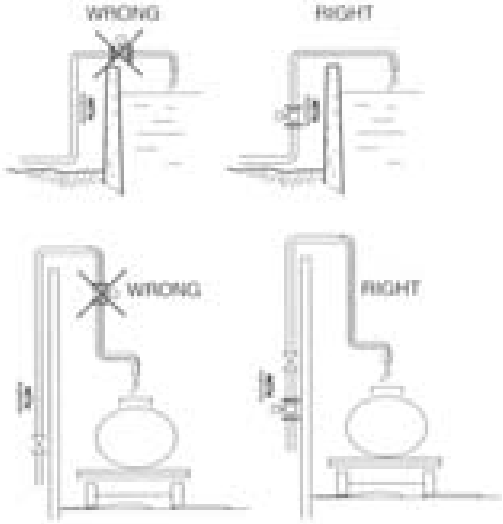
For very low flow rate applications, the flow rate can be increased by reducing the meter size and therefore the measuring accuracy can be improved.

Pipe reducers can be mounted directly to the inlet and outlet of the meter. The reducer can not have an angle greater than 15°. The resultant pressure drop is negligible; in most cases less that 1 psi.



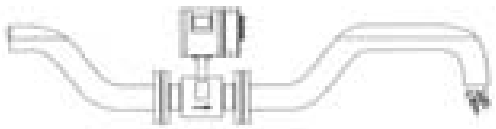
PARTIALLY FILLED PIPE SITUATIONS
Magnetoflow® mag meters are designed to operate in closed, full pipes.

It is relatively common to encounter situations where the process pipe will remain momentarily partially filled due to certain hydraulic conditions. Examples of this include discharge to the atmosphere (lack of back pressure), insufficient line pressure, gravity flow applications, etc.



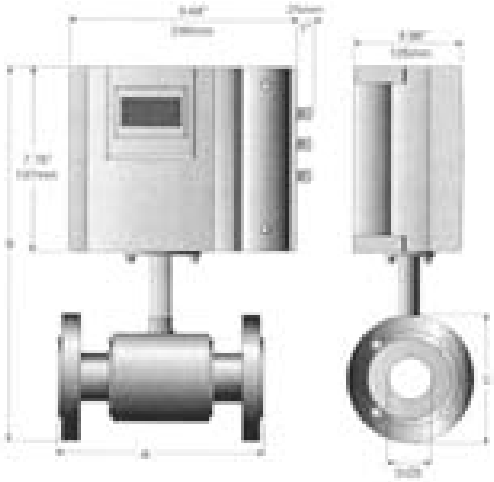
To eliminate the negative effect of these situations on the performance of the mag meter, observe the following guidelines:
- Avoid installing the detector in the highest point of the pipe line
- Do not install the detector in vertical, downward flow sections of the pipe
- ON/OFF valves should ALWAYS be located on the downstream side of the meter
- Select the recommended vertical orientation with flow upwards whenever possible
- Make sure that the flow range of the meter size selected is consistent with the application flow range

To minimize the possibility of partially full pipe flows in horizontal, gravity or low pressure applications, it is recommended to create a pipe arrangement as shown in the figure below. This arrangement ensures the detector remains full of liquid at all times.

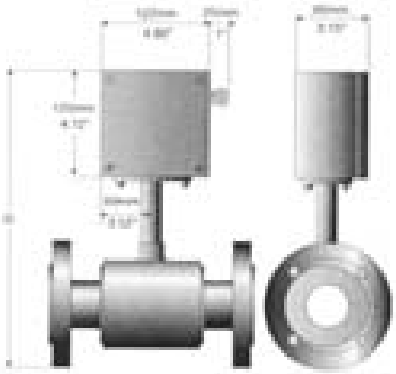


Open Discharge
Horizontal Installation

Open Discharge
Horizontal



Meter with Primo®



Meter with junction box for remote Primo®

Size		A		B		C		D		Est. Weight with Primo		Flow Range LPM		Flow Range GPM	
inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	Lbs	Kg	Min	Max	Min	Max
1/4	6	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.063	20	0.02	5
5/16	8	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.114	34	0.03	9
3/8	10	6.7	170	14.0	356	3.5	89	11.4	288	12	5.5	0.177	53	0.05	14
1/2	15	6.7	170	14.0	356	3.5	89	11.4	288	13	5.5	0.416	125	0.11	33
3/4	20	6.7	170	14.2	361	3.9	99	11.5	293	15	6.5	0.75	225	0.2	59
1	25	8.9	225	14.4	366	4.3	108	11.7	298	20	9.0	1.20	350	0.3	93
1 1/4	32	8.9	225	15.2	386	4.6	117	12.5	318	22	10.0	2.00	575	0.5	152
1 1/2	40	8.9	225	15.4	390	5.0	127	12.7	322	23	10.5	3.00	900	0.8	239
2	50	8.9	225	15.9	403	6.0	152	13.2	335	28	12.5	4.70	1400	1	373
2 1/2	65	11.0	280	17.1	434	7.0	178	14.4	366	54	24.5	8	2400	2	631
3	80	11.0	280	17.3	440	7.5	191	14.7	372	56	25.5	12	3600	3	956
4	100	11.0	280	18.4	466	9.0	229	15.7	398	58	26.5	19	5600	5	1493
5	125	15.8	400	19.6	498	10.0	254	16.9	430	60	27.0	30	8800	8	2334
6	150	15.8	400	20.6	524	11.0	279	17.9	456	62	28.0	40	12700	11	3361
8	200	15.8	400	22.5	572	13.5	343	20.4	518	88	40.0	75	22600	20	5975
10	250	19.7	500	26.8	681	16.0	406	24.1	613	180	82.0	120	35300	30	9336
12	300	19.7	500	28.9	734	19.0	483	26.2	666	209	95.0	170	50800	45	13444
14	350	19.7	500	30.8	782	21.0	533	28.2	716	260	118	230	69200	60	18299
16	400	23.6	590	33.7	856	23.5	597	31.0	788	308	140	300	95400	80	25201
18	450	23.6	590	35.0	890	25.0	635	32.4	822	287	130	380	114000	100	30250
20	500	23.6	590	38.2	969	27.5	699	35.5	901	495	225	470	140000	125	37346
22	550	23.6	590	39.6	1005	29.5	749	36.9	937	441	200	570	170000	150	45188
24	600	23.6	590	42.2	1071	32.0	813	39.5	1003	554	252	680	200000	180	53778
28	700	23.6	590	46.2	1173	36.5	927	44.0	1118	650	295	920	275000	240	73100
30	750	31.5	800	48.3	1228	39.0	984	45.7	1161	704	320	1060	315000	280	84000
32	800	31.5	800	52.2	1325	41.4	1015	49.5	1257	770	350	1200	361000	320	95800
36	900	31.5	800	55.3	1405	46.0	1168	54.1	1374	850	386	1500	457000	400	121000
40	1000	31.5	800	60.0	1525	50.2	1230	57.4	1457	924	420	1900	565000	500	149300
42	1050	36.0	800	66.0	1675	53.0	1346	63.4	1610	1100	500	2100	620000	550	164600
48	1200	39.4	1000	69.9	1775	59.4	1455	67.2	1707	1210	550	2700	814000	720	215100
54	1400	39.4	1000	78.5	1995	68.4	1675	75.9	1927	1364	620	3700	1100000	980	292700

