Irrigation Energy Needs

Michigan Soil and Water Conservation Society

March 7, 2012

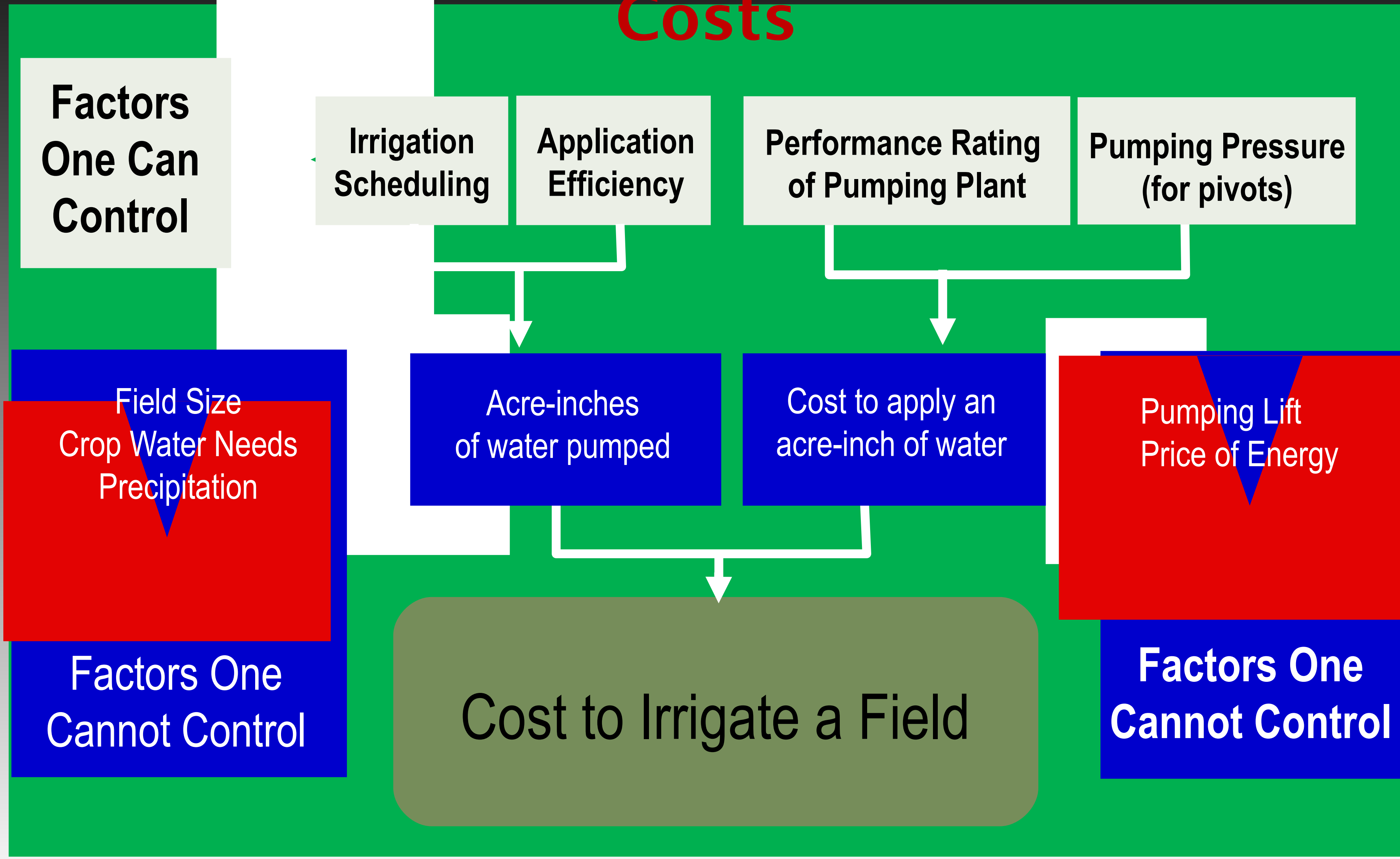
Steve A Miller

BioSystems & Agricultural Engineering

BAE Department of Biosystems and Agricultural Engineering

MICHIGAN STATE UNIVERSITY

Factors Affecting Irrigation Pumping Costs



Purdue Extension
Knowledge to Go

MICHIGAN STATE UNIVERSITY EXTENSION

Minimizing Irrigation Energy Cost

Lyndon Kelley
MSU Extension/Purdue University
Irrigation Management Agent
269-467-5511   Kelleyl.msu.edu

www.msue.msu.edu - find St. Joseph Co.
- then hit the Irrigation button

Lowest irrigation power cost and least energy used results from:

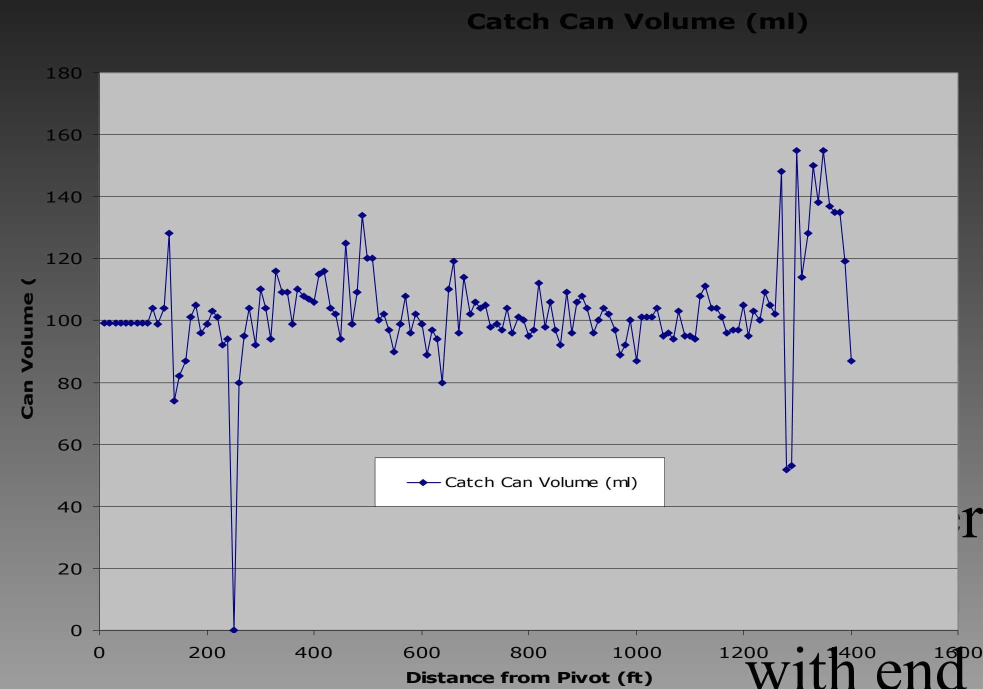
Pumping only water that results in a yield increase over dry land. (Effective)

Lowest cost, most efficient energy source available

Minimum system pressure that results in uniform application with no runoff concerns

