SCADA 101

Supervisory Control and Data Acquisition

Sensors, Data, and How to Use Them

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About the Speaker

Graham Nasby, P.Eng., PMP, CAP
Water SCADA & Security Specialist
City of Guelph Water Services

- 10 years in the consulting sector
- Joined Guelph Water Services in 2015

- OWWA and WEAO Member, Member of OWWA Automation Committee
- Co-chair of ISA112 SCADA Systems standards committee
- Voting member of ISA101 HMI Design standards committee
- Voting member of ISA18 Alarm Management standards committee
- Named Canadian Expert on IEC/SCC-TC65 with Standards Council of Canada

- Has published over 30 papers and articles on automation topics
- Received University of Guelph "Mid Career Achievement Award" in 2014
- Named ISA's technical division leader of the year award in 2013.

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City of Guelph Water Services

- Guelph, Ontario, Canada
- 140,000 residents
- 21 groundwater wells
- 3 water towers
- 549 km of water mains
- 49,000 service connections
- 2,750 fire hydrants
- 46,000 m^3/day [12 MGD]

Presentation Outline

- What is SCADA
- SCADA System Architecture
- Purpose of SCADA Systems

- SCADA View Nodes
- Instrumentation, Wiring, PLCs
- SCADA Network & Servers
- SCADA Screens & Alarm System

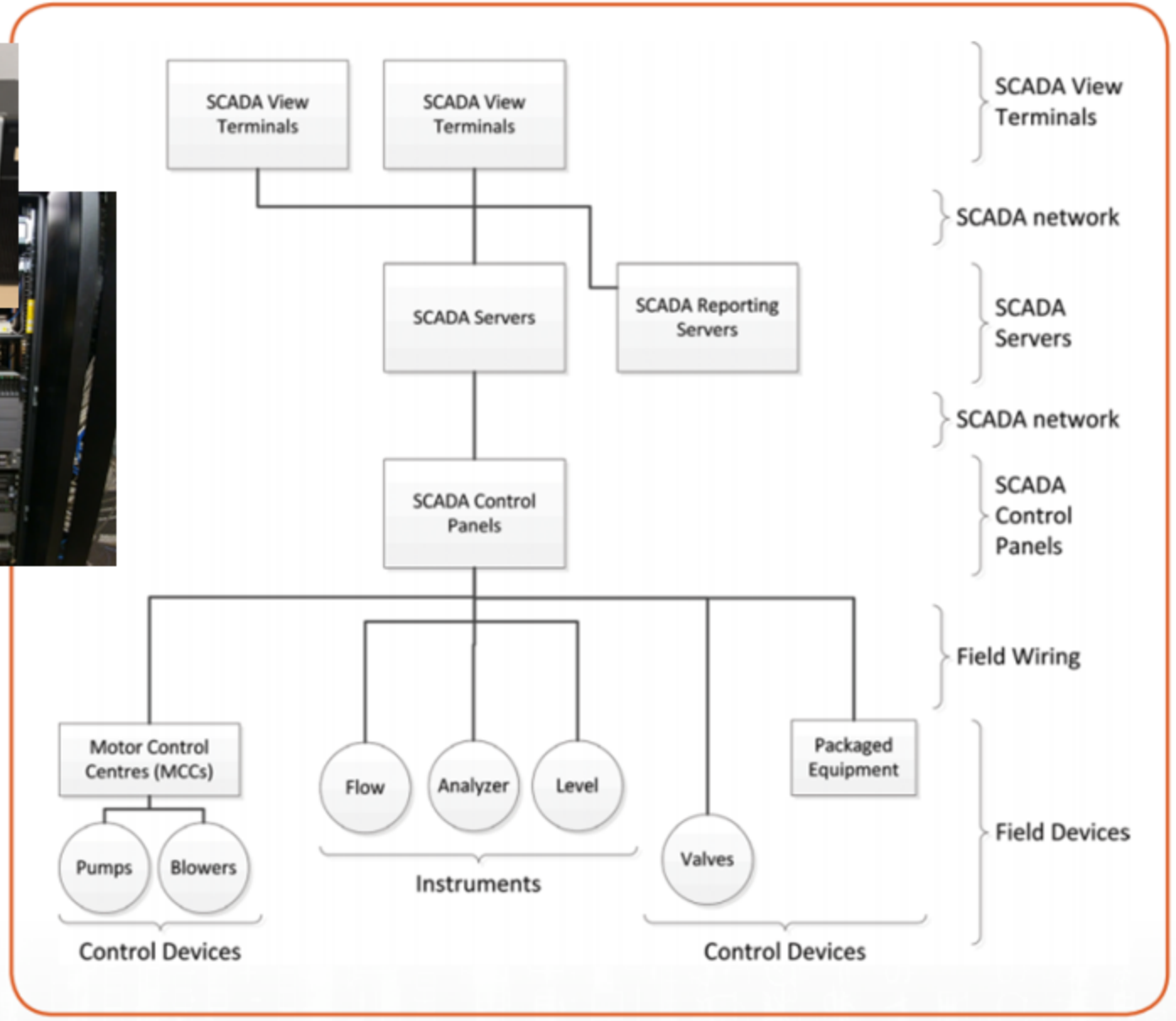
- Groundwater Well Instrumentation
- Current Trends in SCADA Systems