SPECIFICATIONS - Detector

Flow Range: 0.1 - 39.4 fps (0.03-12 m/s)
Sizes: 1/4" to 54" (6 to 1400 mm)
Min. Conductivity: ≥ 5 micromhos/cm
Accuracy: ± 0.25% accuracy of rate from 1-33 fps.
± 0.5% accuracy of rate from 0.1-1.0 fps.
Electrode Materials: Standard: Alloy C
Optional: 316 Stainless Steel, Gold/Platinum Plated, Tantalum, Platinum/Rhodium
Liner Material: PTFE up to 24", Soft and Hard Rubber from 1" to 54", Halar® from 14" to 40"
Fluid Temperature:
With Remote Converter:
PTFE & Halar 311°F, (155°C)
Rubber 176°F, (80°C)
With Meter Mounted Converter:
PTFE & Halar 212°F, (100°C)
Rubber 176°F, (80°C)
Pressure Limits: 150 psi (10Bar) optional 300psi (20Bar)
Coil Power: Pulsed DC

Ambient Temperature: -4°F to 140°F, (-20°C to 60°C)
Pipe Spool Material : 316 Stainless Steel
Optional: Submersible NEMA 6P/IP67 (Remote Amplifier Required) tested at 1.8m (6 feet) for 24 hours
Meter Housing Material: Carbon Steel welded
Flanges: Carbon Steel - Standard (ANSI B16.5 Class 150 RF)
316 Stainless Steel - Optional
Meter Enclosure Classification: Nema 4
Junction Box Enclosure Protection: (For Remote Converter Option) Powder coated die-cast aluminum, Nema 4
Cable Entries: 1/2" NPT Cord Grip
Optional Stainless Steel Grounding Rings:

Meter Size	Thickness (of one ring)
up thru 10"	.135"
12" to 20"	.187"

GROUNDING

IMPORTANT! In order to ensure proper operation, it is essential that the mag meter amplifier's input ground (zero voltage reference) will be electrically connected to the liquid media and to a good, solid earth ground reference.

Conductive Pipe Grounding

To achieve this, the meter body MUST be electrically connected to the liquid media. The mag meter flanges are provided with grounding bolts for this purpose.

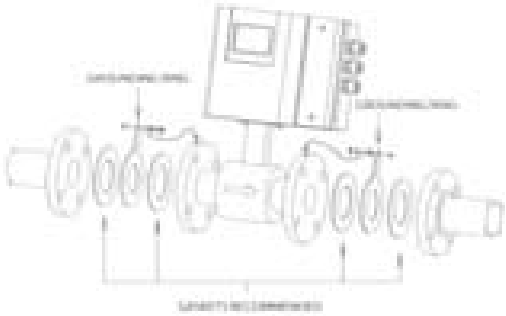
If the pipe material is electrically conductive, simply install grounding straps between these grounding bolts and the mating flanges.

To ensure a good electrical connection at the mating flanges, it is recommended to actually drill and tap the flanges to allow the installation of a grounding screw (not provided).

These grounding straps must be copper wire, at least 12AWG size, and must be connected on both sides (inlet and outlet) of the detector, and to a local earth ground.

IMPORTANT! If the process pipe is not electrically conductive (PVC, fiberglass or cement lined pipes) and the meter was not originally ordered with an optional grounding electrode, a pair of grounding rings must be installed between the mating flanges at both ends of the meter. See figure below.

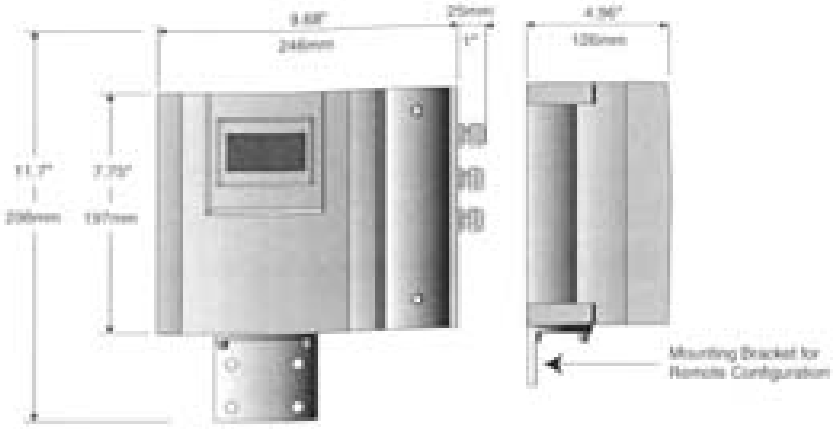
Non-Conductive Pipe Grounding



In this case, the grounding straps should be connected both to the grounding rings and to a good, solid earth ground.

Grounding rings are availabe in stainless steel. If your fluid to be measured is too aggressive for stainless steel, order meter with the optional grounding electrode in material option that will be compatible with the fluid.

PRIMO® AMPLIFIER (3.1 ELECTRONICS)



SPECIFICATIONS

Power Supply: 85-265 VAC, 45-65 Hz
Power Consumption: 20W
Accuracy: ± 0.25% accuracy of rate from 1-39.4 fps.
± 0.5% accuracy of rate from 0.1-1.0 fps.
Repeatability: 0.1%
Minimum Fluid Conductivity: 5.0 micromhos/cm
Flow Direction: Unidirectional or bidirectional, 2 separate totalizers (programmable)
Analog Outputs: 0/4-20mA, 800ohms Max Load, Active 18VDC
Ouput Frequency: Scaled Pulse output, (open collector) Max 5Khz
Digital Outputs:
Voltage sourcing transistor, 24VDC, 100mA max
(3) AC electro-mechanical relays, 48VAC, 0.5 amp max
Outputs: All ouputs are short circuit safe

Noise Dampening: Programmable from 1 to 6
Pulse Width: Programmable up to 500ms
Galvanic Isolation: ≤ 500V
Zero-point Stability: Automatic correction
LCD Display: 4 lines x 16 character back-lit alphanumeric Displays (2) Totalizers, Flow Rate, Alarm conditions
Housing: Cast aluminum, powder coated paint
Housing Rating: NEMA 4X
Mounting: Detector mount or remote mount (bracket supplied)
Cable Connection: 1/2" NPT Cord Grip
Ambient Temperature: -4 to 140° F (-20 to 60° C)
Serial Communication: RS232

WIRING

At installation, be sure to comply with the following requirements:

IMPORTANT!

