Pacific Gas and Electric Company®

# Reducing Energy Use and Costs for Pumping Water

## Advanced Pumping Efficiency Program

Helping California…

# Peter Canessa – Program Manager…

- M.S. Irrigation and Drainage
- Registered Agricultural Engineer in California
- 34 Years in Ag Water and Energy Management
  - Teaching at Cal Poly – SLO, CSU Fresno
  - 16 yrs in Ag energy efficiency programs for PG & E
  - Irrigation scheduling and system design software
  - Non point source pollution reduction/control programs
  - Water conservation program design and implementation
  - Consultant to San Diego – IID-SDCWA water transfer
  - NSW, Australia – on-farm and irrigation district-level water management improvements

# Today's discussion…

1. The basics of pumping systems
2. The Big Three ideas for reducing energy use – plus demand reduction
3. The importance of a Pump Efficiency Test
4. The Adv. Pumping Efficiency Program

# PG&E's Adv Pumping Efficiency Program…

1. Subsidized pump efficiency tests (25 HP or more)
2. Technical Assistance (free, but no site-specific engineering)
3. Incentives for retrofit of inefficient pumps (any size pump)
4. Educational seminars and material (free to all)

www.pumpefficiency.org

Or call (800) 845-6038



Pacific Gas and Electric Company®

# Other PG&E Programs…

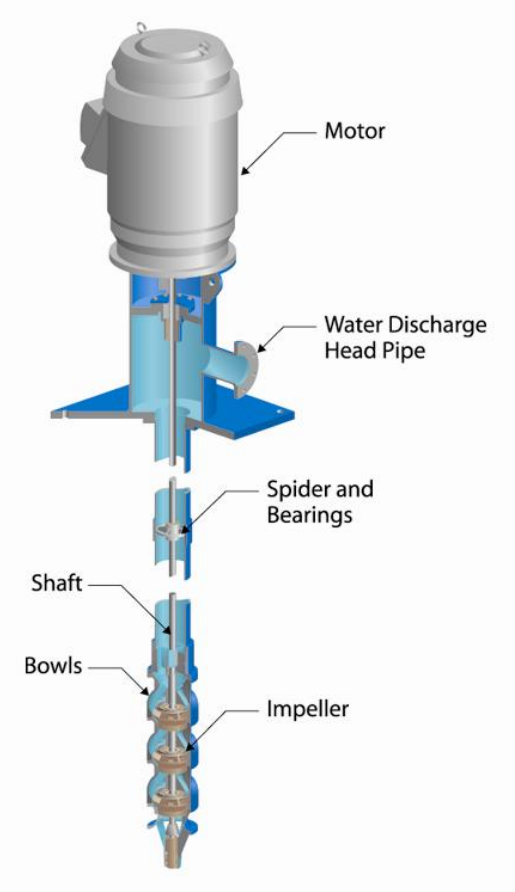
There are many other PG&E Energy Efficiency programs available, including those specifically aimed at wineries and dairies. If you're a homeowner or commercial business be aware of possible incentives and rebates for:

- Insulation
- HVAC
- Heating and refrigeration
- Lighting

# Short primer in pumping…

- Going to hit the high points
  - Four main pumping system components
  - The Pump Performance Curve
  - The Operating Condition vs Bowl Efficiency
  - Overall Pumping Efficiency

# Pumps are Energy Converters…




1. The motor takes the horsepower from electric energy and converts it to mechanical energy.
2. The mechanical energy is fed down to the pump through the shaft.
3. The pump uses the mechanical energy to move water at a certain pressure – "water horsepower".

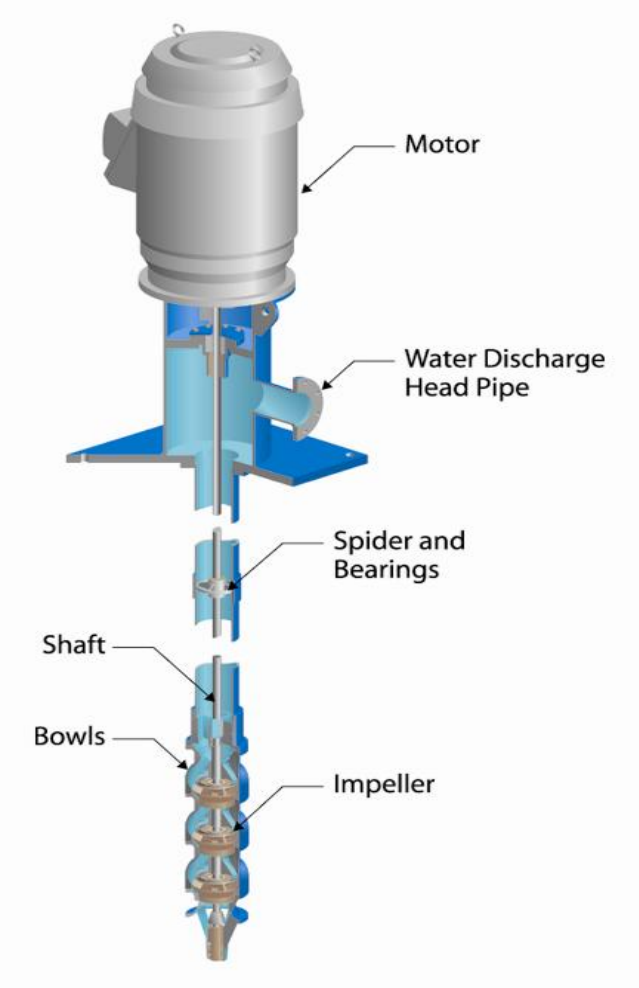
WHP = Flow x TDH / 3960

- Flow in gpm

- TDH in feet of water head

Thus, HP going in as electrical energy and getting converted to WHP out by the pump

# Pumping system is…

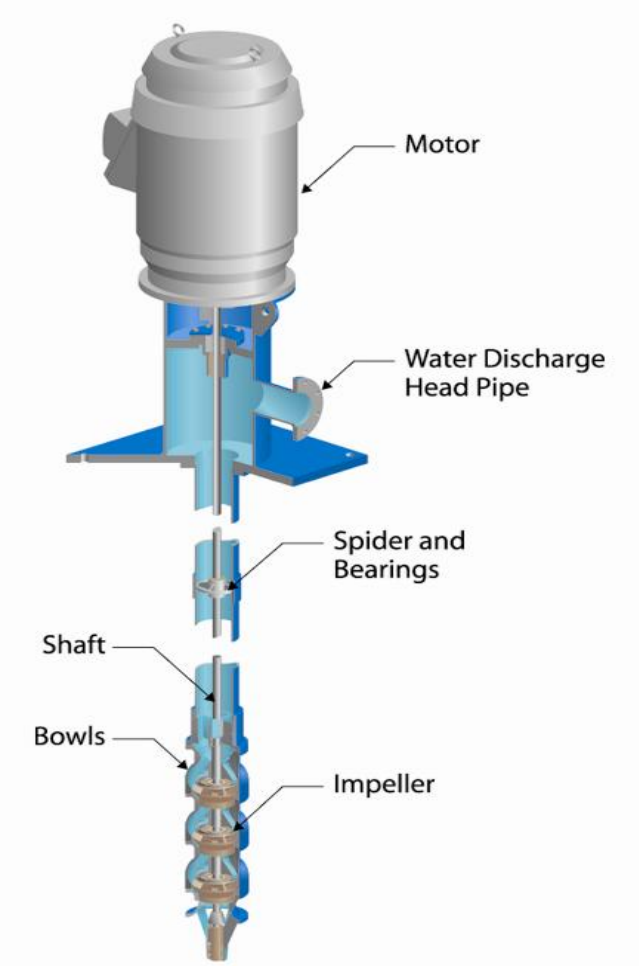



1. The power source – motor or engine
2. Transmission system – shaft, belts, gears
3. The Pump itself
4. <u>Management</u>
   - Specification of system
   - Maintenance of system
   - Operation of system

