Subsurface Drainage Pumped Outlets

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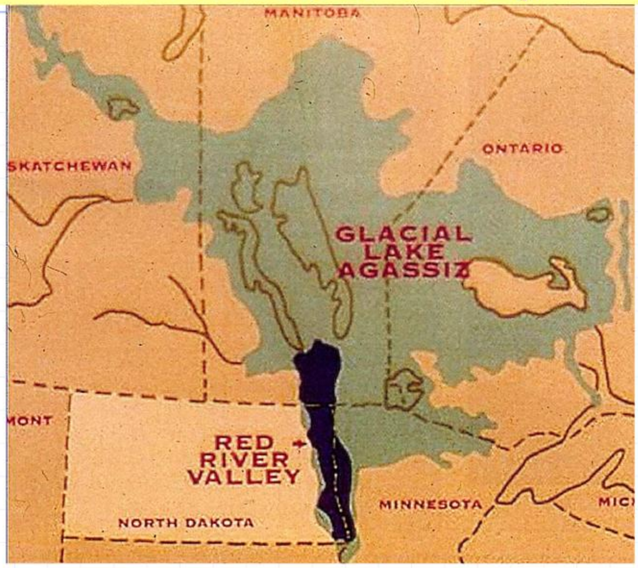
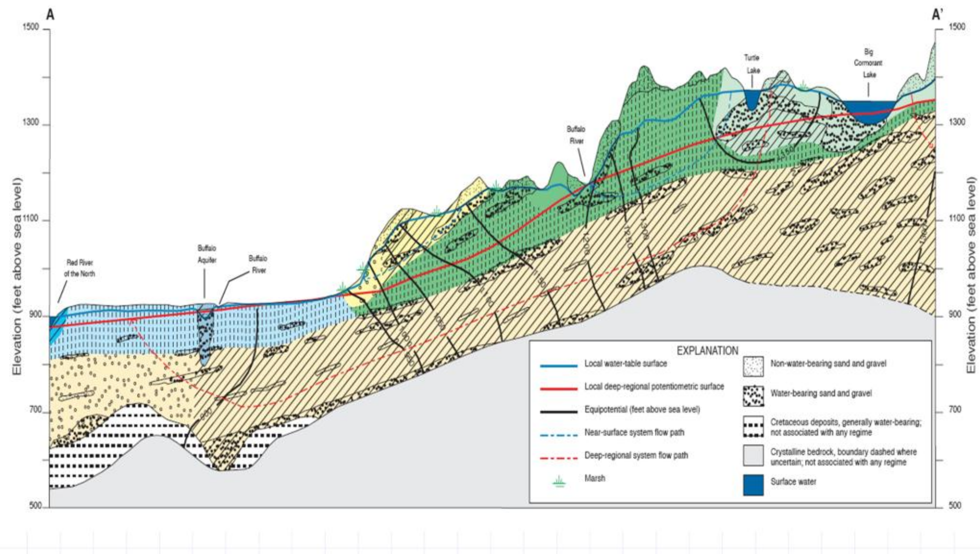
Pump tile outlets are common in the Red River of the North drainage basin. Todd Stanley is a farmer by Grygla, Minnesota and since 1995 has installed over 30 lift stations on property that he farms. He is a great resource for what works and doesn't work when installing and maintaining tile drainage lift stations.

Glacial Lake Agassiz and the Red River Valley



The Red River of the North drainage basin is the remnant of glacial lake Agassiz, formed when the glaciers melted and, as seen on this graphic, the RRV was the southern leg. Being the bottom of a lake means the land topography is very flat and the water table is relatively close to the surface thus the need for lift stations.

Geologic Cross Section of Red River Valley



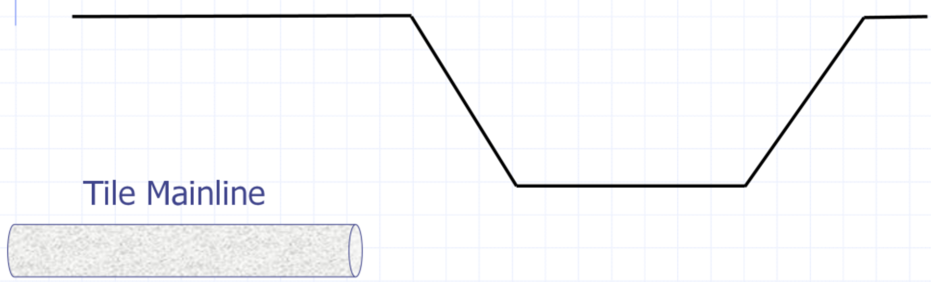
This a geologic slice that shows the topography from Fargo going east into Minnesota lake country. Notice that the blue area is the water table and that the surrounding area contributes not only surface but also ground water for drainage by the Red River of the North.

Typical Lift Station

Note the flat topography. The culvert in front with the flap gate is for surface drainage from the field.

Need For Lift Pump

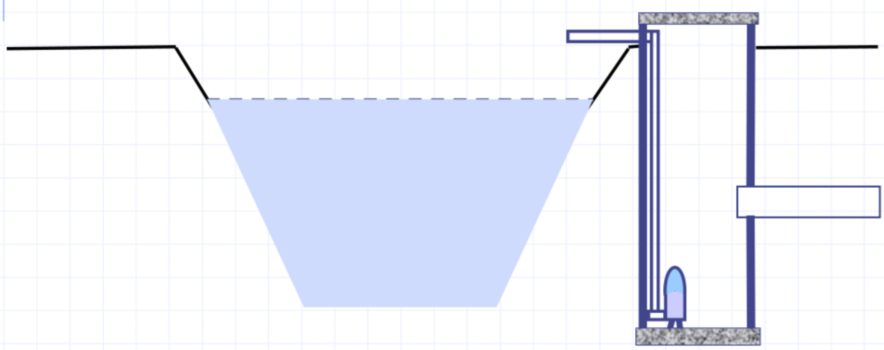
- No Gravity Outlet
  - Shallow ditch, No permission to make ditch deeper
  - Culvert through road is at a higher elevation than the tile main



This area has sufficient slope for a gravity outlet, however, the culvert under the road in the distance sets the outlet elevation and thus a lift station was needed for this drainage project.

Need For Lift Pump

- Outlet (ditch) fills up after a large rain and takes several days to subside
- You want to have control of water leaving the field
- You want to gain more grade on laterals



The ditch in front is a main drainage ditch for this area and after a large rain event or, in the spring with snow melt, it remains full for several days thus the need for this lift station.

Drainage Pump Stations

- Where to Locate?
- Pump Selection
- Power Requirements
- Pump Controls
  - Float (on/off)
    - Sump Storage Volume
  - Variable Frequency Drives

Pump Station Location

- Ideal: Near Drain Outlet and Electric Service
  - Limits pumping distance and pump size
  - No surface drainage (except tile surface inlet)
- In Some Cases: Near electric service is more desireable than near outlet
  - Trade-off: cost of extending electric lines versus cost of piping
- Other Considerations:
  - Potential for vandalism
  - Accessibility after a large rainfall event
  - Soil stability – will it wash away?
  - Impact on neighbors

Note the transformer near the sump and power lines in the distance. The lift pump is about 600 feet from the overhead electric lines.

The location of this lift pump was selected to be close to the electrical supply. Note the transformer on the pole.

Sometimes spring runoff can cause accessibility problems. Consideration of neighbors led to the location of this lift station being installed about 500 feet downstream from the field. The edge of the tree belt in the upper left of the photo surrounds a nearby farmstead and if the lift station had been put by the field, the water would have been pumped into the ditch in front of the farmstead. That would have created a mosquito and cattail problem for the residents of the farmstead.

