Actividad de Difusión

Programa de Formación apoyo a la participación.

Fundación para la innovación agraria FIA.

Propuesta F01 – 1 - R – 0 29

Curso : Automatización de Canales de Riego.

Participante : Rodrigo Romero Jara

Lugar de formación : California Polytechnic State University

Fecha : 19 - 31 de octubre de 2001.

Cursos Abordados

Medición de caudales.

SCADA (Supervisory Control and Data Acquisition).

Modernización de canales.

Balance de agua.

OBJETIVOS DE LA PROPUESTA

GENERAL:

Desarrollar capacidades de innovación tecnológica para la automatización y modernización de canales de riego.

ESPECÍFICOS:

Desarrollar metodologías para la modelación y control de canales de riego.

Capacitar mediante el desarrollo de cursos y seminarios a administradores de canales de riego en el manejo automático de los sistemas y en la formulación de sistemas de modernización de canales.

Automatizar y modernizar el sistema principal de distribución del Canal Bio Bio Norte.

MEDICIÓN DE CAUDALES

Dispositivos de mediciones de flujos en canales abiertos:

WEIRS : (Presas) Estructuras de desbordes construida en un canal, la cual puede ser usada para estimar caudales.

Ventajas

- Simples de construir y bajo costo.
- Simple de instalar y bajo costo.

Desventajas

- Trabaja mejor en un rango bajo de caudales.
- No permite pasar los sedimentos muy bien.

FLUMES : Una flume es una sección en un canal abierto para medir el caudal de agua.

Ventajas

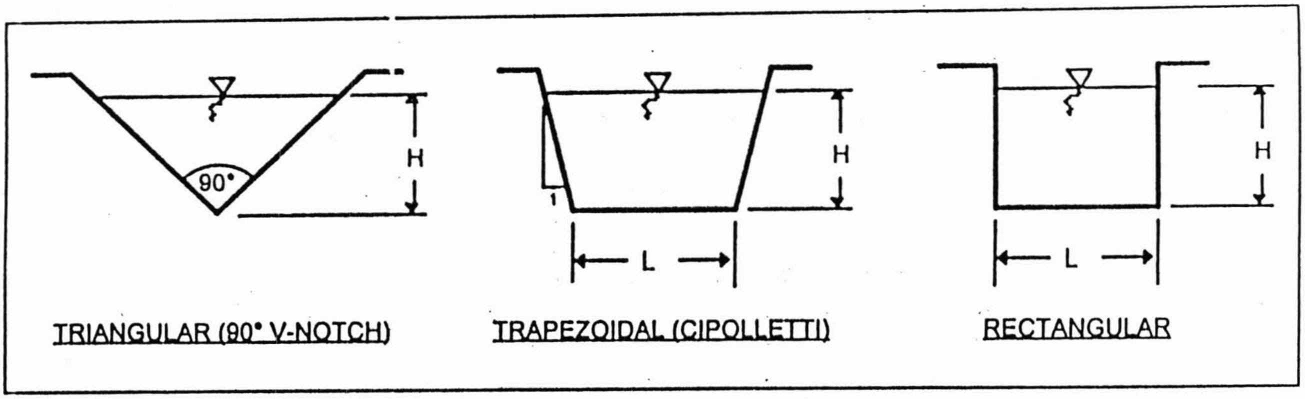
- Puede operar en un rango mayor de caudales.
- Menos problemas de sedimentos.

Desventajas

- Más caras que weirs.
- Requiere mayor precisión en la construcción e instalación.

OTROS.

WEIRS



Triangular (90° V-notch)	Trapezoidal (Cipolletti)	Rectangular Contracted
$Q = 2.5\ H^{2.5}$	$Q = 3.367\ L\ H^{1.5}$	$Q = 3.33(L - 0.2H)H^{1.5}$

where Q is cfs; H is feet; L is feet

General Description:

A weir is defined as an overflow structure built across an open channel. If a weir is constructed and installed to standard conditions, it can be used to make reasonable estimates of water flow rate. Standard conditions exist with established weir size and shape with free-flow steady-state conditions and proper weir-to-pool relationships. If these conditions are met, there is only one depth of water that can exist in the upstream pool for a given flow rate. The discharge rates are determined by measuring the vertical distance from the crest of the weir to the water surface in the pool upstream from the crest. Values of flow rates are obtained by computations using the appropriate equation or by referring to tables that apply to the size and shape of the weir.

Depending upon the shape of the opening, weirs may be termed rectangular, trapezoidal, or V-notch. The bottom edge of the opening is the crest and the side edges are called sides or weir ends. The sheet of water leaving the weir crest is called the nappe. Weirs operate best when they discharge freely into the atmosphere.

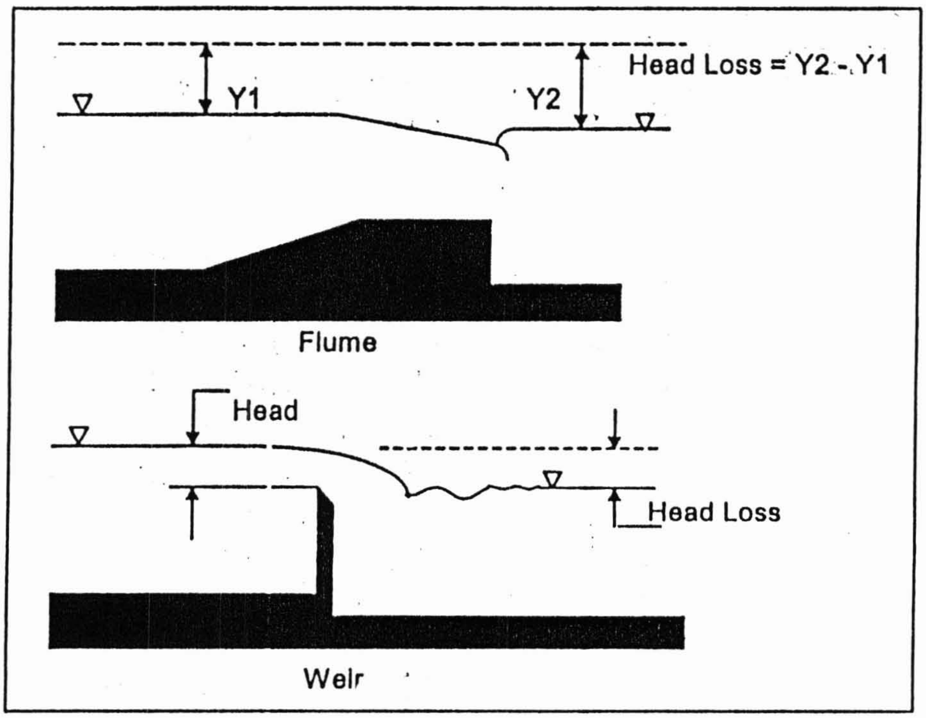
Advantages:

1. simple to construct, resulting in low costs
2. simple to install, resulting in a low costs
3. may be easier to install in an existing system

$$Q \text{ (flow rate)} = AV = CA(2gH)^{0.5} \qquad \text{Eq. (4)}$$

where, C = Constant depending on the flow device and units
A = Area
g = 32.2 feet/second/second
and H = the hydraulic head

Another topic is "head loss". Most flow measurement devices have some head loss requirement in order to operate accurately. Head loss is the difference in water surface elevations between the upstream side and the downstream side of a structure. This is shown in the following figure for the head loss across an orifice.



Volume - **Volume** is equal to an **area** of application multiplied by the **depth** of water applied. For example:

Given:

A grower wants to apply = 0.5 feet of water over a field
Field size = 10 acres.

Find:

Volume of water needed

Formula:

$$V \text{ (volume)} = D \text{ (depth)} \times A \text{ (area)} \qquad \text{Eq. (4)}$$

One Term Means Different Things to Different People - This term is often used with several meanings. Some people mean "flow rate measurement" and others mean "volume measurement", while others think they are talking about "volume measurement" but are really talking about "flow rate measurement". It is easy to be misunderstood when discussing the differences between flow rate, volume and head measurements.. The following was from an actual discussion with a grower who was using local terms for describing the flow of water:

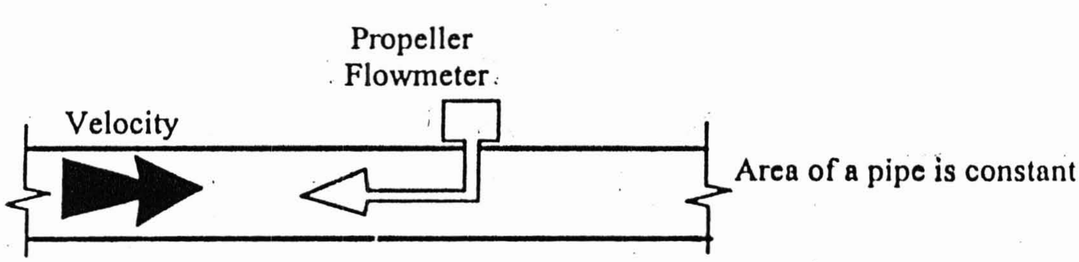
Engineer - "How much water did you put on the field?"

Grower - "I ordered a 10 foot head, got charged for 20 feet, and the district only stacks the water 1 foot over my field."

Engineer - "????"

In this case, the grower was alluding to a 10 CFS flow rate order placed with the ditchrider, 20 AF of volume charged for the irrigation event, and a depth of 1 foot elevation (head) difference between the canal water surface and the growers head ditch.

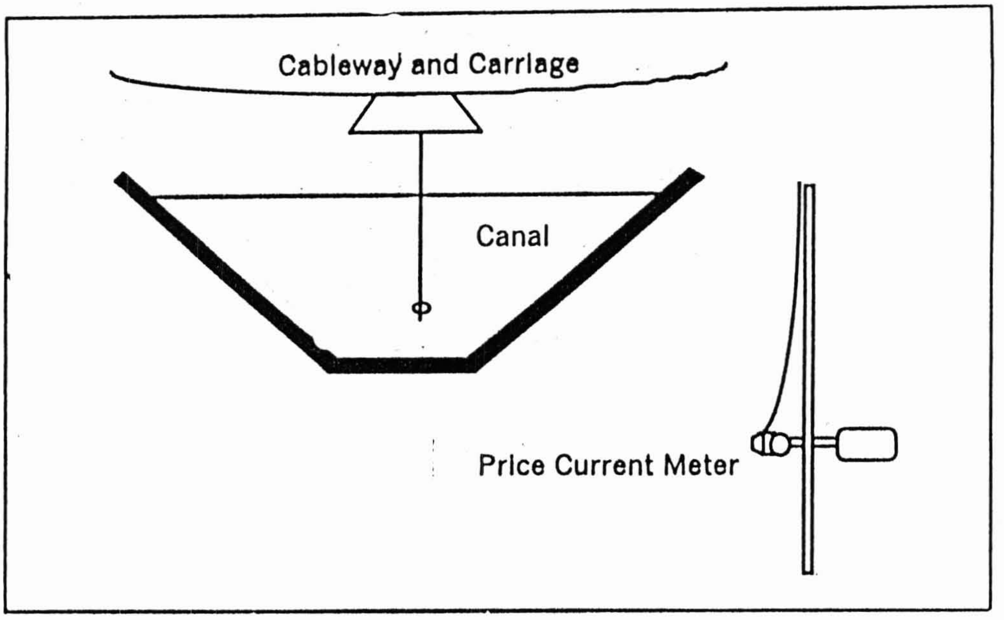
Flow measurement devices - Most devices actually measure flow rate indirectly. The devices actually measure velocity or the hydraulic head of the device first, then formulas, tables, or computer routines are used to solve for the flow rate. When the velocity method is used, the flow rate is based on the equation Q (flow rate) = Velocity × Area. Where the velocity is measured by the device and the area is the known cross sectional area of the measuring point. Example devices include propeller meters and current meters.