Three factor reducing effective water application

2. Lack of system uniformity
· 5-35% loss in effectiveness



r

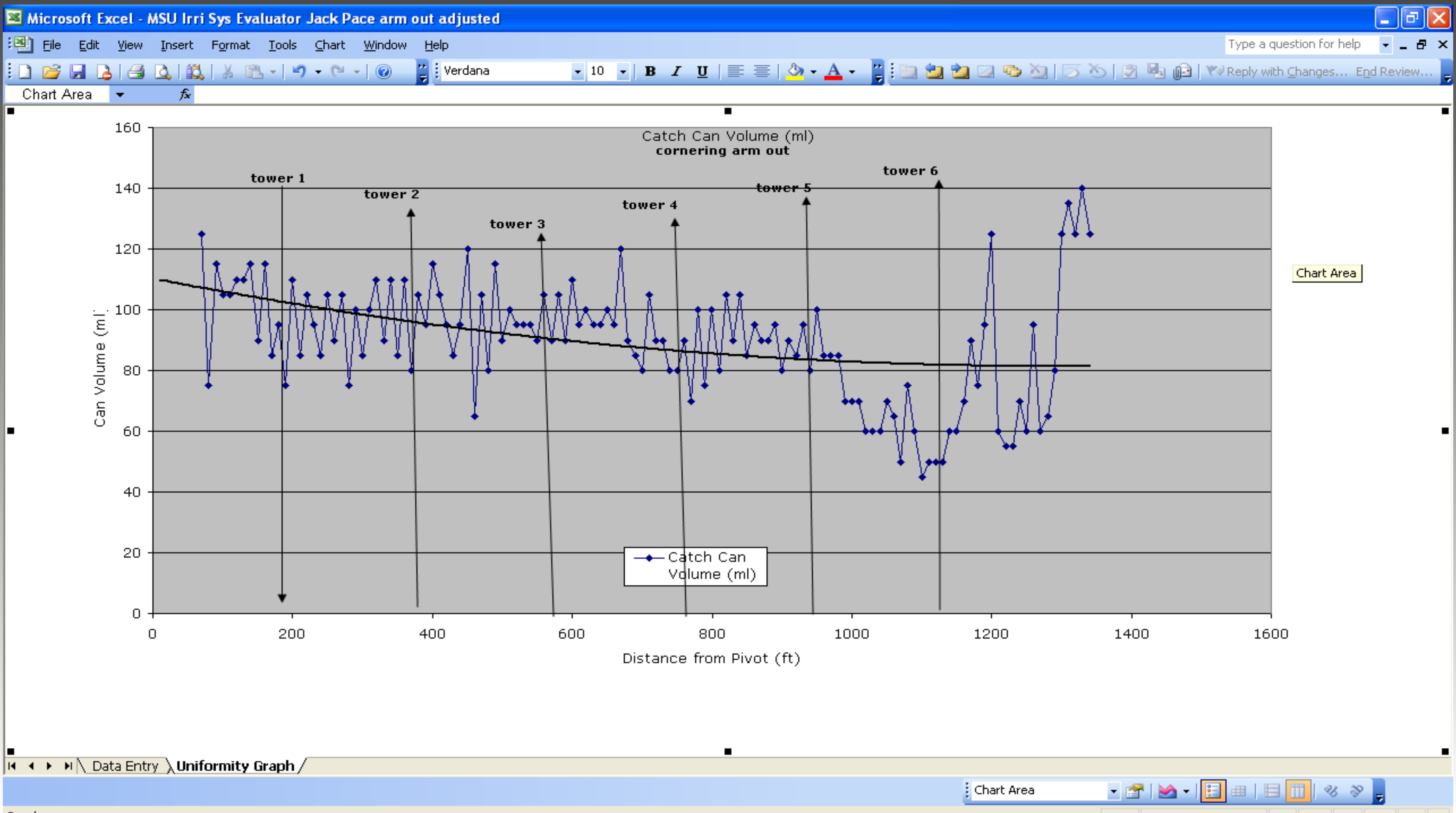
with end gun

1. Irrigation Runoff

(comparing irrigation application rate to soil

3. Evaporative loss to the air
·Minimal loss in our humid area
·0 – 6%
·Estimated 4-6% loss in Nebraska

Water supply over or under design



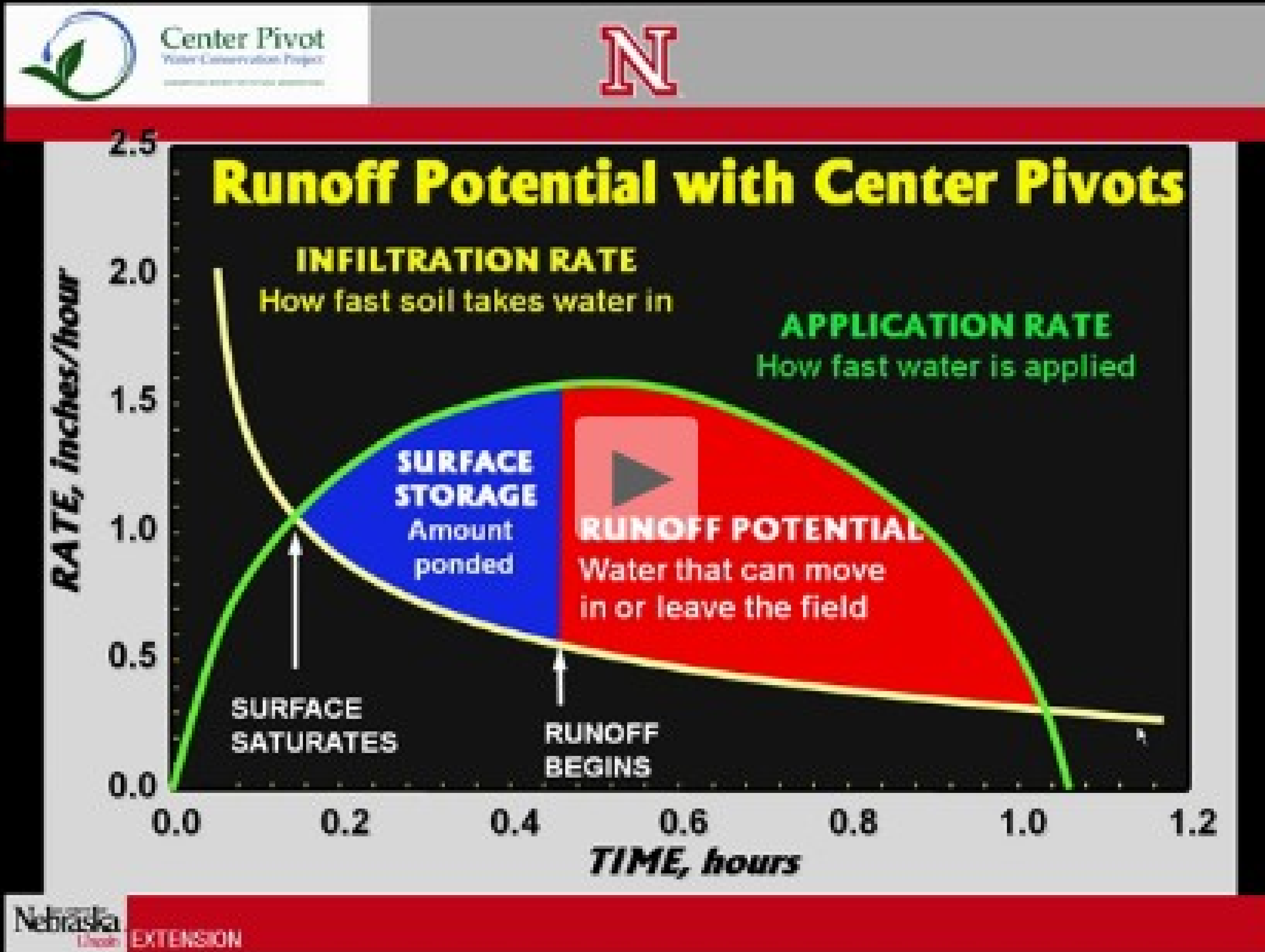
Preventing Irrigation Runoff

(comparing irrigation instantaneous application rate to soil infiltration rate)

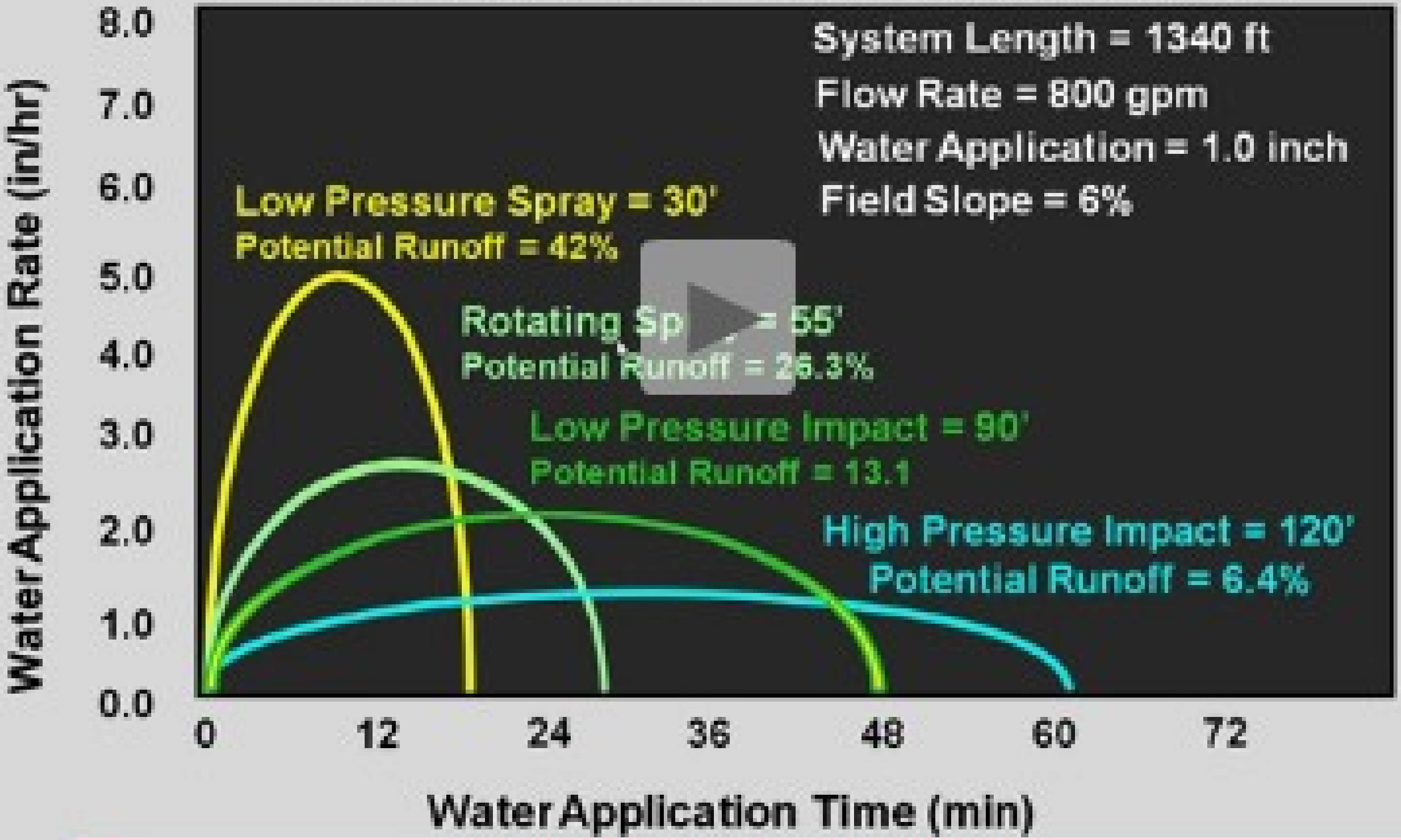
Sprinkler package or nozzle selection along with pressure dictates water application rate.

Factors that <u>increase</u> runoff :

- **Small Wetted area or throw of sprinkler**
- **Low Pressure**
- **Larger applications volumes**
- **Soil compaction**
- **Heavy soils**
- **Slope**
- **Row hilling**

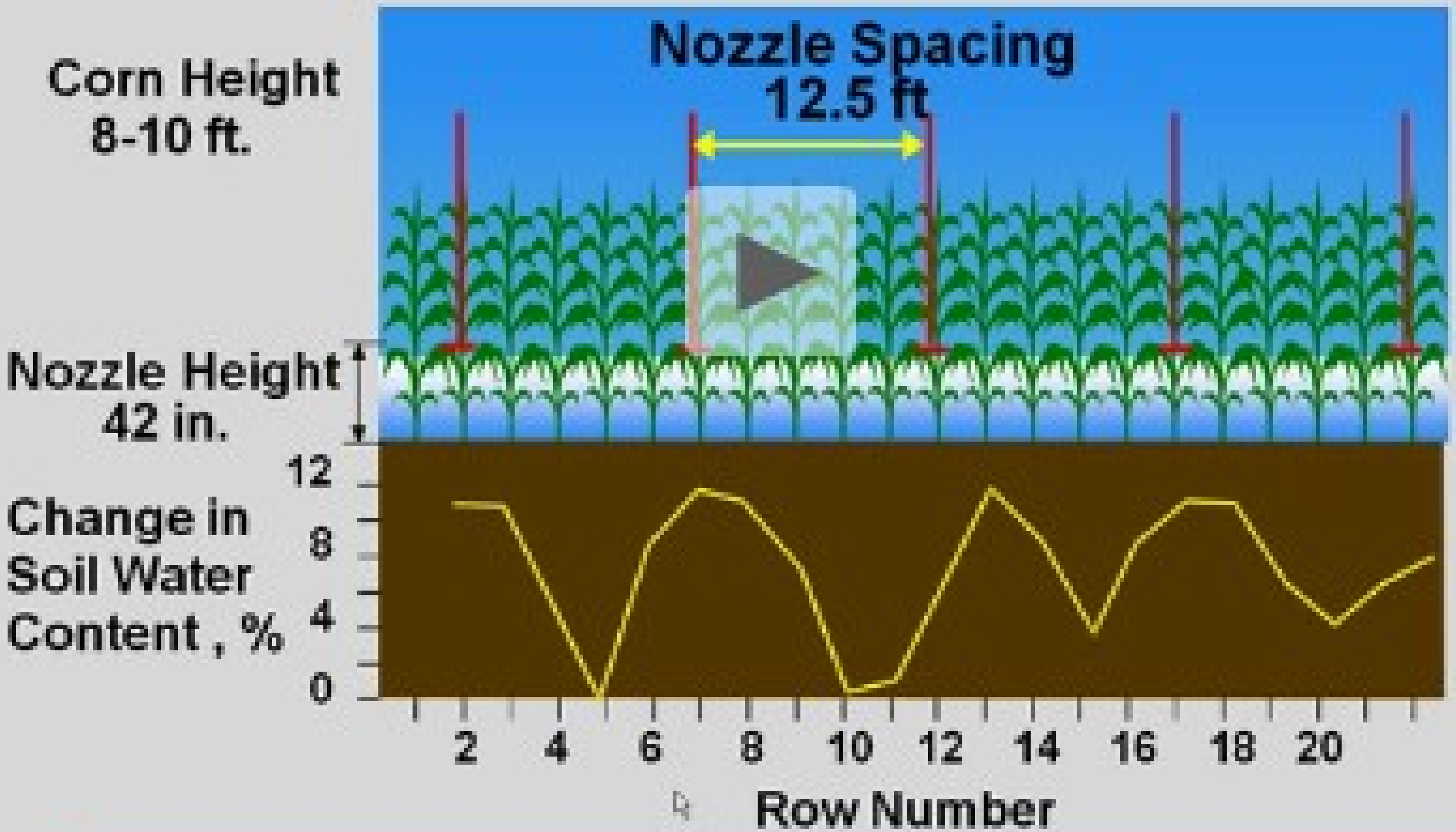

Center Pivot
Water Conservation Project
Runoff Potential with Center Pivots
INFILTRATION RATE
How fast soil takes water in
APPLICATION RATE
How fast water is applied
SURFACE STORAGE
Amount ponded
RUNOFF POTENTIAL
Water that can move in or leave the field
SURFACE SATURATES
RUNOFF BEGINS
RATE, inches/hour
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
TIME, hours
Nebraska
Lincoln
EXTENSION

Peak Application Rates



Nozzle Position Does Matter

In-Canopy Water Distribution Patterns



Irrigation Scheduling Overview and Tools

Steve Miller
William Northcott
Department of Biosystems and Agricultural Engineering
Michigan State University