Pump Selection

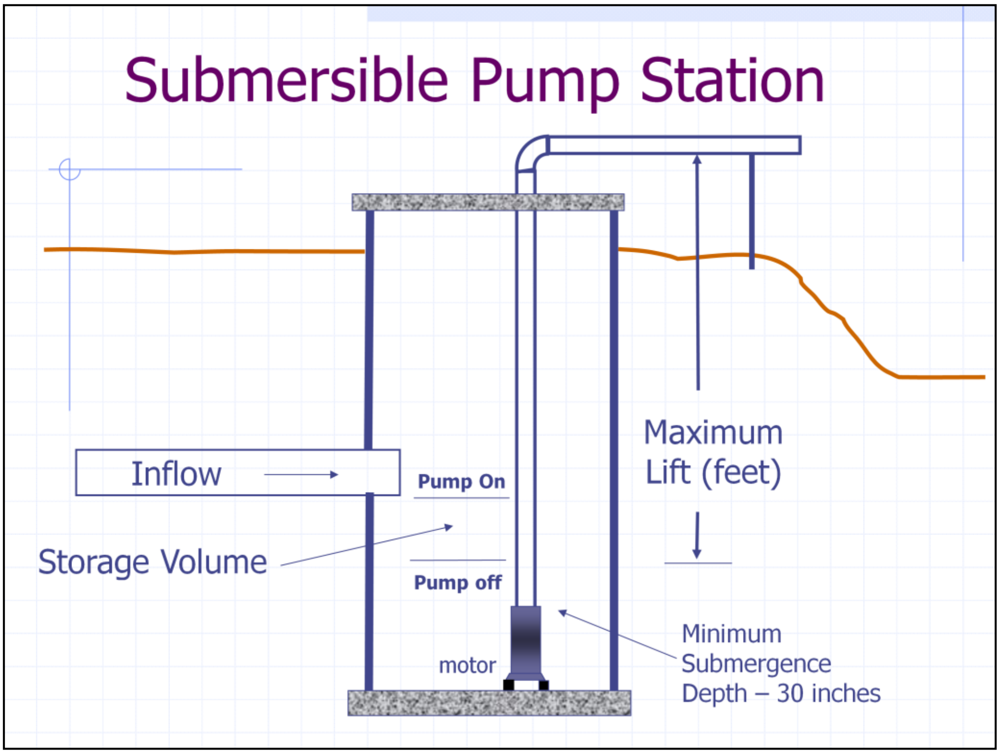
- Need to determine:
  - Flow Rate
  - Total Head
    - Maximum lift + friction losses
- Common pump types
  - Submersible
  - Motor Above Ground
- Pumping Costs

Pump Capacity (Flow Rate)

Q (gpm) = 18.9 * Dc * Area

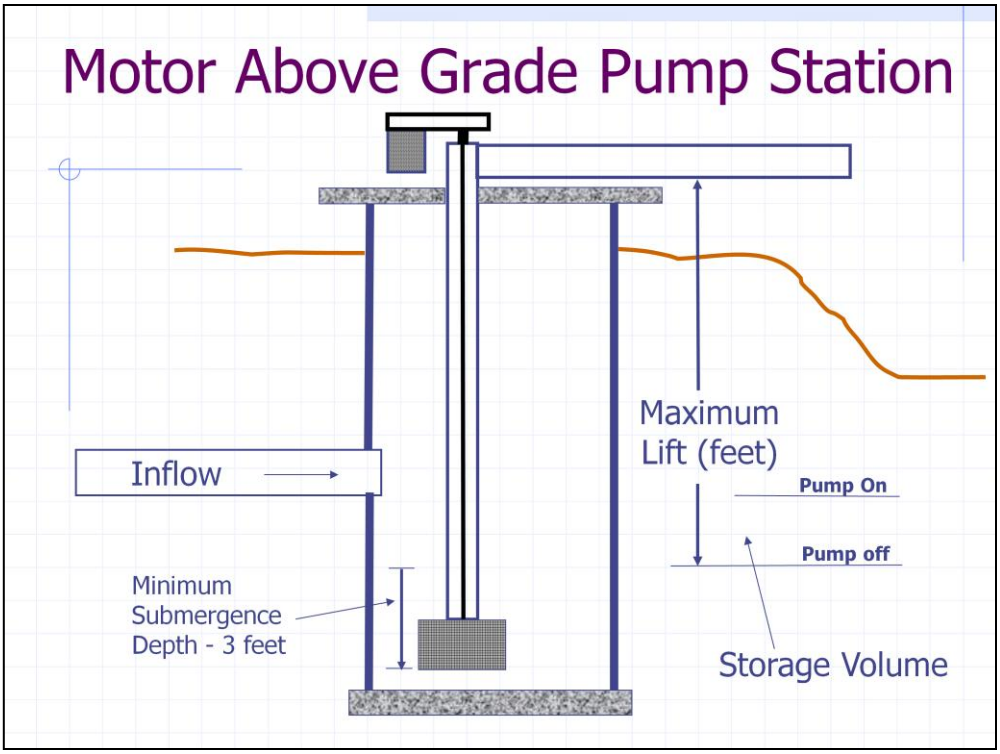
Drainage Coefficient (acre-inches/day)	GPM per acre	Cubic feet per second per acre (ft^3/sec)
¼	4.7	0.01
3/8	7.1	.016
½	9.5	0.021

The 3/8th inch drainage coefficient is commonly used in the Red River Valley.



Total installed depth is between 13 and 15 feet.

Sump at Fairmount Demo Site



Total sump depth is again 13-15 below surface.

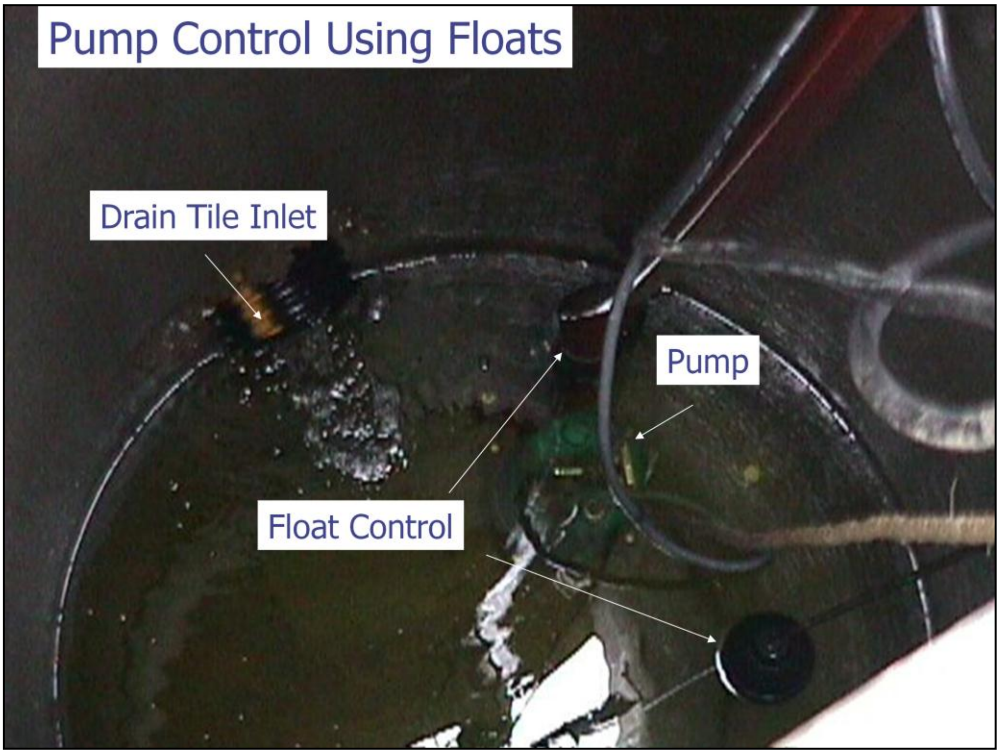
These pumps are variable speed because the pulley on the motor and the pulley on the drive shaft have 3 different diameters – allowing 3 different pump rotation speeds. This allows the farmer to match the pumping rate to the size of the field.

