



**MEASUREMENT
OF
DELTA AGRICULTURAL DIVERSIONS**

July 2011

Prepared by:
Patrick L. Stiehr
RCE # 28296
Watermark Engineering, Inc.
3153 Jenna Court
Roseville, CA 95747
Ph: 916, 774.1111
Email: pstiehr@wtrmark.com

EXECUTIVE SUMMARY

The State Water Resources Control Board (SWRCB) has noticed a public workshop for July 21, 2011 regarding Water Diversion Measurement. I have been asked by water districts that regularly measure their water diversions to provide information that would be helpful to the SWRCB and more specifically, to the Delta Water Master, in determining the availability of modern flow measuring devices and techniques commonly used throughout California. In addition, I have information on costs that will be useful in determining “locally cost effective” based on my 15 years of experience in water measurement in California.

I am a Civil Engineer with a Master’s Degree in Water Resources Planning and Management. My specialty is open and closed channel hydraulics and water measurement. My company, Watermark Engineering, Inc. has been providing flow measurements, complete installation and operation of stream gages, and computation of flow records for irrigation districts, water agencies, cities, counties, and private parties for about 20 years. I am a former stream gager for the US Geological Survey and worked several years for a nearby irrigation district. My resume is included herein.

As noted in the SWRCB notice for the upcoming workshop, water code section 5103 was modified by the legislature in 2009 to require diverters who file Statements of Water Diversion and Use to measure their monthly diversions beginning in January 2012. In addition, water code section 5101 (f) was deleted, which historically provided an exemption from filing a Statement of Water Diversion and Use if the diversion was “included in the consumptive use data for the delta lowlands published by the department (of Water Resources) in its hydrologic data bulletins.” Now that this exemption has been removed, I understand that all water users in the Delta need to provide for water measurement of their diversions by January 2012. This document specifically addresses the feasibility of measuring water diversion in the Delta.

Measuring channel flows in the tidally affected Delta is extremely complex and costly. Conversely, measuring Delta diversions is straightforward, and the tools and technology are readily available. Measuring diversions in the Delta is no more complicated or costly than any other area of the State. Some Delta diversions are made by siphons rather than pumps, and are without power. Modern technology includes inexpensive battery and solar powered means to measure all the types of water diversion in the Delta. There is a cost associated with obtaining good flow data. However, that cost should be considered part of the expense of using water, similar to what most diverters throughout California are required to bear.

Three main procedures outlined herein would be applicable to most of the existing diversions. These three procedures determine the volume of water pumped by using either (1) power meters on the electric water pumps, (2) velocity (Ultrasonic) meters which measure the velocity of water flowing through pipes of either pumped or siphoned water from which the volume of water diverted can be determined, or (3) a weir or control structure and monitoring station to be used in open channel situations. The capital costs for installation would be in the range of \$3,000 to \$5,000 for pump or pipe meters and up to \$10,000 for open channels, the equivalent of paying \$5 to \$10 per acre-foot of water for one year. Maintenance and operations costs would be in the range of \$1,000 per year for all configurations, or the equivalent of less than \$2 per acre-foot of water.

OVERVIEW

There are over 1,800 diversion points within the Delta and over 200 Ag Drainage Returns. See Figures 1 and 2, taken from the Delta Atlas. Three accepted ways to measure the Delta diversions are electrical power meters, measurements of pipe flow, and measurements of open channel flow.

All three measuring techniques require some sort of sensor to detect the measurement parameter(s) and a data logger to record and store the data. Both the sensor(s) and logger require power for operation. Power can be 120 volt, lesser voltage from step-down devices, or battery supplemented with solar panels. The final component of the measuring process is to download the raw data, and then use either simple spreadsheets and math or third party software to compute the flow records.

Flow data at diversion facilities are typically collected at 15-minute intervals, generating 96 data points per day. Computation of flow records can be as simple as multiplying pump hours and discharge rate to get the volume of water pumped to sophisticated software programs that provide graphic aids and standardized correction procedures to accurately generate flow records.

There is the initial installation and calibration of the equipment, then at least monthly inspections and downloads to ensure the equipment is working properly. The fitting of Delta diversions with appropriate measuring devices and with a thoughtful installation will help obtain quality data as well as decrease long-term problems and maintenance. This will be a large undertaking and proper planning will be well worth the effort.