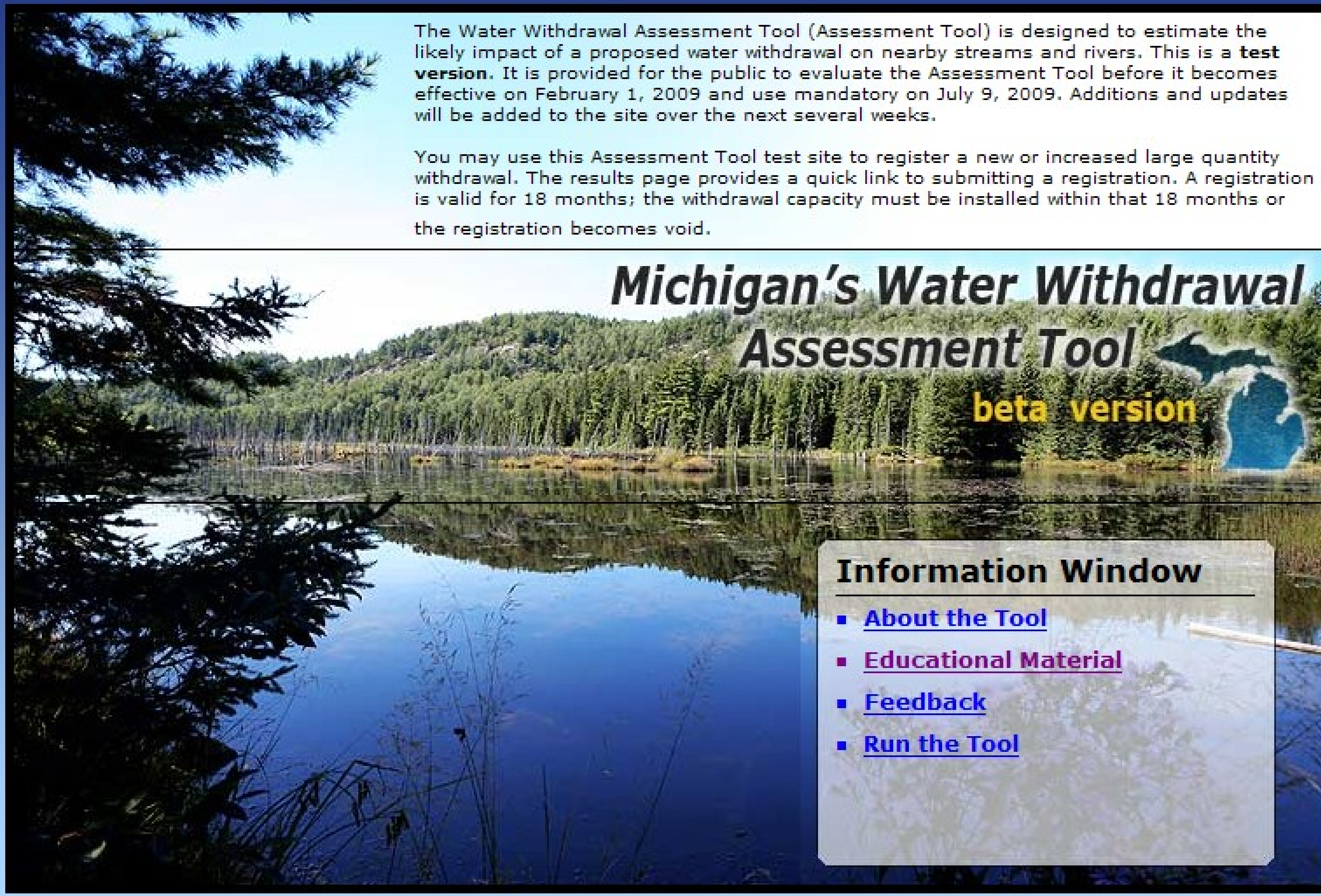



Water use Activities

- Michigan Court of Appeals Nestle (Ice Mountain) vs. local citizens

  - Impacts to stream flow must be considered when evaluating reasonable use

- St Lawrence River Basin Water Resources Compact (Annex 2001)
  - Signed Dec 2005
  - Final Approval 2008



http://www.miwwat.org/

Right to Farm GAAMPs Irrigation Scheduling

- Irrigation scheduling for each unit or field is an integral part of GAAMPs
- Irrigation scheduling is the process of determining when it is necessary to irrigate and how much water to apply
- Information from Record Keeping GAAMPs can be inputs to irrigation scheduling

Irrigation Scheduling

- Process of maintaining an optimum water balance in the soil profile for crop growth and production

- **Irrigation decisions are based on an accounting method on the water content in the soil**

Irrigation Scheduling

- Components
  - Plant Growth and Water Use
  - Soil Water Holding Capacity
  - Rainfall / Irrigation
  - RECORDKEEPING

Plant Growth and Water Use

- Fundamentally crops use water to facilitate cell growth, maintain turgor pressure, and for cooling.
- Crop water use is driven by the evaporative demand of the atmosphere.
- Function of temperature, solar radiation, wind, relative humidity.
- Example, a fully developed corn crop in Michigan can use as high as 0.35 inches per day. (~9,500 gallons / acre)
- Optimum crop growth and health occurs when the soil moisture content is held between 50 – 80% of the "plant available water"

Estimating Plant Water Use

- Crop water use = Evapotranspiration (ET).
- A "potential reference ET (PET)" can be calculated based on weather conditions.
- The standard method – Penman – Monteith.
  - Based on temperature, solar, humidity, wind, rainfall
  - "Well watered grass"
- Michigan Enviro-weather Program calculates hourly PET at each station.

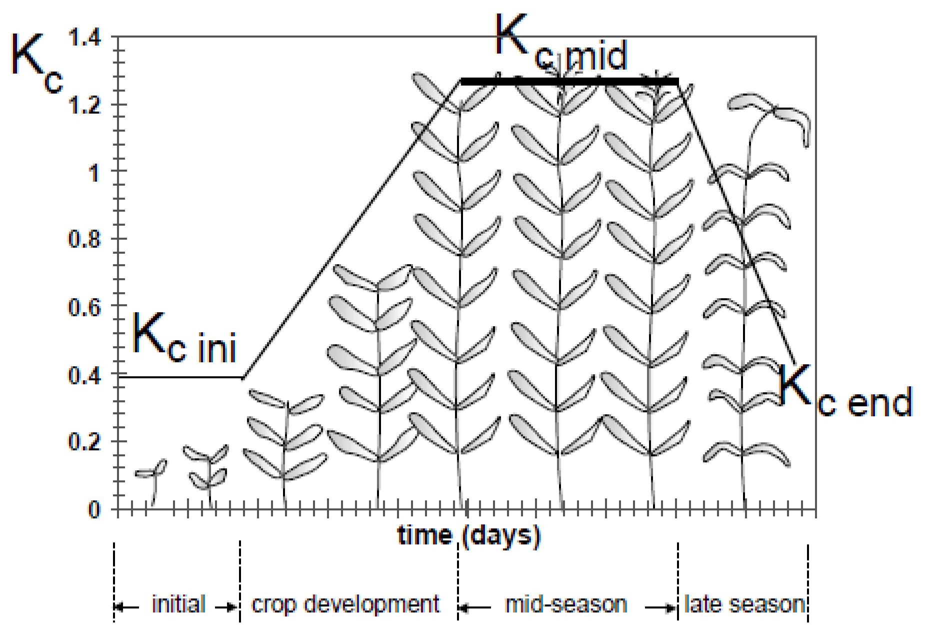
http://www.enviro-weather.msu.edu/

Estimating ET for Different Crops

- Combining a “Crop Coefficient Curve” with the reference ET.
- Crop Curve is a relationship between the specific plants’ growth characteristics and its water use relationship to the reference crop.

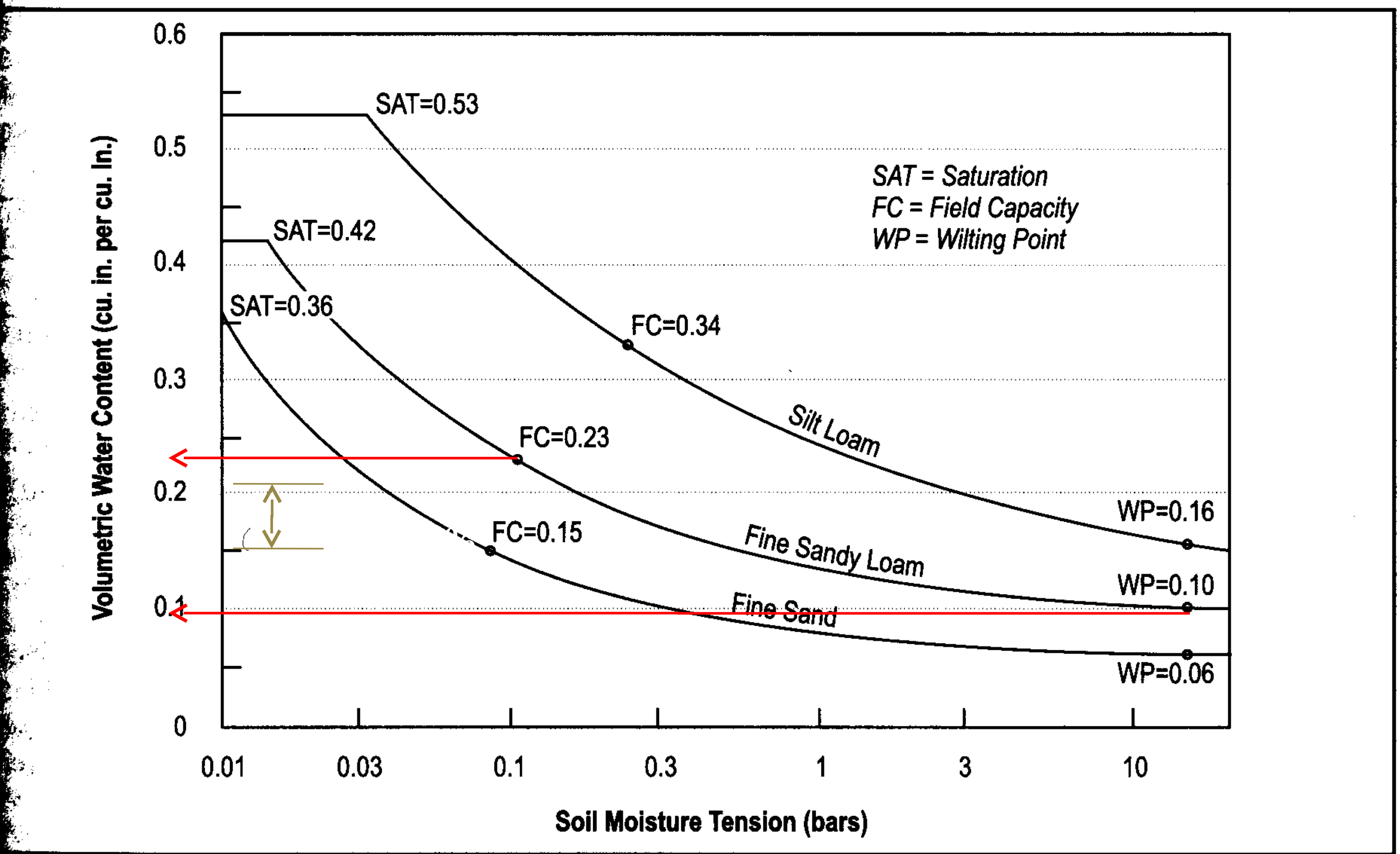
Crop Curve

FIGURE 25
Generalized crop coefficient curve for the single crop coefficient approach



Soil Water Holding Capacity

- Soil act as a reservoir to hold water for plant use.
- The capacity for a soil to hold water is primarily based on the soils texture but can be modified by attributes such as soil organic matter.