Propeller turns in response to a velocity in the pipeline

Q (flow rate) = Velocity * Area

Current Meters



General Description:

This method of flow measurement is based on the equation Q = AV. The current meter is used to estimate the velocity, and the area is measured to determine the flow rate. These are usually used on large water bodies and also to calibrate standard and non-standard water measurement structures. A measurement section is surveyed and the cross sectional area determined. A rating curve is established based on current flow measurements for that site. Once the rating curve has been developed using the current meter, the flow rate can be determined from a rating curve and the measured depth of flow or head at the station. Preferred when large flows are to be measured and the available fall is small. Gauging stations can be set up with relatively little effort and without modification to the channel.

Advantages:

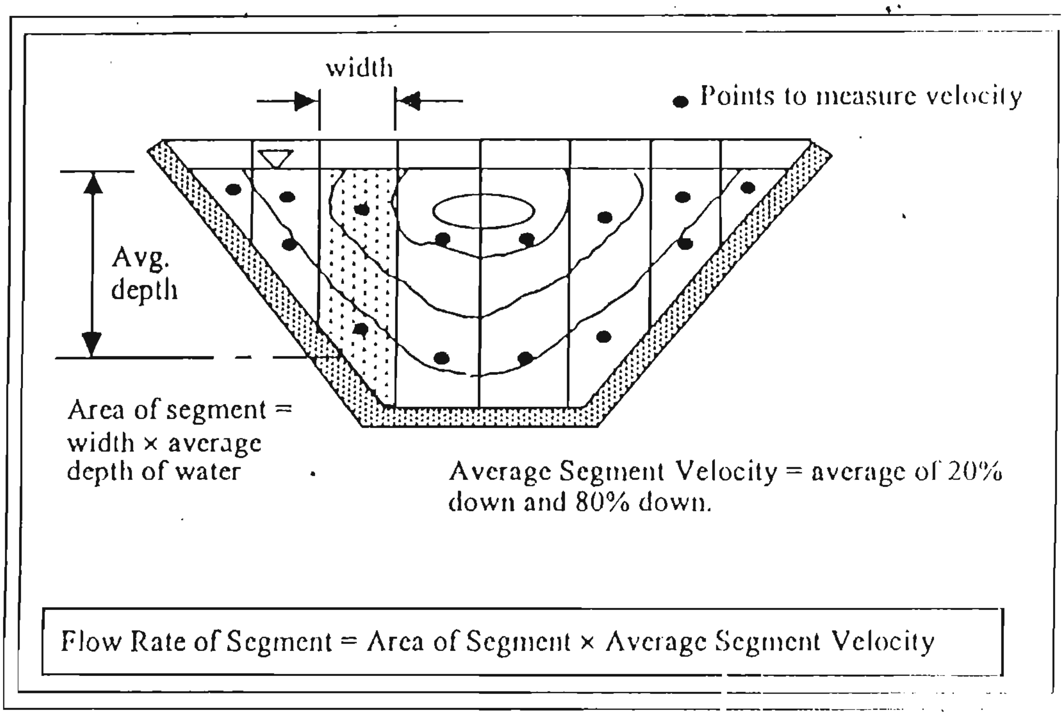
1. standard flow rate measurement device used in most areas
2. simple to operate
3. allows for the "rating" of non-standard devices

Disadvantages:

1. time consuming
2. cross sections can silt up or scour and change with time
3. problems with repeatability

4. Current Meters. Current meters were developed to measure the velocity distribution in open channels. For an open channel flow, the velocity can vary tremendously especially for non-lined channels. Current meters were designed to make multiple readings in a channel. The cross-section is split up into equal width segments and the average velocity and water depth is found for each section. The segment flow rate is the product of the segment area multiplied by the segment average velocity. The total flow rate is the sum of the segment flow rates.

$$Q \text{ (flow rate)} = \text{Sum} \sum ([\text{Segment Area}] \times [\text{Average Segment Velocity}])$$

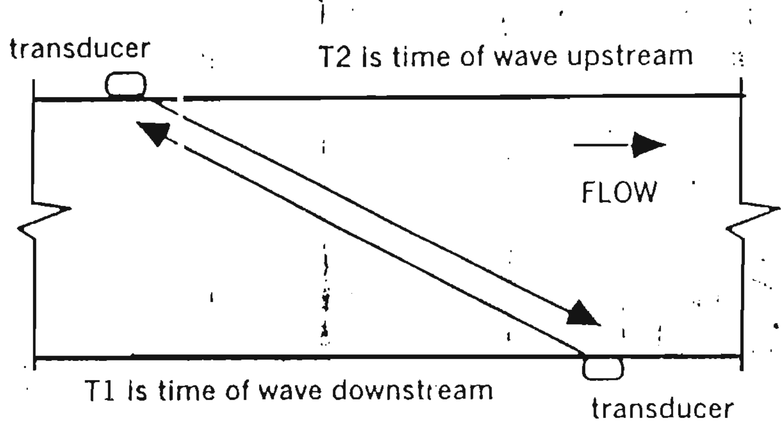


5. Critical Flow Measurement Devices. Current meters require a significant time commitment to obtain a good flow rate estimate. In most irrigation projects, there is a need for a structure where the flow rate could easily be determined by taking a single water level measurement. Flumes and weirs were developed to provide a structure where one water level measurement represented one flow rate. This flow condition is referred to as **critical flow.**

Critical Flow ==> 1 unique water level depth for 1 flow rate

This means there is a unique head-discharge relationship for the device. Although just about any obstruction that adequately backs up water in a channel can be used and

Transit Time Acoustic Meter



Transit Time - Acoustic Meter Flow Rate

$$T1 = \frac{L}{C - V \cos q} \qquad T2 = \frac{L}{C + V\cos\theta}$$

Where:

T1 = Travel time of the acoustic pulse between downstream transducer and upstream transducer

T2 = Travel time of the acoustic pulse between upstream transducer and downstream transducer

C = Speed of sound in water

L = Distance between upstream transducer and downstream transducer

V = velocity of the water

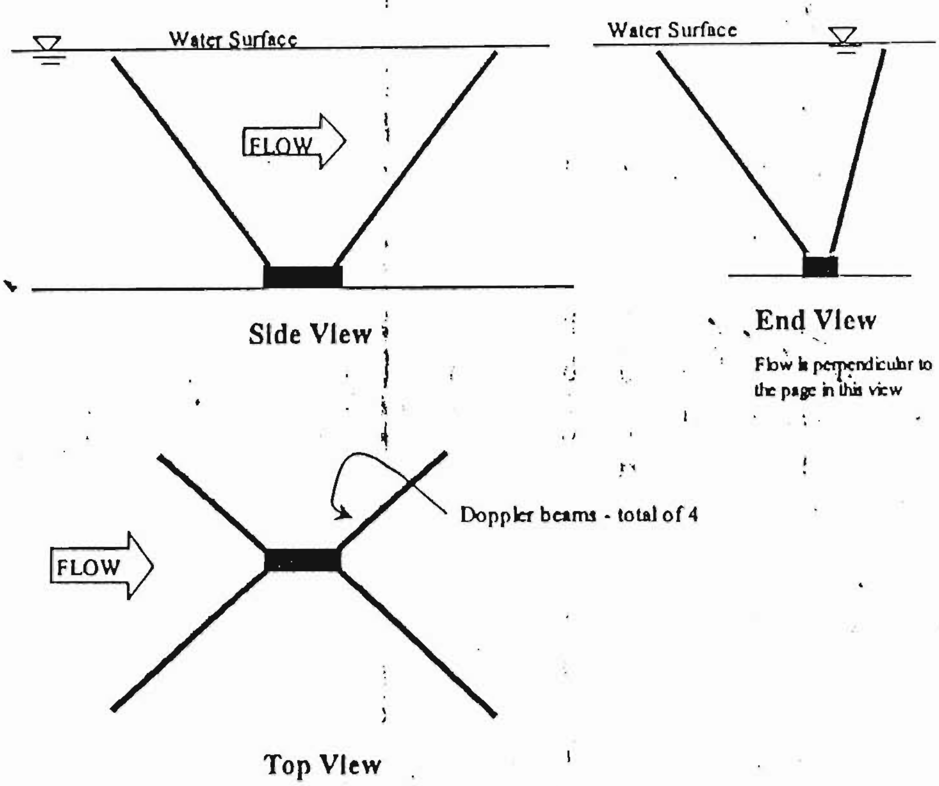
θ = Angle between the acoustic path and the direction of water flow

The above equations are solved for V, independent of C, yielding

$$V = \frac{(T1 - T2)}{(T1T2)} \times \frac{L}{2\cos\theta}$$

Finally, flow rate is found from Q = AV. This requires that the cross section be known and constant.

ACOUSTIC DOPPLER METER



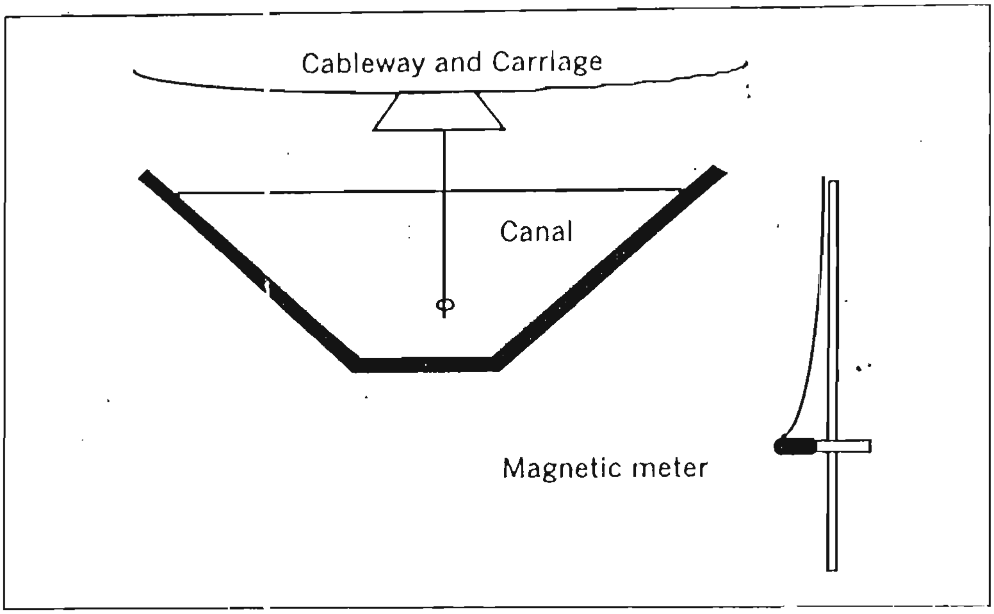
Acoustic Doppler Flow Meter (ADFM)

General Description:

There are several variations of the acoustic Doppler devices. One unit that is starting to get adopted into flow measurement programs is the Acoustic Velocity Flow Meter (AVFM). The unit works using a pulsed Doppler principal. The unit calculates a velocity profile by evaluating the distribution of the velocity. The unit does not assume a uniform velocity profile. There is an ultrasonic sensor located on the center of the unit that shoots up to the water surface to obtain the depth.