Lift Pumps

- Capital investment
  - Pump - $3,000 to $7,000 plus sump construction and installation costs.
  - Total cost may add $15,000 to $20,000 to overall tile project with electric connection charges and if during installation, dewatering is needed

Pumping Costs

- Example of Pumping Energy Costs
  - Grygla, MN Area in 2010 (*Todd Stanley*)
    - 1 rain gage: 34.7 inches
    - 25 electric meters
    - 5020 acres (small amount of surface drainage)
    - Electric Bill – about $30,000
      - Just under $6/acre with a range of $3 to $10.50
      - Smaller fields (55 and 70 acres) were $12.50 and $15/acre.


Pump Control Using Floats
Drain Tile Inlet
Pump
Float Control

Pump Horsepower

Pump Efficiency = 30%

Total Head (ft)	Flow Rate (gpm)			
	500	1000	1500	2000
6	**3**	**5**	**7.5**	**10**
8	**3**	**7.5**	**10**	**15**
10	**5**	**10**	**15**	**20**
12	**5**	**10**	**15**	**20**
14	**7.5**	**15**	**20**	**25**
16	**7.5**	**15**	**20**	**30**

Shaded Area – Single Phase Pumps

Low head pumps, whether submersible or shaft driven, are not very efficient. Common pump efficiency values, depend on the type of impeller design, range from 20 to 30 percent.

Pumps that Use Float Control: Sump Storage Volume

- Depends on:
  - Maximum Inflow Rate
  - Desired Pump Cycle Time
    - 1 Cycle = Time Pump on + Time Pump off (minutes)
    - 10 cycles per hour (every 6 minutes)
    - *Maximum pump cycles occur when tile inflow rate equals half the pump flow rate*
    - Some manufacturers claim their pumps can handle 30 cycles per hour.

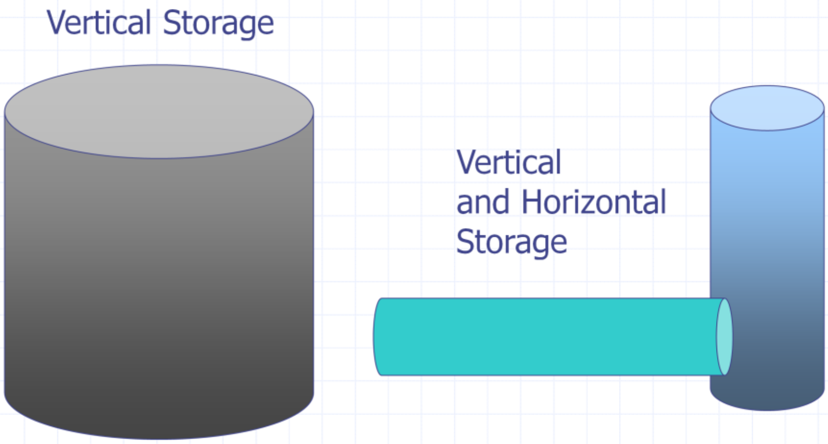
4 years of monitoring pumps has shown that 20 cycles per hour is excessive and leads to premature pump and/or motor failure. Most of the failures are associated with undersized storage volume.

How Much Storage is Needed?

Storage Volume per Acre (ft^3/acre) = 2*Q/N where Q is the gpm per acre and N is the cycles per hour

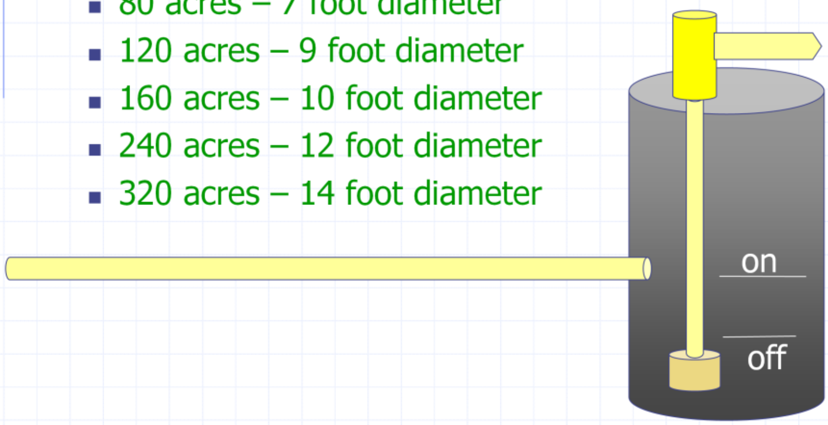
Drainage Coefficient	N – Cycles per hour			
	6	8	10	15
¼	**1.6**	**1.2**	**0.9**	**0.6**
3/8	**2.4**	**1.8**	**1.4**	**1**
1/2	**3.2**	**2.4**	**1.9**	**1.3**

Volume Storage Options



Example – Vertical Storage

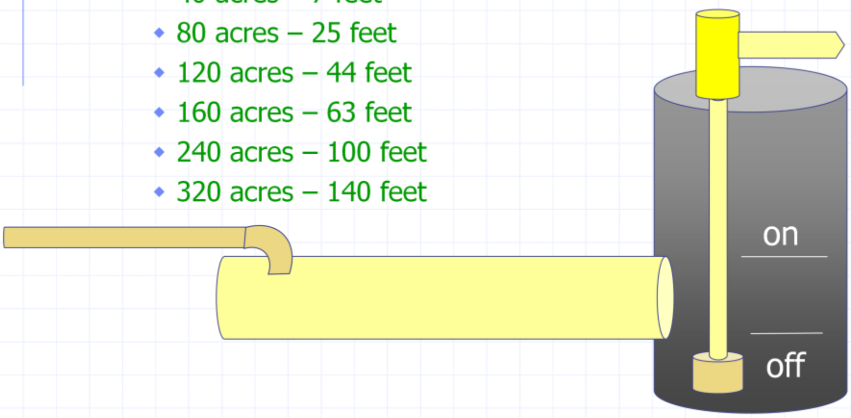
- Dc = 3/8, N =10, 3 ft on/off
  - 40 acres – 5 foot diameter
  - 80 acres – 7 foot diameter
  - 120 acres – 9 foot diameter
  - 160 acres – 10 foot diameter
  - 240 acres – 12 foot diameter
  - 320 acres – 14 foot diameter



The storage at this site is on the low side, it should have about 1000 gallons of storage. After a heavy rain event, we have recorded up to 18 pump cycles per hour on this lift station.

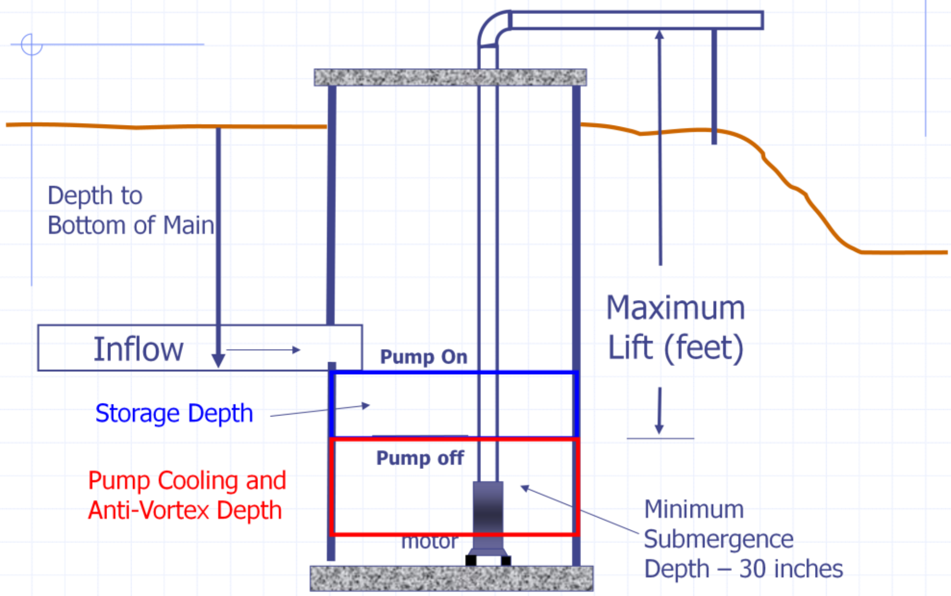
Example – Horizontal Storage

- Dc = 3/8, N =10, 4’ dia sump, 3 ft on/off
  - 2 foot diameter horizontal storage
    - 40 acres – 7 feet
    - 80 acres – 25 feet
    - 120 acres – 44 feet
    - 160 acres – 63 feet
    - 240 acres – 100 feet
    - 320 acres – 140 feet




