Automation of Surface Irrigation Systems

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Phase 1: Cooperating Partners - Imperial Valley (2011-Date)

- UCCE/UC Desert Research and Extension Center (DREC)

- US Bureau of Reclamation Yuma Area Office Water Conservation Field Services Program

- US Bureau of Reclamation Science & Technology Program

- US Bureau of Reclamation Hydraulic Investigations and Laboratory Services Group

- Control Design Inc. (DREC), Rubicon Water (DREC & commercial field)

- Alfalfa Grower

- UCCE (Imperial, Kern, Fresno, and Yolo) and UCD (Daniele and Dan Putnam)- four locations
- California Department of Water Resources
- US Bureau of Reclamation Science & Technology Program
- US Bureau of Reclamation Hydraulic Investigations and Laboratory Services Group
- Control Design Inc., Rubicon Water, Observant, (tule ET sensors?)
- Alfalfa Growers
California

• Alfalfa is California’s largest agricultural water user
  - About 1 million acre of alfalfa
  - About 4.0 - 5.5 million ac-ft of water per year

• Surface (flood) irrigation is the primary method of irrigation for alfalfa and other field crops in California

• Imperial Valley (2015):
  – 128,623 acres  (140,134 acres same month last year)
  – Water use 6.5-7 ac-ft/ac
Irrigation Methods in California:

1- Surface irrigation (flood):
   - Border strip (flat) irrigation (slope 0.1-0.2%)
   - Furrow irrigation (slope)
   - Basin irrigation (zero slope)

2- Sprinkler Irrigation (various types)

3- Drip Irrigation (various types)
   - Surface drip
   - Subsurface drip
Surface irrigation:

- Water application methods where water is applied over the soil surface by gravity (no energy is needed).

- Most common irrigation system throughout the world

- Has been used for thousands of years

- Land leveling practices over the past century made it more efficient

- High efficiency possible on medium and heavy soils
Surface irrigation methods:

- Border (flat) irrigation
  Runoff rate: 5-20% (vary)

- Furrow (bed) irrigation
  Runoff rate: 15-30% (vary)

Surface runoff:
  Water losses: lower efficiency
  Nutrient losses: surface runoff & deep percolation
  Pesticides losses: mostly surface runoff &
  some with deep percolation

* Usually no runoff with basin irrigation
Surface Irrigation

Applied water = Root zone storage + runoff + deep percolation

- Surface runoff (B)
- Root zone storage (A)
- Deep percolation (C)
On-Farm Water Conservation = Higher Application Efficiency (AE)

IRRIGATION = Evapotranspiration (ET) + DEEP PERCOLATION + Runoff

\[ A + B + C \]

Application Efficiency (AE) = \[ \frac{A}{A+B+C} \]

To achieve higher efficiency, reduce B and/or C

BUT

Need to have a balance,
Deep Percolation sometimes is needed for salinity control
(650 ppm ~ 0.9 tons of salt/ac-ft)
Runoff is needed for Uniformity (100% AE means under irrigation)
Automated Surface Irrigation Field Test Site

- Border irrigated field
- 60’ wide borders
- 1200’ run length
  - Supply Canal
  - Runoff Canal

Flow Measurement
Typical low desert 80-acre alfalfa field
- flow rate, Q: 15-20 cfs
- Border length: 1200-1,250 ft
- Border width: 60-205 ft
- Slope: ~ 1.5 ft/1000 ft
- Water use: ~ 6.5-7 ac-ft/ac per year
- Runoff rate: ~ 15-20%
- No. of irrig.: ~ 16-18 events (24 hr per irrig.)
- Irrigation labor: ~ $5,100/year (80-ac)
Volume applied = Surface storage + Subsurface storage

flow rate * time = \( d \times L \) + \( z \times L \)
Automation of Surface Irrigation Systems

• Irrigators typically work in 24-hr shifts

• Make decisions on when to turn the water off based on a number of variables (flow rate, advance rate, crop height, etc)

• Automation: smart decisions based on accurate and real-time data (flow rate, advance rate, automated gates, ETc, and other variables)
Optimization (Automation of surface irrigation systems)

- The process of considering all flood irrigation variables to improve on-farm irrigation efficiency
- Adjust irrigation time to allow for changing crop roughness (height and density of the crop)
- Adjusting border/set length to allow for variable soil type across the field
- Adjusting flow rate to an irrigation set (one or more border/land) to improve efficiency
- Computer simulation models are needed
- Accurate measurements during irrigation events (flow rate and advance rate)
Optimization