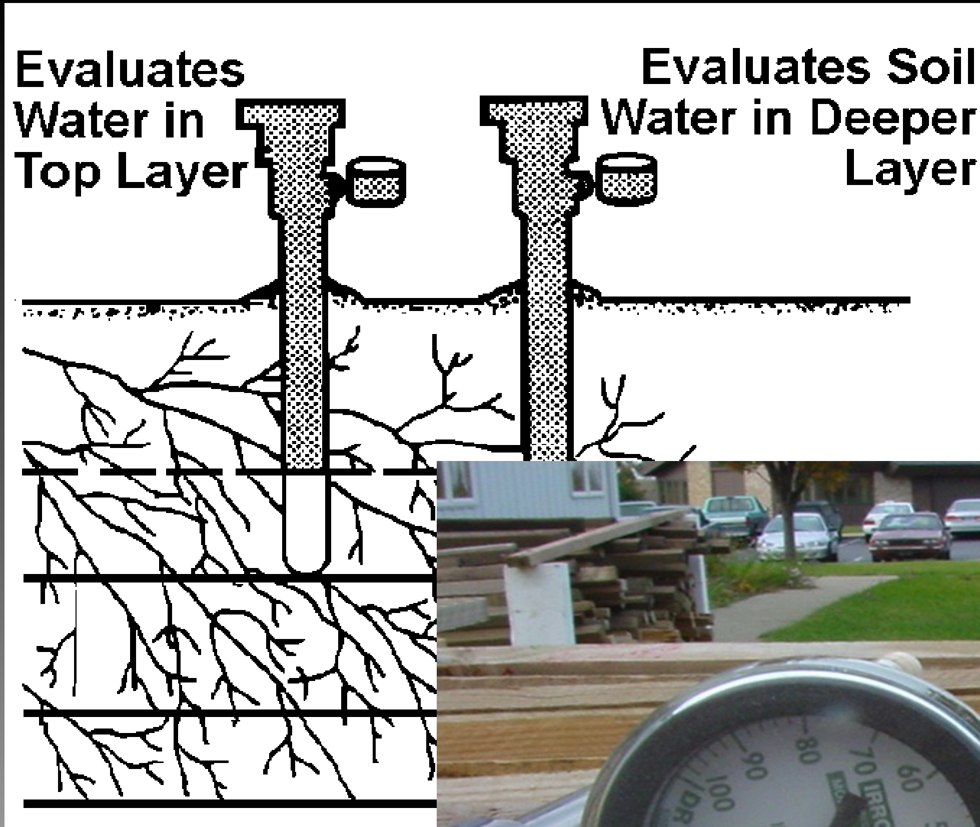
ure 2-4. Soil water content-moisture tension relationship.

rce: *Irrigation Systems Management.*

Determining Soil Moisture

- Actual soil water content measurement
- Indirectly by determining moisture tension
- Soil moisture estimation
- Next Slides from Dr. Ronold Goldy

Tensiometers


Evaluates Water in Top Layer
Evaluates Soil Water in Deeper Layer


DRY
WET
IRROMETER
18"
45 cm
12"
30 cm
IRROMETER


Eurodrip Low Flow
12 Inch Spacing
17 gal/100'/hr
3 hr

Frequency Domain Reflectometry

IRRIGATION SCHEDULING METHODS, INC.

PRISM-CMP Moisture Probe

Checkbook Register

SOIL WATER BALANCE SHEET

(Make copies as needed)

Field____________________Crop___________________Emergence date_______________
Pumping Capacity___________gpm per acre=__________net application inches per day
Available Water Capacity____________inches in root zone of_______________inches

Growth Stage	Vegetative	Critical Growth	Maturing
Allowable	______%	________%	_______%
Soil Water Deficit	______inches	________inches	_______inches

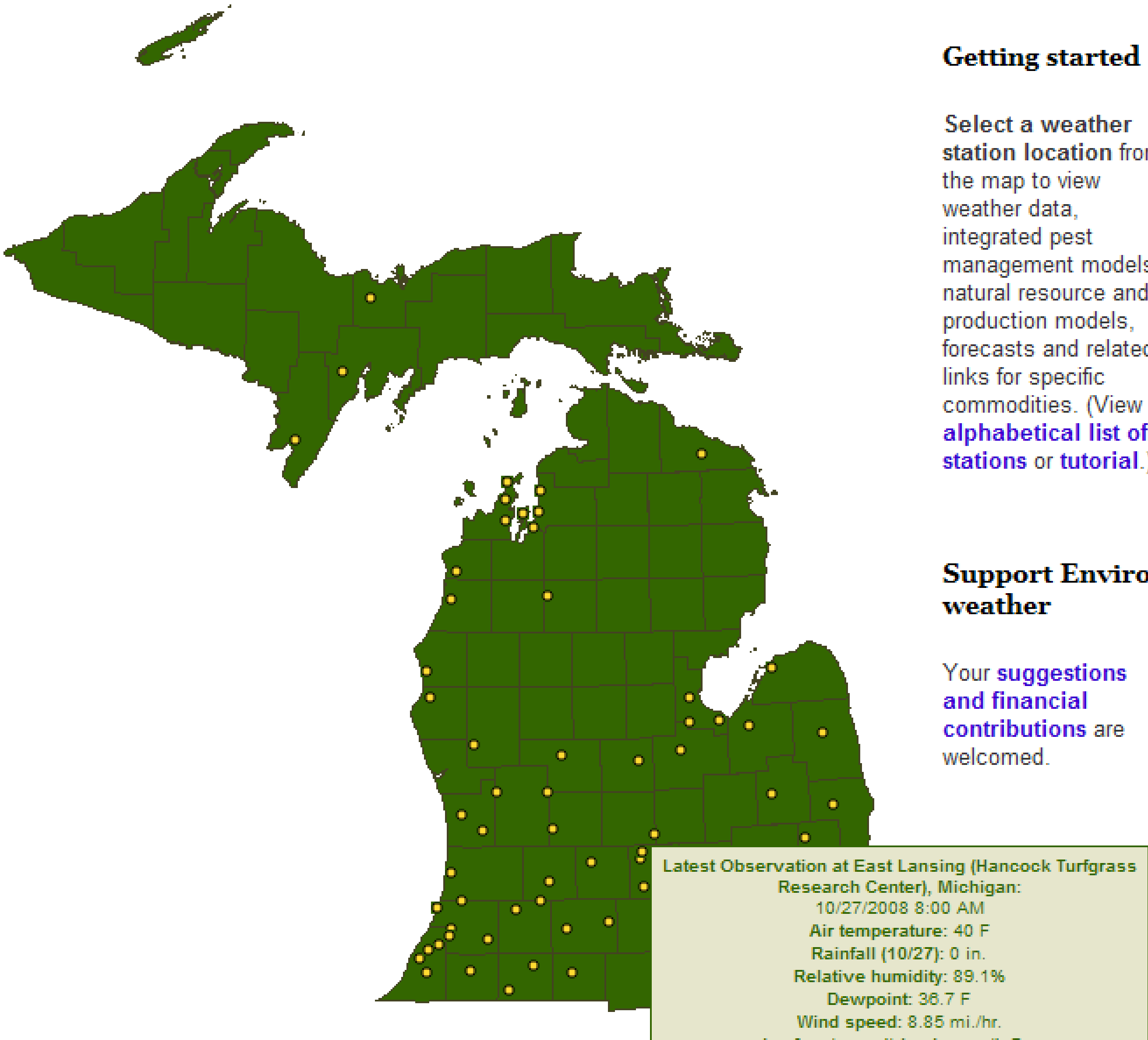
Week after emergence	Date	Soil water field reading		Maximum temperature	Add	Subtract		Soil water deficit	
		A	B		Crop water use	Rainfall	Net irrigation	A	B

Back to home

Enviro-weather

Weather-based pest, natural resource, and production management tools

MICHIGAN STATE UNIVERSITY



Getting started

Select a weather station location from the map to view weather data, integrated pest management models, natural resource and production models, forecasts and related links for specific commodities. (View **alphabetical list of stations** or **tutorial**.)

Support Enviro-weather

Your **suggestions and financial contributions** are welcomed.

Enviro-weather

Back to home

Weather-based pest, natural resource, and production management tools

MAWN Station: Coldwater

Commodity/Report: ....Crop ET estimates

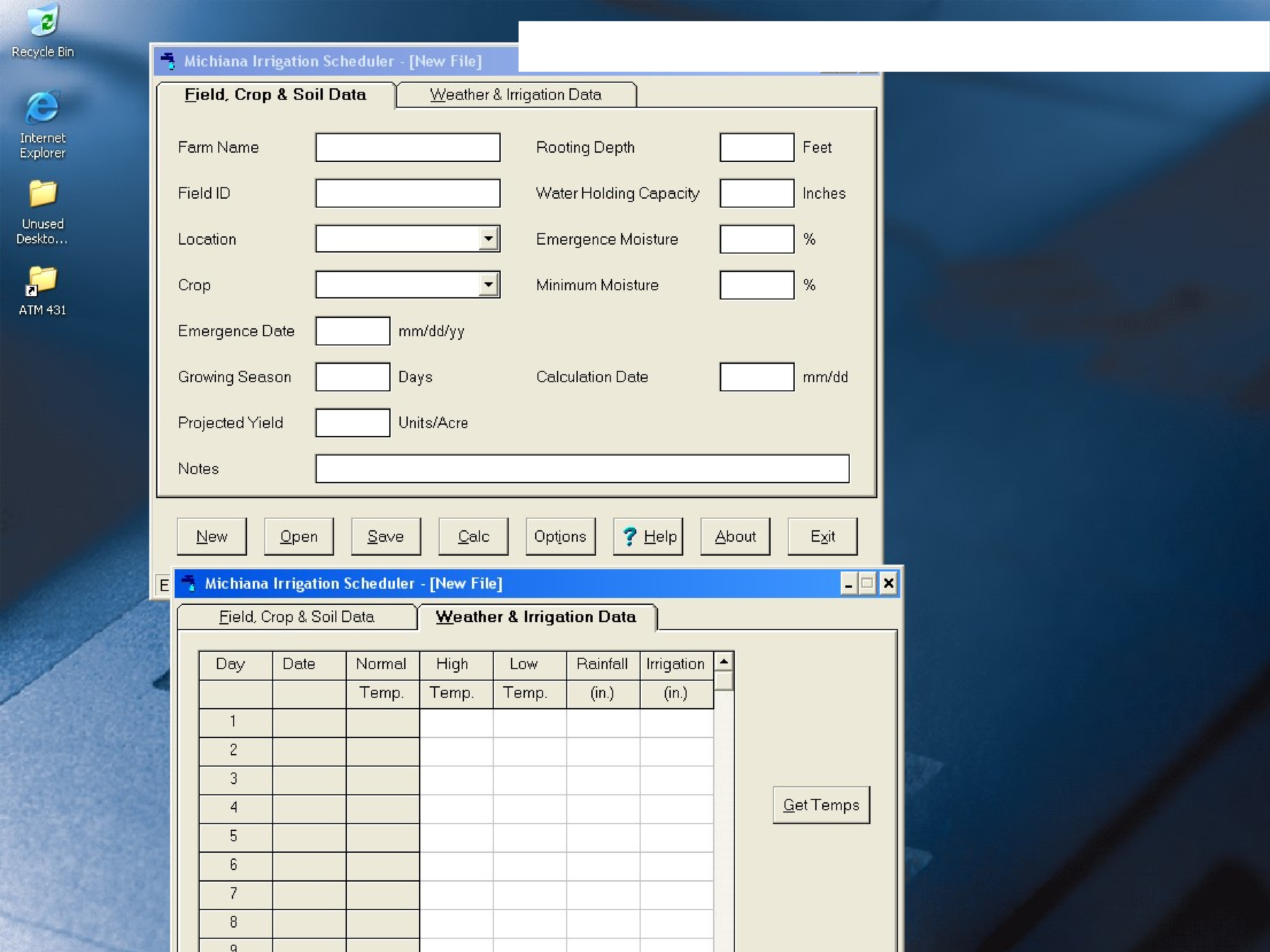
- Use default/current date
- Change date range

Estimated crop evapotranspiration at Coldwater (Report issued 6/26/2009 9:35)