POWER METERS

The general category would be a power and energy meter that monitors pump operation. The meter would be connected to a data logger to record the status of the motor at selected time intervals. This approach is probably the least expensive to install and would have low annual operation and maintenance costs. Two typical meters are shown in Attachment 1.

The accuracy of these data is highly dependent on the calibration of the pump capacity or pump test. Pump tests should be performed a minimum of once per two years and more often if the pump tests are inconsistent. The intake head (water level) should be measured and recorded at a marked measuring spot during each test.

Pumping rates are partially dependent upon upstream water level, and the water level in the Delta tidal environment changes constantly. Measuring the head during each pump test would provide data to adjust flow-rate calculations as the water level changes. If a power meter is used, then recording water elevations would be needed to improve accuracy of the computed volume of water pumped. There are easy methods to measure water level, and depending on the location within the Delta, continuous recorded water level data at one site could be used at other nearby diversions. The accuracy of the power meters is expected to be within 10% or less, dependent upon the configuration of the pump, the pump tests, and accuracy of the water level data.

Pump piping should be documented with dated pictures and a general description of the facilities. If the facilities or configuration is changed, an additional pump test should be made. It would also

benefit the diverter to know when the pump efficiency is low, which would increase his power cost to deliver water. He would also be overestimating the quantity of diverted water.

PIPE FLOW METERS

Measuring the water flowing in the diversion pipe may be the most efficient and cost-effective means of measuring water diverted in the Delta. The changing water levels in some areas may make power meters more complicated and less accurate.

There are numerous types of meters to measure flow in pipes. One Internet supplier indicated that they carry over 200 different flow meters from 25 manufactures. A technical representative of the supplier indicated Differential Pressure Meters, Magmeters, and Ultrasonic meters would fit the application, with the ultrasonic meter probably having the least overall cost for installation, annual operation, and maintenance. The cost for the data logger, data collection, and production of flow records would be similar, regardless of the type of meter used.

Ultrasonic meters have no moving parts, they suffer no pressure loss, and they provide maintenance-free operation - important advantages over conventional mechanical meters such as positive displacement meters (PDs), turbines, orifice plates, vortex meters, and also in many cases, coriolis mass meters.

Moreover, ultrasonic flow meters are generally more accurate and reliable compared to many competing systems. Ultrasonic flow measurement uses the transit time principle, whereby opposite sending and receiving transducers are used to transmit signals through the flow. The signal travels faster when moving with the flow stream compared to against the flow stream. The difference between the two transit times is used to calculate the flow velocity. The material and diameter of the pipe is coded into the device so that flow rate can be determined.

Power would be readily available at pumped diversions to operate the sensors and recorders. However, there are siphon diversions with no electric connection. Where the irrigated land is many feet below the water surface, siphons are used. In these cases, the siphon is started by removing the air from the pipeline, and then the suction on the lower discharge side of the levee “pulls” the water through the pipe and falls onto the field. The siphon can be primed in several ways and sometimes is done as simply as making a connection to the vacuum line on the intake manifold of a truck or tractor. The falling water keeps the siphon running until air is once again allowed to enter the line and the siphon is broken. In any case, when the siphon is operating, the pipe is full of water on the water side of the levee, and its velocity can be measured.

The simplest installation is to secure the meter to the outside of the pipe. Costs are less compared to penetrating the pipe, and there is less chance of corrosion or contamination of the sensors. Accuracy will be slightly less compared to internal sensors, but they are less likely to become fouled and certainly easier to maintain. Accuracy would be expected to be within 1 to 5%.

Typically design recommendations recommend that the transducers for the meter be installed along a straight reach of pipe, the length of the straight portion to be at least 10 diameters upstream and five diameters downstream from the any significant bend. For a 12-inch pipe this would require about 15 feet of relatively straight pipe. A second recommendation is mounting the transducers upwards sloping pipe. In essence, the meter would be installed along the discharge pipe on the waterside as it slopes up and goes through the levee. It will be full when it is flowing. Based on several recent observations, the diversions are similar in configuration, and that the upslope pipes

on the water side of the levee have adequate straight pipe properties. Typical diversions are shown on Photos 1 and 2.