The velocity is measured by transmitting a continuous wave of known frequency and analyzing the echoes back-scattered from the materials floating in the water. The echoes are used to determine a Doppler shift. The transducers measure a spectrum of the Doppler shifts which are proportional to the velocity of the water. The key to the accuracy of this type of device is the interpretation of the signals.

Magnetic Meters



General Description:

This type of meter measures flow using the Faraday law of electromagnetic induction. This law states that as a conductor moves through a magnetic field, a voltage is produced. The magnitude of this voltage is directly proportional to the velocity at which the conductor moves through the magnetic field. When the flow approaches the sensor from directly in front, then the direction of the flow, the magnetic field, and the sensed voltage are mutually perpendicular to each other. Hence, the voltage output will represent the velocity of the flow at the electrodes. The sensor is equipped with an electromagnetic coil that produces the magnetic field. A pair of carbon electrodes measure the voltage produced by the velocity of the conductor, which in this case is the flowing liquid. The measured voltage is processed by the electronics and output as a linear measurement of velocity. This information was furnished by Marsh- McBurney.

Advantages:

1. appear to have good repeatability
2. becoming the standard for entities doing multiple readings
3. procedures for metering a site are similar to the procedures for the Price AA current meter

Disadvantages:

1. time consuming to use as compared to a flume
2. cross sections can silt up or scour and change with time

SCADA
(Supervisory Control and Data Acquisition)

Permite un sistema computacional para el desarrollo de procesos y da un control de supervisión individual.

El operador de un canal es ayudado paso a paso de lo que ocurre en el sistema, pero conserva el control sobre los procesos.

SCADA necesita saber lo que esta sucediendo, esto es la adquisición de información. En la industria del riego la información puede incluir nivel de agua, caudal, estado de bomba (encender o apagar), chequear la posición de compuertas, etc.

La comunicación es el segundo punto importante, si una persona en la oficina esta supervisando un sistema. esta persona necesita saber lo que esta sucediendo en terreno, esta información debe ser comunicada a el sistema supervisor. SCADA requiere que la información desde un punto sea presentada al supervisor de forma que se pueda entender.

Supervisory Control significa que el operador supervisa el proceso, pero no es responsable de completar cada tarea individual requerida por el proceso.

Las variadas tareas son dejadas a el controlador (Controller). El supervisor puede hacer cambios a los procesos, como cambiar el caudal en un canal o el nivel de agua, pero el controlador (controller) lleva a cabo las tareas requeridas para hacer la combinación de los procesos a la instrucción del supervisor.

El controlador (controller) es un pequeño computador que es programado para manipular los aparatos controlando los procesos.

El controlador (controller) apagará o encenderá una bomba o ajustará una compuerta, así el caudal en un canal será el que el operador ajuste.

Ventajas

- Disponibilidad de información en tiempo real presentando en una ubicación central.
- Manejos en los peak de demanda.
- Reduce pérdidas debido a derrames.
- Conservación de energía.
- Mejor servicios a los consumidores.
- Agrega flexibilidad a los consumidores.
- Registro de información para análisis operacionales.
- Capacidad de alarma.
- Más eficiente uso de mano de obra.

SENSORES

Es un sistema SCADA pueden ser usados para medir cualquier cosa que pueda ser convertido en una señal electrónica.

En riego puede medir nivel de agua, presión, caudal, velocidad del agua, temperatura, estados de bombas, posición de compuertas, etc.

En general, hay al menos tres sensores de comunicación:

- Señal análoga.
- Señal discreta.
- Señal digital.

ACTUADORES Y RELAY

Son los aparatos que implementan comandos desde el RTU, en general el RTU envía una señal discreta a un relay. El relay entonces enciende o apaga una bomba u opera una compuerta.

PLC Y RTC

Controladores programables lógicos y Unidades terminales remotas.

PLCs y RTUs representan la inteligencia en un sitio controlado SCADA.

El PLC es uno de los muchos componentes en un RTU. Los otros componentes en el RTU incluye baterías, relays, aparatos de comunicación.

Los RTUs son los cerebros de un SCADA, reciben la información desde los sensores, transmite la información a el master, este hace los cálculos basados en la información de los sensores para determinar que acción tomar e iniciar las acciones requeridas.

RTUs contienen toda la información y poder computacional necesario para controlar un sitio.

Si la comunicación con el master falla, el RTU continuará para operar el sitio de acuerdo a las últimas instrucciones recibidas desde el master.

COMUNICACIONES

Sin buenas comunicaciones no opera un SCADA.

SCADA comunicación puede incluir cualquiera de los siguientes medios de comunicación:

- Teléfono.
- Celulares.
- Radio.
- Satélites.
- Red local aérea (Law).
- Red ancha aérea (Wap).

Pasos para el desarrollo de un sistema SCADA

1. Evaluación del sistema.
   - Modernización.
   - SCADA.
2. Desarrollo de un plan maestro.
3. Planificación SCADA.
   - Radio test.
   - Prioridades.
   - Costos estimados.
4. Requerimientos para calificación.
   - Planificación SCADA.
     - Menos costo estimado.
5. Reuniones con vendedores.
6. Requerimientos para ofertas.
7. Selección integra / Negociar contrato.

A typical SCADA system includes the following components:

- Sensors
- Actuators and Relays
- PLC/RTU
- Communications Link
- Master Station

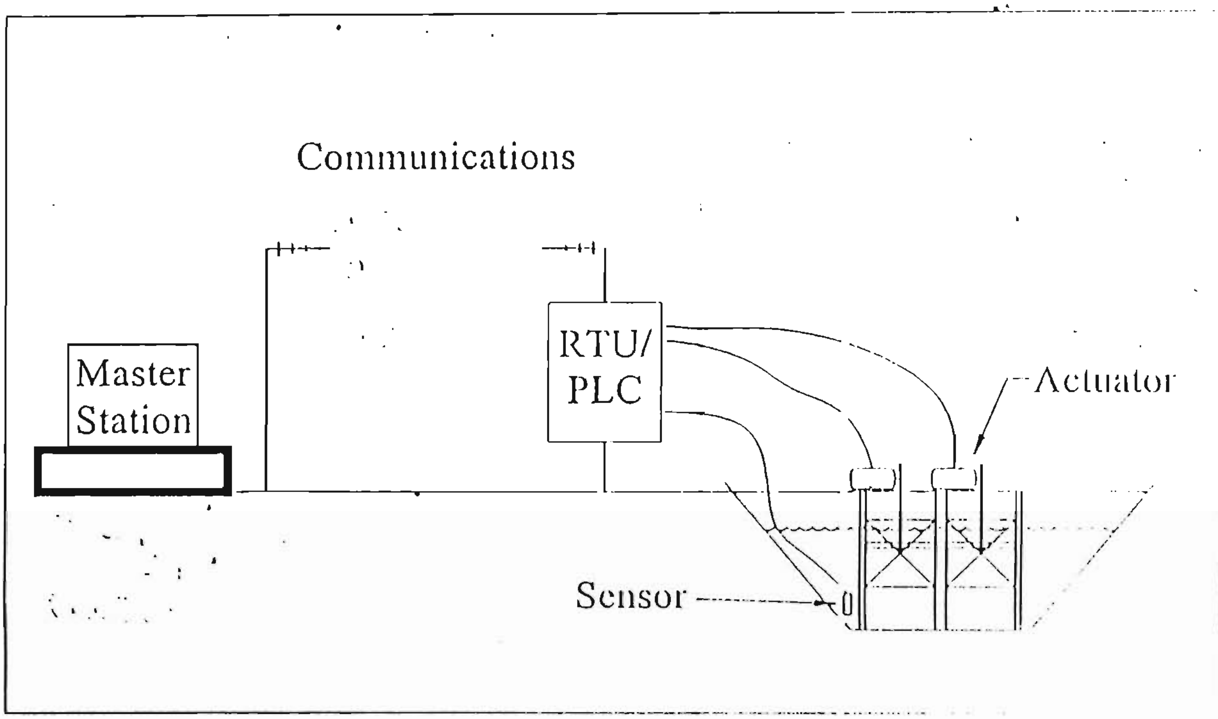


Figure 1 Elements of an Irrigation SCADA System

The sensors collect the required data and send it to the Remote Terminal Unit (RTU). The Programmable Logic Controller (PLC) in the RTU receives the data, decides if adjustments to the actuators are required then makes any of the required adjustments. At the same time, the RTU sends the data over the communications link to the Human Machine Interface (HMI). The HMI receives the data, displays the important data on a

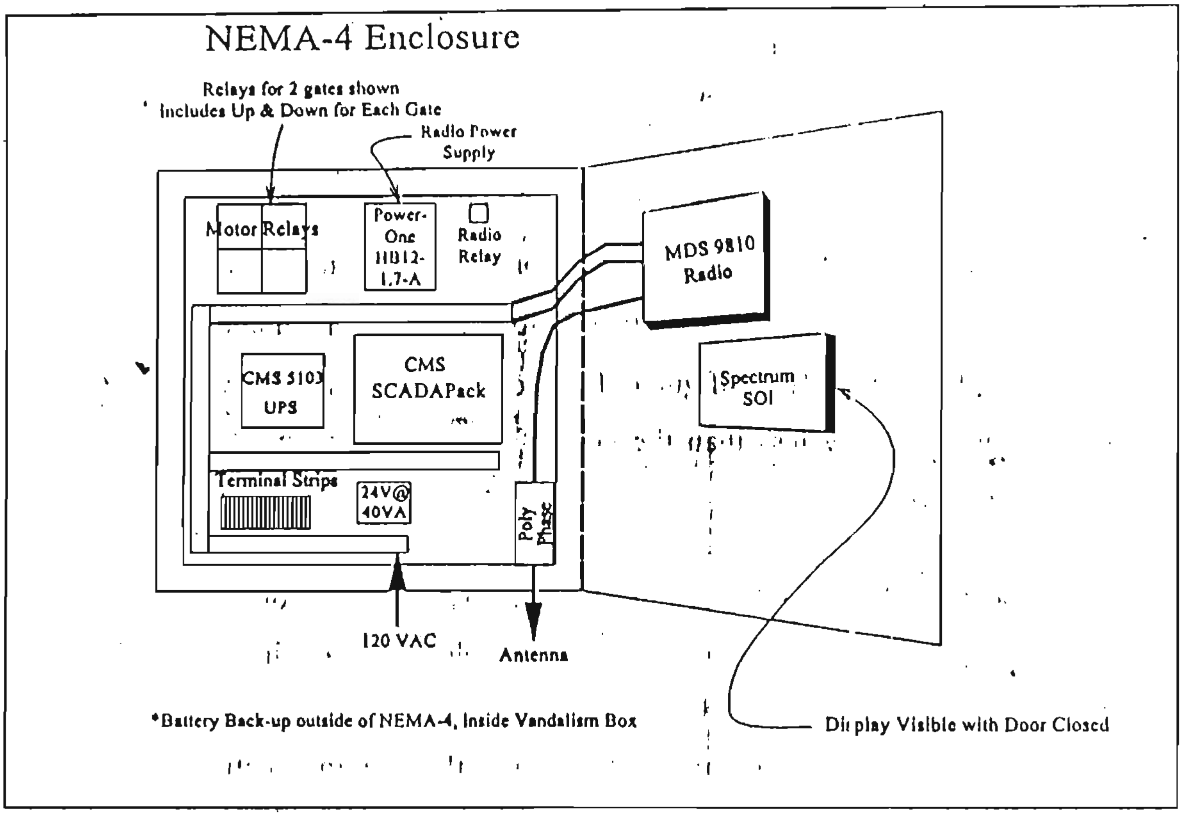


Figure 3. Typical field RTU.