Change crop: Corn   Emergence date: 5/20/2009

2400   GDD (86/50 method)   Calendar days

2009		Temperature (F)		GDD	Rainfall	Reference PET						
Day	Date	Min	Max	86/50 method	(in.)	(in.)	GDD since 5/20	Percent total growth	Kc(coefficient)	PET today	PET since 5/20	Rainfall since 5/20
Fri	6/19	63.8	80.6	22.2	1.75	0.1	475	19%	0.73	0.07	2.36	4.87
Sat	6/20	66.1	82.3	24.2	0.64	0.18	499	20%	0.76	0.14	2.5	5.51
Sun	6/21	63.2	87.3	24.6	0	0.19	524	21%	0.79	0.15	2.65	5.51
Mon	6/22	64.3	84.4	24.4	0	0.22	548	22%	0.81	0.18	2.83	5.51
Tues	6/23	64.9	89.1	25.5	0	0.21	574	23%	0.84	0.18	3.01	5.51
Wed	6/24	68.5	95.4	27.3	0	0.24	601	25%	0.9	0.21	3.22	5.51
Thu	6/25	69.2	91.8	27.6	0	0.22	629	26%	0.92	0.2	3.42	5.51
Forecast data:												
Day	Date	Min	Max	86/50 method	(chance)	(in.)	GDD since 5/20	Percent total growth	Kc(coefficient)	PET today	PET since 5/20	Rainfall since 5/20
Fri	6/26	67	86	26.5	32%	0.24	655	27%	0.95	0.23	3.65	5.51
Sat	6/27	59	83	21	7%	0.2	676	28%	0.98	0.2	3.85	5.51
Sun	6/28	65	79	22	82%	0.21	698	29%	1	0.21	4.06	5.51
Mon	6/29	60	71	15.5	58%	0.15	714	29%	1	0.15	4.21	5.51
Tues	6/30	56	72	14	51%	0.15	728	30%	1.03	0.15	4.36	5.51
Wed	7/1	58	79	18.5	22%	0.2	746	31%	1.05	0.21	4.57	5.51
Thu	7/2	63	82	22.5	41%	0.17	769	32%	1.06	0.18	4.75	5.51


Recycle Bin
Internet Explorer
Unused Deskto...
ATM 431
Michiana Irrigation Scheduler - [New File]
Field, Crop & Soil Data
Weather & Irrigation Data
Farm Name
Field ID
Location
Crop
Emergence Date
mm/dd/yy
Growing Season
Days
Projected Yield
Units/Acre
Notes
Rooting Depth
Feet
Water Holding Capacity
Inches
Emergence Moisture
%
Minimum Moisture
%
Calculation Date
mm/dd
New
Open
Save
Calc
Options
Help
About
Exit
Michiana Irrigation Scheduler - [New File]
Field, Crop & Soil Data
Weather & Irrigation Data
Day
Date
Normal Temp.
High Temp.
Low Temp.
Rainfall (in.)
Irrigation (in.)
1
2
3
4
5
6
7
8
Get Temps

Microsoft Excel - Irr_cbook_const_2006_test

Field Identifier	**Test field 1 - Constantine**
Crop	**Corn**

User fills out the data in light yellow

Estimates of Potential ET can be found at the MSU AgWeather site: http://www.agweather.geo.msu.edu/mawn/irrigation/

Depth and Canopy Cover Coeff, as a function of the percentage of the growing season.

To use the Table, first determine the length of the growing season and rooting depth for the variety of your crop, then extrapolate data from emergence date.

For example, 120 day Corn36 (a corn variety with an effective rooting depth of 36 inches) and has an emergence date of May 15th, 10% of the growing season is May 27th.

10% of 120 = 12 15 + 12 = 27

Clear Columns

Fill in Date

Fill in Root Depth

Fill in Canopy Cover

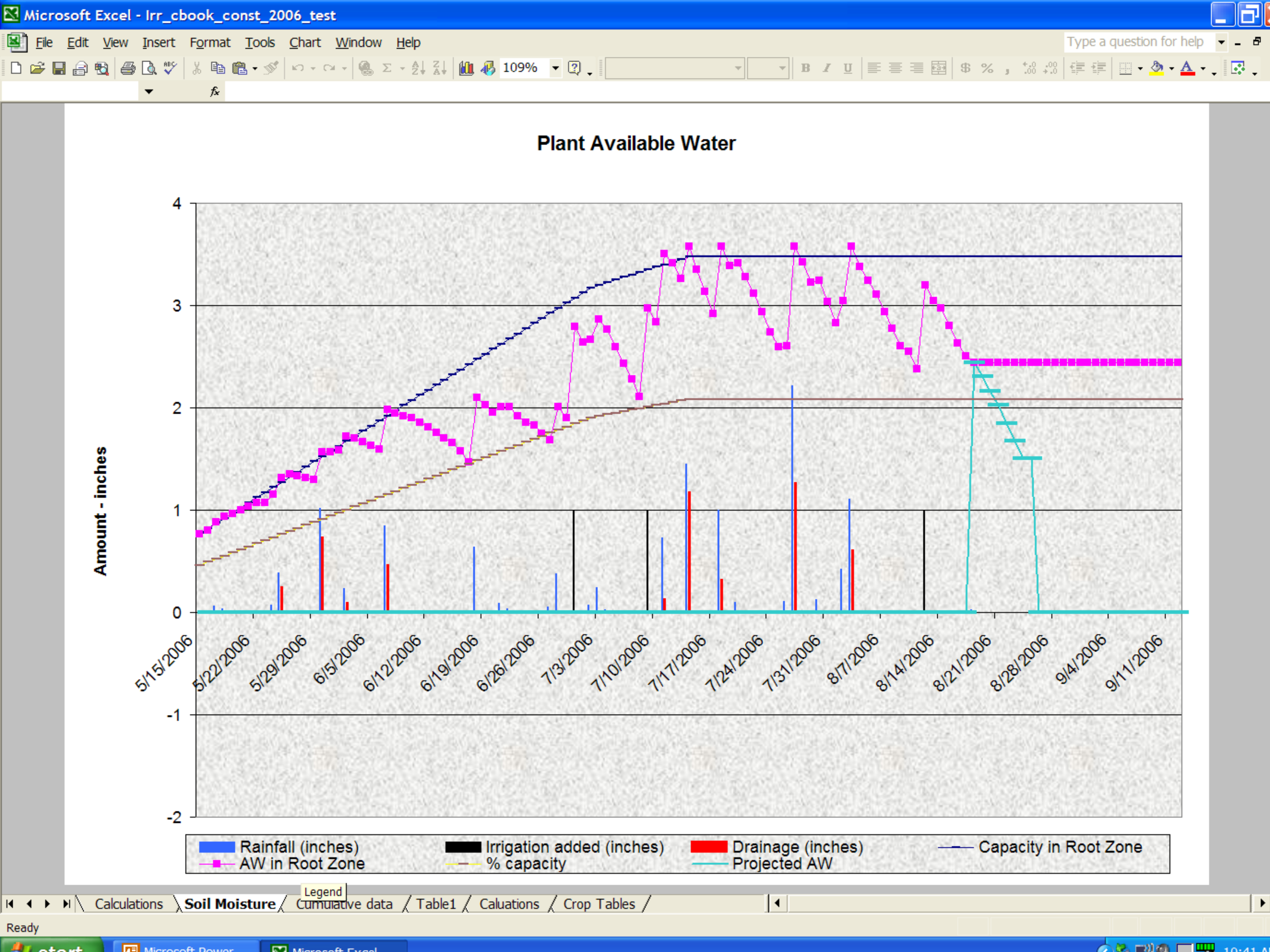
Crop (Corn24 or Corn36):	Corn36
Length of Growing Season (days):	120
Emergence Date (mm/dd/yyyy):	5/15/2006

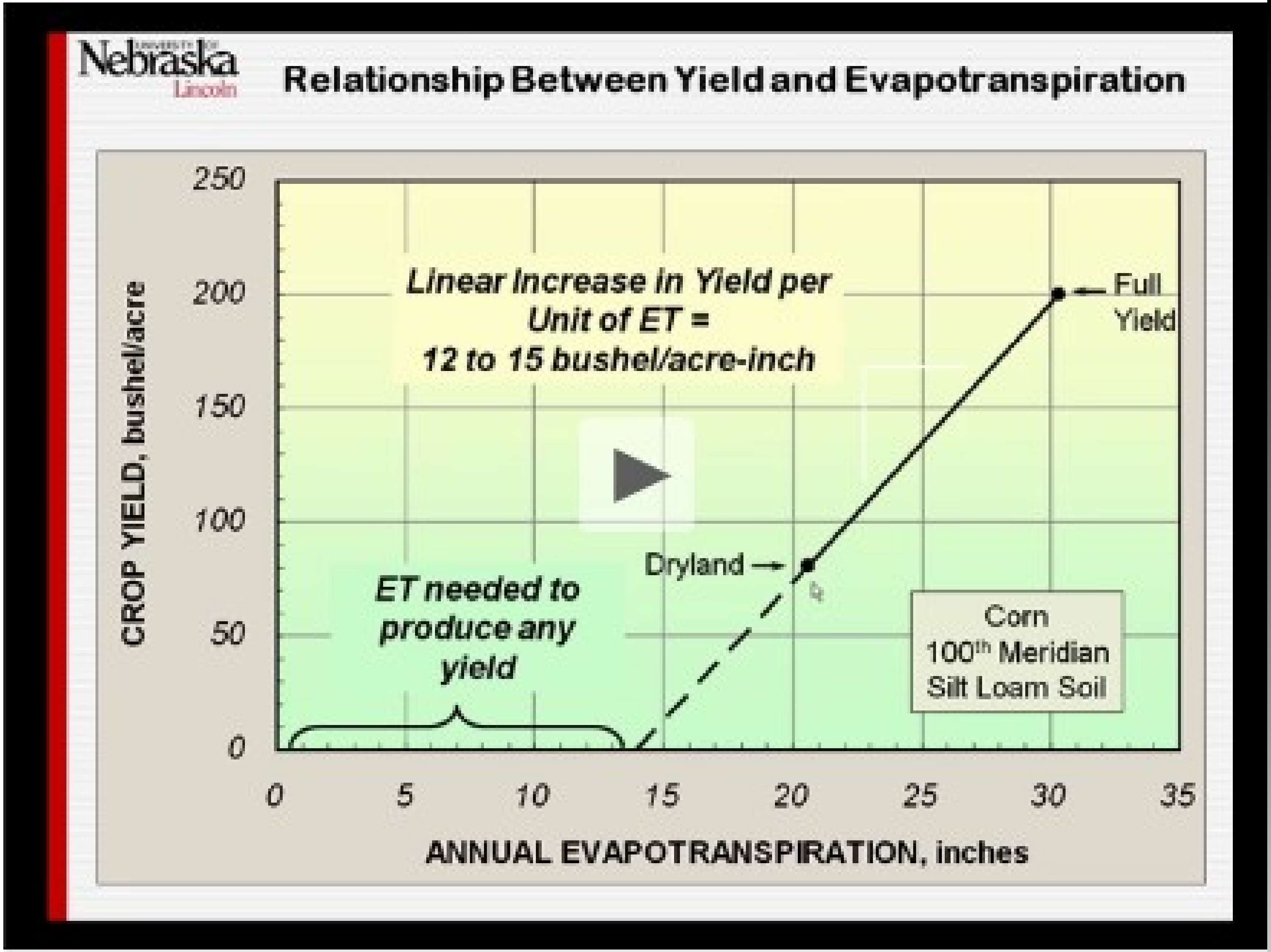
Available water (AW) holding capacity of soil - (inches water/inch soil). See Table 1 or Soil	AW (in/in)	Capacity filled (%)
	0.13	99

Irrigation increment/amount per application (inches)	**1**	**Irrigate at this % of Available Soil Water in Root Zone**	**60**

	User Enters					Calculated in XLS								
Date	Root Depth (inches)	Rainfall (inches)	Irrigation added (inches)	Potential ET (inches)	% Canopy Cover (Kc)	ET modified for crop (inches)	Capacity of root zone (inches)	Available Water in root zone (inches)	% capacity filled	Drainage (inches)	Additional capacity of root zone (inches)	Proj ETO	Proj ET	NOTES
15-May	6.0				0.23		0.77	0.76	99	0.00				
16-May	6.4	0		0.057	0.24	0.01	0.82	0.80	97	0.00	0.02		0	
17-May	6.8	0.06		0.134	0.24	0.03	0.87	0.88	101	0.00	0.00		0.00	
18-May	7.2	0.04		0.115	0.25	0.03	0.92	0.94	102	0.00	0.00		0.00	