Horizontal Storage, 70 ft of 2’ dia
Dual-wall pipe, 4’ diameter vertical
Concrete riser pipe

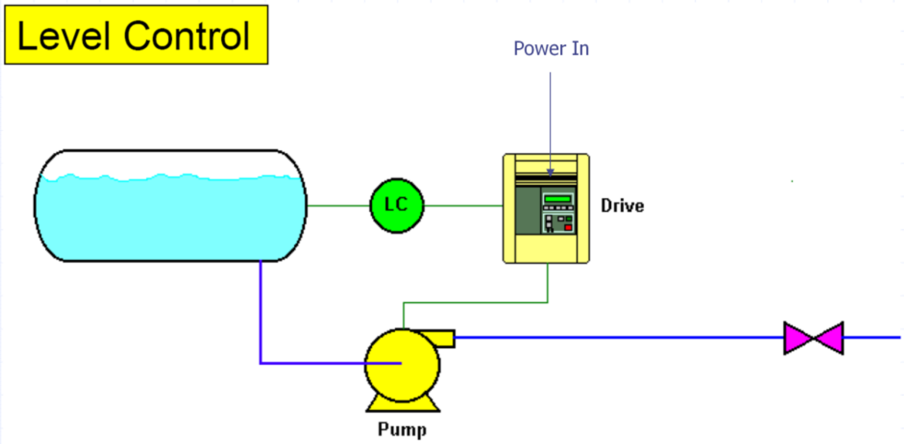
Sump Construction



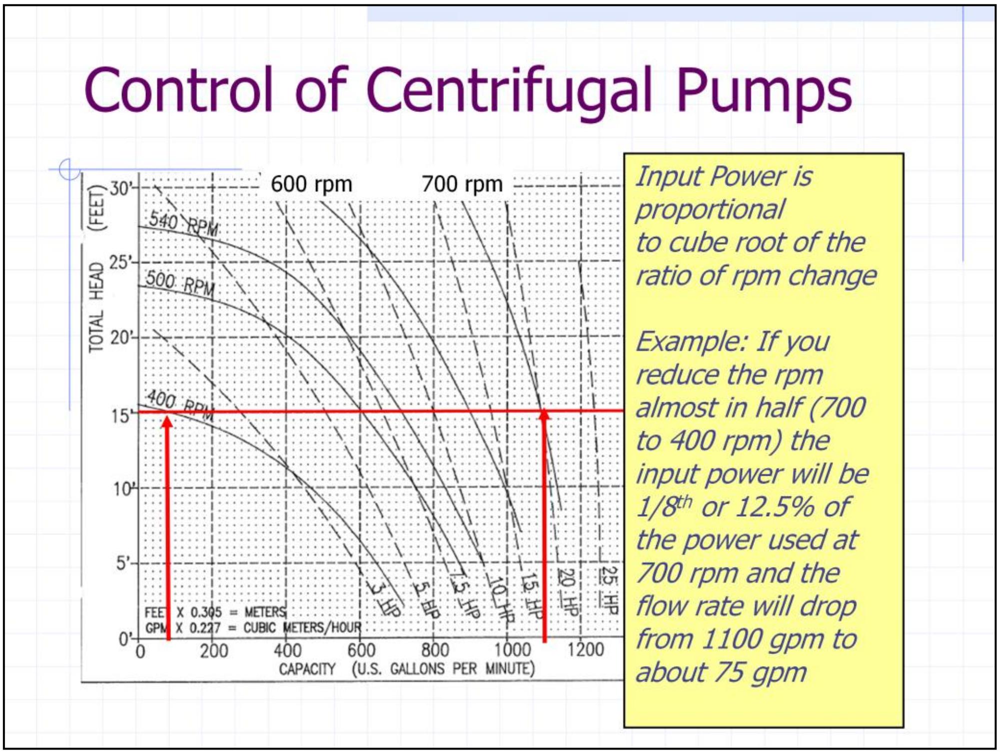
New Technology – Variable Frequency Motor Controllers VFD's for Pump Control

- On the market for about 2 years
- Eliminates the need for storage
- Sump depth can be less
- Less wear on motors
  - Soft start options
- Uses water level sensor to control speed of pump
- Reduces energy use

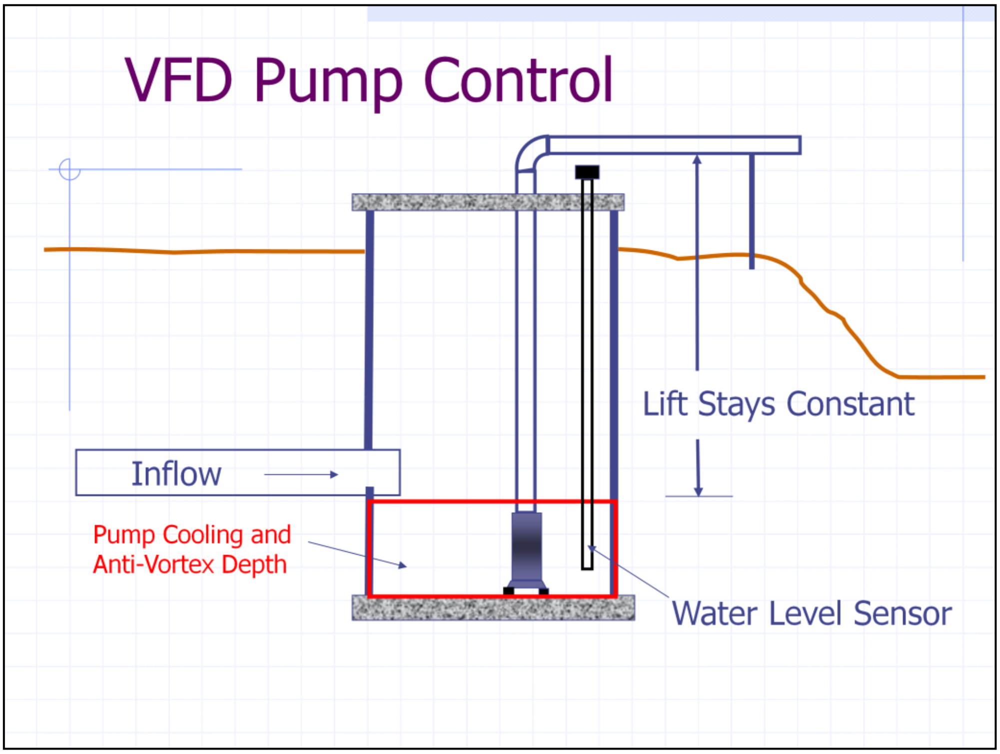
Water Level Control



Courtesy of Steve Clayton
Fusion Technologies



This is a pump characteristic curve for a low head pump. In a drainage lift station, the head stays relatively constant (in this example at 15 feet) thus the power use and flow rate will vary greatly with a change in rpm via a VFD. As the flow into the sump decreases or increases the pump rpm will be adjusted by the VFD.



Note that the sump depth with VFD pump control will be less than for a float controlled pump. The sump depth will be about 9 to 12 feet from the surface.