# Important Terms…

- OPE – Overall Pumping Efficiency
  - Measure of how much of the energy you buy results in a flow of water at pressure (e.g., 600 gpm at 60 psi)
  - Runs from 0 – 100% (state ave. = 53%)
  - The higher the better
  - Important because we can test for it and it serves:
    - As a benchmark
    - Allows estimates of potential cost savings

# OPE is a Combination of Efficiencies…




- Motor Efficiency – 90-95%
- Transmission Efficiency – 95-97%
- Bowl Efficiency – 60s – high 70s

Thus, OPE = ME x TE x BE

Good OPE:

.66 (66%) = .93 x .97 x .73

# Motors…

- Different efficiency ratings available
- Rewinds must be done by competent shops
- Older motors, with many rewinds might actually be operating in mid-80s range

# Transmission systems…

- Good installation for alignment
- Good maintenance for packing, oilers, belt slack, etc.

# Our Focus…

# Bowl Efficiency

## The Pump Itself

# The "Pump Performance Curve"…

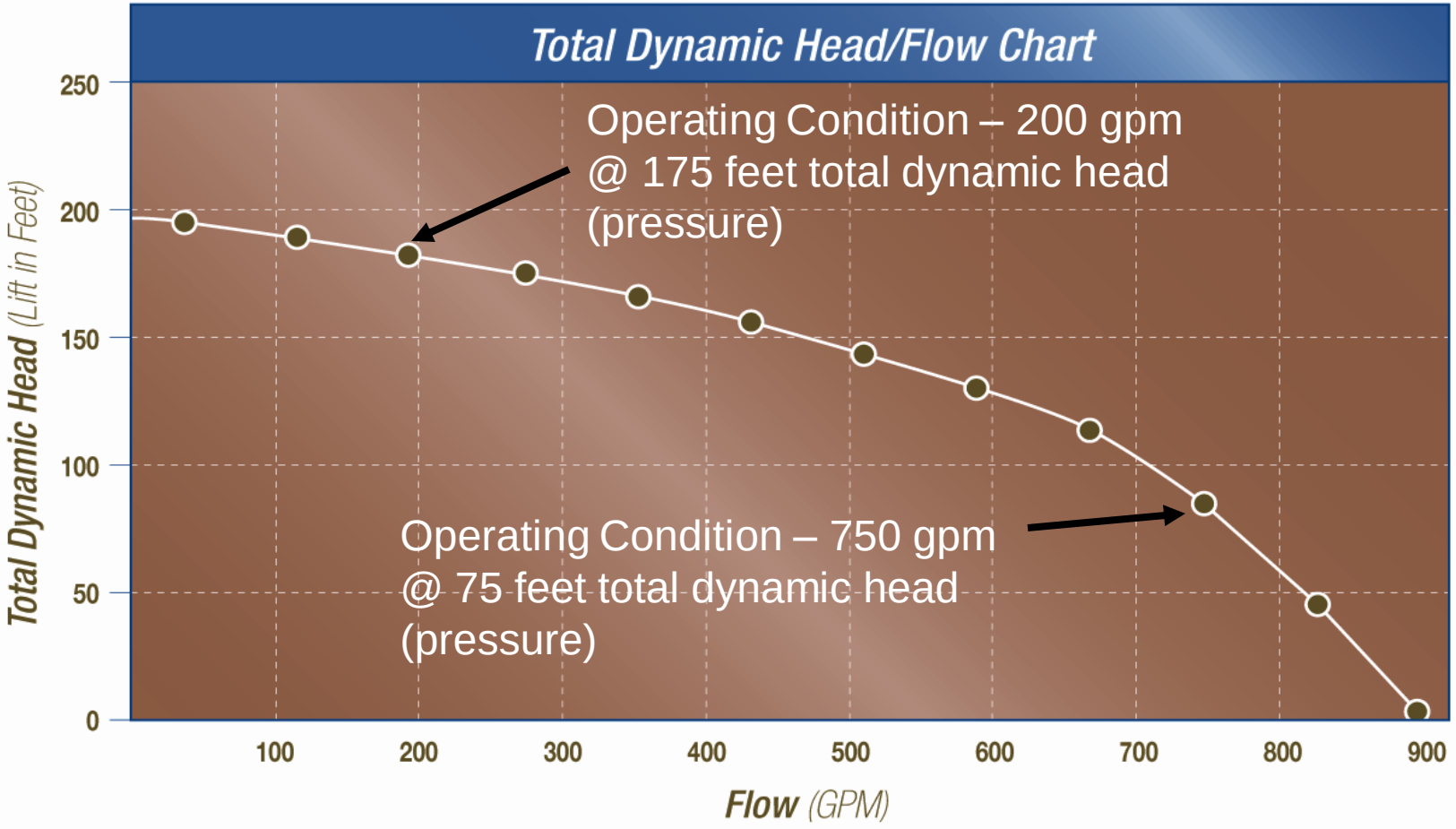
- A pump can provide a range of combinations of flow and pressure (i.e., high pressure and low flow – to – low pressure and high flow).

- Pump manufacturers know this and supply "Pump Performance Curves" for each pump.

- Performance curves show the different combinations of flow and pressure (TDH) that a particular pump can develop –

  the "Operating Conditions".