- Disconnect power to the unit before attempting any connection or service to the unit
- Do not bundle or route signal lines with power lines
- Keep all lines as short as possible
- Use twisted pair shielded wire for all output wiring
- Observe all applicable local electrical codes

For the AC power connections use three wire sheathed cable with overall cable diameter of 0.2" to 0.45" (5mm to 12mm). For signal output use 18 to 22 gauge (0.25 mm² to 0.75mm²) shielded wire. Overall cable diameter between 0.12" to 0.35" (3mm to 9mm).

WIRING FOR REMOTE PRIMO® CONFIGURATION

Wiring between the detector and the Primo amplifier comes complete from the factory. If your installation requires the use of conduit, the following are recommended steps for wiring of the detector to the amplifier.

1. Remove the junction box lid. Carefully remove the wires connected to the terminal blocks that run to the Primo amplifier. Note which wire goes into which terminal. The chart below may be of assistance for reference of wire color and terminal connection.

2. Run cable through conduit from Primo amplifier location, retaining the wiring of the cable to the amplifier as supplied.

3. Complete conduit assembly on both ends and rewire cable into junction box as wired when received. See wiring diagram below.

Connection No.	Description	Wire color
11	Coil	Green
12	Coil	Yellow
13	Main Shield	Yellow/green
45	Electrode	White
44*	Electrode Shield	Black
46	Electrode	Brown
40	Empty Pipe	Pink
44*	Empty Pipe Shield	Black

*Connections with the No. 44 are tying on the same potential

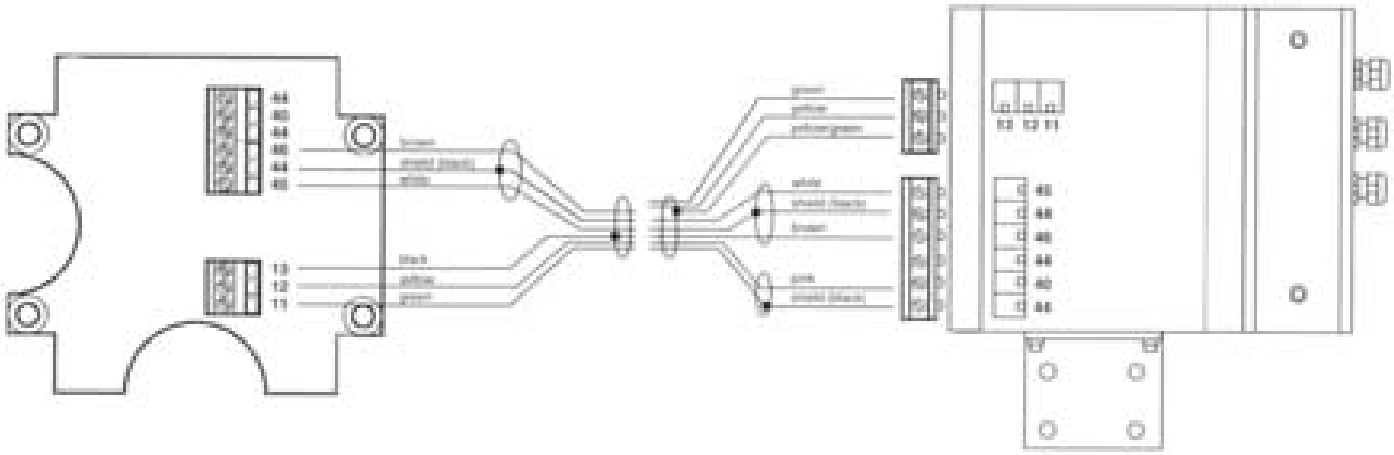
Remote style Primo Amplifier models can be ordered with longer cable than our standard stock lengths of the standard cable; 15, 30, 50 and 100 feet. The following chart shows the cable style options and the maximum flow medium temperature that can exist in the application environment at a given length of that cable.

		Cable Size		
		Standard	Medium	Large
		AWG 23	AWG 20	AWG 18
		0.25mm²	0.50mm²	0.75mm²
		Fluid Temperature		
Cable Length (Ft)	100	311F	311F	311F
	125	308F	311F	311F
	150	294F	311F	311F
	175	283F	311F	311F
	200	275F	311F	311F
	225	260F	312F	311F
	250	249F	309F	311F
	275		300F	311F
	300		296F	311F
	325		289F	311F
	350		283F	311F
	375		278F	309F
	400		272F	305F
	425		268F	302F
	450		260F	298F
	475		255F	294F
	500		249F	291F

Empty Pipe Detection Considerations

Cable Length (ft)	Minimum Conductivity Required (µS/cm)
0 (Meter Mount)	5
100	20
500	100

Wiring for Remote Primo Configuration



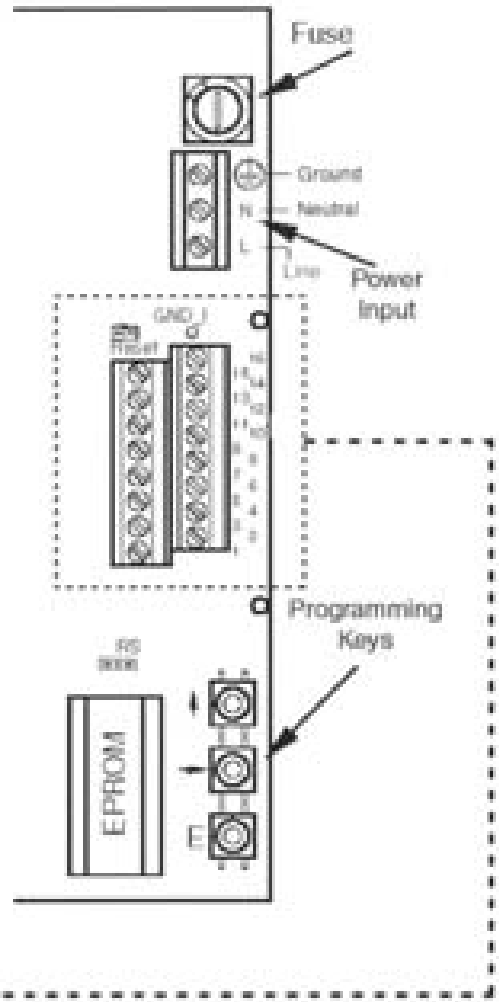
WIRING INPUTS AND OUTPUTS TO THE PRIMO® AMPLIFIER

Once the wiring between the sensor and the amplifier is done proceed to wire any inputs and outputs to the Primo amplifier.