A drainage pump station installed in 2011 in West Fargo, ND. The black box is the VFD controller.

The VFD controller.

The water level sensor is a pressure transducer in the grey box that is connected to the 2-inch diameter PVC pipe that extends to near the bottom of the sump.

The sump lining is 4 foot diameter corrugated plastic with a metal cover.

Sump Construction

- Casing Materials
  - Corrugated Metal
  - Plastic
  - Concrete
- Main Line entrance into sump – must be sealed very well on the outside to prevent "washouts".
- Bottom Material
  - Concrete
  - Gravel or Rocks (at least 6 inches thick)
- Some situations may require dewatering to install the sump casing

Lift Pump Management

- During the Season
  - Check if Pump is Operating
- Annual Maintenance
  - Ice damage to floats, wires, vertical piping
  - Silt accumulation in the sump
  - Some aboveground pumps require oil or grease

Lift Station Advantages

- You control water table in the field. The pump can be turned off at any time.
- Allows you to pump water even when drain outlet is full

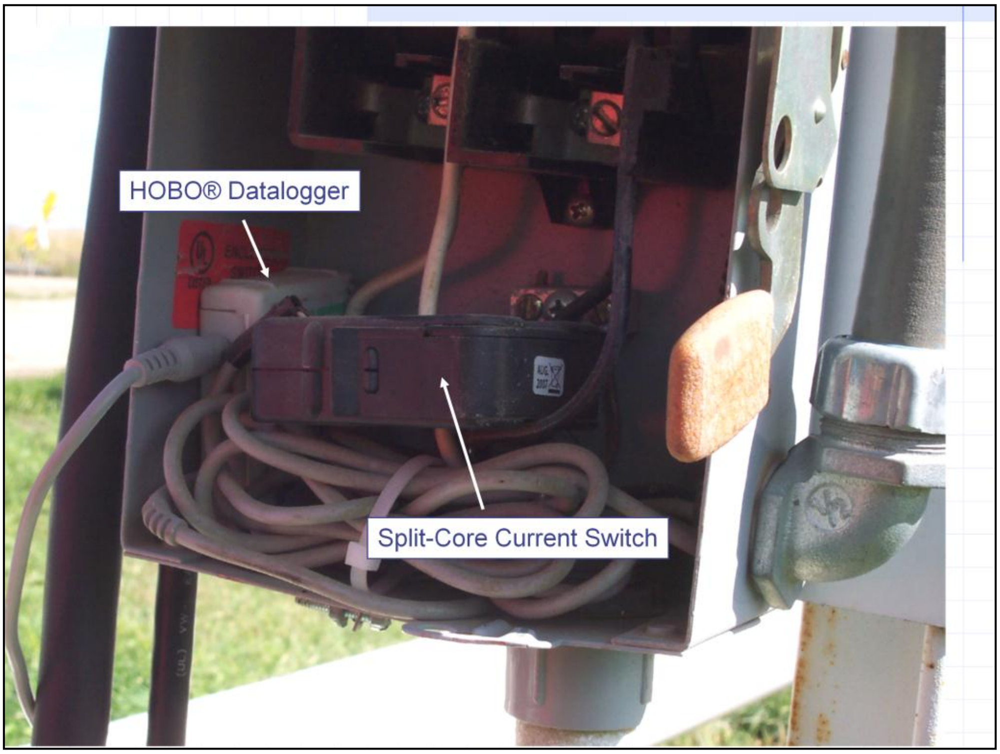
Lift Station Disadvantages

- Ice and Winter Conditions
- Operating Costs per year
- Wash Outs
- Maintenance
- Installation Problems
  - High water table
  - Sealing inlet pipe
  - Gravel or concrete bottom?
- Visible sign of flowing water can cause public concerns about flooding

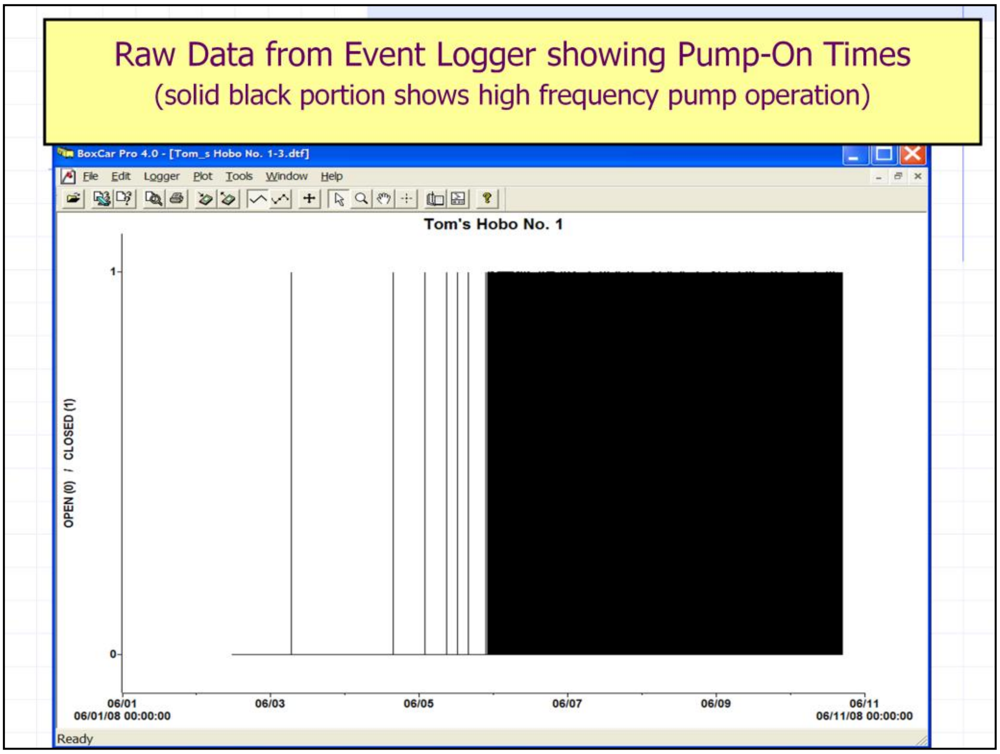
This drainage lift station is next to a major road and some people get irate if they see water being pumped during a flood event. This is one farmers solution. The outlet of the pump is protected so people driving by cannot see if water is being pumped.

Measuring the Flow Rate from a Float Operated Lift Station

At each lift station, we install a combination tipping-bucket rain gage and a manual rain gage. Both record to 1/100th of an inch.



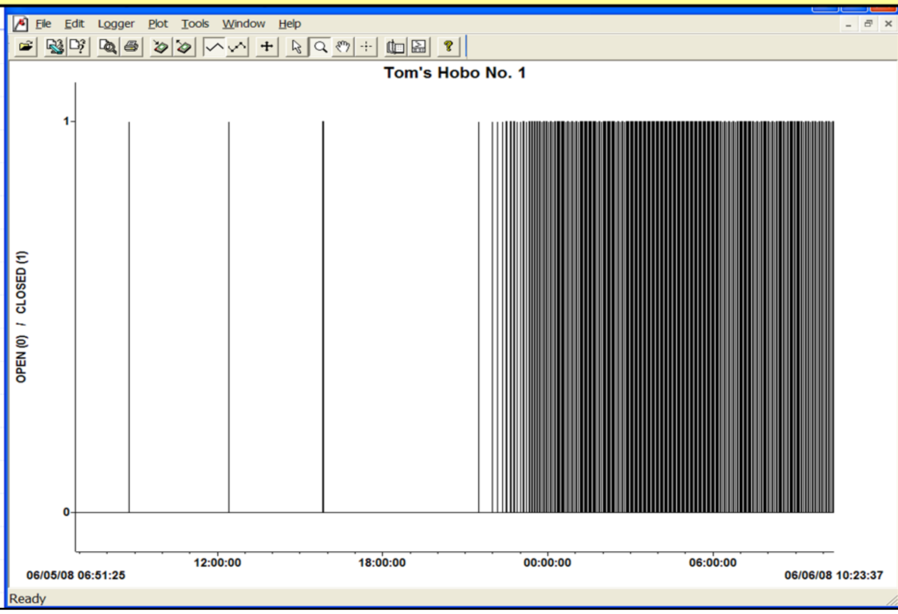
We use a split-core current switch connected to a small datalogger to time-stamp when the pump starts and stops.