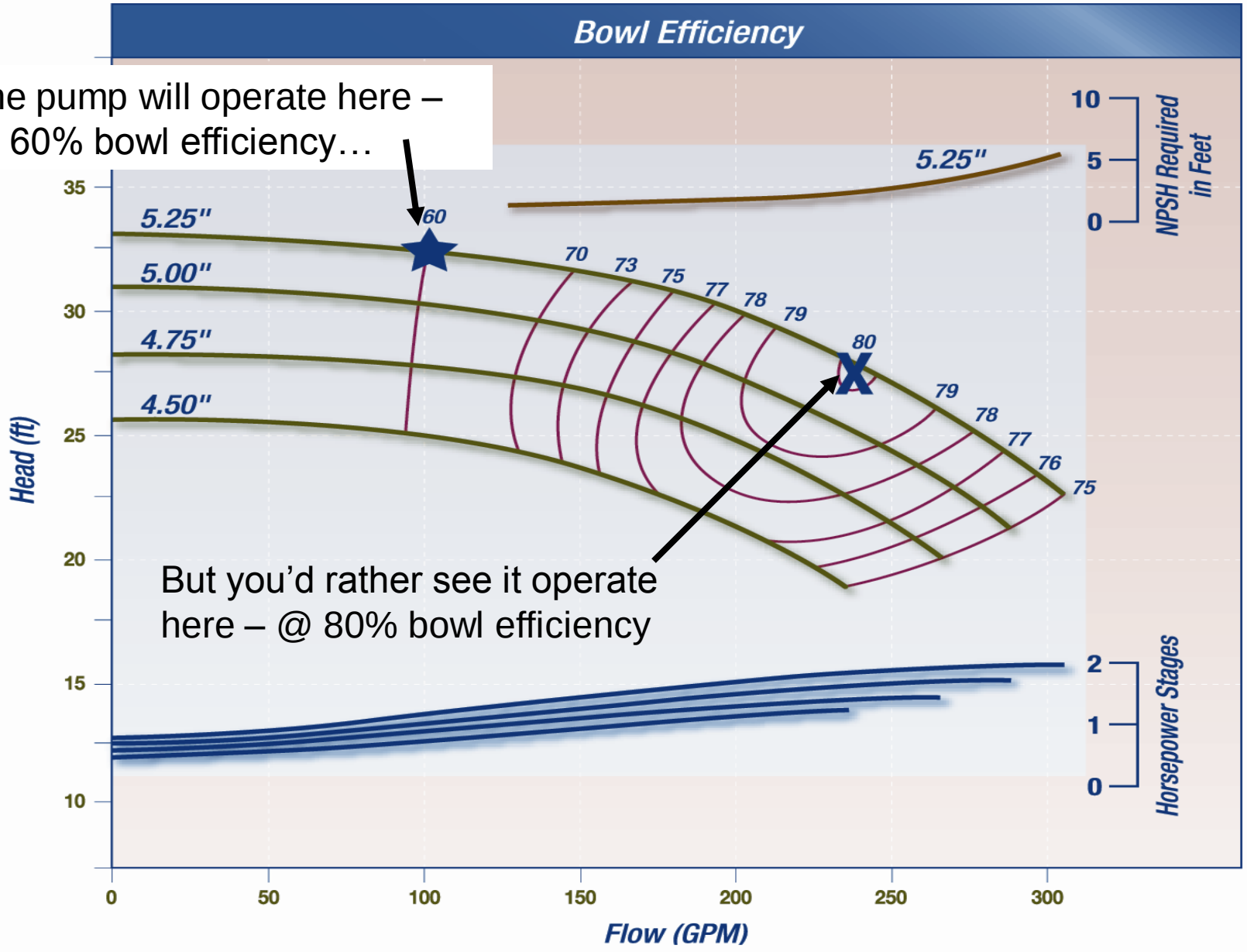
# Simple Pump Performance Curve…



# Bowl Efficiency…

- However, each Operating Condition has an associated "Bowl Efficiency".
- The manufacturers know this also and provide these on the performance curves.
- Bowl Efficiencies change due to the physics of the water flow, turbulence, at different flow rates.

# Manufacturers Pump Performance Curve…



# Pump Selection…

- Thus, if the required "Operating Condition" is known, the pump engineer can choose a pump with high "Bowl Efficiency" and thus, maximize "Overall Pumping Efficiency".

- I would choose the pump just shown if I needed 250 gpm at 27.5 psi (BE = 80%)– I would not choose it if I needed 100 gpm at 32.5 psi (BE = 60%)

# Big Ideas for Reducing Energy Use and Costs

# Demand Reduction…

- Demand/Load vs. Energy Use
  - Demand – peak kiloWatt (horsepower) demand during peak use periods
  - Energy Use – total kiloWatt-hours (gallons of gas/diesel) used

- Reducing peak demand reduces potential for brown-outs/black-outs – VERY IMPORTANT FOR CALIFORNIA!

# Demand Reduction – how to…

HP = Flow x Pressure / OPE

- Reduce pressure and/or flow requirements
  - Drip irrigation
    - Lower flows maybe than flood
    - Higher pressure requirements
    - Control and higher irrigation efficiency may allow "off-peak" operation
  - Low pressure sprinkler nozzles
    - Check pumping plant before and after for overall pumping efficiency

# Demand Reduction – how to…

- Operate off-peak
  - Pump into reservoirs for storage of water needed for on-peak period
  - Drip systems that allow more control (assuming flexibility in the water supply)

# Demand Reduction…

- Call PG&E if you think you have a project that will reduce your peak load demand
- Check with PG&E for different rate schedules that incent you to operate off peak
- Make sure you are on the correct rate to minimize demand charges!

# Important Terms…

- kWh/AF – kiloWatthours/Acre-Feet
  - How much energy, as kWh, it takes to pump an acre-foot through a system
  - Like it as low as possible

- TDH – Total Dynamic Head
  - Total pressure developed by a pumping system (Lift + Discharge Pressure)
  - Generally measured in feet of water head

# Reducing Energy Use in General…

- Three equations are important for:
  - Estimating annual energy use for irrigation
  - Identifying the three main ideas for reducing that energy use

(not going to do a lot of math, we want to show you that there is science behind the message)

# Energy and Water…

1. kWh/year = kWh/AcFt x AcFt/year

- kWh/year – annual kiloWatt-hours energy use
- kWh/AcFt – how many kWh needed to pump an acre-foot of water through the system
- AcFt/year – how many acre-feet pumped per year

# Energy and Water…

2. AcFt/Year = $\frac{\text{Acres} \times (\text{ETc} - \text{EffRain})}{(1 - \text{LR}) \times \textbf{\textit{IrrEff}})}$

- Acres – area irrigated
- ETc – net annual crop water use
- EffRain – rainfall effective in supplying part of the crop water needs
- LR – leaching requirement – related to salinity control
- **IrrEff – irrigation efficiency (water management)**

# Energy and Water…

$$3.\ \text{kWh/AcFt} = \frac{1.024 \times \textbf{\textit{TotlDynHead}}}{\textbf{\textit{OvrlPmpEff}}}$$

- ***TotlDynHead – total pressure developed by the pumping system (lift plus discharge pressure)***
- ***OvrlPmpEff – overall pumping efficiency (how good is the pumping plant itself)***

# Idea 1-Improve water management…

$$\text{AcFt/Year} = \frac{\text{Acres} \times (\text{ETc} - \text{EffRain})}{(1 - \text{LR}) \times \textbf{\textit{IrrEff}}}$$

*(all things equal – increasing **IrrEFF** will reduce AcFt/Year)*

- System distribution uniformity (absolutely need uniformity before highest efficiency possible – DU evaluations are available!)
- Irrigation scheduling – know how much water needs to be applied per irrigation
- Maintain control of application – plan your irrigation, irrigate to the plan!

**Check out www.waterright.org for irrigation scheduling and tutorials on water management**

# Improved Water Management…

- Know how much water needs to be pumped
  - Irrigation scheduling and crop water use
  - Soil/plant-based moisture measurements
  - Know your system's application rate/performance – control it!
- Know how much water has been pumped – FLOWMETERS!