Reference: SCADA System Cost and Feature Comparison

ctober 3, 2000
repared by Cal Poly ITRC.

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phone: 805-756-2434
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Range of Options - From Simple Water Level Alarm to Fully Automated Control Capability

	Control Microsystems SCADA Pack*	Moscad_L RTU*	Campbell Scientific CR510*	Automata* Mini-P	Isaacs Radios 700 Series	Isaacs Radios 600 Series
ffice Equipment						
Office Equipment Cost - Includes cost of office radio, antenna, computer system (if required), software and other SCADA electronics (if required)	$13,500	$13,300	$6,100	$6,500	$4,200	$2,400
Integrator Cost for Office - Install Office Equipment, General Office Programming, Office Debugging	$5,500	$4,500	$2,500	$1,400	$1,000	$300
ffice Antenna Mast - Parts, labor and equipment to Plant pole, labor and equipment to attach and wire equipment to pole	$2,000	$2,000	$2,000	$2,000	$200	$200
Subtotal - Office Equipment	***$21,000***	***$19,800***	***$10,600***	***$9,900***	***$5,400***	***$2,900***
ield Equipment (One RTU)						
RTU (Field) Equipment Cost (one RTU) - Includes cost of PLC and all RTU components, radio, antenna, and NEMA 4 enclosure. Does not include antenna mast or vandalism enclosure	$8,500	$6,900	$6,400	$3,400	$3,100	$900
Integrator Cost for One RTU - Build RTU, RTU Programming, Installation, Debugging	$1,800	$3,200	$1,500	$700	$300	$300
Integrator Cost to Program Office System for RTU (develop screens, integrate into office HMI software)	$1,000	$1,000	$1,000	$1,000	$300	$300
Antenna Mast - Also serves as vandalism enclosure mount if applicable.	$2,000	$2,000	$2,000	$2,000	$200	$200
Vandalism Enclosure	$750	$750	$750	$750	None	None
Subtotal - One Field RTU	***$ 14,050***	***$ 13,850***	***$ 11,650***	***$ 7,850***	***$ 3,900***	***$ 1,700***

Cost for Installation of a "System" - Including Office Equipment, 6 RTUs, Training, and District Administrative Costs

ffice Equipment	$21,000	$19,800	$10,600	$9,900	$5,400	$2,900
ield Equipment - 6 RTUs	$84,300	$83,100	$69,900	$47,100	$23,400	$10,200
ntegrator Cost - Training	$4,000	$2,800	$2,000	$1,500	$800	$800
istrict Administrative Cost, Includes basic design, integrator election, staff expenses for training, inspection	$21,800	$8,000	$11,500	$5,400	$3,700	$1,000
ystem Total Cost	***$131,100***	***$113,700***	***$94,000***	***$63,900***	***$33,300***	***$14,900***

eatures/Capabilities

igh or Low Water Notification/Alarm	Yes	Yes	Yes	Yes	Yes	Yes
ater Level Reporting	Yes	Yes	Yes	Yes	Yes	No
igital Inputs	20	16 (modular)	up to 2	4 (optional)	0	1
nalog Inputs	8	8 (modular)	4	4	1	0
igital Outputs	12	6 (modular)	1	3 (optional)	0	0
nalog Outputs	2 (optional)	4 (modular)	2	0	0	0
emote Manual Control	Yes	Yes	Limited	Limited	No	No
utomatic Control	Yes	Yes	Limited	No	No	No
xpandable (in function)	Yes	Yes	Limited	No	No	No
pen Architecture	Yes	Limited	Limited	Limited	No	No
rice assumes this power input to RTU:	110 v	110 v	110v	10v	long life battery powered	long life battery powered
rice includes, per RTU	1 Ultrasonic water level sensor	1 Ultrasonic water level sensor	1 Ultrasonic water level sensor	1 Ultrasonic water level sensor	1 Ultrasonic water level sensor	1 "Presence of Water" sensor
otors, pumps, actuators included?	No	No	No	No	No	No

MODERNIZACION DE CANALES

Es un proceso técnico y administrativo con el objetivo de mejorar la utilización de recursos (agua, medio ambiente, trabajo, etc.) y el servicio de entrega de agua a los agricultores.

Regla N° 1 para la modernización

"Siempre piensa de cómo tu acción mejorará el servicio a los usuarios del agua (agricultor)".

La función de un sistema de riego (canalistas) es proveer de agua de una manera oportuna y confiable, así el agua puede ser eficientemente usada para la producción de cultivos.

Justificación para modernización de canales (muchas de estas modernizaciones requiere algún tipo de automatización).

1. Asegura el abastecimiento confiable de agua a los agricultores, esto es en el tiempo y cantidad requerida.

2. Asegura un abastecimiento de agua flexible a los agricultores.

3. Reducir restricciones a la capacidad de los agricultores para lograr altas eficiencias en el riego intrapredial a través del abastecimiento de agua confiable y flexible.

4. Eliminar conflictos sociales los cuales siempre ocurren si el abastecimiento del agua es poco confiable.

Algunas secundarias justificación son:

1. Mejor sistema de operación (seguro) del canal, a través de la reducción de pérdidas y fluctuación en los niveles de agua.

2. Alivia la operación de un canal.

3. Aumenta la capacidad del sistema

<u>Control Corriente Arriba</u> v/s (Upstraim)

<u>Control Corriente Abajo</u> (Downstraim)

<u>Usptraim Control</u> :(Supply) Es el control del movimiento de una estructura de chequeo basado en los cambios del nivel de agua inmediatamente aguas arriba de esta estructura.

Upstraim Control es sinónimo con sistema de abastecimiento.

<u>Downtraim Control</u> : (Demand) Es sinónimo de demanda de requerimientos (entregas) para el flujo abajo del alcance del canal (pero no necesariamente para los turnos individuales).

Downstraim Control implica una reacción de una compuerta para cambios flujo abajo de esta, es un usuario orientado.

Downstraim Control son casi siempre automatizados, para un control manual requiere continuos ajustes.

Upstraim Control puede ser automático o manual.

2. Minimize the water level changes which occur throughout the length of the upstream pool on a daily or hourly basis as a result of canal flow rate changes.

Fig. 11.1 shows that there may be very minor water level changes immediately upstream of the gate, but that the water levels immediately downstream of a gate will change much more. Fig. 11.2 shows the effect of doubling the number of gates. Reduction of the gate spacing results in:

1. Less turnout flow rate variation at the upper end of the pool (the head on the turnouts is more constant).
2. Less damage to concrete lining, as water levels are not drawn down as much at the upper ends.
3. Reduced wave travel time due to less wedge storage.

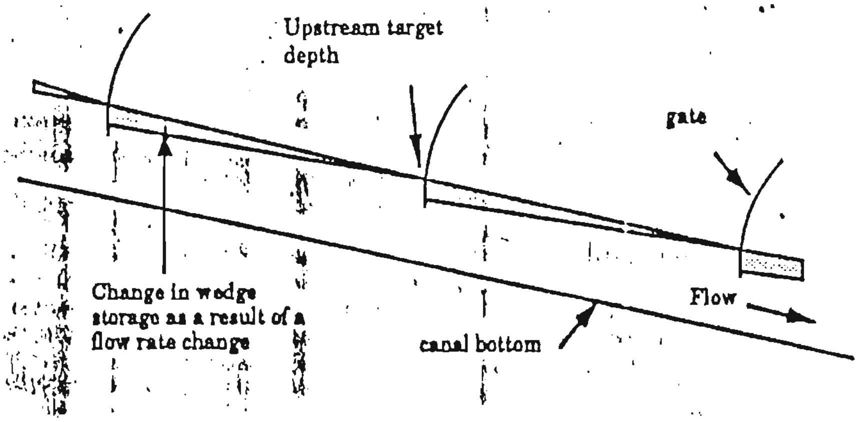


Fig. 11.1. Wedge storage change with upstream control. An increased flow rate at the source must first fill up this volume to establish a new water profile before the new steady state condition is established at the downstream end. Gates are adjusted to maintain a constant water level immediately upstream (Burt, 1987).

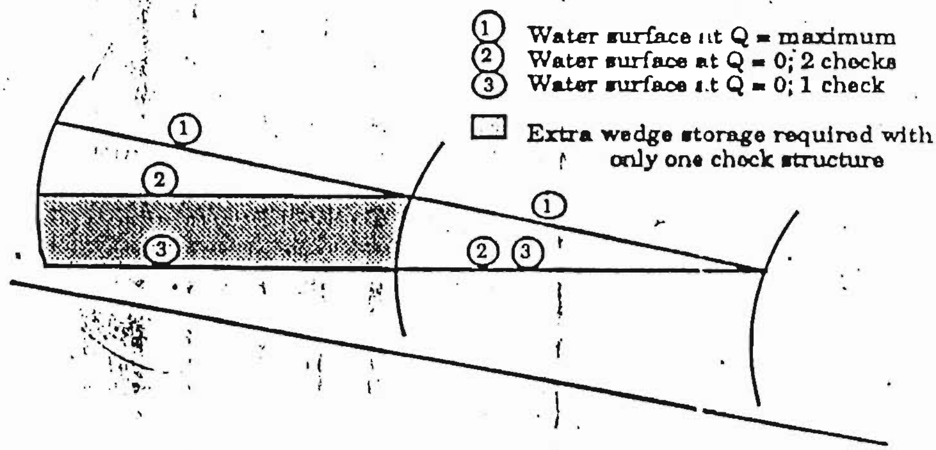


Fig. 11.2. Effect of reducing a pool length in half by doubling the number of check structures. Upstream control (Burt, 1987).