Photo 1. Typical Pump Diversion



Photo 2. Typical Pump Diversions

The data logger could be housed in a small secure and ventilated shelter attached to the pump structure or attached to the pipe near the meter. Conduit would be used to protect communication cables and power wires to both the meter and the logger. A connection from the pump power source would complete the installation.

To gain economy of scale and some uniformity of the installation, either the various Delta water agencies or groups of diverters could contact suppliers and then use the technical support of the manufacturers and/or suppliers to select standard equipment and develop operation and maintenance guidelines and protocol. The agency could also purchase one or more portable meters that would be needed to check and recalibrate the installed meters. There should also be a clearinghouse where the flow data are stored and analyzed when the need arises.

It is expected there would be significant help available from the suppliers as well as significant savings if the suppliers expected to sell several hundred units rather than just a few. Typical meter information from two different manufacturers is provided as Attachment 2.

Please note that there are many manufacturers and products available to measure flow. The information provided herein is for information purposes only and not an endorsement of any manufacturer or product.

OPEN CHANNEL FLOW MEASURING

A recent tour through a portion of the Delta indicated most diversions were single pumps that discharge to a small irrigation ditch or a nearby pipeline. However, there were two relatively large channels that carry irrigation water some distance away from the river and probably serve large acreages. See Photos 3 and 4. Typically, the farther a field is from the Delta water source, the more likely an open channel is used to convey the irrigation water. These channels are filled with Delta water via a gravity connection or a bank of siphons or pumps. Where there are multiple supply points or a large gravity intake, measuring the flow at a control structure or along the open channel may be more cost-effective and operationally more efficient compared to a meter on each of the multiple supply pipes.

The hydraulics of an open channel are more complex compared to a pipeline because there are two variables that determine flow rate. In a pipe flowing full, the cross-sectional area is known, so the only variable to measure is velocity. In an open channel, both area and velocity need to be measured to determine flow rate.



Photo 3. Delivery Channel in South Delta



Photo 4. Delivery Channel in South Delta

A typical gage on a natural water course has a structure that houses equipment that measures and records water level on selected time intervals, usually every 15 minutes. Flow measurements are made periodically to determine the relation between stage (water level) and discharge (flow rate). The measurements are typically plotted and a best fit curve is drawn that defines the relation between stage and discharge, called a rating. After the rating has been developed, each recorded data point (stage) is converted to discharge based on the rating. Periodic flow measurements are needed to verify or slightly modify the rating. The carrying capacity or conveyance of the channel can change over time due to scour, sediment deposition, aquatic growth, or downstream conditions. Typically, accuracy is within 5 to 8%, dependent upon watershed characteristics, the type, and stability of the channel, and the quality and frequency of the measurements. Typical measurements are made using current-meters and more recently, acoustic-Doppler meters. Measurements are typically made six to eight times per year. Photo 5 is a typical gage along a diversion canal with a capacity of about 400 cfs. This gage was installed and flow was monitored for several years as part of a canal loss study.



Photo 5. Typical Gaging Station and Measuring Bridge Over Irrigation Canal

Irrigation channels are often designed and constructed with a weir. The weir provides a stable and standard configuration where there is a unique relation between stage and flow rate. Without a weir, an irrigation channel could have a wide range of flow at a given depth, dependent on downstream conditions.

As an example, assume an irrigation ditch is near bank full, and there is only one small diversion downstream. The flow rate would be low. Conversely, assume there are numerous diversions operating at full capacity. The flow rate in the channel would be significantly greater, but the water elevation could be essentially the same. Hence the need for a flume or weir to establish a control section that has a stable and unique rating.

An alternative control structure would be a standard gated structure such as a Waterman slide gate. Many standard gates have been rated at hydraulics labs and the ratings are reasonably accurate. To compute flow rate, the amount of the gate opening, the upstream water level, and the downstream water level have to be known. There are additional data requirements, and the computational effort increases with the number of gate changes. There would also be a learning curve to adjust the gate opening to have optimal head loss across the structure while not impacting deliveries.