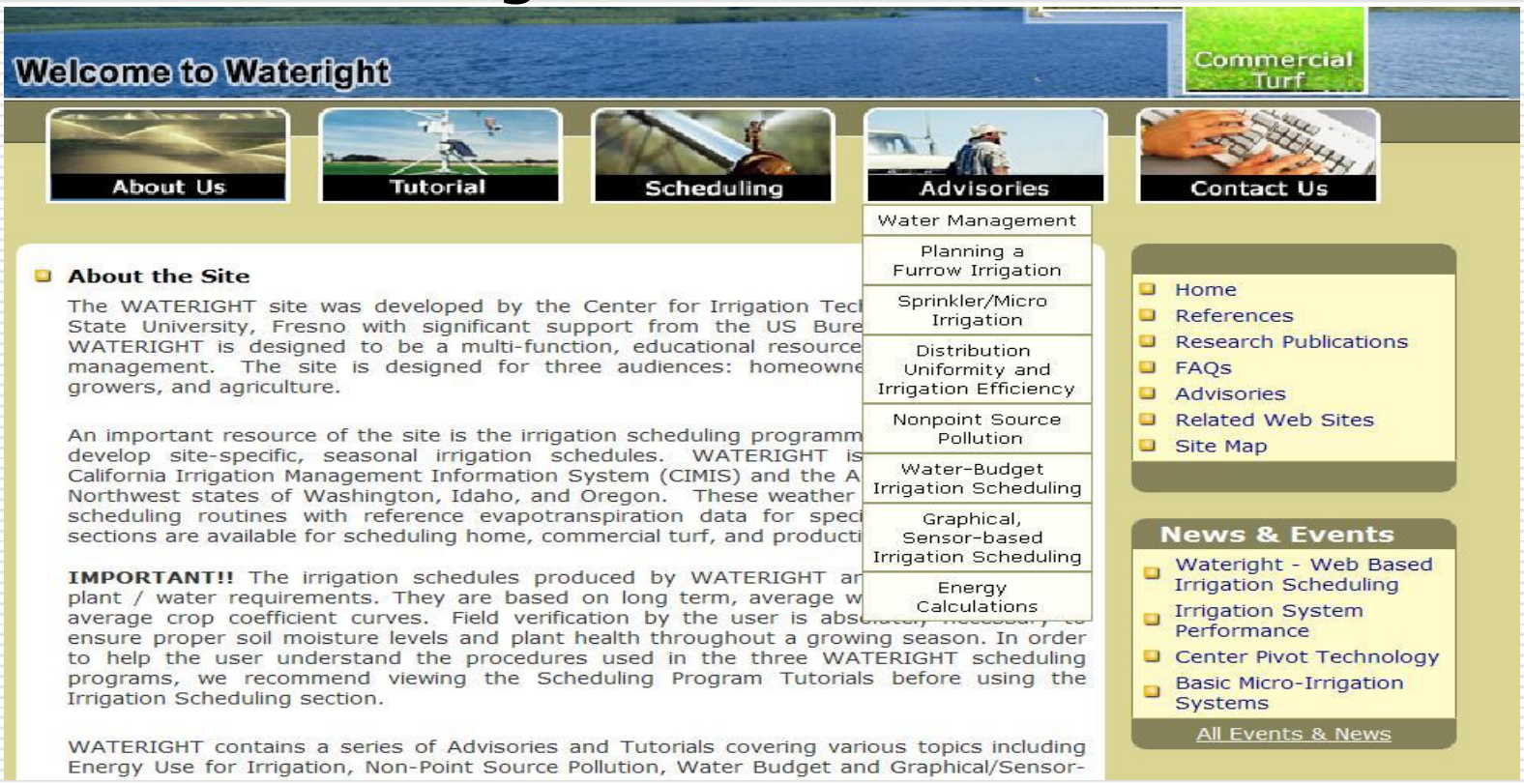
# Improved Water Management…

- "Embedded energy" concept – now coming to fore in California
  - Energy used in delivering water to a point of use
    - Water Well obviously
    - Pumping into canal systems
  - Very important in LA/San Diego and Bay Area

APEP can provide seminars on agricultural water management alone

# WWW.WATERIGHT.ORG

- Education as to Ag, turf, homeowner water management



# WATERIGHT – Irrigation Scheduling

**Seasonal Irrigation Schedule**

| For Week Ending | Average Year ETo | Average Year Rain | This Year ETo | This Year Rain | Averages for Week Kc | Averages for Week ETc | Root Zone | Avail. | Change This Yr vs Avg Yr | Total ETc to Date |
|---|---|---|---|---|---|---|---|---|---|---|
| | In/Day | In/Wk | In/Day | In/Wk | | In/Dy | Ft | In | % | In |
| 5/22/2009 | 0.23 | 0.08 | N/A | N/A | 0.35 | 0.08 | 1.00 | 1.96 | N/A | 0.56 |
| 5/29/2009 | 0.25 | 0.09 | N/A | N/A | 0.35 | 0.08 | 1.71 | 3.35 | N/A | 1.12 |
| 6/5/2009 | 0.26 | 0.07 | N/A | N/A | 0.36 | 0.09 | 2.63 | 5.15 | N/A | 1.73 |
| 6/12/2009 | 0.27 | 0.08 | N/A | N/A | 0.46 | 0.11 | 3.55 | 6.95 | N/A | 2.52 |
| 6/19/2009 | 0.28 | 0.03 | N/A | N/A | 0.71 | 0.18 | 4.00 | 7.82 | N/A | 3.78 |
| AVE. YEAR: Irrigate 6/20/2009: Net= 3.99 In. Gross= 5.32 In. | | | | | | | | | | |
| 6/26/2009 | 0.29 | 0.00 | N/A | N/A | 0.89 | 0.24 | 4.00 | 7.82 | N/A | 5.49 |
| 7/3/2009 | 0.29 | 0.00 | N/A | N/A | 0.93 | 0.24 | 4.00 | 7.82 | N/A | 7.20 |
| AVE. YEAR: Irrigate 7/5/2009: Net= 4.14 In. Gross= 5.52 In. | | | | | | | | | | |
| 7/10/2009 | 0.29 | 0.00 | N/A | N/A | 0.95 | 0.26 | 4.00 | 7.82 | N/A | 9.01 |
| 7/17/2009 | 0.29 | 0.00 | N/A | N/A | 0.95 | 0.25 | 4.00 | 7.82 | N/A | 10.76 |
| AVE. YEAR: Irrigate 7/19/2009: Net= 4.02 In. Gross= 5.37 In. | | | | | | | | | | |
| 7/24/2009 | 0.29 | 0.00 | N/A | N/A | 0.95 | 0.26 | 4.00 | 7.82 | N/A | 12.55 |
| 7/31/2009 | 0.28 | 0.00 | N/A | N/A | 0.95 | 0.24 | 4.00 | 7.82 | N/A | 14.26 |
| AVE. YEAR: Irrigate 8/2/2009: Net= 3.95 In. Gross= 5.26 In. | | | | | | | | | | |
| 8/7/2009 | 0.28 | 0.00 | N/A | N/A | 0.95 | 0.25 | 4.00 | 7.82 | N/A | 16.00 |

Assumes that you can control the irrigation event so as to apply about 5.3 inches gross at 75% IE

# Idea 2- Reduce pressure in the system…

$$kWh/AcFt = \frac{1.024 \times \textbf{\textit{TotlDynHead}}}{OvrlPmpEff}$$

*(all things equal – Reducing **TotlDynHead** reduces kWh/AcFt)*

Valves / Sprinkler selection / Pipe sizing / Correct Pumps

Note PG&E programs for major improvement projects – always call your PG&E rep if contemplating major system changes that will affect energy use! Many incentive opportunities need PG&E's involvement before construction begins.

# Idea 3 - Increase Pumping Plant Efficiency

$$\text{Kwh/AcFt} = \frac{1.024 \times \text{TotlDynHead}}{\textbf{\textit{OvrlPmpEff}}}$$

*(all things equal – Increasing **OvrlPmpEff** reduces kWh/AcFt)*

- Retrofit because of a worn pump
- Retrofit because of a pump that is operating off its design condition
- Variable Frequency Drives?

Advanced Pumping Efficiency Program can help!

# The 3rd Idea for Reducing Energy Use

Maximize Overall Pumping Efficiency!