IMPORTANT! For safety reasons leave AC power connections to the unit as the last step. Follow all the safety precautions and local code to prevent electrical shock and/or damaging of the electronic components.

1. Loosen the two bolts on the red amplifier cover. Remove the cover. Inside the amplifier you will see a terminal strip similar to the one depicted in the figure to the right.

Board Accessible with Red Cover Removed



POWER

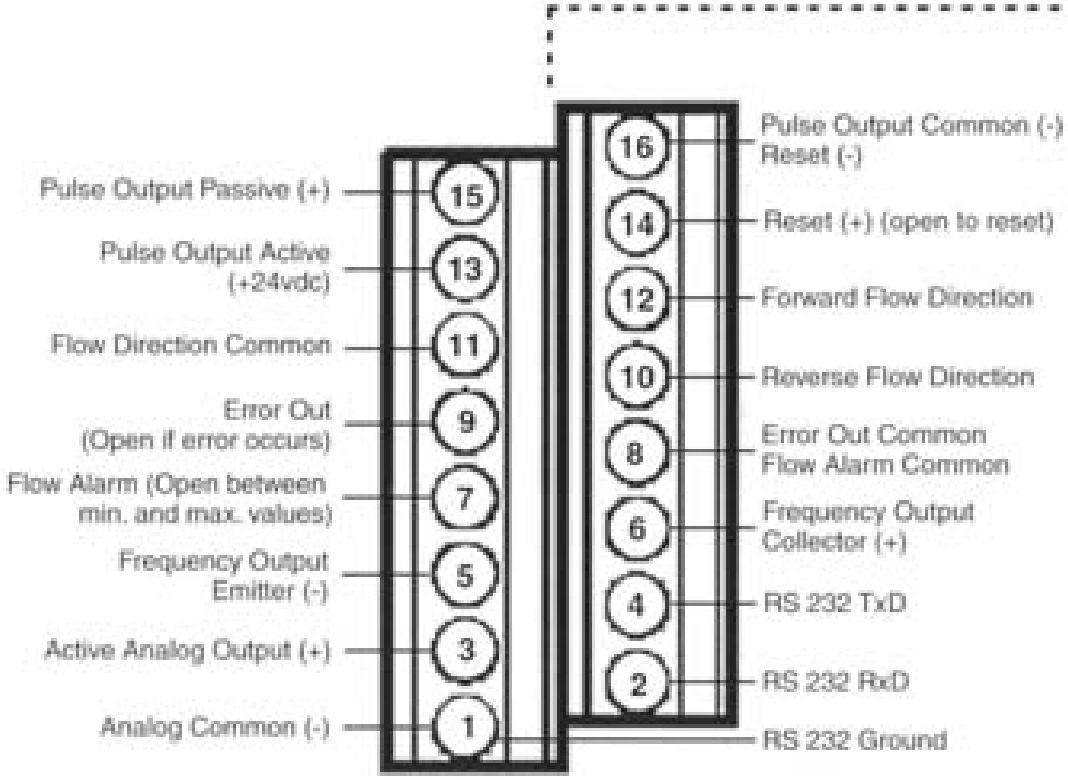
⚠CAUTION
To prevent accidents, power connection should be made only after all other connections have been completed.

The PRIMO amplifier is a microprocessor based device. **It is important that the power supply be as "clean" as possible.** Avoid using power lines that feed heavy loads such as pumps, motors, etc. If dedicated lines are not available, a filtering or isolation system might be required.

It is recommended that the internal fuse protection be maintained. Use a 2 amp slow blow fuse.

How to connect the amplifier to remote digital indicators/totalizers that do not require external power supply
This connection is intended for use with indicators that do not require an external power supply such as the ER series indicators from Badger Meter. For the ER-6, ER-8 or ER-9, connect terminal 15 of the Amplifier to terminal 2 of the ER series and terminal 16 to ground or terminal 1 of the ER indicator.

For connection to the PC 100 Controller, connect terminal 15 of the amplifier to terminal 14 of the PC 100 and terminal 16 of the amplifier to terminal 12 of the PC 100.



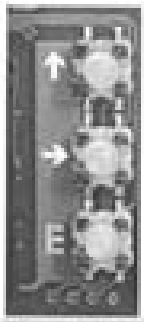
PROGRAMMING (3.1 Electronics)

The Primo® amplifier comes preprogrammed from the factory and in most instances will not require any additional manipulation. However, if you will be using the flow signal outputs or need to reprogram the meter to suit your particular needs, it will be necessary to familiarize yourself with the programming procedures.

Programming of the Primo Amplifier
This section gives step by step instruction on how to program each of the functions of the amplifier and an explanation of the choices that are available for each one.

First, using a small flat screwdriver, remove the red cover from the main amplifier housing. At the lower right corner of the unit you will see three square buttons. These buttons are used to perform all programming procedures.

Programming Keys



NOTE: The programming buttons have been placed inside the amplifier enclosure to prevent tampering or accidental reprogramming of the unit. After programming, be sure to reassemble the red cover on the enclosure.

The four line 16 digit LCD display of the Primo amplifier will guide you through each of the programming options/steps. The main screen will display:

1st Line:	Flow Rate
2nd Line:	Totalizer (TOT+ or TOT1)
3rd Line:	Totalizer (TOT- or TOT2)
4th Line:	Displays revision of software to assist in troubleshooting. This line is also used to display any error messages that may occur during operation of the meter.

The main display screen will be in one of the following modes. (See Flow Direction on page 11 for additional detail.)

Uni-Directional Mode

```
RATE   0.0000 GPM
TOT1       1000 G
TOT2       1000 G
V3.10Ues
```

Bi-Directional Mode

```
RATE   0.0000 GPM
TOT+      0.000 G
TOT-      0.000 G
V3.10Ues
```

By pressing the Enter or E key (bottom key), you will be at the main submenu screen. If no entry is done within 5 minutes while in any of the programming parameters, the program returns automatically to the main screen. Even during the parameter setting mode, the meter will be measuring and totalizing any flow that occurs.

```
 factors
 outputs/totals
>measurement
 back          E=End
```

There are three main submenus: factors, outputs/totals and measurement. Each submenu gives access to the following appropriate functions:

Factors:
1) Detector factor
2) Pipe diameter
3) Password protection

Outputs/Totals:
1) Reset totals
2) Analog outputs
3) Pulse outputs
4) Frequency
5) Flow alarm

Measurement:
1) Unit
2) Full scale
3) Low flow cutoff
4) Empty pipe detection
5) Flow direction
6) Filter
7) Error list

PROGRAMMING OF MEASUREMENT PARAMETERS

When the programming submenu screen appears, notice the right arrow on the far left side. Using the up ↑ arrow key, you can position the arrow in front of the submenu that you wish to interrogate. We recommend starting with the "measurement" submenu followed by the "outputs/totals" submenu and finally the "factors" submenu.

```
 factors
 outputs/totals
>measurement
 back          E=End
```

Use the ↑ key to position the > arrow next to "measurement" and press the → key. The following screen will appear:

UNIT OF MEASURE

```
 unit
 change
>next parameter
 back          E=End
```

This is where you will select the unit of measurement for the flow rate indication and the totalizers. Use the ↑ key to place the → arrow next

to "change" and press → key. The first unit of measurement screen will appear:

```
flow rate unit
 GPM
^ up   > down
E Enter
```

Using the ↑ or → keys select the desired unit of measure for flow rate indication.