Calculations / Soil Moisture / Cumulative data / Table1 / Caluations / Crop Tables


Microsoft Excel - Irr_cbook_const_2006_test
File Edit View Insert Format Tools Chart Window Help
Type a question for help
109%
Plant Available Water
Amount - inches
4
3
2
1
0
-1
-2
5/15/2006
5/22/2006
5/29/2006
6/5/2006
6/12/2006
6/19/2006
6/26/2006
7/3/2006
7/10/2006
7/17/2006
7/24/2006
7/31/2006
8/7/2006
8/14/2006
8/21/2006
8/28/2006
9/4/2006
9/11/2006
Rainfall (inches)
Irrigation added (inches)
Drainage (inches)
Capacity in Root Zone
AW in Root Zone
% capacity
Projected AW
Legend
Calculations
Soil Moisture
Cumulative data
Table1
Caluations
Crop Tables
Ready



Dryland 21 inches/80 bushel or 0.26″/bushel
With irrigation full yield 30 inches/200 bushels or 0.15″/bushel

Michigan Farm Energy Audit Program

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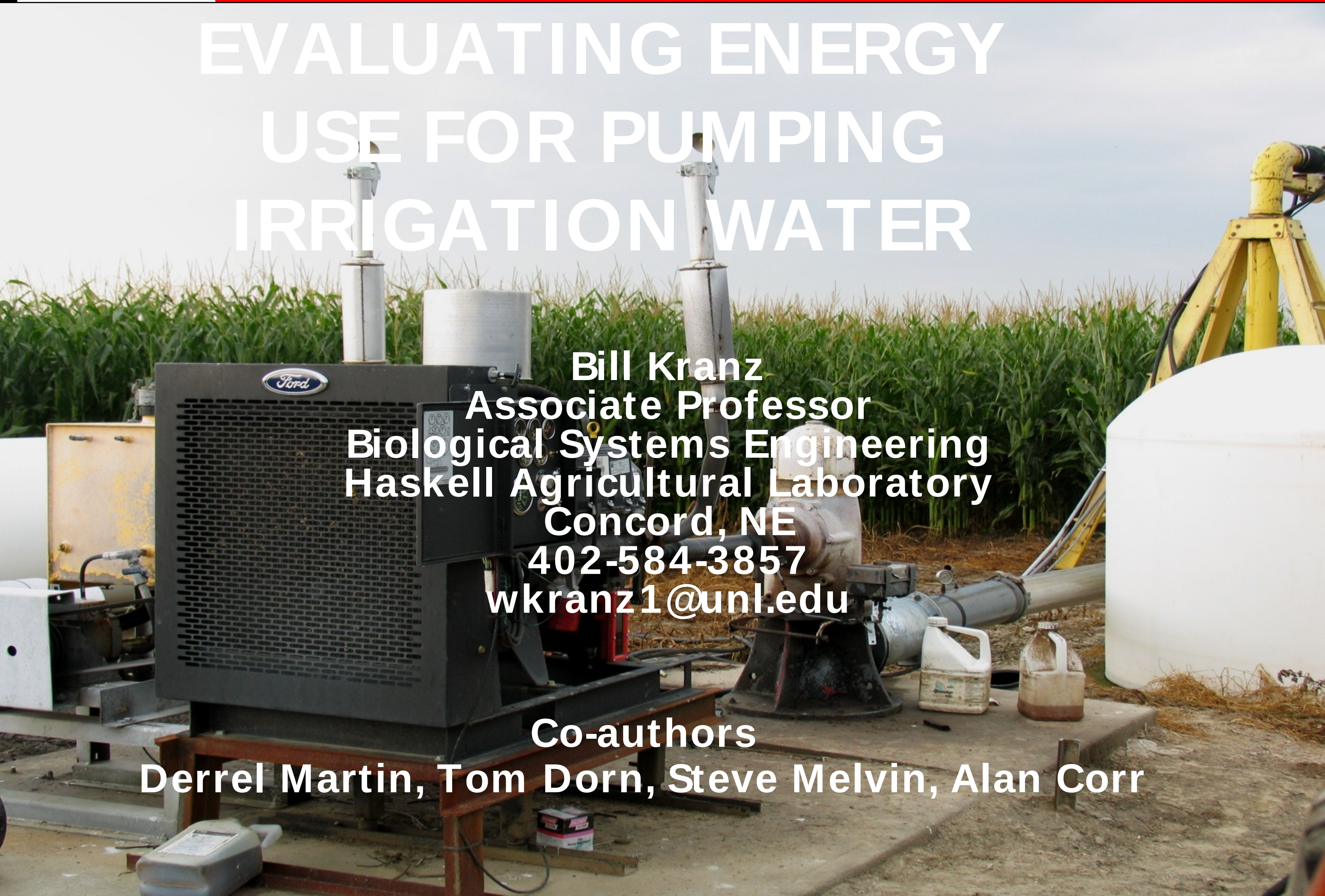

EVALUATING ENERGY USE FOR PUMPING IRRIGATION WATER

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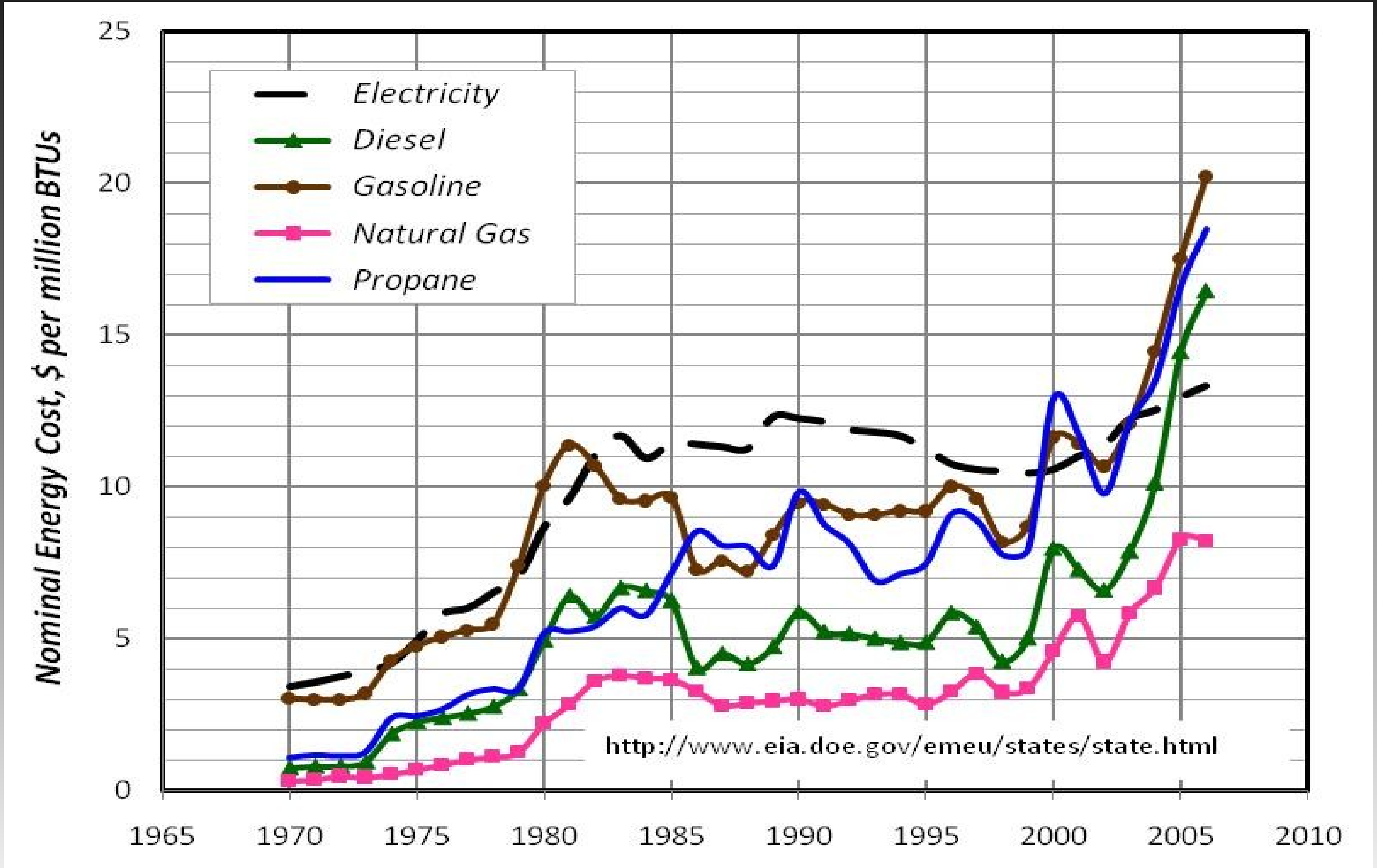
Farm Energy
Audits

Surge of Energy Cost

How it got started – Rising Energy Cost



Nebraska North Central Region SARE Grant, 2011

What is a Farm Energy Audit?

A Farm Energy Audit is an essential management tool in developing a comprehensive energy plan for your farm or rural business.

- It can pinpoint areas for reducing energy costs and energy use.
- It helps prioritize implementation projects based on energy efficiency improvements, payback period, capital outlay or implementation duration and complexity.
- A farm energy audit can also improve operational efficiency as well as identify potential areas for renewable energy application.
- Certified Farm Energy Audits are required for participation is State, Federal and Utility energy efficiency programs.

Farm Energy Audit Process

Certified Farm Energy Audit

Confidential Certified Energy Audit Report

Alternative Energy
- Anaerobic digesters
- Biomass
- Geothermal
- Wind
- CHP

Certified Energy Audits (ASABE S612)

<u>Professional Engineer (PE)</u>
<u>Certified Energy Manager (CEM)</u>
<u>State Certified Farm Energy Auditor</u>
<u>USDA-NRCS Technical Service Provider</u>

Set priorities & implement suggestions

Not all audits are the same.

Selling Points For A Tier II Farm or Rural Business Energy Audit

Selling Point #1:

Reduced Energy Costs/Increased Profits

Irrigation

Make: Caterpillar
Model: 3208, 225hp
Age: 1978 or 31 years old
Yearly maintenance cost: $238.92
2009 repair cost: $371.49

Irrigation

Recommended ECM	Energy Reduction (MMBTU)	Energy Reduction (kWh)	Energy Savings ($/yr)	Cost to Implement ($)	Payback (years)
Replace the well pump diesel engine with an electric motor and variable frequency drive.	**395.304**		**$5,176** **$6,685**	**$40,221**	**7.8** **6.0**

Irrigation Energy Audit

Average Annual Diesel Cost – Existing System

Pivot #	Average Annual Diesel Fuel Usage (gallons)	Average Annual Diesel Fuel Cost ($) 2.71	Average Annual Diesel Fuel Cost ($) 3.50	Electrical Cost ($/yr) at 0.1135/kWh
1	2,600	7,046	9,100	$2,834
2	775	2,100	2,712	$1,265
3	590	1,599	2,065	$1,023
4	225	610	788	$166
Total	4,190	11,355	14,665	$6,179

Irrigation Energy Audit

Electrical Use & Cost – Proposed Electrical Pump and VFD

Pivot #	Total Dynamic Head	Water Pumped acre-ft/yr	kWh/ac-ft of water	Electrical Usage (kWh/yr)	Electrical Cost ($/yr) at 0.1135/kWh
1	279	57.7	432.7	24,968	$2,834
Pivot #1 w/ cornering retracted	253	28.4	392.4	11,144	$1,265
2	340	17.1	527.34	9,018	$1,023
3	315	12.6	488.57	6,156	$699
Pivot #3 w/ end gun off	296	3.7	458.32	1,696	$192
4	285	3.3	442.04	1,459	$166
			Total	54,441	$6,179

A30 | fx | Total Energy Saved

	A	B	C	D
0	water savings	1	inches	
1	acres	130	acres	
2	water savings	130	ac-inch	
3				
4	pumping lift	140	ft	
5	pressure at pump	50	psi	
6	total head	256	ft	
7				
8	energy source	Electricity		
9	performance rating	80	%	
0	multiplier	14.12		
1	energy use	41.04	kWh	per ac-inch
2				
3	cost of energy	$0.12	$ per	kWh
4	$ savings per acre-inch	$4.92	$ per ac-inch	
5	$ savings per acre	$4.92	$ per ac	
6	total dollar savings	$640	$	
7				
8	Total Energy Saved	5,335	kWh	
9		3,413	BTU/unit	
0	Total Energy Saved	18,207,765	BTU	

Additional savings, associated with no-till, would come from reduced labor, fuel, and farm equipment.