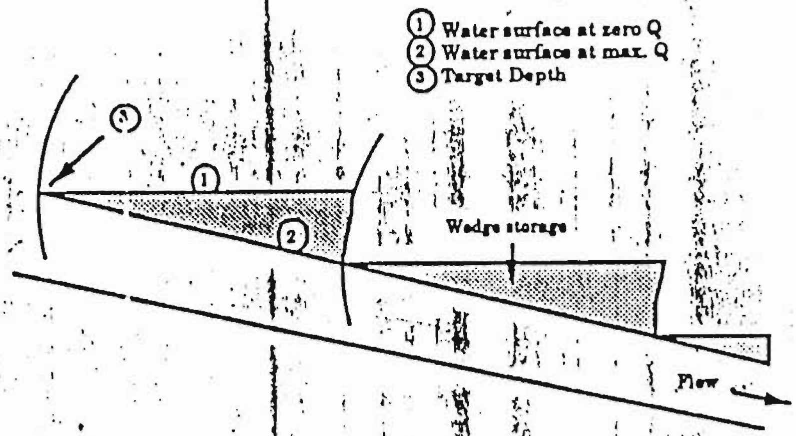


Fig. 11.12. Water surface profiles and target depth location for downstream control with level top canals.

In the case of a large elevation drop across a check structure, the Danaldean system and Littleman and electronic controllers are generally less expensive than the Neyrtec-type equipment. The Neyrtec-type equipment has a float rigidly attached to the radial gate, which necessitates the use of an AVIO gate with an expensive pipeline transition incorporated into the drop.

Turnouts are located immediately downstream of the check structure. The backwater effect of one gate must extend upstream to the next gate, as shown in Fig. 11.12. The close spacing is not an optional decision, as it was with upstream control.

Downstream control with level top canals is an automatic, responsive control which is capable of transmitting a message in the upstream direction. When a turnout is opened, the water level in the upstream pool drops. This drop in water level is transmitted upstream at a velocity of celerity minus the water velocity (c-V). When the change arrives at the upstream gate, that gate opens slightly to compensate. The reaction automatically continues upstream from pool to pool.

When a flow rate to a downstream pool increases, the upstream pool must supply the required additional flow rate out of its wedge storage. That storage is not replenished until the water surface disturbance travels upstream to the next gate, and then returns with the corrective, new flow rate. A rule of thumb for the required volume of wedge storage is:

$$\text{Volume} = \frac{Q \times T}{2} \quad [11.4]$$

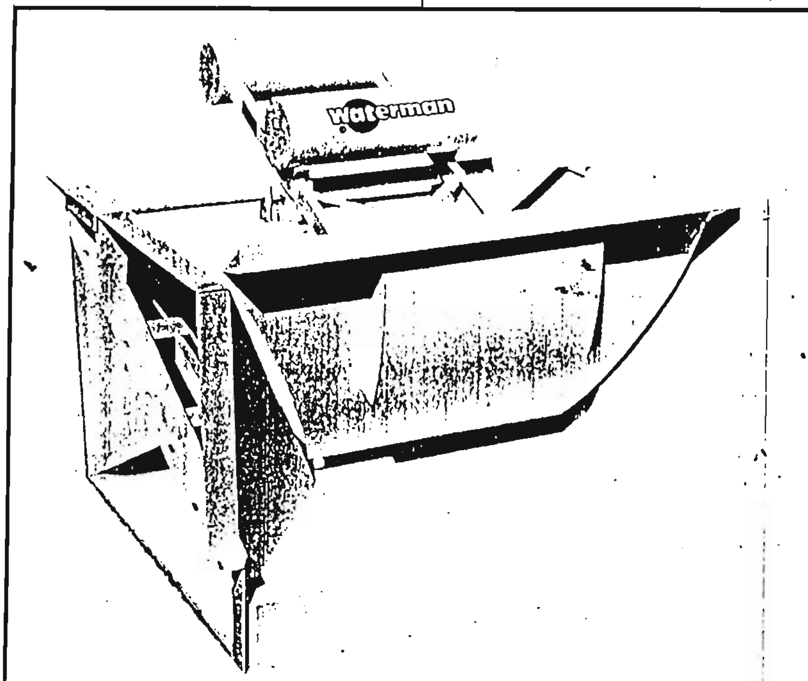
$$\text{where } T = \frac{L}{(gh)^{0.5} + V} + \frac{L}{(gh)^{0.5} - V} \quad [11.5]$$

in which Q = maximum flow rate in the reach in question, h = (cross-section area) / (width at the water surface), and V = Q / (cross-sectional area).

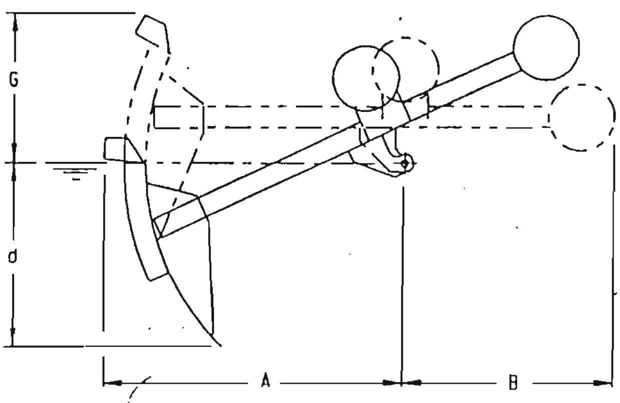
The wedge storage requirement for downstream control is appreciably more than for upstream control. In general, the canal cross section must be considerably wider for downstream control, or instability will result.

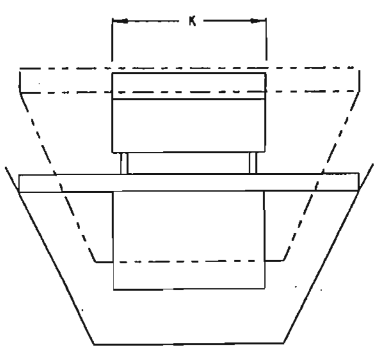
On steep ground with long pools, level top canals require considerable earthwork to construct the canal banks at the downstream end of each pool. This earthwork can be reduced by installing more check structures, but then the cost of structures increases. For a general idea,

WATERMAN TYPE "C" GATE OVERALL DIMENSIONS AND CLEARANCES



WATERMAN TYPE C AUTOMATIC LEVEL CONTROL GATE
MOUNTED IN A WATERMAN PREFABRICATED CONTROL STRUCTURE





MODEL	A Ft. - In.	B Ft. - In.	G Ft. - In.	K Ft. - In.	d Ft. - In.	W Ft. - In.	V Ft. - In.
C-1	2 - 6	1 - 8	1 - 2	1 - 10	1 - 2 ¼	2 - 10	1 - 4½
C-2	2 - 6	1 - 8	1 - 3	1 - 10	1 - 3¾	3 - 2	1 - 6
C-3	2 - 6	1 - 8	1 - 4	1 - 10	1 - 5¾	3 - 6	1 - 8½
C-4	2 - 6	1 - 8	1 - 6	1 - 10	1 - 7¾	3 - 11	1 - 10½
C-5	3 - 6	2 - 5	1 - 8	2 - 6	1 - 10	4 - 4	2 - 1½
C-6	3 - 6	2 - 5	1 - 10	2 - 6	2 - ¾	4 - 11	2 - 4½
C-7	3 - 6	2 - 5	2 - 1	2 - 6	2 - 4	5 - 7	2 - 8
C-8	4 - 9	3 - 5	2 - 2	3 - 4	2 - 7 ½	6 - 3	3 - 0
C-9	4 - 9	3 - 5	2 - 6	3 - 4	2 - 11½	7 - 0	3 - 5
C-10	4 - 9	3 - 5	2 - 10	3 - 4	3 - 3½	7 - 9	3 - 9½
C-11	6 - 2	4 - 0	2 - 11	5 - 4	3 - 8	8 - 8¼	4 - 5
C-12	6 - 2	4 - 0	3 - 5	5 - 4	4 - 1¼	9 - 10⅛	4 - 11¼
C-13	7 - 9	4 - 10	3 - 9	6 - 8	4 - 7	11 - 0	5 - 6⅛
C-14	7 - 9	4 - 10	4 - 5	6 - 8	5 - 3	12 - 3⅝	6 - 3⅝
C-15	9 - 8	6 - 2	4 - 9	8 - 3	5 - 11	13 - 11¼	7 - 1⅜
C-16	9 - 8	6 - 2	5 - 6	8 - 3	6 - 6¾	15 - 7	7 - 7⅛
C-17	12 - 2	7 - 9	6 - 0	14 - 0	7 - 4¼	17 - 4¾	8 - 10
C-18	12 - 2	7 - 9	7 - 0	14 - 0	8 - 2½	19 - 8¼	9 - 11
C-19	15 - 6	9 - 8	7 - 5	18 - 0	9 - 2¼	21 - 11¾	11 - ¾
C-20	15 - 6	9 - 8	8 - 8	18 - 0	10 - 4	24 - 7¼	12 - 5¼
C-21	17 - 3	11 - 6	9 - 3	21 - 0	11 - 7¾	27 - 10⅝	14 - 2½

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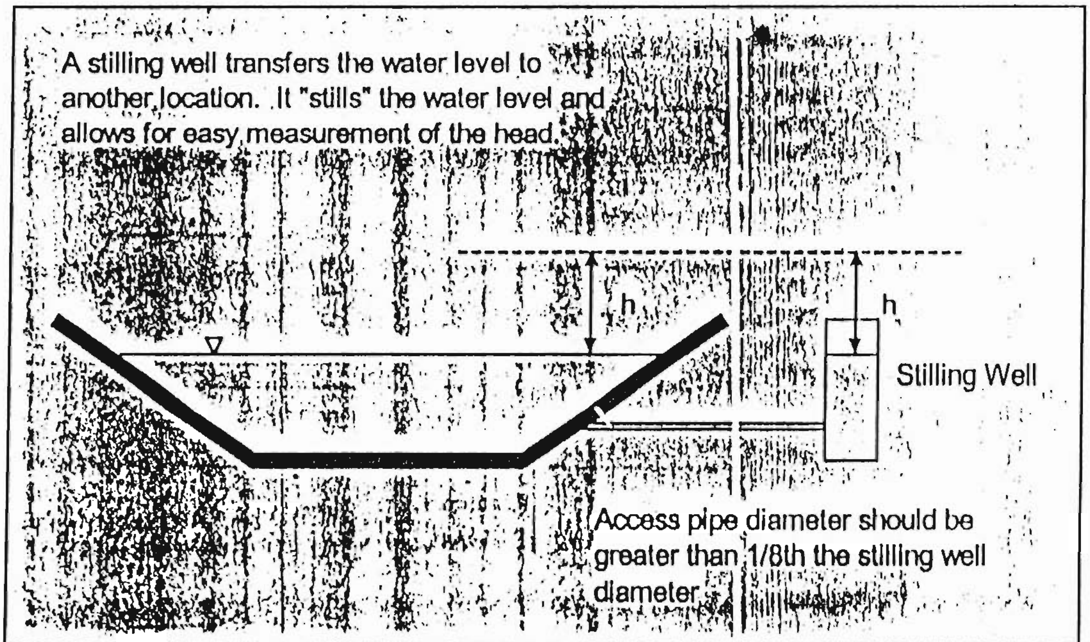
- Pressure transducers

- Ultrasonic transensor

Stilling wells- Stilling wells must be used in areas where the water level is fluctuating due to turbulence or waves caused by wind. The diameter should be at least 12 inches. They can be located in the canal or off the canal. Float recorders can be installed on the top of the stilling well to monitor the water level over time.