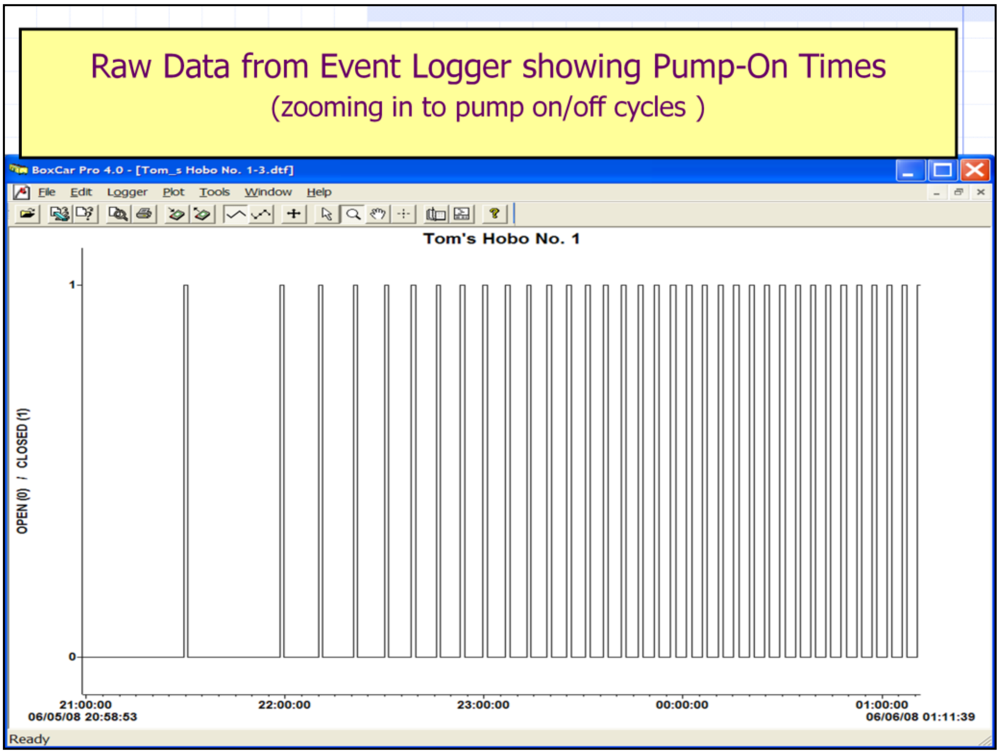


Each black line is when the pump was running.

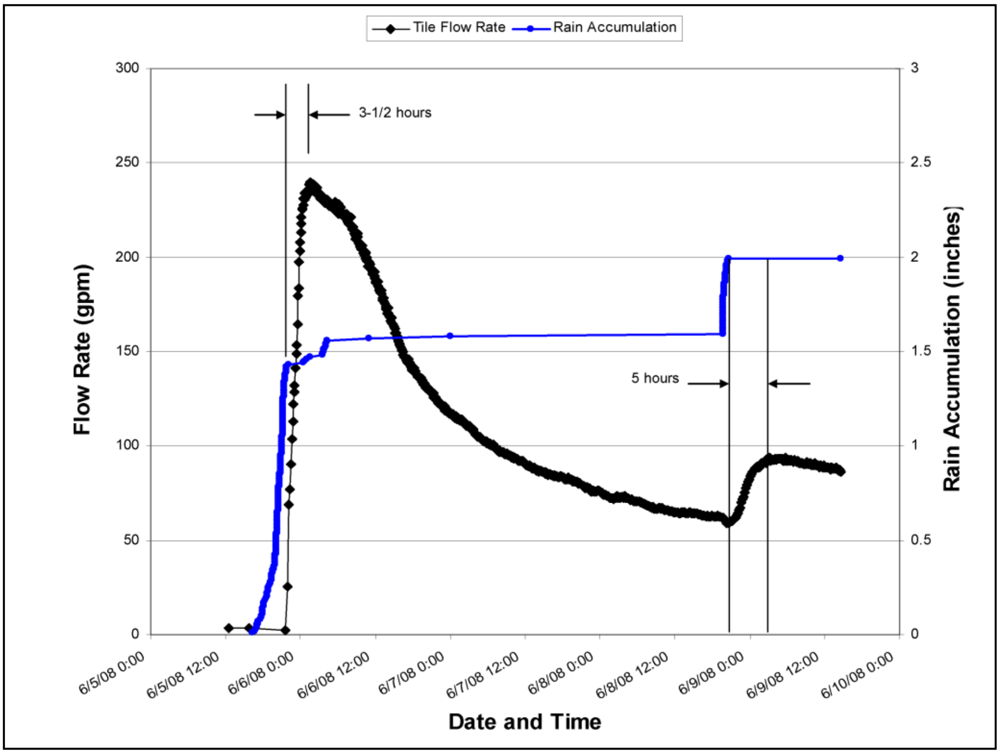
Raw Data from Event Logger showing Pump-On Times

(zooming in to when pump cycling begins to increase)