Choices are:

L/h	Liters/hour
L/m	Liters/minute
l/s	Liters/second
m³/h	Cubic meters/hour
m³/m	Cubic meters/minute
m³/s	Cubic meters/second
GPM	US gallons/minute
MGD	US million gallons/day
LB/M	US liquid pounds/minute
oz	US fluid ounces/minute
IGM	Imperial gallons/minute

The existing totalizer values are automatically converted into the selected unit of measure.

After selecting unit of measure for flow rate, press Enter. You will see the following screen for selecting unit of measure for the totalizer.

```
totalizer unit
 G
^ up   > down
E Enter
```

Choices are as follow; any existing values on the totalizers will automatically be converted into the new selected unit of measure

L	Liter
m³	Cubic meter
G	US gallons
MG	US million gallons
Lb	US liquid pounds
oz	US fluid ounces
IG	Imperial gallons
aft	Acre feet
ft³	Cubic feet

After the totalizer unit of measure selection, press the E key the following screen will appear:

FULL SCALE (MAXIMUM FLOW)

If you changed the unit of measure, the full scale or maximum flow may also need to be changed to reflect the maximum flow rate with the new unit of measure. **This is a very important parameter as it relates to other parameters including frequency output, low-flow cut-off, alarm outputs and analog signal outputs.** Adjust the desired new full scale setting based on your meter size and your applications requirements, making sure that it falls within the suggested flow range of the meter.

```
full scale
        237  GPM
^ up   > down
E Enter
```

When done, press enter and then the → key and the next parameter will appear.

```
full scale
change
>next parameter
back        E=End
```

This is the same full scale parameter as previously visited. It is positioned here to provide ability to change full scale setting if no unit of measure change is necessary.

The full scale can be chosen in a range of 0.4 up to 39.4 ft/sec. A flow value is assigned to the analog output as well as the frequency output by the full scale scaling. The scaling is valid for both flow directions.

NOTE: If the flow rate is exceeding the full scale setting by more than 5%, an error is indicated that the selected full scale range is exceeded. (Terminals 7 and 8)

Once this is done, press E and then the → key and the next parameter will appear:

LOW FLOW CUTOFF

This is the low flow cutoff function. It is used to assign a low flow rate at which measurement will stop, preventing measurement and thus totalization errors. This parameter can be programmed from 0 % up to 10% of selected full scale flow rate.

```
low flow cutoff
change
>next parameter
back        E=End
```

Place the > arrow next to "change" and then press the → key. The following screen will appear:

```
low flow cutoff
        4.7 %
^ up   > down
E Enter
```

The factory setting is 0.2%. Increasing this value will help prevent false readings during "no flow" conditions due to fluid movement in the pipe caused by vibrations or piping arrangements.

Using the ↑ and → keys select a value and then press ENTER.

Press → key and you will see the next parameter:

EMPTY PIPE DETECTION

The empty pipe detection parameter when programmed to be ON will provide an error relay indication if the meter is partially filled with liquid. This will also show an empty pipe error message on the display.

```
empty pipe det.
change
>next parameter
back        E=End
```

Position the > next to "change" and press the → key. The following screen will appear:

```
empty pipe det.
 OFF
^ up   > down
E Enter
```

NOTE: The empty pipe detection can be calibrated if required if the fluid conductivity is different than water or the remote cable length is significantly changed.

Use the ↑ and → keys to turn the feature ON or OFF as desired.

If off is selected, hit ENTER and then the →key to go to the next parameter. If ON is selected, hit ENTER and the following screen will appear:

```
calibrate ?
 YES
^ up   > down
E Enter
```

To proceed with calibration, leave "YES" selected and hit ENTER for the next screen.

The pipe has to be filled with the media that will be measured by the meter. A value between 0 and 5000 mV will be measured and displayed. The value increases with decreasing conductivity, increasing cable length or size. For normal water, the value should be between 10mV and 500mV. Afterwards the signal difference between full and empty pipe is determined by the hysteresis value.

```
fill the pipe !
Value    =360mV
^ cancel
E pipe full now
```

Make sure your pipe is full of fluid and when ready, hit ENTER. This new screen is the hysteresis value entered. This value is set at the factory at 1000 mV to allow some variation in empty pipe detection to eliminate the potential for false "empty pipe signals." It is not necessary for this value to be changed.

```
Hysteresis Value
          1000 mV
^ up   > down
E Enter
```

When calibration is complete, hit ENTER.

The switching threshold for the empty pipe detection is when the measuring signal "full pipe" plus hysteresis value is exceeded (i.e. = 360 mV+ 1000 mV). The maximum value for the switching threshold is at 4000 mV.

If full pipe calibration value is higher than 3000mV, please contact customer service for assistance.

Hit →key for next parameter screen:

FLOW DIRECTION

The flow direction can be programmed to uni- or bi-directional modes.

```
flow direction
change
>next parameter
back        E=End
```

Place the > next to "change" and press the → key. One of the following (2) screens will appear:

Uni-directional totalizes the flow only in one direction (flow direction on the detector label). If the fluid is flowing in the opposite direction, the counter will indicate zero on the display and no outputs. Both totalizers can be used as resettable counters in this mode. The totalizers are indicated as "TOT1" and "TOT2".

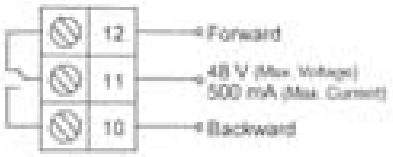
```
flow direction
uni-directional
^ up   > down
E Enter
```

The bi-directional setting measures the flow in both directions. The first totalizer (TOT+) is measuring in the forward flow direction and the second totalizer (TOT-), the reverse direction. A change of flow direction is indicated via the flow direction relay.

```
flow direction
bi-directional
^ up   > down
E Enter
```

Relay Wiring Terminals

Flow Direction Relay



Using the ↑ and → key select which flow direction mode you want and press ENTER. Hit the → key to go to the next parameter.