Periodic current-meter measurements are made to verify that the rating is applicable, but the number of measurements is usually much less, and the accuracy of the flow data is better with a well-designed weir or control structure.

For the open channels within the Delta, the type of weir or control structure to be used and the configuration of the weir or gate and monitoring gage would be site specific. If the inflow is from multiple pumps or siphons, then a minor head loss would be acceptable, and a vee-notch weir, sharp-crested weir, trapezoidal weir, or Parshall flume could be used. If the diversion is gravity from a Delta channel and available head is limited, then a low-head weir or gate structure may be more appropriate.

The cost to purchase the monitoring and recording equipment, to provide a shelter, and to install some sort of control or weir in the channel would probably range from \$5,000 to \$15,000. Annual operation and maintenance costs would be in the \$1,500 per year range. These costs are greater compared to an Ultrasonic meter monitoring a single pump. However, an irrigation channel often provides water for a large farm or several farms, so the cost is probably comparable considering the channel serves more acres.

As suggested above, the local delta agency could take the lead to find and hire qualified personnel to design and oversee the installation. Much of the work could be completed using farm equipment and farm labor. And as noted earlier, there should be economy of scale if several sites are presented as one large project rather than individual projects.

SUMMARY

There are many resources, specifically the Bureau of Reclamation, the US Geological Survey, and universities that can provide ideas, technical support, design information, and construction guidance. There are also many people with specialized experience available to help. This isn't an overly difficult project, but it does need to be well planned and done properly to control costs and to ensure long term performance.

The costs and effort to measure water diversions in the Delta using modern technology seem quite reasonable and would be commensurate with what other water users outside the Delta are currently doing. The actual amount of water taken at the diversions within the Delta could be accurately determined and become real and useful data for the SWRCB and others.

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following the decimal point) and the display unit (Wh, kwh,MWh, GWh) are featured on the electric energy display.

The setting software allows you to set the Yokogawa CW120/CW121 power meter's measurement conditions through a PC and save measurement data on a PC when the unit is connected to the PC through an RS-232 or RS-485 port. The Yokogawa CW120/CW121 power meter, in addition to proprietary communication, also supports MODBUS, PC-link, and Power Monitor protocols. PC-link is a protocol for Yokogawa's temperature controllers and PLCs.

POWER METER INFO

Data saving interval can be set in the range of one second to one hour ^{2/4}

117 x 161 x 51 mm (W x H x D)

Large backlit display

Files and Links



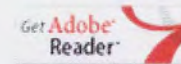
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- **Compact and lightweight** : Size and mass reduced by 2/3 (compared with model FLV).
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- **Wide application range** : $\phi 13$ to $\phi 6000$ mm applicable pipe diameters
- **Quick and easy setup** : Simple menu guided setup from the front panel or PC interface

* Advanced ABM method: anti-bubble measuring method.

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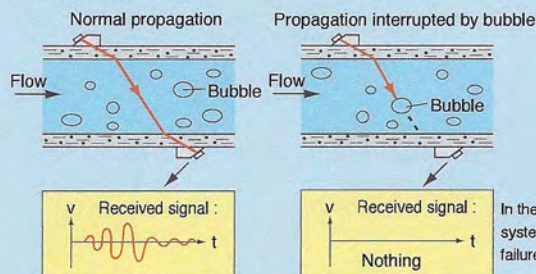
Applicable pipe diameter is $\phi 13\text{mm}$ to $\phi 6000\text{mm}$

PIPE METER
AZ
2/5

- High accuracy measurement of fluid flow rate: 1.0% of rate
- Quick response: 0.2 sec. or less (quick response mode)
- Minimal Influence by the pressure of measured fluid and temperature
- Superior anti-bubble performance
(Advanced AMB method * is adopted.)

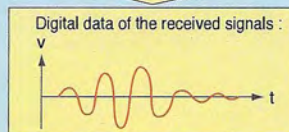
* Advanced AMB method: anti-bubble measurement method

- Advanced received signal digital processing results in higher performance flow measurement

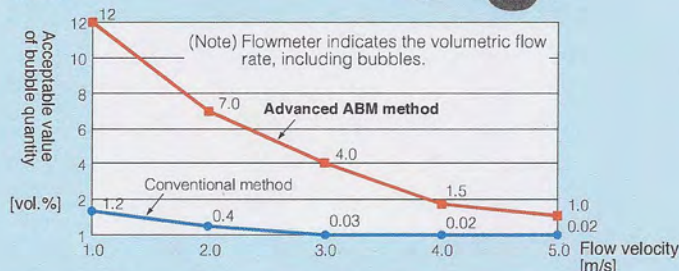


In the case of an analog system, measurement failure will occur.