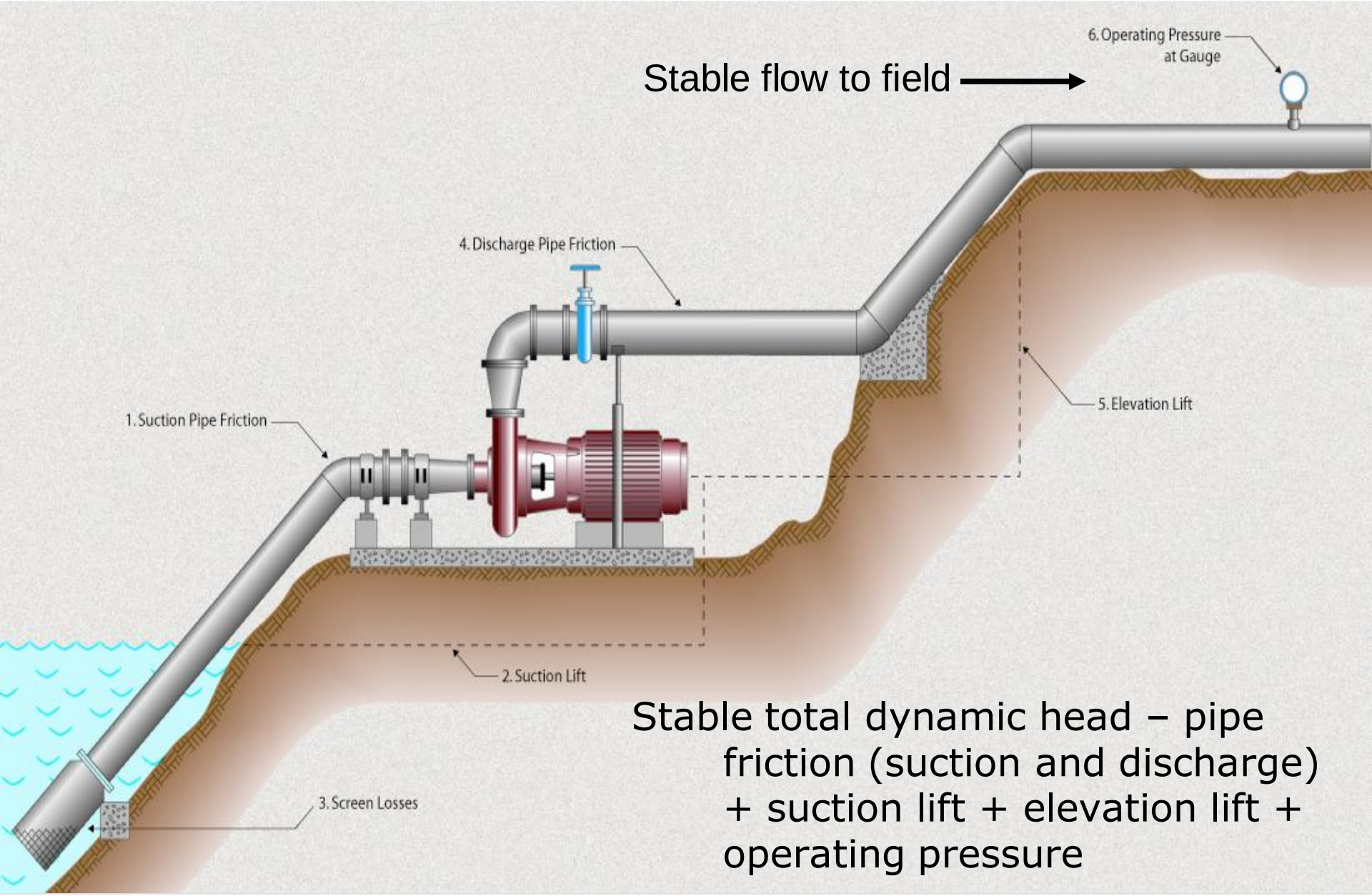
# Why does a pump become inefficient?

If efficiency is poor, or the flow/head is not sufficient:

- The pump may be physically deteriorated
- The required "operating condition" has changed
  1. Well has deteriorated
  2. Change in irrigation system
  3. Systemic change in water table

# Pump Selection - Stable Condtions…

A pond or reservoir supplying a drip irrigation system



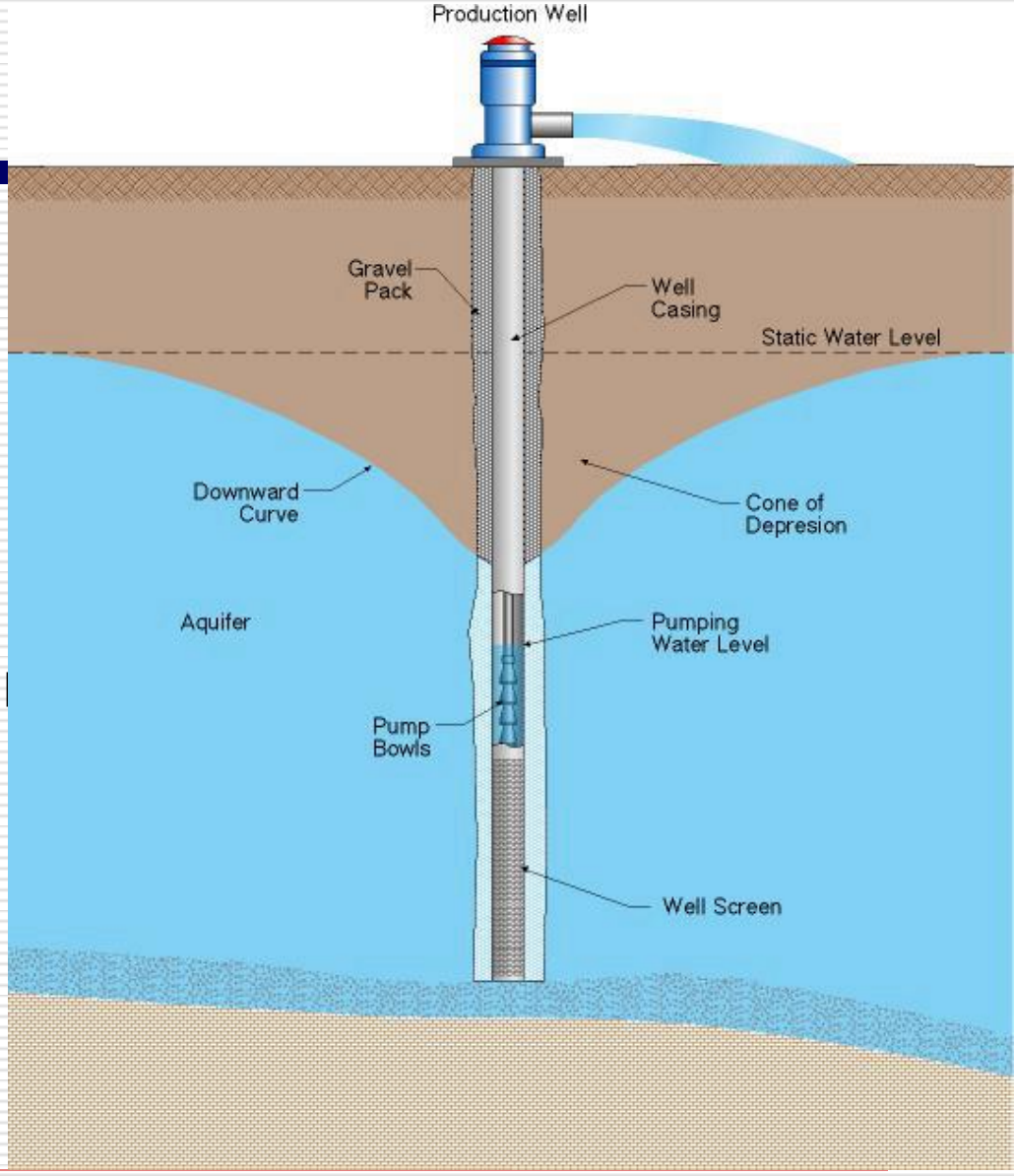

Stable total dynamic head – pipe friction (suction and discharge) + suction lift + elevation lift + operating pressure

# Operating Conditions Can Change…

- Pumping Water Level Varies – possibly important in large reservoirs but more likely for water wells
- Different size planting blocks or sets
- Different emission devices in blocks
- Maturing crop – adding emitters
- Poor filter selection or maintenance – excessive (and variable) losses through filter