Lookup table:

				BTU/unit	http:
Diesel	1	gallons	gallon	129400	http:
Electricity	14.12	kWh	kWh	3413	
Gasoline	1.443	gallons	gallon	120000	
Natural Gas	0.2026	MCF	MCF	1027000	http:
Propane	1.814	gallons	gallon	91333	

Irrigation Energy Audit

Recommended ECM	Energy Reduction (MMBTU)	Energy Reduction (kWh)	Energy Savings ($/yr)	Cost to Implement ($)	Paybac k (years)
Replace the well pump diesel engine with an electric motor	297.9		$3,600	$11,152	3.1
Total of ECM's with Payback less than 5 years	297.6		$3,600	$11,152	3.1

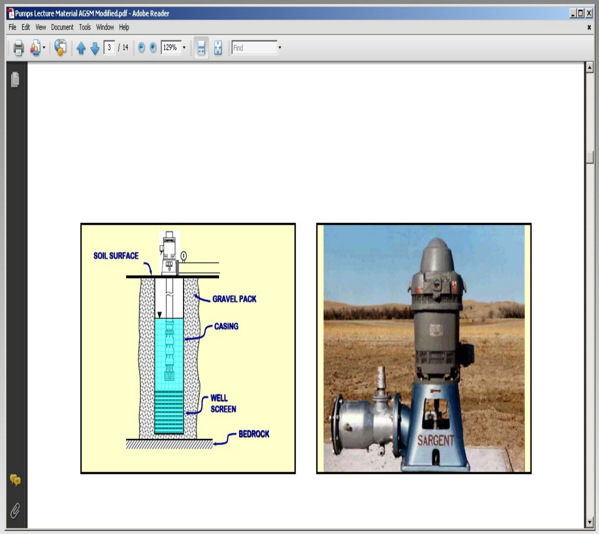
Pumps

Energy Consumption

An index, called Performance Rating, is used to evaluate the performance and is calculated by:

$$\textbf{Performance Rating} = \frac{\text{Actual Performance}}{\text{Performance Criteria}}$$

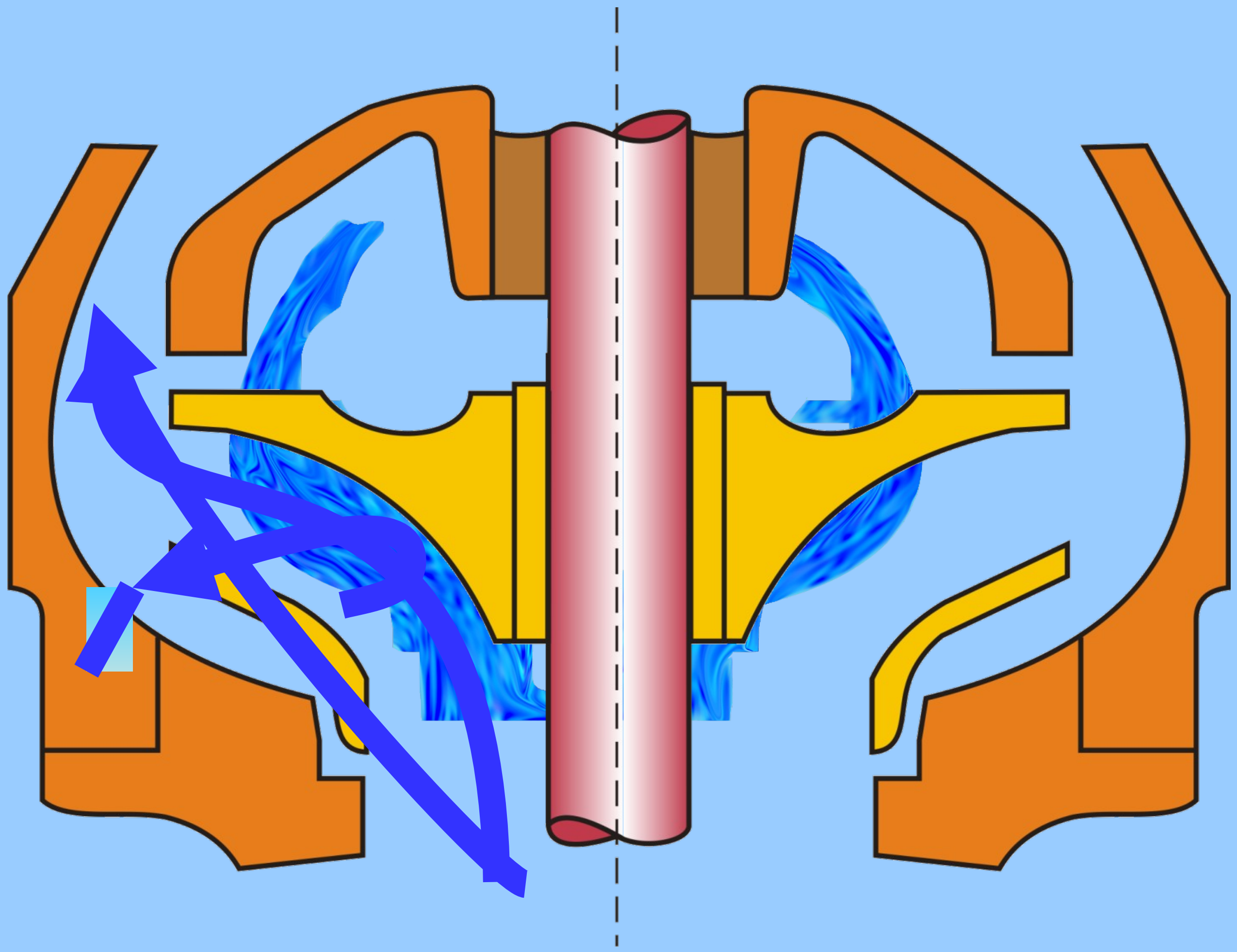
PR = Actual Fuel Used / Criteria



Deep Well Turbine

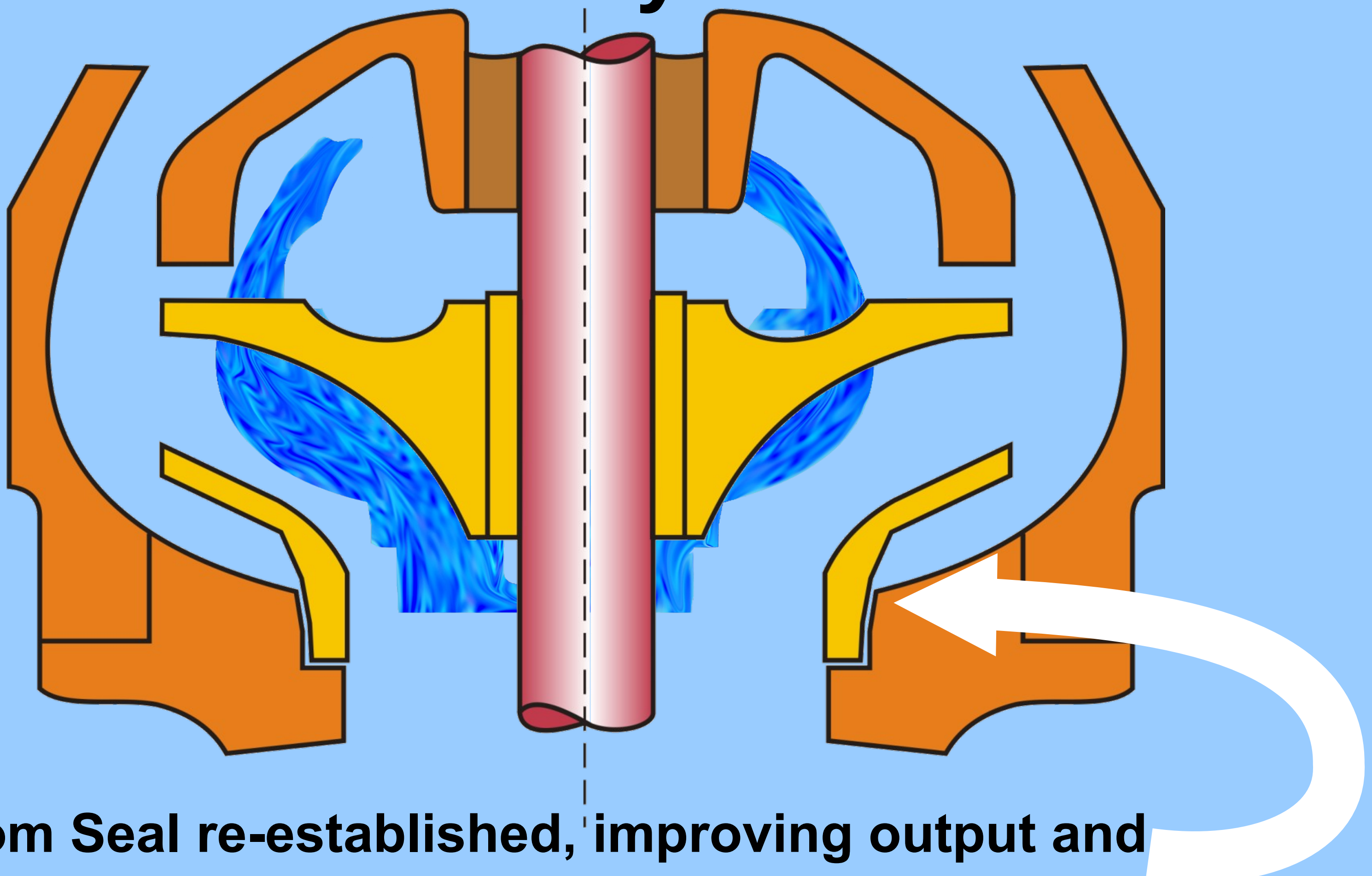
Centrifugal

Pump with Worn Seal



Some water is re-pumped and re-pressurized

Impeller Adjustment is Key



Bottom Seal re-established, improving output and efficiency (may increase per hour energy use)

Energy Content of Different Fuel Sources

Energy Source	Average Energy Content		Nebraska Pumping Plant Performance Criteria		Engine or Motor Efficiency %	Pumping Plant Conversion %
	BTU	Horsepower hour	Engine or Motor Performance hp-hr/unit	Pumping Plant Performance whp-hr/unit†		
1 gallon of diesel fuel	138,690	54.5	16.7	12.5	31	23
1 gallon of gasoline	125,000	49.1	11.5	8.66	23	18
1 gallon of liquefied petroleum gas (LPG)	95,475	37.5	9.20	6.89	25	18
1 thousand cubic foot of natural gas	1,020,000	401	82.2	61.7	21	15
1 therm of natural gas	100,000	39.3	8.06	6.05	21	15
1 gallon of ethanol ☒	84,400	33.2	7.80	5.85	X	X
1 gallon of gasohol (10% ethanol, 90% gasoline)	120,000	47.2	11.08	8.31	X	X
1 kilowatt-hour of electrical energy	3,412	1.34	1.18	0.885	88	66

‡ Conversions: 1 horsepower = 0.746 kilowatts, 1 kilowatt-hour = 3412 BTU, 1 horsepower-hour = 2,544 BTU

† Assumes an overall efficiency of 75% for the pump and drive.