Summed 128 or 256 times for a single output



Synchronized summation of received signals

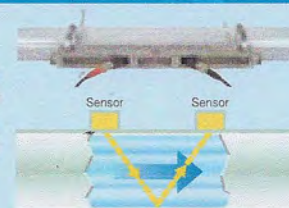


- A wide range of detectors is available, and no piping work is required
(A detector is simply attached to the exterior of the piping.)

Classification	Appearance	Detector type	Applicable pipe inner diameter (mm)	Measured fluid temperature	Mounting/structure
Compact type		FLSE1	$\phi 25$ to $\phi 100$	-20 to 100°C or 0 to 120°C	· V method mounting · Jet structure (equivalent to IP65)
		FLSE2	$\phi 50$ to $\phi 225$		
Small diameter type		FLD2	$\phi 13$ to $\phi 100$	-40 to 100°C	· V mounting method · Watertight structure (equivalent to IP67)
High temperature type		FLD3	$\phi 50$ to $\phi 400$	-40 to 200°C	· V or Z method mounting · Splash-proof structure (equivalent to IP52)
Common type		FLW1	$\phi 50$ to $\phi 300$	-40 to 80°C	· V method mounting · Watertight structure (equivalent to IP67) · Submersible type available
Large diameter type		FLW4	$\phi 200$ to $\phi 1200$	-40 to 80°C	· V or Z method mounting · Watertight structure (equivalent to IP67) · Submersible type available
		FLW5	$\phi 200$ to $\phi 6000$		

Measuring principle

With ultrasonic pulses propagated diagonally between the upstream and downstream sensors mounted on the exterior of the pipe, the flow rate is measured by detecting the time difference caused by the flow.



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The GE Panametrics AquaTrans AT868 ultrasonic flow meter combines state-of-the-art flow measurement capability with a low-cost transmitter package that can be installed right at the process measurement point. The AquaTrans AT868 is designed specifically for water and wastewater applications in full pipes. Fluid types include acoustically conductive fluids, such as most clean liquids and many liquids with entrained solids or gas bubbles.

The all-digital AquaTrans AT868 ultrasonic flow meter has no moving parts and requires minimal maintenance. This GE

This meter requires sensors and mounting hardware purchased separately.

Sensor

[C-RS](#) Standard 2"+
[C-PT](#) High-Temp 2"+
[UTXDR](#) Standard 1/2 to 16"
[CF-LP](#) 1/2 to 2" High Temp

Mounting Hardware

[CF](#) Fixed Installation 2"+

Features

Manufactured by [GE Panametrics](#)

NIST Calibration available

Economical non-intrusive flow measurement

Simple setup and installation

Suitable for wide range of pipe sizes and materials

Suitable for lined pipes

PIPE METER 4/5

Panametrics flow meter has an onboard microprocessor, which uses patented Correlation Transit-Time™ technology for long-term, drift-free operation. Automatic adjustment to changing fluid properties and dynamically configured operating software simplify programming. An optional second channel gives the AquaTrans AT868 ultrasonic flow meter the ability to measure flow in two pipes or average two paths on the same pipe for increased accuracy. Simple setup and installation make the AquaTrans AT868 your complete ultrasonic flow metering system.

Two-channel/two-path version available

Velocity, volumetric and totalized flow

Internal keypad for field programming

Choice of Wetted or Clamp-On Transducers

Ultrasonic flow transducers are classified as either wetted or non-wetted (clamp-on). Clamp-on transducers are clamped onto the outside of the pipe and never come into contact with the process fluid. Wetted transducers are mounted into the pipe or flowcell in direct contact with the process fluid. Clamp-on transducers offer maximum convenience, flexibility, and a low installation cost compared to traditional flow metering technologies. With proper installation, wetted transducers provide maximum accuracy (better than 1% of reading) in most applications.