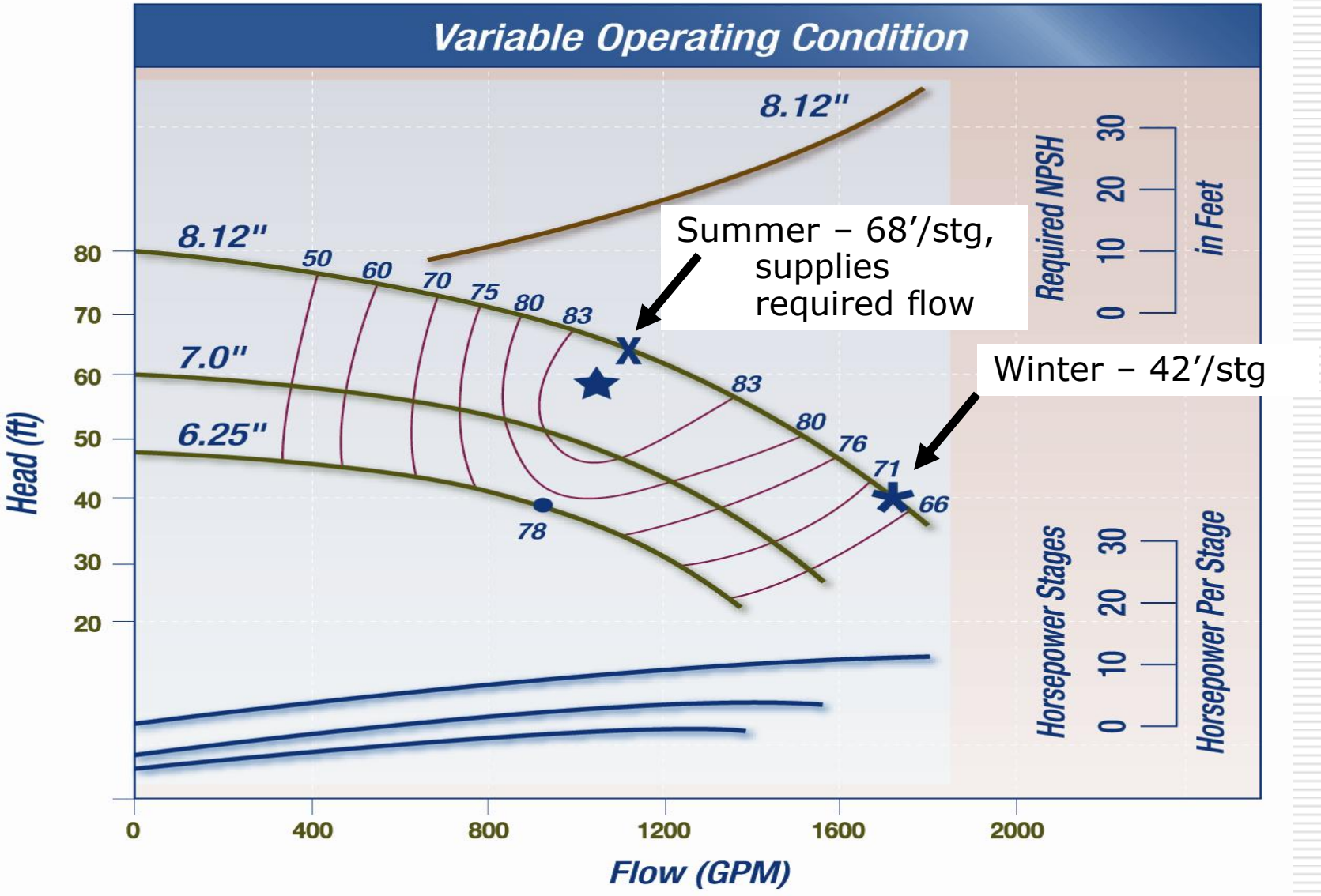
# Unstable Situation…

- Seasonal change in water table (Static or Standing Water Level) - varies as season progresses – thus, Pumping Water Level varies
- Systemic change in water table



# Choosing a pump for instability…

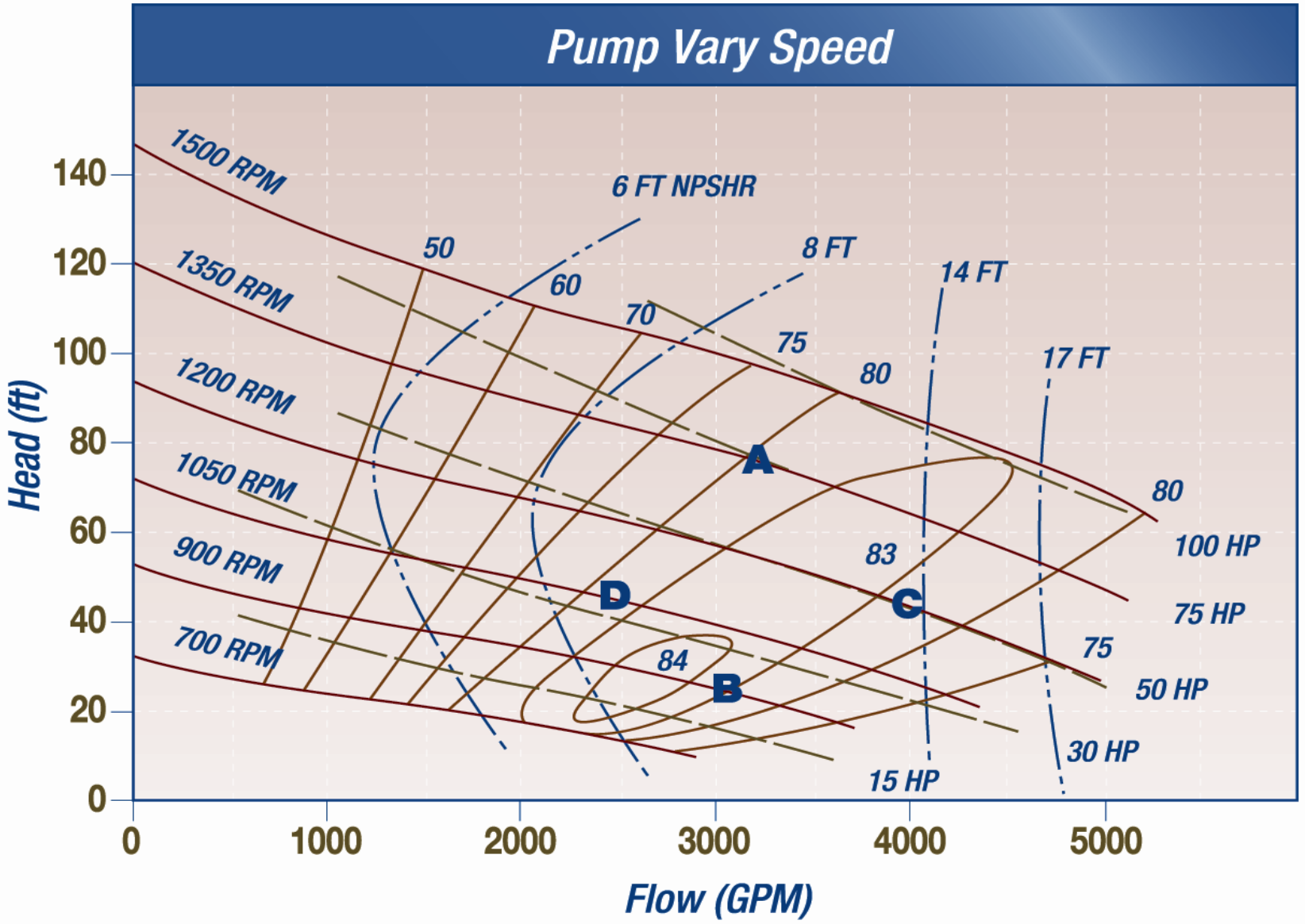
- Try to identify the operating condition most used – e.g., summer irrigation
- Plan for changes (more emitters)
- If conditions are "constantly unstable" (golf courses, drip systems with uneven blocks) – investigate the use of a Variable Frequency Drive



# Varying Speed of Pump…

- Varying the rotational speed of a pump changes the performance curve, just as trimming an impeller.
- This may help you meet variable operating conditions in real time (i.e. you can't install different diameter impellers "on the fly").
- You can do this with Internal Combustion engines or Variable Frequency Drives (VFD's)

# Pump Curves at different speeds – same pump in field, different speed



# The Pump Efficiency Test…

The pump efficiency test is the first step in maintaining and improving OPE!