Staff gauges- Staff gauges (as well as other water level measurement devices) are readily available from a number of commercial suppliers. The staff gauges come in a variety of formats for the printed numbers. An option is to have customized staff gauges made that have the direct flow rates printed on the gauge. This is commonly done on Replogle Flumes. Note that staff gauges are meant to be read in a vertical position. If they are installed on the side slope of a canal, a correction must be made for the slope of the gauge. The following figure is a staff gauge.

Bul. PF2.0

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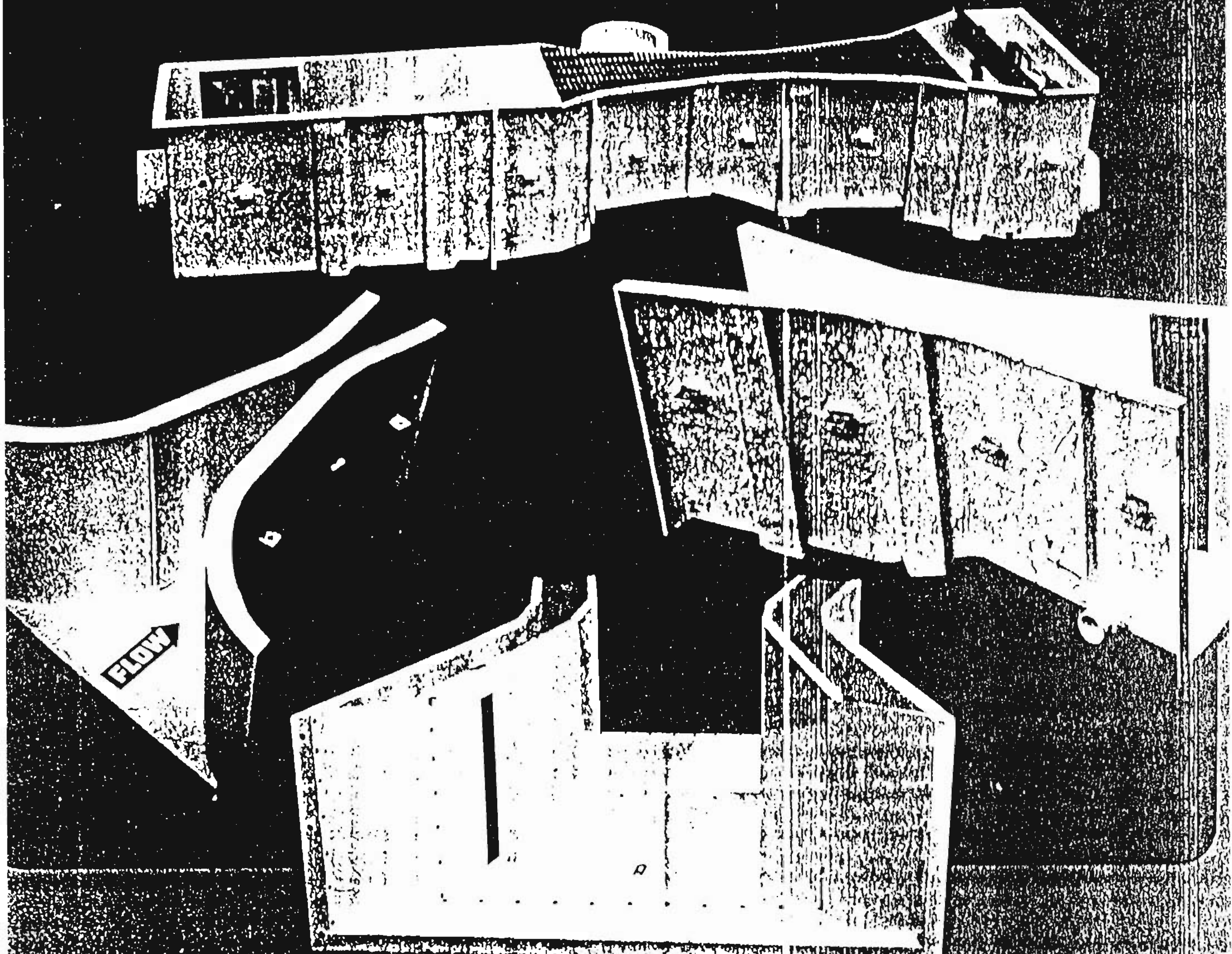

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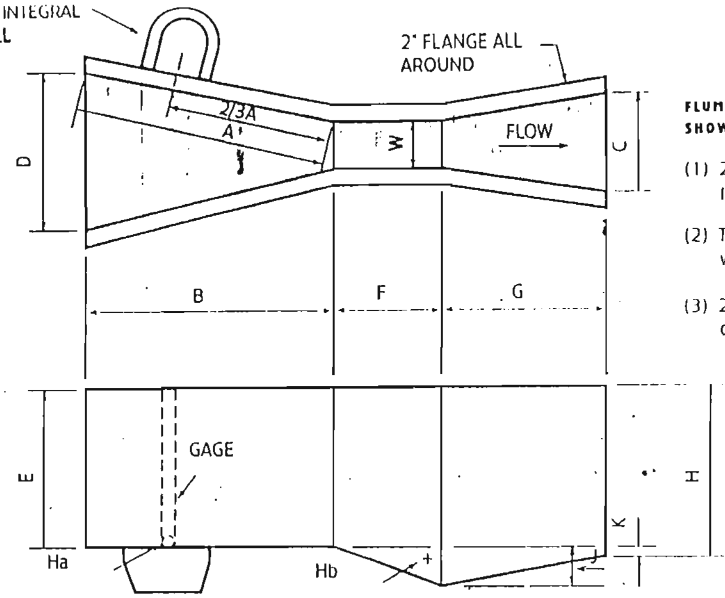
TING FLUMES

per setting and size is essary for successful ration. Frequently the vation of the crest of the ne is governed by the ximum allowable head. ere the crest of the flume is re than 6" above the nnel bottom, a short sloping roach to the inlet end of flume should be provided. nes must always be set with inlet section level.

NDY FACTS TO REMEMBER

u.ft. = 7.48 gals
igd = 694.4 gpm
igd = 1.55 cfs
fs = 449 gpm
fs = 0.646 mgd



FLUME DETAILS NOT SHOWN IN THIS DRAWING:

(1) 2" Side and bottom ribs which provide rigidity

(2) Top cross ties or temporary wood stiffeners

(3) 2" side clips for anchoring in concrete

A	2/3A or 2/3(W/2+4)	B	C	D	E	F	G	H	J	K
1'-2 9/32"	0'-9 17/32"	1'-2"	0'-3 21/32"	0'-6 19/32"	0'-9"	0'-3"	0'-8"	0'-9 1/4"	1 1/8"	3/4"
1'-4 5/16"	0'-10 7/8"	1'-4"	0'-5 5/16"	0'-8 13/32"	0'-9"	0'-4 1/2"	0'-10"	0'-9 7/8"	1 11/16"	7/8"
1'-6 3/8"	1'-0 1/4"	1'-6"	0'-7"	0'-10 3/16"	2'-0"	0'-6"	1'-0"	2'-1"	2 1/4"	1"
2'-0 7/16"	1'-4 5/16"	2'-0"	1'-3 1/2"	1'-3 5/8"	2'-0"	1'-0"	2'-0"	2'-3"	4 1/2"	3"
2'-10 5/8"	1'-11 1/8"	2'-10"	1'-3"	1'-10 5/8"	2'-6"	1'-0"	1'-6"	2'-9"	4 1/2"	3"
4'-6"	3'-0"	4'-4 7/8"	2'-0"	2'-9 1/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
4'-9"	3'-2"	4'-7 7/8"	2'-6"	3'-4 3/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
5'-0"	3'-4"	4'-10 7/8"	3'-0"	3'-11 1/2"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
5'-4 1/4"	3'-6 3/4"	5'-3"	3'-6"	4'-6 3/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
5'-6"	3'-8"	5'-4 3/4"	4'-0"	5'-1 7/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
6'-0"	4'-0"	5'-10 5/8"	5'-0"	6'-4 1/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
6'-6"	4'-4"	6'-4 1/2"	6'-0"	7'-6 5/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
7'-0"	4'-8"	6'-10 3/8"	7'-0"	8'-9"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
7'-6"	5'-0"	7'-4 1/4"	8'-0"	9'-11 3/8"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
8'-0"	5'-4"	7'-10 1/8"	9'-0"	11'-1 3/4"	3'-0"	2'-0"	3'-0"	3'-3"	9"	3"
14'-3 1/4"	6'-0"	14'-0"	12'-0"	15'-7 1/4"	4'-0"	3'-0"	6'-0"	4'-6"	1'-1 1/2"	6"
16'-3 3/4"	6'-8"	16'-0"	14'-8"	18'-4 3/4"	5'-0"	3'-0"	8'-0"	5'-6"	1'-1 1/2"	6'

Download the Program

- Download 32-bit WinFlume - The 32-bit version is appropriate for Windows 95/98/Me/NT 4.0/2000 systems.
- Download 32-bit CCE Version of WinFlume - This is the USDA-Approved Common Computing Environment (CCE) version of the 32-bit WinFlume program. This version is only available to employees of the U.S. Dept. of Agriculture.
- Download 16-bit WinFlume - The 16-bit version is designed for Windows 3.1x systems.
- A user's manual in Adobe Acrobat (PDF) format is included in each setup kit. This file can be viewed on screen or printed to produce a hard-copy manual. If you do not already have the Adobe Acrobat Reader installed on your system, you may download it from the Adobe web site.

If you experience problems or have comments or suggestions for improving the software, please contact me at twahl@do.usbr.gov

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Last Modified: March 5, 2001
Bureau of Reclamation, Department of Interior

BALANCE DE AGUA

Un balance de agua es una medición de todo el volumen de agua que entra y deja un espacio tridimensional sobre un período de tiempo, cambios en un interno almacenaje de agua deben ser también considerados.

Tanto los límite espaciales y temporales de un balance de agua deben ser claramente definidos en orden a controlar y discutir un balance de agua.

Un completo balance de agua no esta limitado solo al agua de riego, agua de lluvia y aguas subterráneas, incluye toda el agua que entra y deja los límites espaciales.

Water Balance Components

The following is an example of the simple partitioning of the water balance. All of the components that enter and leave the 3-dimensional boundaries are included in the water balance. Any water that is recycled within the boundaries of the evaluation might be considered interesting but are not used for the water balance. Figure 1 shows the components for a typical water balance.