☒ Nebraska Pumping Plant Criteria for fuels containing ethanol were estimated based on the BTU content of ethanol and the performance of gasoline engines.

Pumping Plant Performance Criteria

Amount of work produced per unit of energy used

Energy Type	Engine or Motor Output / Energy Use Rate hp / (unit/hr)	Energy Added to Water / Energy Use Rate, whp / (unit/hr)	Energy Unit
Diesel	16.7	12.5	gallon
Gasoline	11.5	8.66	gallon
Propane	9.2	6.89	gallon
Natural Gas	82.2	61.7	1000 ft3
Electricity	1.18	0.885	kWh

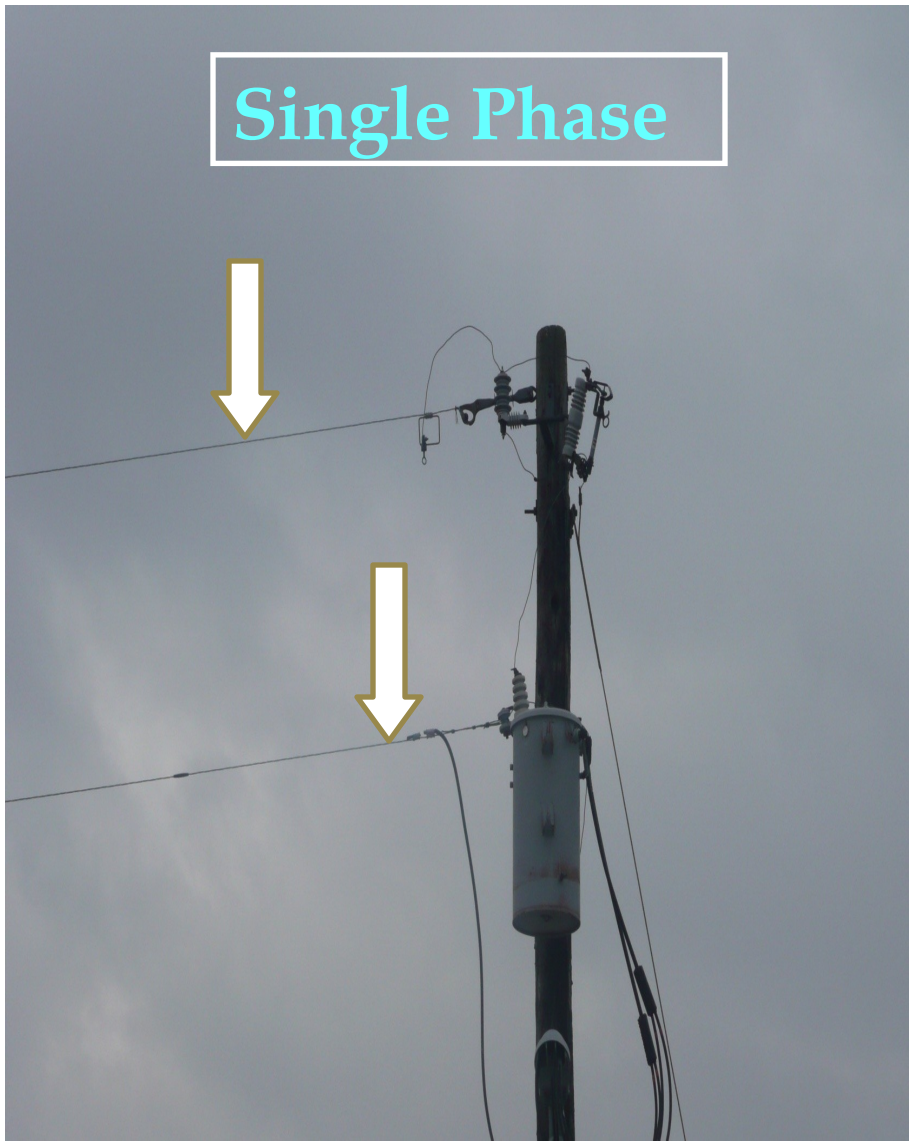
Pumping plants exceeded the NPC. (15% of 165 tests in 1980-81)

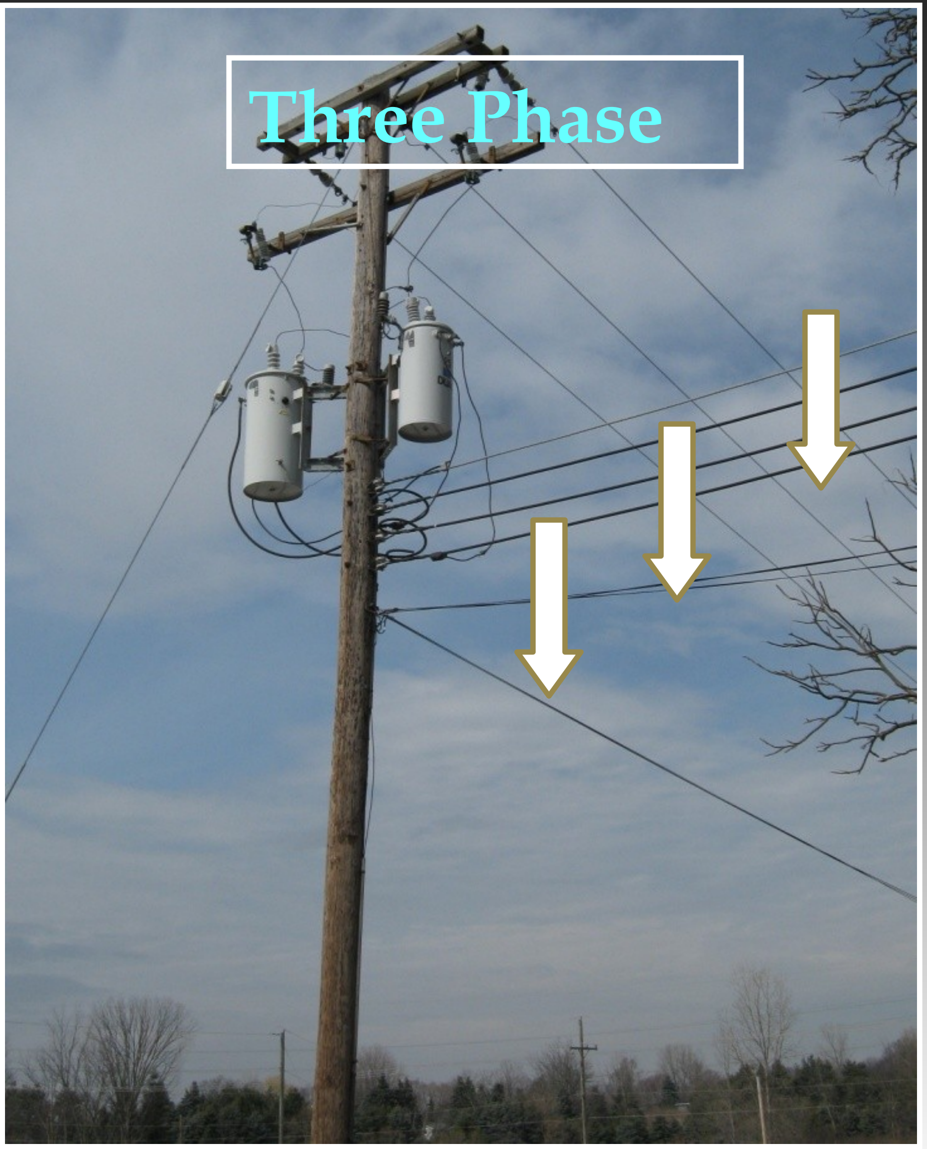
North Central Region SARE Grant, 2011

Selling Point #2:

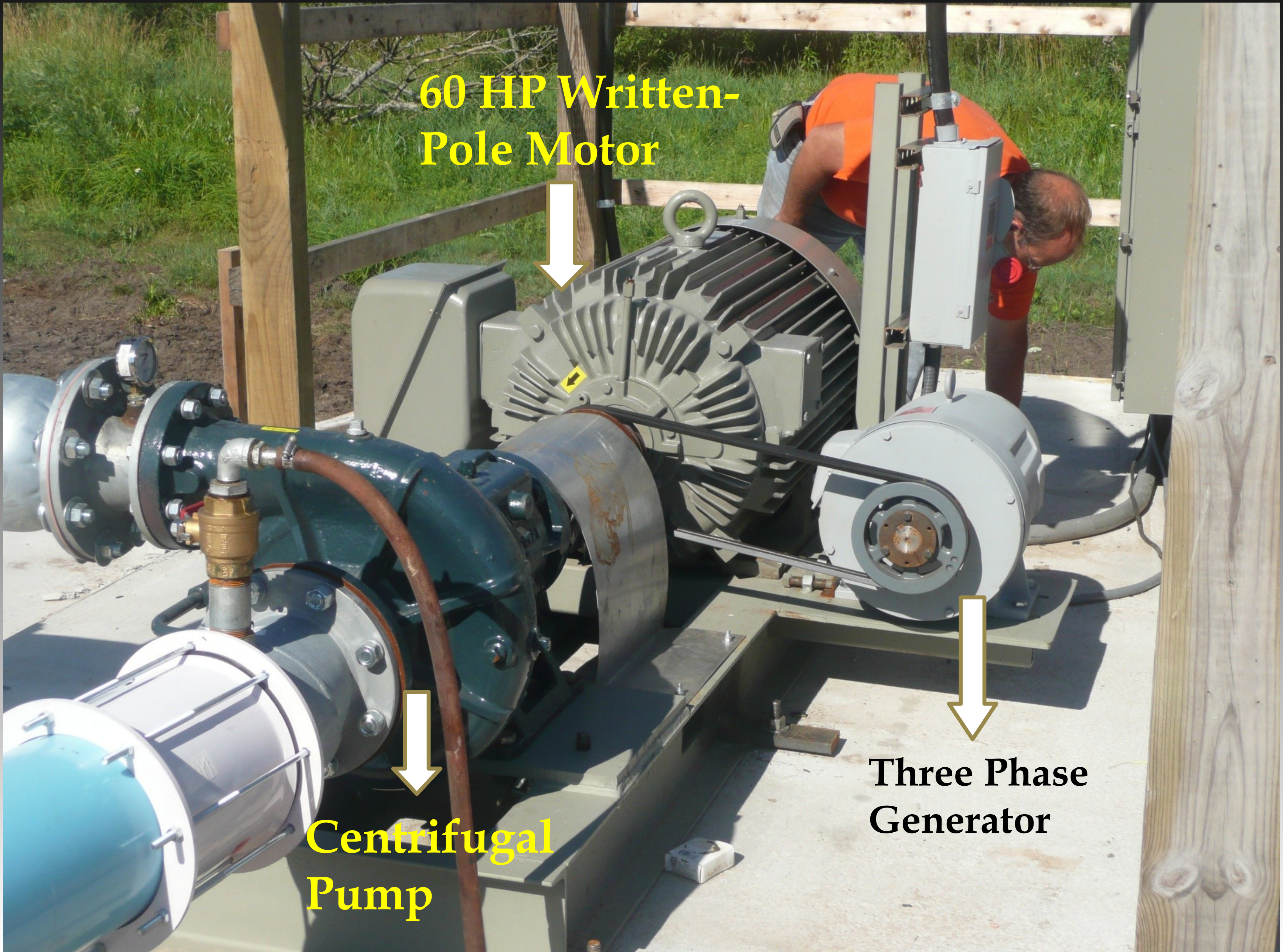
Operations Solutions by auditors who understand the farm operations.

Electric Service





Written- Pole Motors Single Phase Motors



Written- Pole Motors

Selling Point #3:

Financial Options to Ease the Burden

$$$

Selling Point #4:

Reduce the Operation’s Carbon Foot Print and Be Environmentally Responsive

Be Part of the 4TH Great Human Revolution

1. AGRICULTURAL
2. INDUSTRIAL
3. INFORMATION
4. ENERGY AUTONOMY

Be Green, Go Green

Questions