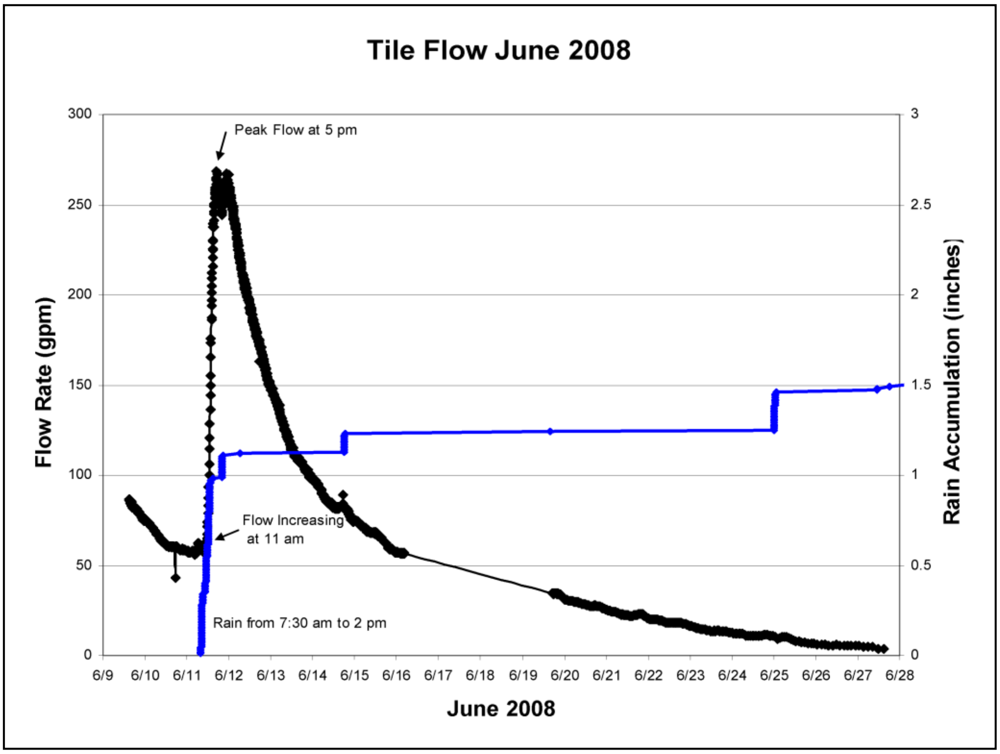




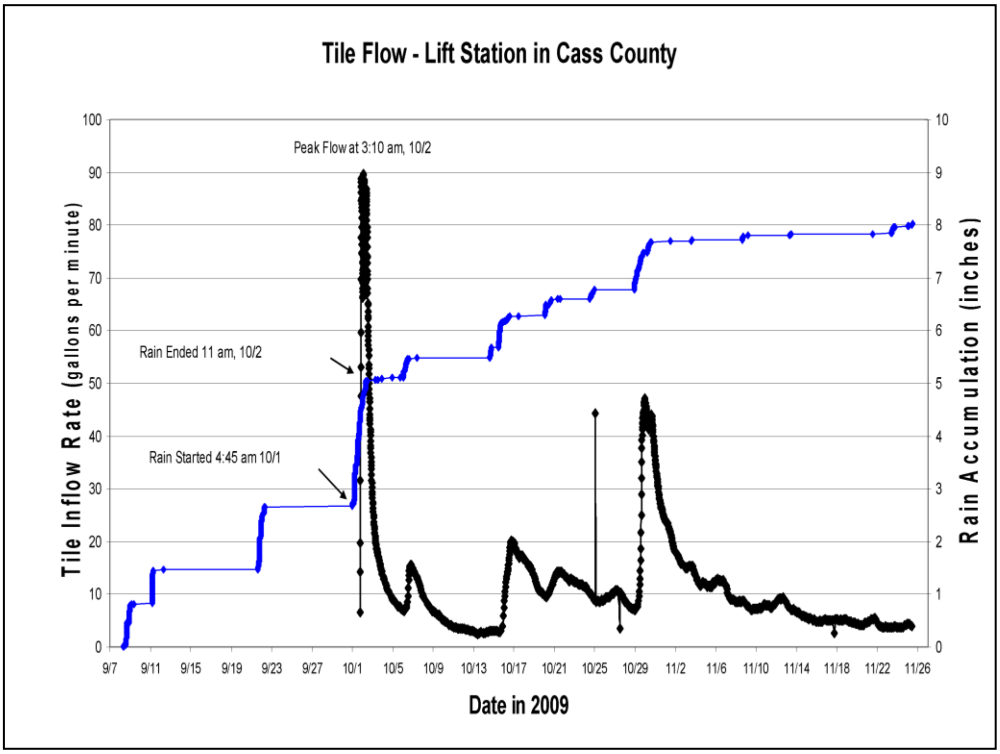
Note that the pump-on interval increases near the middle of the graph.



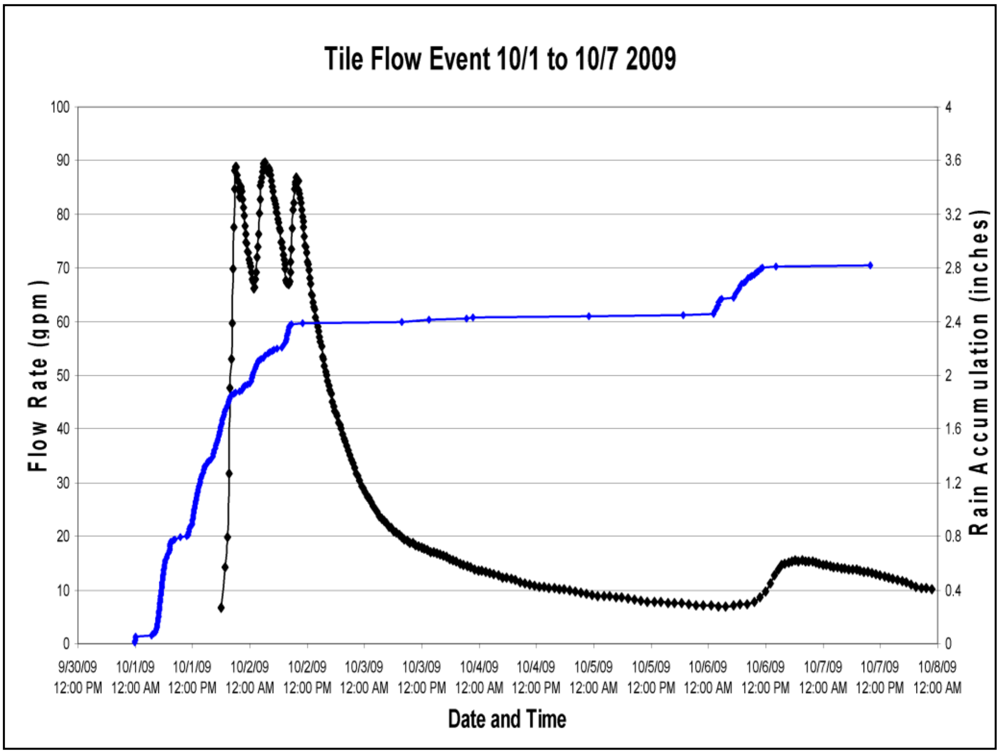
Note the rapid response of the pump to tile inflow and the recession curve after the rain stopped.



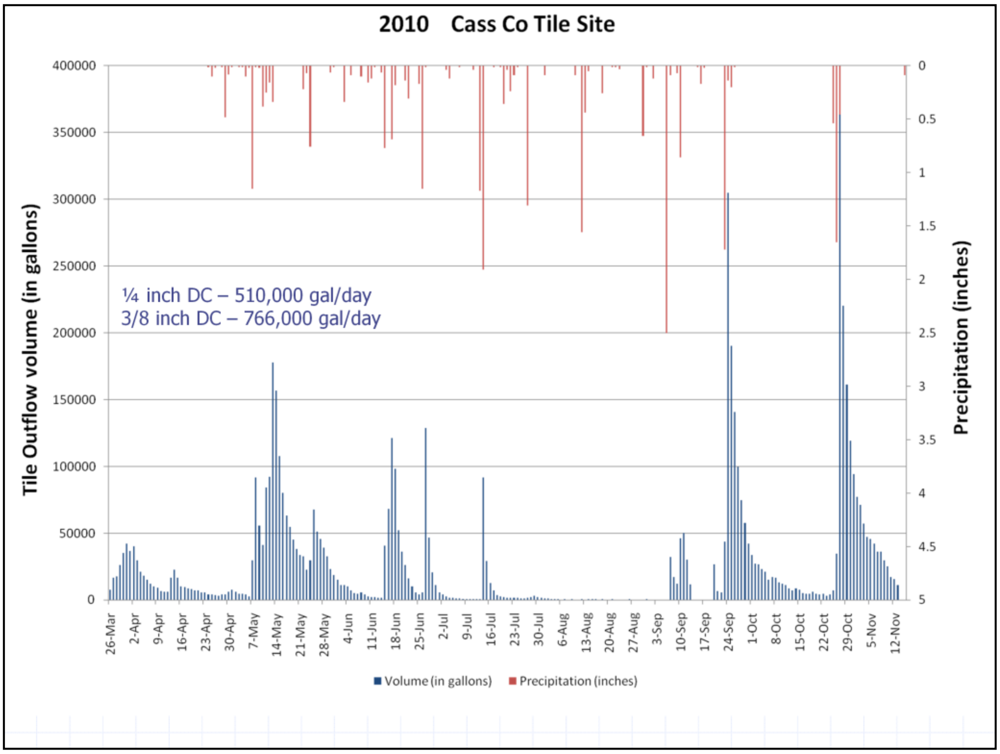
Tile Flow June 2008
Peak Flow at 5 pm
Flow Increasing at 11 am
Rain from 7:30 am to 2 pm
Flow Rate (gpm)
Rain Accumulation (inches)
June 2008
300
250
200
150
100
50
0
3
2.5
2
1.5
1
0.5
0
6/9
6/10
6/11
6/12
6/13
6/14
6/15
6/16
6/17
6/18
6/19
6/20
6/21
6/22
6/23
6/24
6/25
6/26
6/27
6/28