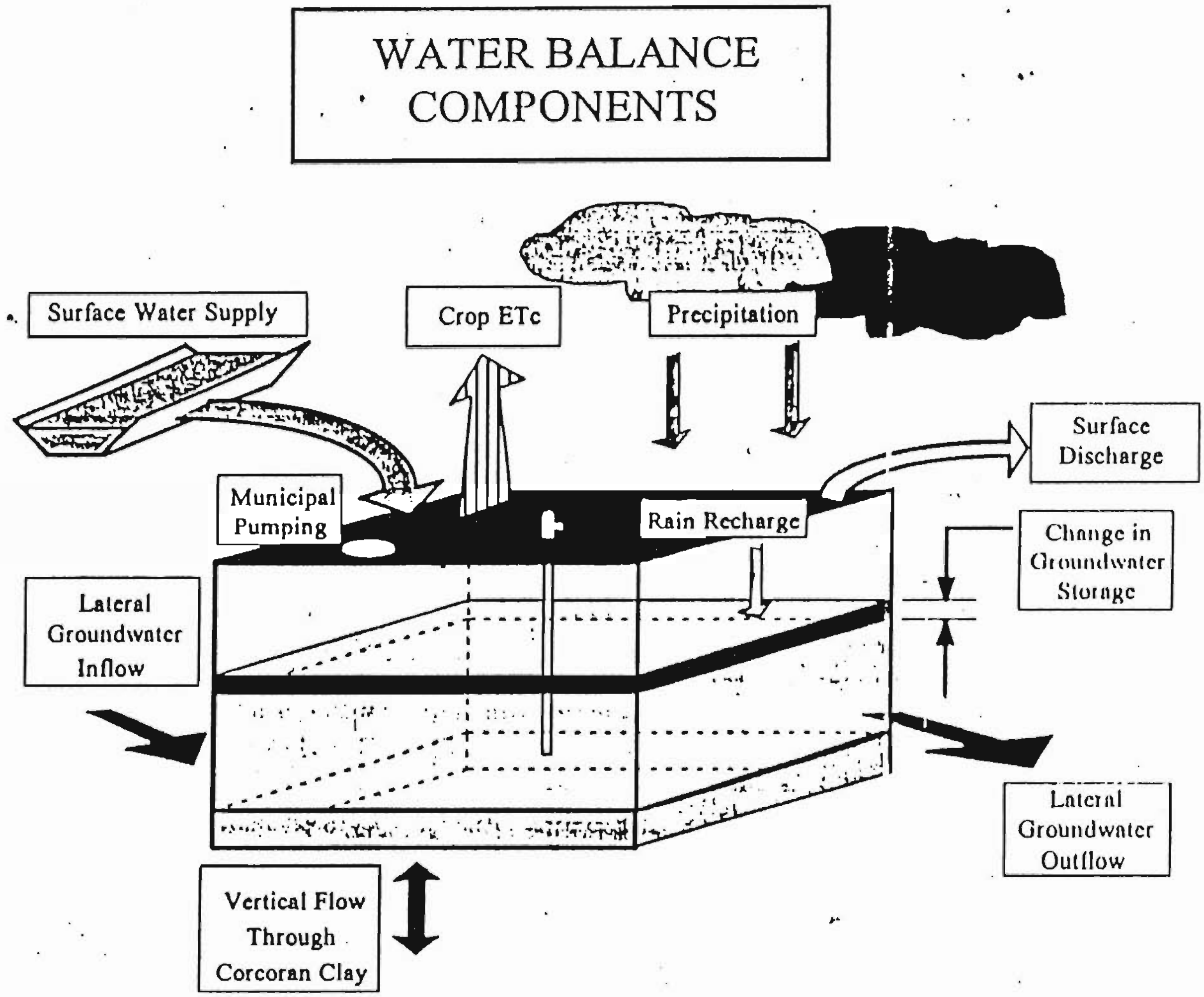


Figure 1. Water Balance Components

Groundwater

The groundwater system in the southern San Joaquin Valley provides a supply of irrigation water when surface deliveries to the area are reduced in water short years. The groundwater system in the service area is divided into two aquifer systems divided by the Corcoran Clay layer. The components which influence the groundwater supply are shown graphically in Figure 2.

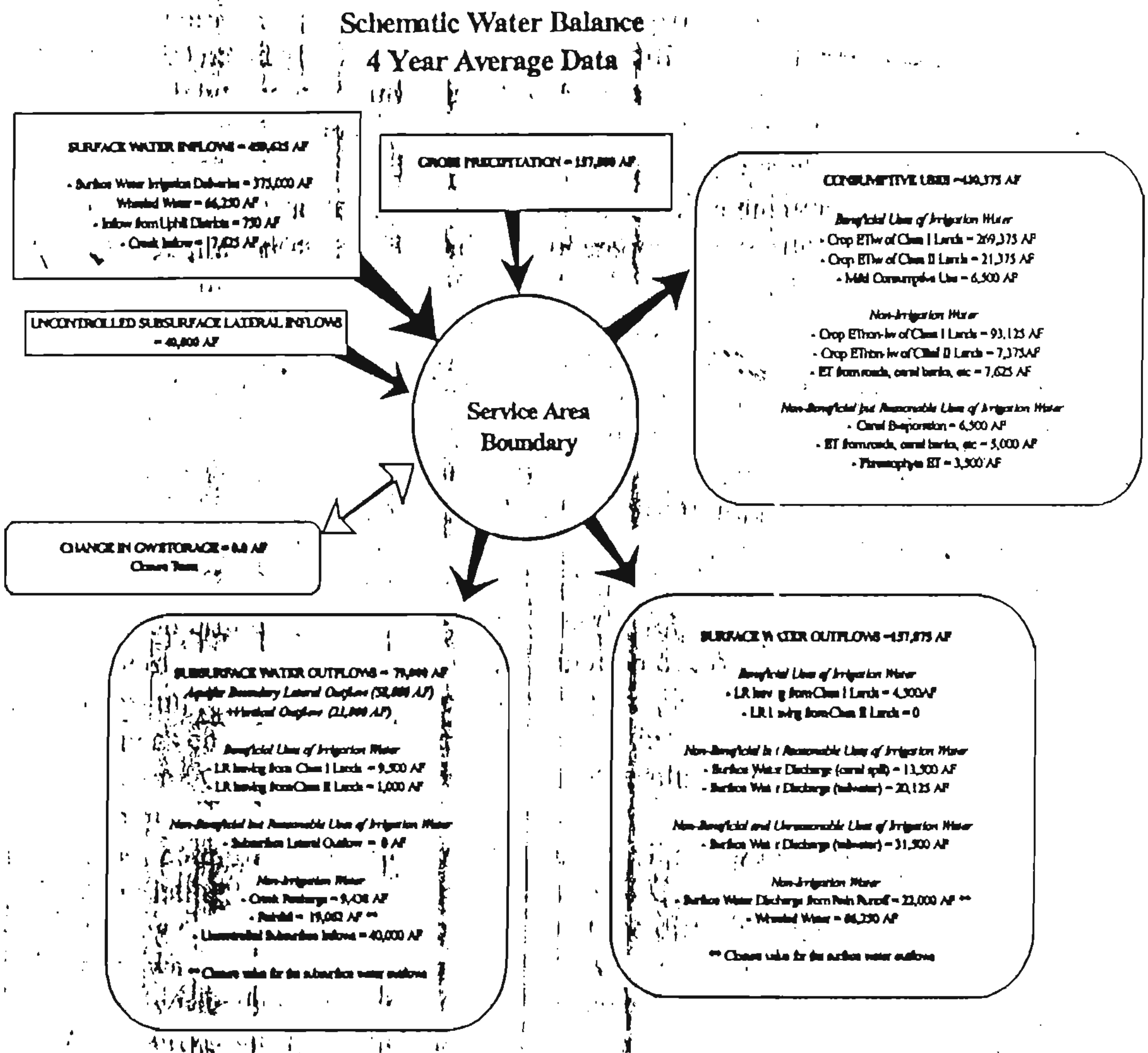


Fig. 2. Schematic of Detailed Water Balance (from Styles and Burt, 1998).

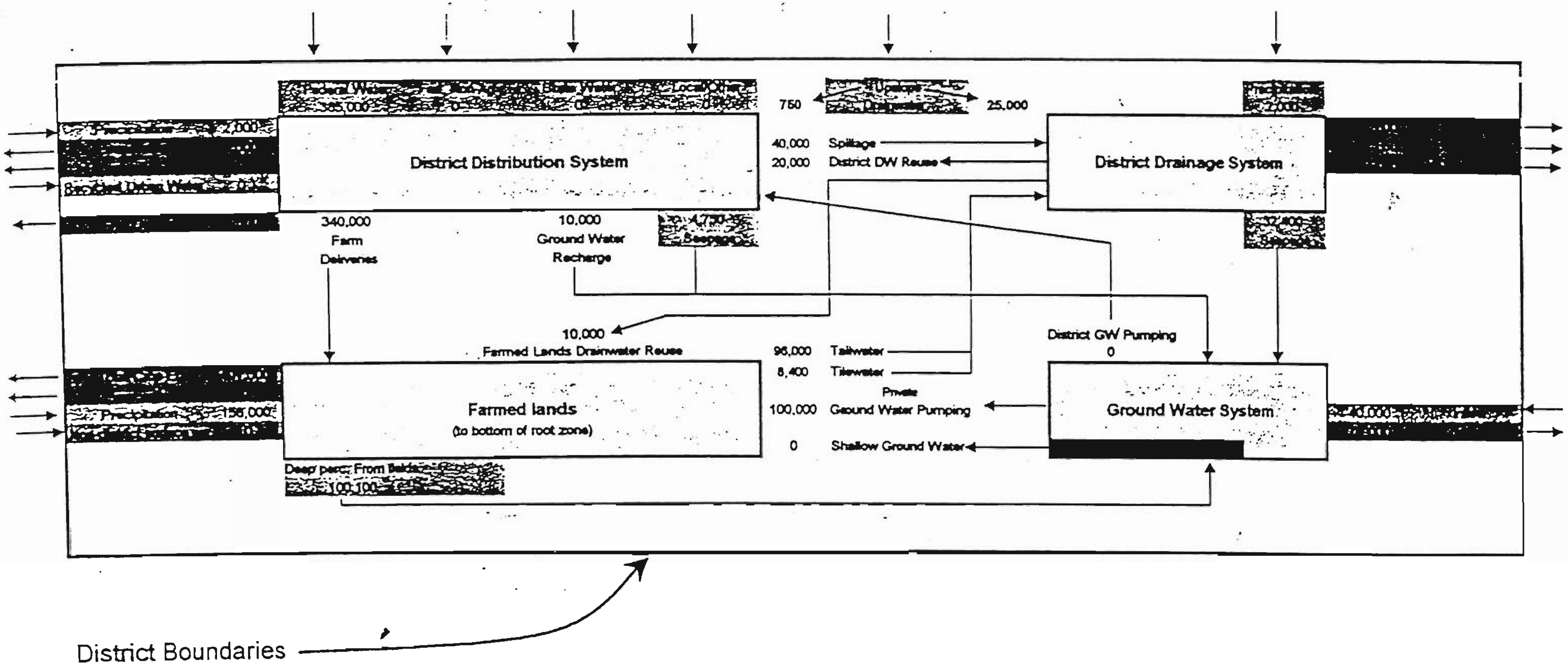
SUMMARY

The complexity of water demands requires that we understand our water sources and water destinations. It is only with a good water balance in hand that we can make good long-term decisions on overall water conservation and management plans.