FILTER DAMPENING

This feature is for dampening of all output signals and flow rate display. This function has no effect on the totalizers.

The factory setting is 1. If you notice too much back and forth oscillation of the flow rate indication, increase this value incrementally until the display is more stable. Your choices are 1 though 6 or "Inactive." To change the filter value, place the arrow next to "change" and press the → key. The following screen will show:

```
 filter
 change
>next parameter
 back        E=End
```

```
 filter
    1
 ^ up   > down
 E Enter
```

Using the ↑ and → keys select the desired filter value and then press ENTER. Hit → key to go to last parameter of this submenu.

ERROR LIST (MESSAGES)

The error list in the program menu indicates the last 8 error types that have occurred and the frequency of each. The sum of all switching on processes can be read on the "Power Up - Counter." This can assist in checking possible power failures.

```
 error list
 change
>next parameter
 back        E=End
```

Line up the > with "change" and hit the → key. This will bring up the 1st error. Continue hitting the → key to toggle through the last 8 errors that occured, with #1 being the most recent error and the power-up indication screens.

```
 error list
2) No Error
  0 x occurred
 >next  E=End
```

Any error is indicated via the error relay as well as displayed on line 4 of the LCD display. The relay is normally closed during normal operation and is opened when an error occurs.

Error Relay

Now hit the → key again and you will be at the screen for clearing all the error list information.

```
 error list
E=clear err list

 ^next
```

Hit Enter to clear and the following screen will appear with "Done" indication.

```
 error list
E=clear err list
Done
 >next  E=End
```

An overview of the possible errors and causes can be found in the Troubleshooting section.

Now hit enter twice and you will be back at the submenu screen.

PROGRAMMING OF OUTPUTS/TOTALS PARAMETERS

The next submenu is outputs/totals.

From the main submenu screen, position the > next to the "outputs/totals" submenu and press the → key.

```
 factors
>outputs/totals
 measurement
 back        E=End
```

The following screen will appear:

RESETTING OF TOTALIZERS

This parameter is used to reset either of the totalizers to zero.

```
 Reset Totals
 change
>next parameter
 back        E=End
```

Line up the > with change and hit → key.

```
Reset Totals
Tot+
Tot-
>back          E=End
```

Now line up the > next to the totalizer you wish to reset. Hit → key and that totalizer will now indicate "DONE."

```
Reset Totals
>Done
Tot-
back           E=End
```

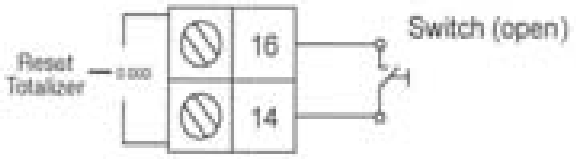
If desired to reset the other totalizer, repeat the same steps.

```
Reset Totals
Done
>Done
back           E=End
```

The "TOT2" totalizer in the uni-directional flow mode, can be reset externally.

The following is the wiring connections diagram for external reset.

External resetting



When finished, hit Enter. Hit → key to go to the next parameter.

ANALOG OUTPUTS

This parameter is for selection of the desired analog output and also calibration if required.

```
analog outputs
change
>next parameter
back           E=End
```

The following are the options available for the analog output ranges.

4 to 20 mA
0 to 20 mA
2 to 10 mA
0 to 10 mA

Press the →key at the "change" line the following screen will appear:

```
analog outputs
 4 - 20 mA
^ up   > down
E Enter
```

Press ↑ or → keys until you find the type of analog output that you desire among the following screens:

```
analog outputs
 0 - 20 mA
^ up   > down
E Enter
```

```
analog outputs
 0 - 10 mA
^ up   > down
E Enter
```

```
analog outputs
 2 - 10 mA
^ up   > down
E Enter
```

NOTE: The flow value is limited to 105% of the programmed full scale value. If this value is exceeded, an overflow error will appear on the LCD display. In bi-direction operation, the flow direction is indicated via the flow direction relay. The following diagram illustrates wire connections for the analog ouput signal.

Analog output (active)

Once you have selected the output, press the ENTER key to select that particular output. You will then be at the calibration screen. You should calibrate the analog output after you have it connected to your PLC or chart recorder.

```
calib output ?
 YES
^ up   > down
E Enter
```

If calibration is in fact desired, hit ENTER again to get to the following screen:

```
Outputs will not
equal flow if
you continue!
>continue  E=End
```

This is an important reminder to make sure that if the meter is part of a closed loop system, you must put the system in manual operation while performing the calibration process.

Hit the → key to continue and this screen will appear:

```
Offset: 4.000 mA
Signal =    0%
 ^ up  > down
E continue
```

Hooking up an ammeter in series with the connected chart recorder (Terminals 1 and 3), you may use the ↑ and → keys to calibrate the 4mA signal for "0" flow. Hit ENTER to continue.

```
Range: 20.000 mA
Signal =  100%
 ^ up  > down
E continue
```

Now the 20 mA signal may be calibrated for 100% flow based on maximum flow rate set in programming.

NOTE: When you use a different analog output setting than 4-20mA, (i.e. 0-20mA) the output calibration will still be performed with 4-20mA and applied to the selected setting (i.e. 0-20mA).

Hit ENTER to complete calibration and the → key for next parameter.

PULSE OUTPUTS

The pulse output parameter will determine how many pulses per gallon, liter, etc. will be sent out to remote counters, controllers, etc. It will also set how many decimal digits will be displayed on the totalizers. If, for example, you choose 100 pulses per gallon, then the display totalizers will have two digits after the decimal point.

```
 pulse outputs
 change
>next parameter
 back        E=End
```

Move the > arrow next to "change", then press the → key and the following screen will appear:

```
 pulse value
        1 puls/G
 ^ up  > down
 E Enter
```

Use the ↑ and → keys to change the value to the desired pulse rate. This value may be set from .001 to 10,000 pulses/unit of measure. Maximum frequency of 10kHz can not be exceeded. Based on maximum flow rate setting, the program will not permit a value that exceeds this frequency.

Press ENTER when you have programmed the desired number.

```
 pulse width
        50 %
 ^ up  > down
 E Enter
```

This parameter is pulse width, or the time duration that each pulse will be "ON". The 50% setting means 50% on 50% off. You can set the width in increments of 5 ms from 5-500 ms. The factory setting is 20 ms. Program this parameter to match the required pulse width of the remote accessory that will receive the pulse output. For output to any AMR device, see steps below.

```
 pulse width
   50ms (AMR)
 ^ up  > down
 E Enter
```

Hit enter and the next screen is:

```
 pulse type
 normally open
 ^ up  > down
 E Enter
```

This parameter permits changing of the factory setting of "Normally Open" for the pulse output to "Normally Closed." After complete, hit enter and the → key for the next parameter.