Transit Time Flow Measurement Technique

The transit time technique uses a pair of transducers with each transducer sending and receiving coded ultrasonic signals through the fluid. When the fluid is flowing, signal transit-time in the downstream direction is shorter than in the upstream direction; the difference between these transit times is proportional to the flow velocity. The GE Panametrics AquaTrans AT868 ultrasonic flow meter measures this time difference and uses programmed pipe parameters to determine flow rate and direction.

Applications for the AquaTrans AT868 Ultrasonic Flow Meter

- Potable water
- Wastewater
- Sewage
- Discharge water
- Treated water
- Cooling and heating water
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Files and Links



[AquaTrans AT868 Ultrasonic Flow Meter Data Sheet PDF](#) (590 KB)



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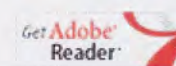
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- Dynasonics (14)
- Fuji Electric (3)
- GE Panametrics (7)
- Krohne (3)
- Maco (3)
- Sondar (1)
- Tekscq (1)

Price:

- Under \$100 (4)
- \$200 - \$499 (1)
- \$500 - \$999 (1)
- \$1000 - \$2499 (16)
- Over \$2500 (10)

Technology:

- Doppler (7)
- Transit Time (14)
- Doppler/Transit Time Hybrid (2)
- Open Channel (3)

Mounting:

- Portable Clamp-on (8)
- Semi-Permanent Clamp-on (10)
- Permanent in-line (4)

Application:

- Fluids < 1% solids or bubbles (15)
- Ultra-clean fluids (15)
- Fluids 1-2% solids or bubbles (13)
- Fluids 2-10% solids or bubbles (12)
- Slurry with greater than 10% solids (7)
- Non-full pipes or open channel (3)
- Gray Water (2)

Sorted By: Popular

Sort

Showing 1 to 32 of 32 products.

Name

[Dynasonics TFX Ultra Ultrasonic Flow Meter](#)
Clamp-on ultrasonic flow and energy meters for liquids



Price

Starting at \$1,755.00

[GE Panametrics TransPort PT878](#)
Compact and portable transit time ultrasonic flow meter



\$5,300.00

[Fuji Electric Portaflo-C Ultrasonic Flow Meter](#)
Next-generation, portable, transit-time ultrasonic flow meter for non-invasive flow measurement



\$4,999.00

[GE Panametrics AquaTrans AT868](#)
Transit time ultrasonic flow meter and liquid flow transmitter



Starting at \$2,350.00

[Fuji Electric Time Delta-C Ultrasonic Flow Meter](#)
The latest advance in high-performance transit-time flow measurement



Starting at \$2,249.00

[GE Panametrics DigitalFlow DF868](#)
Full-featured, fixed-installation liquid flowmeter



Starting at \$4,550.00

[Sondar 5000 Ultrasonic Flow Meter](#)
Ultrasonic open channel flow and level measurement for weirs and flumes



Starting at \$1,400.00

[Krohne UFM 3030 Ultrasonic Flow Meter](#)
Universal 3-beam in-line ultrasonic flow meter for liquids



Starting at \$1,652.00

[Dynasonics TFXL Series Ultrasonic Flow Meter](#)
Ultrasonic flow meter for liquids with moderate amounts of suspended solids or aeration
Replaces the YD50-C



Starting at \$1,080.00

[Dynasonics Series DFX Doppler Ultrasonic Flow Meter](#)
Measures the flow of liquids that contain sound reflectors, suspended solids, or gas



Starting at \$1,780.00

INFORMATION ONLY
NOT AN ENDORSEMENT

PIPE METER
5 of 5

A2



Patrick L. Stiehr, P.E.