Although water balances have been computed for decades, good water balances are in their infancy for irrigation projects. This is especially true for the subsurface components, where we typically have very little good quantified information about flow between irrigation districts.

This paper identifies key concepts and components of water balances, and also lists common errors that should be avoided. Water districts and planners are

Standard District Water Balance Structure for Water Management Planning



Standard District Water Balance Structure for Water Management Planning

Ag Distribution System (DIS)

1998 Month	Federal Ag Water (acre-feet)	Federal Non Ag Water (acre-feet)	State Water (acre-feet)	Local / Other (acre-feet)	District Ground Water (acre-feet)	Recycled Urban (acre-feet)	Upslope Drain Water (acre-feet)	DIS Drain Water reuse (acre-feet)	Precipitation (acre-feet)
	INPUTS								
January	32,083	0	0	0	0	0	63	1,667	167
February	32,083	0	0	0	0	0	63	1,667	167
March	32,083	0	0	0	0	0	63	1,667	167
April	32,083	0	0	0	0	0	63	1,667	167
May	32,083	0	0	0	0	0	63	1,667	167
June	32,083	0	0	0	0	0	63	1,667	167
July	32,083	0	0	0	0	0	63	1,667	167
August	32,083	0	0	0	0	0	63	1,667	167
September	32,083	0	0	0	0	0	63	1,667	167
October	32,083	0	0	0	0	0	63	1,667	167
November	32,083	0	0	0	0	0	63	1,667	167
December	32,083	0	0	0	0	0	63	1,667	167
TOTAL	385,000	0	0	0	0	0	750	20,000	2,000

Ag Distribution System (DIS)

1998 Month	Non-Ag deliveries (acre-feet)	Spillage (acre-feet)	Evaporation (acre-feet)	Farm deliveries (acre-feet)	Ground Water recharge (acre-feet)	Riparian ET *(acre-feet)	Seepage (acre-feet)
	OUTPUTS						Closure
January	541	3,333	542	28,333	833	0	397
February	542	3,333	542	28,333	833	0	396
March	542	3,333	542	28,333	833	0	396
April	542	3,334	542	28,333	833	0	395
May	542	3,334	542	28,333	833	0	395
June	542	3,334	542	28,333	833	0	395
July	542	3,333	542	28,333	833	0	396
August	542	3,334	542	28,333	833	0	395
September	542	3,333	542	28,333	833	0	396
October	541	3,333	542	28,333	833	0	397
November	541	3,333	542	28,333	833	0	397
December	541	3,333	542	28,333	833	0	397
TOTAL	6,500	40,000	6,500	340,000	10,000	0	4,750

*only estimates expected

Farmed Lands (FL)

1998 Month	Farm deliveries (acre-feet)	Private Ground (acre-feet)	Precipitation (acre-feet)	FL Drainwtr reuse *(acre-feet)	Shallow Ground Water *(acre-feet)	Evaporation (acre-feet)	Total crop ET (acre-feet)	Tailwater *(acre-feet)	Tilewater *(acre-feet)	Deep perc. From fields (acre-feet)
	INPUTS					OUTPUTS				Closure
January	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
February	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
March	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
April	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
May	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
June	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
July	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
August	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
September	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
October	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
November	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
December	28,333	8,333	13,000	833	0	0	33,458	8,000	700	8,342
TOTAL	340,000	100,000	156,000	10,000	0	0	401,500	96,000	8,400	100,100

*only estimates expected

Standard District Water Balance Structure for Water Management Planning

Dist. Drainage System (DRA)

	INPUTS					OUTPUTS					Closure
1996 Month	Tailwater (acre-feet)	Tilewater (acre-feet)	Upslope Drain Water *(acre-feet)	Spillage (acre-feet)	Precipitation (acre-feet)	Drainwtr outflow (acre-feet)	DIS Drainwtr reuse (acre-feet)	FL Drainwtr reuse (acre-feet)	Evaporation (acre-feet)	Riparian ET *(acre-feet)	Seepage / Intercept (if neg) (acre-feet)
January	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
February	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
March	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
April	8,000	700	2,083	3,334	167	7,708	1667	833	1083	292	2,701
May	8,000	700	2,083	3,334	167	7,708	1667	833	1083	292	2,701
June	8,000	700	2,083	3,334	167	7,708	1667	833	1083	292	2,701
July	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
August	8,000	700	2,083	3,334	167	7,708	1667	833	1083	292	2,701
September	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
October	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
November	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
December	8,000	700	2,083	3,333	167	7,708	1667	833	1083	292	2,700
TOTAL	96,000	8,400	25,000	40,000	2000	92,500	20,000	10,000	13000	3,500	32,400

* only estimates expected

Ag Groundwater System (GW)

	INPUTS					OUTPUTS					Closure
1996 Month	Seepage (DIS) (acre-feet)	Seepage (DR) (acre-feet)	Deep perc. From fields (acre-feet)	Ground Water recharge (acre-feet)	Ground Water inflow *(acre-feet)	Ground Water outflow *(acre-feet)	Interception (acre-feet)	District Ground Water (acre-feet)	Private Ground Water (acre-feet)	Shallow Ground (acre-feet)	Net ground water exchange (acre-feet)
January	397	2,700	8,342	833	3,333	6,583	0	0	8,333	0	688
February	396	2,700	8,342	833	3,333	6,583	0	0	8,333	0	687
March	396	2,700	8,342	833	3,333	6,583	0	0	8,333	0	687
April	395	2,701	8,342	833	3,333	6,583	0	0	8,333	0	687
May	395	2,701	8,342	833	3,333	6,583	0	0	8,333	0	687
June	395	2,701	8,342	833	3,333	6,583	0	0	8,333	0	687
July	396	2,700	8,342	833	3,333	6,583	0	0	8,333	0	687
August	395	2,701	8,342	833	3,333	6,583	0	0	8,333	0	687
September	396	2,700	8,342	833	3,333	6,583	0	0	8,333	0	687
October	397	2,700	8,342	833	3,333	6,583	0	0	8,333	0	688
November	397	2,700	8,342	833	3,333	6,583	0	0	8,333	0	688
December	397	2,700	8,342	833	3,333	6,583	0	0	8,333	0	688
TOTAL	4,750	32,400	100,100	10,000	40,000	79,000	0	0	100,000	0	8,250

*only estimates expected

Sample Water Balance

Priority	Flow Path	Source/Basis	Flow Path Title/Description	1998	1999	2000	2001	Average
			Ag Distribution System (DIS)					
1	DIS1	input	Federal Ag Water	385,000				385,000
1	DIS2	[illegible]	Federal Non-Ag Water	0				0
1	DIS3	[illegible]	State Water	0				0
1	DIS4	[illegible]	Local / Other	0				0
1	DIS5	[illegible]	District Ground Water	0				0
1	DIS6	[illegible]	Recycled Urban	0				0
1	DIS7	[illegible]	Upslope Drain Water	750				750
1	DIS8	[illegible]	DIS Drain Water reuse	20,000				20,000
1	DIS9	[illegible]	Precipitation	2,000				2,000
1	DIS10	output	Non-Ag deliveries	6,500				6,500
1	DIS11	output	Spillage	40,000				40,000
1	DIS12	output	Evaporation	6,500				6,500
1	DIS13	output	Farm deliveries	340,000				340,000
1	DIS14	output	Ground Water recharge	10,000				10,000
2	DIS15	output	Riparian ET	0				0
Calc	DIS16	closure	Seepage	4,750	0	0	0	4,750
			Farmed Lands (FL)					
1	FL1	[illegible]	Farm deliveries	340,000				340,000
1	FL2	[illegible]	Private Ground Water	100,000				100,000
1	FL3	[illegible]	Precipitation	156,000				156,000
2	FL4	[illegible]	FL Drainwtr reuse	10,000				10,000
2	FL5	[illegible]	Shallow Ground Water	0				0
1	FL6	output	Evaporation	0				0
1	FL7	output	Total crop ET	401,500				401,500
2	FL8	output	Tailwater	96,000				96,000
2	FL9	output	Tilewater	8,400				8,400
Calc	FL10	closure	Deep perc. From fields	100,100	0	0	0	100,100
			Dist. Drainage System (DRA)					
1	DRA1	[illegible]	Tailwater	96,000				96,000
2	DRA2	[illegible]	Tilewater	8,400				8,400
2	DRA3	[illegible]	Upslope Drain Water	25,000				25,000
2	DRA4	[illegible]	Spillage	40,000				40,000
2	DRA5	[illegible]	Precipitation	2,000				2,000
1	DRA6	output	Drainwtr outflow	92,500				92,500
1	DRA7	output (DIS8)	DIS Drainwtr reuse	20,000				20,000
2	DRA8	output (FL4)	FL Drainwtr reuse	10,000				10,000
2	DRA9	output	Evaporation	13,000				13,000
2	DRA10	output	Riparian ET	3,500				3,500
Calc	DRA11	closure	Seepage / Intercept (if neg)	32,400	0	0	0	32,400
			Ag Groundwater System (GW)					
Calc	GW1	input (DIS16)	Seepage (Canal)	4,750				4,750
/		[illegible]	Seepage (Drainage)	32,400				32,400
Calc	GW2	[illegible]	Deep perc. From fields	100,100				100,100
1	GW3	[illegible]	Ground Water recharge	10,000				10,000
2	GW4	[illegible]	Ground Water inflow	40,000				40,000
2	GW5	output	Ground Water outflow	70,000				70,000
Calc	GW6	output	Interception to drains	0				0
1	GW7	output (DIS5)	District Ground Water	0				0
1	GW8	output (FL2)	Private Ground Water	100,000				100,000
1	GW9	output (FL5)	Shallow Ground Water	0				0
Calc	GW10	closure	Net ground water exchange	8,250	0	0	0	8,250

	1998	1999	2000	2001	Average
District Boundaries (Inflows)	610,750	0	0	0	610,750
District Boundaries (outflows)	602,500	0	0	0	602,500
Net Change in GW Storage	8,250	0	0	0	8,250

CONCLUSIONES FINALES

MEDICIÓN DE CAUDALES:

Contar con estructuras que permitan dar confianza a los usuarios del sistema, las cuales a su vez sean un buen control para la institución que administra el recurso.

SCADA:

Importante para contar con información real de lo que ocurre en terreno, la cual es importante para tener una buena utilización del recurso y tomar decisiones adecuadas en el tiempo oportuno.

MODERNIZACION:

Es un proceso tendiente a dar EQUIDAD, CONFIABILIDAD y FLEXIBILIDAD a los usuarios.

BALANCE DE AGUA :

Indispensable para el desarrollo de cualquier sistema que tiendan a la modernización de canales.