WIRING OF AMR UNIT TO MAG METER

AMR Wiring Diagram

Step 1: Check to make sure your pulse output settings are correct per chart.

Maximum Flow Rate	Pulse Output Setting
Less than 5500 gpm	1 pulse per 100 or 1000 gallons
Greater than 5500 gpm	1 pulse per 1000 gallons
Less than 5500 Cu. Ft./min.	1 pulse per 100 or 1000 Cu. Ft.
Greater than 5500 Cu. Ft./min.	1 pulse per 1000 Cu. Ft.

Step 2: Set pulse width to "50 ms (AMR)"
Step 3: Set pulse type to "normally open"

The following diagram is for other wiring connections for pulse outputs.

FREQUENCY OUTPUT

This is the Frequency Output parameter. The setting can range from 500 Hz up to 5000 Hz for the Full Scale Value. (Example: If 1600 Hz is selected, then when meter display indicates full scale value, this output is equal to 1600 Hz).

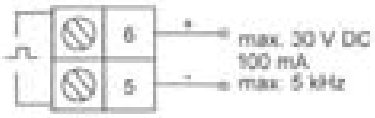
```
 frequency
 change
>next parameter
 back        E=End
```

If a change is desired, line up > cursor with change and hit → key.

```
 frequency
          1000 Hz
^ up   > down
E Enter
```

When complete, hit Enter.

Frequency output (passive)



Hit → key for next parameter.

FLOW ALARMS

This parameter allows the setting of a minimum and maximum percentage (%) of the Full Scale flow rate value. Settings can be made in 1% increments from 0 to 100%. The minimum value must be smaller than the maximum value.

```
 flow alarm
 change
>next parameter
 back        E=End
```

Move the > next to "change" and press the → key. The following screen will appear:

```
min. flow
          10 %
^ up   > down
E Enter
```

Use the ↑ and → keys to select the minimum flow percentage and press ENTER; the following screen will appear:

```
max. flow
          100 %
^ up   > down
E Enter
```

Use the ↑ and → arrows to change the maximum flow percentage and press ENTER.

NOTE: On the signal output, the relays will remain energized until the flow rate returns to within the flow limits.

Flow Alarm Relay

Press ENTER again to return to submenu screen.

PROGRAMMING OF FACTORS PARAMETERS

The third and last submenu "Factors" contains parameters that usually do not require changes.

Press ENTER until you reach the submenu screen if not already there.

```
>factors
 outputs/totals
 measurement
 back        E=End
```

Position the > next to the "factors" submenu and press the → key. The following screen will appear:

DETECTOR FACTOR (FIELD CALIBRATION)

This is the Detector factor setting. When the meter was calibrated, this value was programmed in this parameter as a result of that calibration. Each detector has its individual factor. This detector factor is also included on the label of the meter body.

```
 detector factor
 change
>next parameter
 back        E=End
```

Line up the > with "change" and hit → key. This is the detector factor setting.

```
 detector factor
          68.85
^ up   > down
E Enter
```

With this parameter, you can fine tune your calibration to meet your applications needs. If you find that the meter is off by a certain percentage, you can modify the detector factor to achieve the desired accuracy.

Even though all meters are factory calibrated using water, sometimes your specific installation and fluid parameters make it necessary to recalibrate a meter under actual operating conditions with the liquid being metered.

The following instructions are provided to assist in performing an on-site calibration check and adjustment. This procedure may require either a test tank or vessel of known capacity or a second flow meter installed in the same line.

ACCURACY TEST

1. Place a test tank of calibrated volume at the output of the meter.
2. Operate meter until test tank is filled to the appropriate calibrated level. Since meter accuracy can vary somewhat with flow rate, we recommend making test run at the same flow rate used in actual operation.
3. Record quantity indicated on display totalizer.
4. Repeat run three times and calculate an average for the (4) tests.
5. Perform the following calculation to determine the percent of accuracy of the meter.

$$\frac{\text{Qty. Delivered in vessel}}{\text{Average Meter Reading}} \times \text{Old Detector Factor} = \text{New Detector Factor}$$

Example 1.

$$\frac{100 \text{ Gallons}}{95 \text{ Gallons}} \times 68.85 = 72.47$$

In this example, the meter accuracy is low and must be increased by a calibration correction.

Example 2.

$$\frac{100 \text{ Gallons}}{104 \text{ Gallons}} \times 68.85 = 66.20$$

In this example, the meter accuracy is high by 4% and must be reduced by a calibration correction.

When finished with detector factor parameter, hit ENTER and then hit → key to go to the next parameter.

METER/PIPE SIZE

```
pipe diameter
change
>next parameter
back        E=End
```

Place the arrow next to "change" and press the → key. The following screen will show:

```
pipe diameter
DN50  -  2"
^ up  > down
E Enter
```

This parameter will come preprogrammed from the factory matching the line size of the detector. However, if you replace the entire amplifier in the field, you may need to reprogram this parameter.

Select the pipe diameter of your flow meter by using the ↑ and → keys to match your meter size.

When complete, press Enter.

Hit → key to go to the next parameter.

PASSWORD PROTECTION

This is the password protection parameter. The unit will be set at "0" (no password required) from the factory. If activated, whenever you want to go into any of the submenus, the unit will ask for the password number.

```
Password
change
>next parameter
back        E=End
```

To activate the password, line up the > with "change" and hit → key.

```
Password
                0
^ up  > down
E Enter
```

Change "0" to any desired number from 1 to 999. Hit enter and after returning to the main screen, you will always have to enter the new password to get into the submenus. If the password is lost or forgotten, a factory "333" password value can also be used to satisfy the password entry. If later no password is desired, change the value back to "0", hit Enter and a password will no longer be required to enter any of the submenus.

Hit ENTER twice and you will be back at the main screen.

LANGUAGE SELECTION

The software permits the selection of English or Spanish languages. To change the language, switch off power to Primo Amplifier. While holding the ENTER key down, re-power the unit. Hit ENTER to get to the following screen:

```
^ English
> Spanish
E continue
V3.10Ues16.10.02
```

Select desired language and hit ENTER several times until main menu screen appears.

TROUBLESHOOTING

The Magnetoflow® mag meter should give you many years of maintenance free operation. However, should it malfunction, there are certain things that we recommend you check before contacting our technical support department or your local Badger® Representative.