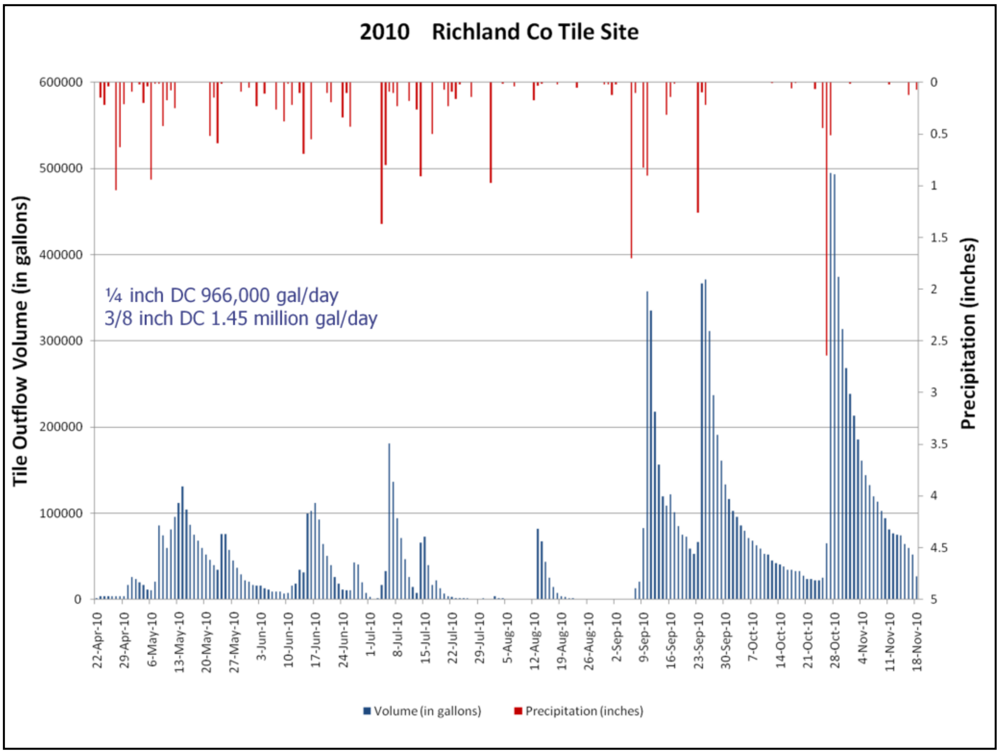
The field where this lift station was installed was dry up to September 8th. Note that it took almost 5 inches of rain before the tile started to flow.



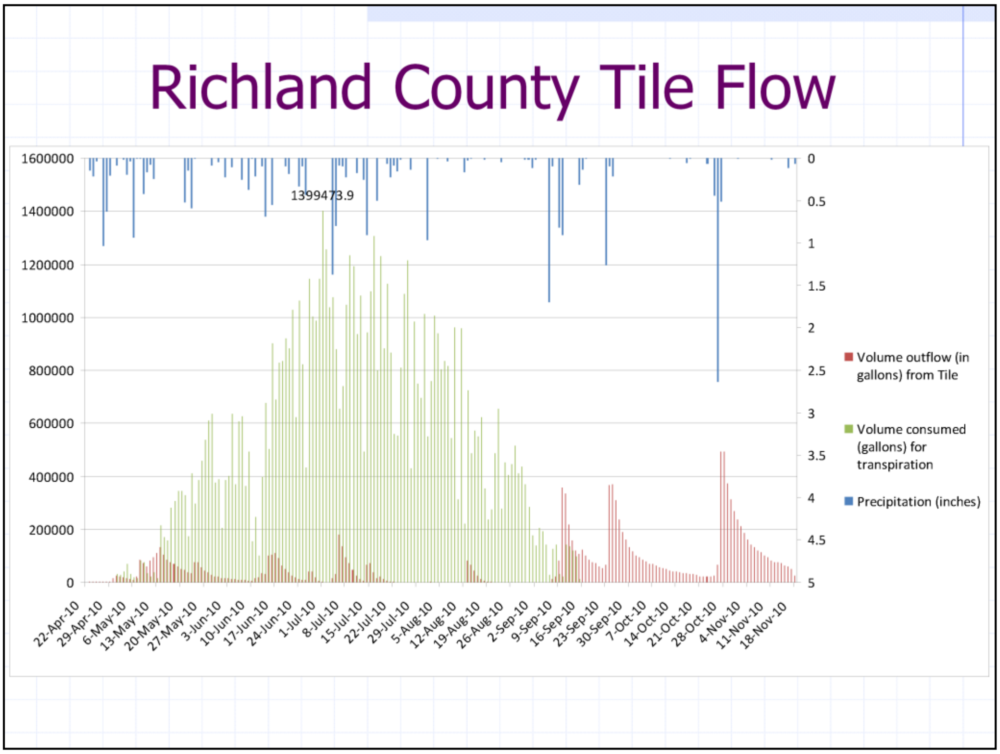
Note response of tile outflow to changes in variation of rainfall.



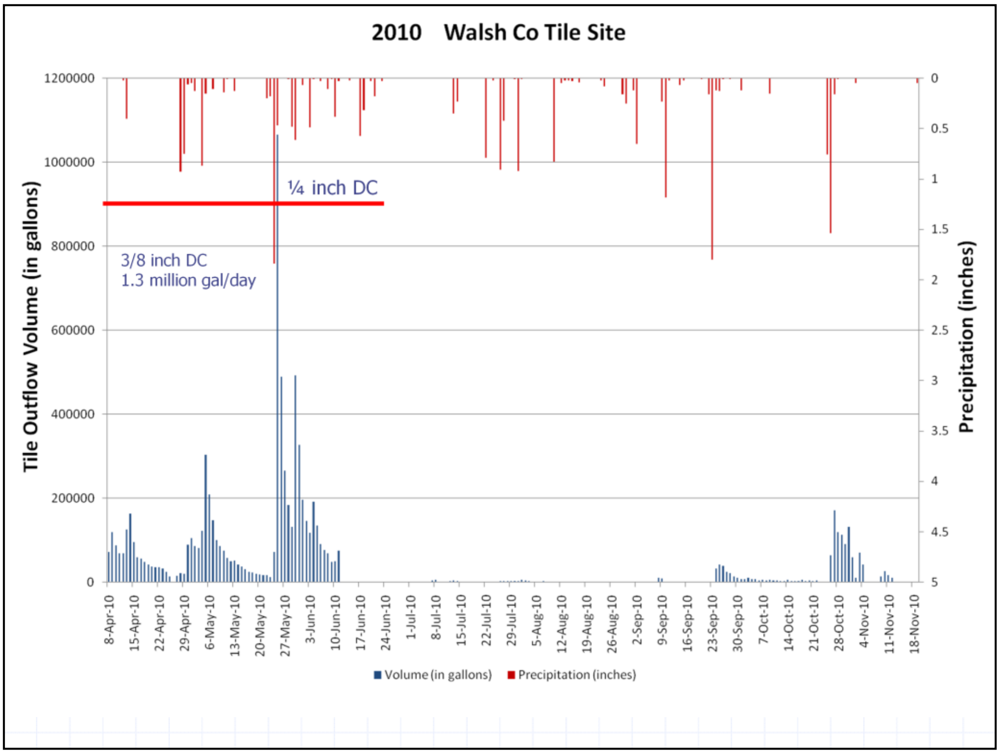
Full season flow volume from a drainage pump station at the Cass County site. Rain is on the top (scale on right)



Flow volume from our Richland County site.



Same graph as previous but corn ET during the growing season added (green bars). This is a 142 acre corn field and around the 4^{th} of July, the corn removed about 1.4 millions gallons on that day whereas the maximum tile outflow occurred in November and that was about 500,000 gallons.



Flow volume from our Walsh County monitoring site.


Questions? Observations! Thoughts!!