A test report from APEP will include:

1. Report of test measurements and calculations

2. **Pumping cost analysis – helps you make an informed decision as to whether to retrofit or not!**

# How is a pump test done?

- Measure input kiloWatt power to pump
  - "time" meter
  - Actual measurements in panel

1 kiloWatt = .746 Horsepower

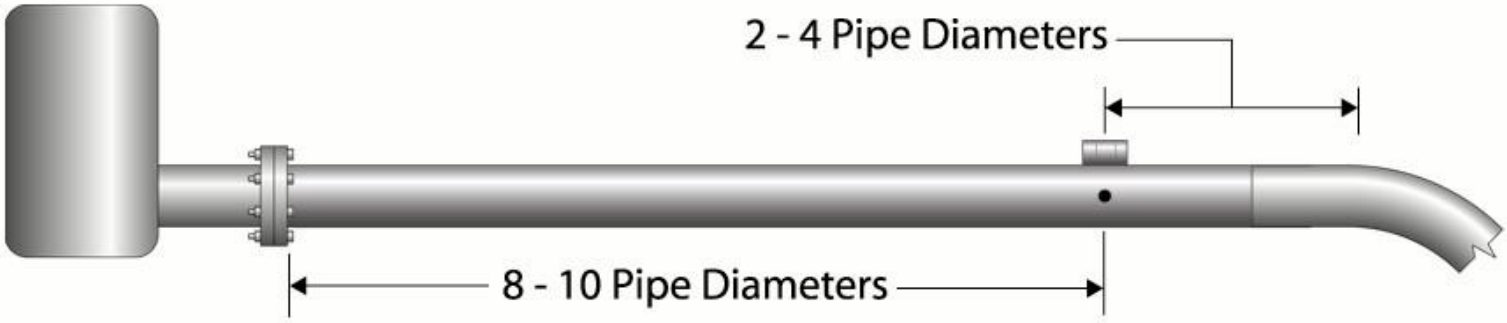
# How is a pump test done?

- Measure total dynamic head
  - "sound" a well
    - Pumping Water Level
    - Recovered Water Level
    - Standing Water Level
  - Read input pressure on a booster
  - Then read discharge pressure

# How is pump test done?

- Measure flow rate
  - Pitot tube
  - “Magmeter”

# Accurate readings…




- Pump engineers agree that getting an accurate flow rate measurement is enhanced by constructing a pump station with a discharge pipe that has plenty of clean space to conduct the test. The diagram above shows a good clean discharge pipe for conducting the test and the distance required for good flow rate measurement.

# Use of manometer and pitot tube…

# Test Provides the Basics…

- Flow Rate – enough for a drip or sprinkler system? Enough for a crop at max ETc?
- Discharge Pressure – enough for a drip or sprinkler system?

  *Do you know your system requirements?*
- Well conditions (PWL, RWL, SWL)

# Measurements and Calculations...

| | | | |
|---|---|---|---|
| **Test Date:** | 10/8/2003 | **Tester:** APEP | |
| **Run** | 1 | | |
| **1. Standing Water Level** | | 131 | |
| **2. Pumping Water Level** | | 179 | |
| **3. Draw Down** | | 48 | |
| **4. Recovered Water Level** | | 131 | |
| **5. Discharge Pressure at Gauge** | | 3.5 | |
| **6. Total Lift** | | 187 | *If Flow Velocity (line 7)* |
| **7. Flow Velocity** | | 7.6 | *is less than 1* |
| ***8. Measured Flow Rate- GPM*** | | **1,195** | *ft/second, the accuracy* |
| **9. Customer Flow Rate** | | 0 | *of the test is suspect.* |

# Other Important Variables…

- Specific Yield (if a well) – keep track of this to see if the well is plugging up
- Motor Load – should be 90-110%
- Cost to Pump an Acre-Foot (based on "melded" $/kWh, energy and demand charges – you tell us)
- Energy Cost - $/hr to run the pump
- **<u>OVERALL PUMP EFFICIENCY</u> – benchmark for performance – state wide average is now 53% for all turbines, 43% for submersibles**

# Measurements and Calculations...

| | | |
|---|---|---|
| **10. Specific Capacity (GPM/Ft draw)** | 24.9 | *Note any major* |
| **11. Acre Feet per 24 Hr.** | 5.3 | *difference between the* |
| **12. Cubic Feet per Second (CFS)** | 2.7 | *"Measured" flow rate and* |
| **13. Horsepower Input to Motor** | 130 | *the "Customer's (line 8/9)* |
| **14. Percent of Rated Motor Load (%)** | 97 | |
| **15. Kilowatt Input to Motor** | 97 | |
| **16. Kilowatt Hours per Acre Foot** | 441 | |
| **17. Cost to Pump an Acre Foot** | $70.54 | |
| **18. Energy Cost ($/hr.)** | $15.52 | |
| **19. Base Cost per kWh** | $0.160 | |
| **20. NamePlate RPM** | 1,780 | |
| **21. RPM at Gear head** | 0 | |
| ***22. Overall Plant Efficiency- OPE*** | **43.7** | |

**Remarks:**

All results are based on conditions during the time of the test. If these conditions vary from the normal operation of your pump, the results shown may not describe the pump's normal performance.

# Overall Pump Efficiency…

- The benchmark for performance
  - 5-20 HP – 42%
  - 21-50 HP – 52%
  - 51-200 HP – 57%
  - 200+ HP – 59%

- For participating pump retrofit projects
  - Pre-retrofit – 42%
  - Post-retrofit – 62% (about 33% annual energy savings)

# The Pumping Cost Analysis…

Assumptions are made based on measurements and "before / after" pump cost comparison prepared. Note that a KEY assumption is that the **same amount of water** is pumped before and after the retrofit

| | EXISTING EFFICIENCY | | IMPROVED EFFICIENCY | ESTIMATED SAVINGS |
|---|---|---|---|---|
| **6. kWh/AF:** | 438 | | 370 | 68.4 |
| **7. Estimated Total kWh:** | 77,134 | | 65,095 | 12040 |
| **8. Average Cost per kWh:** | $0.16 | | | |
| **9. Average Cost per hour:** | $15.43 | | $14.92 | $0.51 |
| **10. Average Cost Per Acre Ft.:** | $70.11 | | $59.17 | $10.94 |
| **11. Estimated Acre Ft. Per Year :** | 176.0 | ← Same! → | 176.0 | |
| **12. Overall Plant Efficiency:** | 43.7% | | 67.0 | |
| ***13. Estimated Total Annual Cost:*** | **$12,341.52** | | **$10,415.13** | **$1,926.39** |