Note: If the fluid measured has a high concentration of conductive solids, deposits may accumulate on the internal liner walls and electrodes. These deposits will cause a reduction of the measuring output. Thus, it is recommended to remove the meter and inspect the liner and electrodes after 6 months. If deposits are found, remove them with a soft brush. Repeat inspection process every 6 months or until an appropriate inspection cycle, (likely longer) can be established for the specific application. Some general conditions as follows:

DESCRIPTION	POSSIBLE CAUSE	RECOMMENDED ACTION
Flow is present but display is "0"	Signal cable not connected.	Check signal cable.
	Detector mounted opposite of the main flow direction (see arrow on the nameplate).	Turn detector by 180° or switch terminal 45 and 46 or reprogram to biodirectional mode.
	Coil or electrode cables exchanged.	Check cable connections for cross wiring.
Inaccurate measuring	Parameter wrong.	Check the parameters (transmitter, detector factor and size) according to attached data sheet.
	Pipe not fully filled.	Check if meter is fully filled.
No display	No power.	Apply power.
	Incorrect power.	Check power value.
	Wiring connections.	Check power input/output connections.
	Fuse blown.	Replace fuse. (2 Amp slow blow 5 x 20 mm)
Flow rate value known to be wrong	Maximum flow rate setting.	Change setting.
	Detector Factor.	Check value on label.
	Deposits on electrodes and/or liner.	Check and remove deposits.
	Incorrect pipe size programmed.	Check size if necessary.
Flow rate indication unstable	Filter value too low.	Increase filter value setting.
	Cable issue.	Make sure cable is shielded and not vibrating.
	Grounding issue.	Make sure meter is properly grounded to a good earth ground.
	Partially full pipe.	Make sure pipe is full of fluid.
	Air.	Make sure fluid does not contain air bubbles.
	Amplifier location - outside electrical interference.	Make sure amplifier is not too close to sources of electrical interference.
	Chemical injections.	Check location of injection in relation to location of meter.

ERROR MESSAGE EXPLANATION

Some general conditions to keep in mind: When certain connections are sensed by the electronics, the following error messages can be indicated on the display (line 4) as well as on relay 3. The relay is closed during normal operation and is opened by an error appearing.

The following error messages can appear:

ERROR MESSAGE	POSSIBLE CAUSE	RECOMMENDED ACTION
Err: Detector	No detector connection with amplifier.	Check detector and cable connections in accordance with Instruction Manual.
	Connection between amplifier and detector interrupted.	Contact Technical Support.
	Supply voltage too low.	Contact Technical Support.
	Grounded coils in meter.	Contact Technical Support.
	Water in detector.	Contact Technical Support.
Err: Output	Micro processor output control defective.	Contact Technical Support.
Err: unknown	Program error.	Contact Technical Support.
Err: empty pipe	Pipe may not be full.	Make sure all trapped air is out of system. If fluid or fluid conductivity recalibrate the parameter.
Err: full scale	Actual flow rate is exceeding the programmed full scale value by more than 5%.	Reduce flow rate or increase the programmed full scale value.
Err: AD-Range	AD-Converter is exceeding signal limits.	Check the grounding scheme of the meter installation. See grounding section in manual.
Err: AD-Init	Initialization of AD-Converter unsuccessful.	Contact Technical Support.

If additional assistance is required, please contact our **TECHNICAL SUPPORT department at 1-800-456-5023** or contact your local Badger® Representative.

8"

SN 0706-074/34700360

NOM. SIZE 0.0200/8"

FLANGES ANSI B 16-5 RF

MFR TEMP 212 F

MAX PSI 150PSI

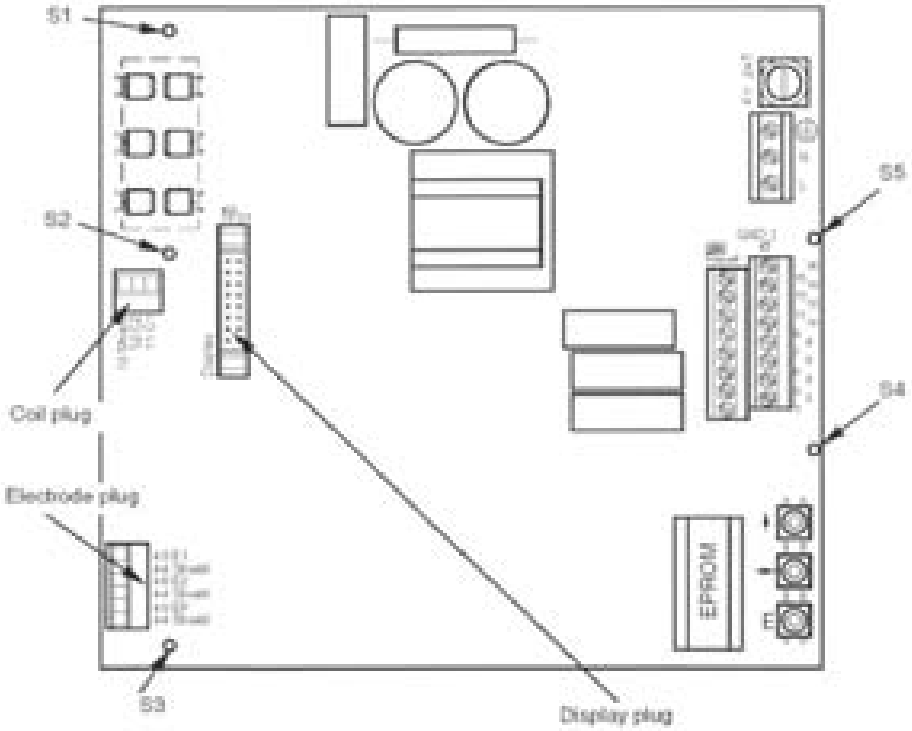
ELECTRODES ALLOY C

LINER HARD RUBBER

DATE 195-30

ROT. PATINS
CEMA 6P

COMPLETE BOARD ASSEMBLY REPLACEMENT



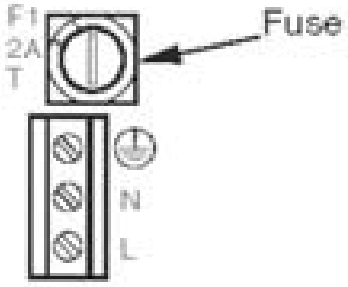
⚠ WARNING
Make sure power to Primo® amplifier is off before proceeding.

1. Pull the electrode, coil and display wiring plugs. Loosen the screws S1 to S5 and remove the existing board assembly.
2. Put in new board assembly and reassemble screws to S1 and S5. Reinstall the (3) wiring plugs.
3. Program the new board assembly with the previous detector factor and meter size.

FUSE REPLACEMENT

⚠ WARNING
Make sure power to Primo amplifier is off before proceeding.

Fuse type: 250 V, 2 A (time-lag)



Please see our website at

www.badgermeter.com

for specific contacts.

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