Experience Summary

Patrick Stiehr has over 25 years of experience in water resource projects with significant specialized experience in studies, planning, design, and construction of drainage and irrigation projects. He has an extensive background in all phases of hydrology and open channel hydraulics. He spent ten years with the U.S. Geological Survey, stream gaging, conducting flood insurance studies, and a variety of related open channel studies. Within the private sector, he has completed several major master drainage studies, numerous drainage studies with open and closed conduits, detention, and water quality components. He has operated and maintained up to 40 stream gages per year continuously for more than 10 years. Design experience includes a variety of conveyance facilities and structures. Construction management experience includes major canal improvements and a variety of storm drainage projects

Education

B.S., Agricultural Engineering, California State University, Fresno, 1970

M.S., Civil Engineering, Water Resources Planning and Management, Colorado State University, 1978

Registration

P.E.: California, Arizona, Nevada, Colorado, New Mexico, and Texas.

Licensed General Contractor (Inactive): California, Nevada, New Mexico

Experience

Mr. Stiehr started his career with the US Geological Survey, Sacramento office. Experience included stream gaging, records computations, water quality sampling, and sediment sampling and analysis. Mr. Stiehr was responsible for gages throughout Northern California while working in the basic data section of the USGS, including the Sacramento River gaging program from Butte City to Sacramento for several years. Experience also included several years in the projects section where he co-authored a report on Sacramento River flooding in the Butte Basin. He was also project manager for 19 flood insurance studies. During the 10 years with the USGS, Mr. Stiehr performed a variety of functions as a hydrographer, hydrologist, and water resources engineer.

Recent stream gaging experience includes responsibility for two gages along the Middle Fork of the Stanislaus River and five gages (Stanislaus River and four canal diversions) near Oakdale. The gages are FERC license requirements within the TriDam Project. During the rainy season, Mr. Stiehr also operates and maintains five gages owned by the City of Vacaville and has provided extensive stream gaging services and flow measurements for Solano County Water Agency and Placer County Water Agency. The gaging services included site selection, installation, periodic visits and measurements, and analysis of recorded data to produce flow records.

Mr. Stiehr designed and helped install five stream flow gages for the City of Vacaville. He has monitored winter flows along these unregulated streams for the past 10 years. He also installed gages for Solano county Water Agency in the same general area.

He also designed and helped install a gage along Secret Ravine, a gage along Miners Ravine, and 30 small gages to monitor irrigation spills that flow into the two ravine watersheds. The three-year project was part of a canal efficiency study for Placer County Water Agency.

As District Engineer and Assistant General Manager for Oakdale Irrigation District, Mr. Stiehr managed two water delivery divisions and the maintenance division on the district. He analyzed a variety of hydraulic problems and designed appropriate improvements ranging from minor canal work to complete design of selected reaches of the system. He also developed a more detailed monitoring program at key locations within the system including installation of recording gages and control structures. Mr. Stiehr developed estimates of water budgets and delivery for various areas of the district. He evaluated several conjunctive use and reclamation projects during several years when water supply was limited.

Working for a private engineering firm, Mr. Stiehr was construction manager for \$19 million of system improvements for Oakdale Irrigation District through the U.S. Bureau of Reclamation PL984 program. The project was completed over four winters by yearly contractors and force account personnel. It consisted mainly of replacing about 55 miles of open canals with pipelines and new control and delivery structures. The replacement program was based on an analysis of the existing system including infiltration and seepage losses, delivery efficiency, and maintenance history.

Flood Drainage Evaluation: Project manager for evaluation of the February 1986 floods in the Arden area of Sacramento. Analysis included review of historical rainfall and runoff data, and use of HEC-1 and HEC-2 to analyze the drainage basins of Strong Ranch and Chicken Ranch Sloughs with statistical correlation to the historical American River flow records, City of Sacramento, California.

Mr. Stiehr recently completed a four year canal loss study along the South Main Canal for Oakdale Irrigation District. Tasks included site selection and complete installation of three gages located progressively downstream of an existing gage, collection of stage data, current-meter measurements, analysis and computation of stream flow records, and preparation of summary report. He also recently made several flow measurements to help define the flow rating at a new flume installed by the district.

Professional Affiliations

ASCE – Water Resources Technical Group
ACI – Committee 346, Cast-in-Place Concrete Pipe.

Publications

Co-authored “*Hydraulic Analysis of Floodflows in Butte Basin at State Highway 162,*” U.S. Geological Survey Open-file Report 74-148, 1974.

“*Preliminary Analysis of Arizona Streamflow-Data Network for Regional Information,*” U.S. Geological Survey Open-file Report 81-920, 1981