- Soil type 114 & 115 (heavy soils)- lower flow rate or high flow rate will work depending on the time of the year (considerations: erosion rate & scalding)
- Soil type 106 or 110 (lighter soil)- higher flow rate to increase efficiency
- Soil type 115 & 106 (change flow rate during the irrigation event)
Automated Surface Irrigation:
Previous UCCE-USBR efforts (unsuccessful)
Now 80-ac field (has state of the art system)

Motorization of Existing Gates:

Existing Port Gates
Gates Motorized w/Linear Actuators
Automated Surface Irrigation:

Current Project: Turnout Flow Control Prototypes
Automated Surface Irrigation:

Current Project: Turnout Flow Control

Prototypes
Automation of Surface Irrigation Systems
Automated Surface Irrigation
Automation Demonstration Layout
Turnout System Compatible with Automated Operation:

Tarp Gate Turnout

- Linear Actuator Operator
- 2 Rectangular Frames,
  - Vertical Stationary Frame
  - Hinged Frame
- Fitted Tarp
Turnout System Compatible with Automated Operation:

Tarp Gate Turnout

“Drop-In” Installation & “Self Contained System”
Turnout System Compatible with Automated Operation: Tarp Gate Turnout

Canal Bank or Culvert Outlet Installation
Automated Surface Irrigation Field Test:

Automation System Stations

Flow Measurement – Main Control Station
Automated Surface Irrigation Field Test:

Flow Measurement

- Two-level “venturi solution” flow measurement @ long-throated flume.
- Third level measured to monitor canal fill below flume.
Automated Surface Irrigation Field Test:
Automation System Stations

Turnout Stations
Automated Surface Irrigation Field Test:
Automation System Stations

Field Advance Sensing Station
Automated Surface Irrigation

Automation System Stations

Field Runoff Measurement Station
Automation Operating Cycle: Startup

- Main Control (MC)
  - MC placed in “Auto” Mode
  - MC monitors canal fill
  - MC keeps “running average” flow rate
Automation Operating Cycle: Once Canal has Filled → Start Irrigation

- Main Control (MC)
- Field Advance (FA)
- Section 1 Gate (G1)
  - MC activates FA
  - MC opens G1
  - MC computes inc vol
  - MC keeps sect vol total
  - MC keeps field vol total
Automation Operating Cycle: Water Sensed @ Field Advance

- Main Control (MC)
- Field Advance (FA)
- Section 1 Gate (G1)
- Section 2 Gate (G2)
- Runoff Station (RO)
  - FA alerts MC
  - MC identifies Tgt Vol
  - MC opens G2
  - MC closes G1
  - MC Activates RO
  - MC estimates ending time
Automation Operating Cycle: Section 1 Runoff Measurement Complete

- **Main Control (MC)**
- **Section 2 Gate (G2)**
- **Runoff Station (RO)**

- RO reports RO Vol to MC
- MC compares RO Vol & Tgt Vol
- MC adjusts Tgt Vol if needed
- MC estimates ending time
Automation Operating Cycle: Target Volume reached for Section 2 (& subsequent sections)

- Main Control (MC)
- Section 2 Gate (G2)
- Section 3 Gate (G3)

- MC opens G3
- MC closes G2
- MC updates estimated ending time
Automation Operating Cycle: End of Irrigation

- Main Control (MC)
- Section n Gate (Gn)

- MC in alert mode
- Activities for end of irrigation expected to be “site specific”
Automation Operating Cycle: Operation w/Field Advance Sensor in Each Section

- **Main Control (MC)**
- **Section n Gate (Gn)**
- **Field Advance n (FA_n)**

- FA_n(s) placed at "cut-off" locations
- One or multiple FA units may be used
- FA placement may be adjusted from section to section
Automated Surface Irrigation Field Test

Additional system components:

Office Base Station
Automated Surface Irrigation Field Test
Additional system components:

Portable Station
Automated Surface Irrigation Field Test:

Current Project Status:

- Programming for basic functions has been developed and tested for each station type
- User menu functions of Main Control program are currently being refined
- Main Control programming for multiple field sensor option is being developed.
Summary and Desired Outcomes

• Water conservation (reducing runoff to less than 5% of applied water)
• Labor savings (one irrigator per 4 fields vs 1 irrigator per field)
• Value of conserved water (currently $285 per ac-ft in IID service area)
• Drought and limited water supplies (deficit irrigate the lower end of the field)
Thank you