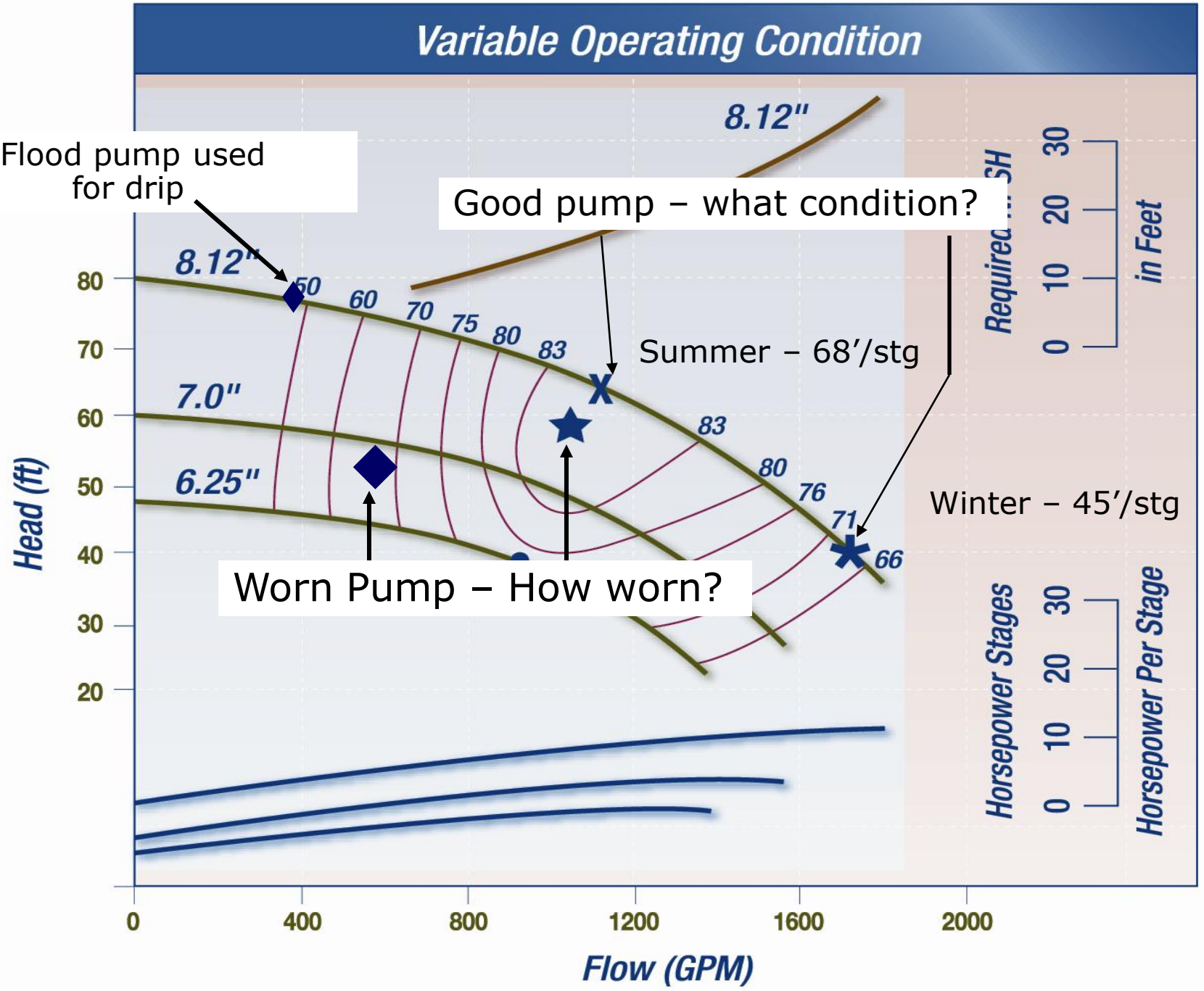




# Why does a pump become inefficient?

If efficiency is poor, or the flow/head is not sufficient:

- The pump may be physically deteriorated
- The required "operating condition" has changed
  1. Well has deteriorated
  2. Change in irrigation system
  3. Systemic change in water table


Variable Operating Condition
Flood pump used for drip
Good pump – what condition?
Summer – 68'/stg
Winter – 45'/stg
Worn Pump – How worn?
8.12"
7.0"
6.25"
50
60
70
75
80
83
76
71
66
Head (ft)
80
70
60
50
40
30
20
0
400
800
1200
1600
2000
Flow (GPM)
Required NPSH in Feet
Horsepower Stages
Horsepower Per Stage
0
10
20
30

# Multi-Condition Tests…

- Test of OPE at several operating conditions.
  - Especially important if you are using a pump you don't know or have moved a pump from some other installation
- Are you trying to operate off the most efficient operating condition?
- Is the pump worn?

# Pump Efficiency Tests…

- Snapshot of the pumping plant <u>at the operating condition(s) tested</u>
- More helpful if:
  - You have original specifications and pump performance curve
  - Done on a regular basis
  - Done at normal operating conditions (testing a well in winter?)

# Reducing Energy Use and Costs…

There is help available through PG&E's

Advanced Pumping Efficiency Program

# APEP offers…

- Knowledge/Education
  1. Know how to install an efficient pump
  2. Know how to maintain an efficient pump
  3. Know how much water needs to be pumped
  4. Know how much water has been pumped

- Technical Assistance

- Subsidized pump efficiency tests for pumps 25 HP or more

- Incentives for pump retrofit (any size pump)





# APEP Basic Eligibility…

- PG&E non-residential electric or natural gas account paying the Public Purpose Programs Fund charge
- Primarily used for pumping water for…
  - production agriculture
  - landscape or turf irrigation
  - municipal purposes, including potable and tertiary-treated (reclaimed) water
- Specifically excluding pumps used for industrial processes, raw sewage, or secondary-treated sewage.

# Pump Tests – Simply…

1. Customer contacts a Participating Test Company:
   - Visit the web site – www.pumpefficiency.org
   - Call us – 1-800-845-6038

2. Arrange for test with the Test Company

3. Test performed and report delivered

4. Test Company takes care of paperwork, CIT pays the Test Company directly

# Retrofit Incentives - Eligible Projects…

- ONLY retrofit of either impeller or bowl, or both
  - Physical wear
  - Systemic change in required operating condition
- Pump must be operating
- Must have a pump test performed both before and after the project

**SPECIFICALLY DO NOT WORK WITH VFDs!!!!!**

# Retrofit Incentives – Eligibility…

- Project cannot have started before Jan 1, 2006.

- Results of pump tests both before and after the project are required. Pre-test can be anytime after January 1, 2002. Post-test done within six (6) months after the application is approved.

*These tests do not have to be done by our testers!*

- The pumping plant must be operational. The Program will not provide an incentive to repair a broken or inoperable pumping plant.

# Retrofit Incentive – Simply…

1. Customer obtains and fills out the application, then submits with copy of pre-project pump test.

2. We review and issue Letter of Approval.

3. When project is complete the customer submits:
   i. Copy of an invoice marked PAID
   ii. Copy of the post-retrofit pump test

4. CIT reviews, recalculates incentive as necessary and issues approval package to PG&E.

# Retrofit Incentive – Simply…

WE DO 90% OF PAPERWORK!

# In Summary…

- Went over the basics of pumping:
  - The "pump performance curve" with "bowl efficiencies" identified
  - The "operating condition" – the specific combination of flow and TDH
  - OPE – overall pumping efficiency
    - A benchmark for performance
    - We can test for it!
  - Stable vs. unstable pumping situations

# In Summary…

Three main ideas for reducing energy use:

1. Improve water management
2. Reduce pressure in the system
3. Increase pumping plant efficiency

# In Summary…

- A Pump Test is the first step for pumping efficiency!
  - If OPE is poor – is it because:
    - Poor physical condition?
    - A pump not operating at its best operating condition?
  - Pump Test also provides
    - Basic system data
    - A pumping cost analysis

# In Summary…

- PG&E's Adv Pumping Efficiency Program offers:
  - Subsidized pump efficiency tests (25 HP or more)
  - Incentives for retrofit of inefficient pumps (any size)
  - Educational seminars and material (free to all)

www.pumpefficiency.org

Or call (800) 845-6038

- Also, www.wateright.org for water management