What is SCADA?

SCADA = Supervisory Control and Data Acquisition

Not SCADA

Typical SCADA Architecture



Why we have SCADA systems

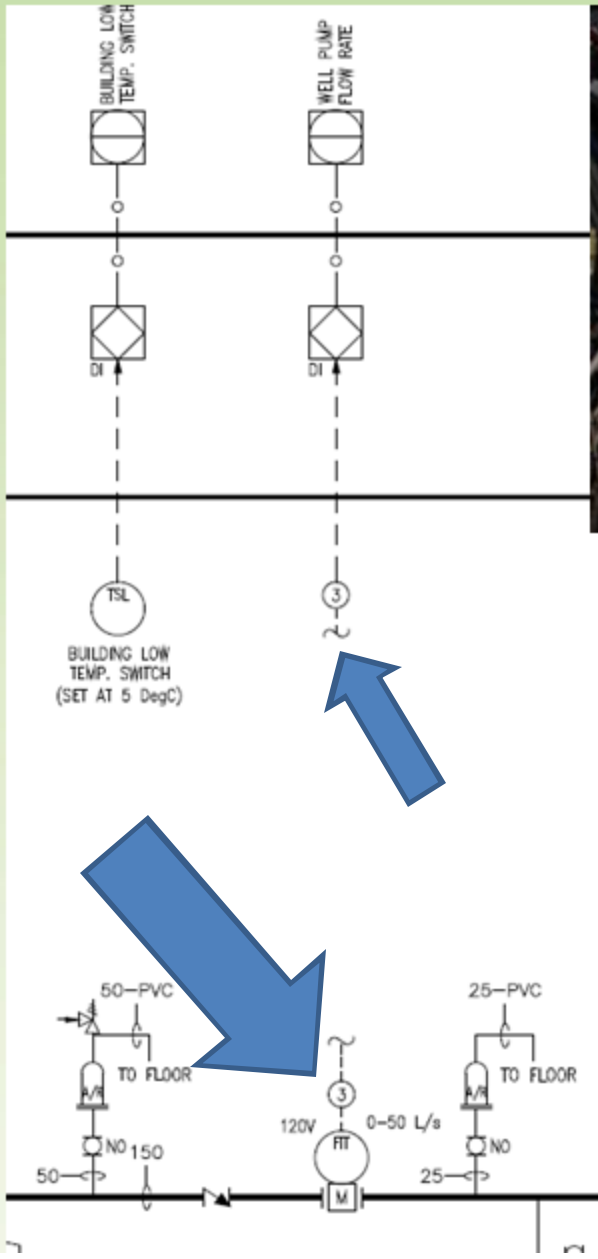
- Unattended automatic control of water facilities
- Logging of critical control parameters
  - Chlorine Residuals (e.g., every 5 minutes)
  - Turbidity
  - Well Flow Rates & Daily Flow Totals
  - POE Flow Rates & Daily flow Totals
  - Tower Levels & Pressure

- Provides "visualization" of water facilities to Operators
- Enables remote monitoring and control by Operators
- Triggering and Annunciation of Alarms
- Automated responses (increase chlorine dose, shutdown, etc.)
- Reporting based on logged process data

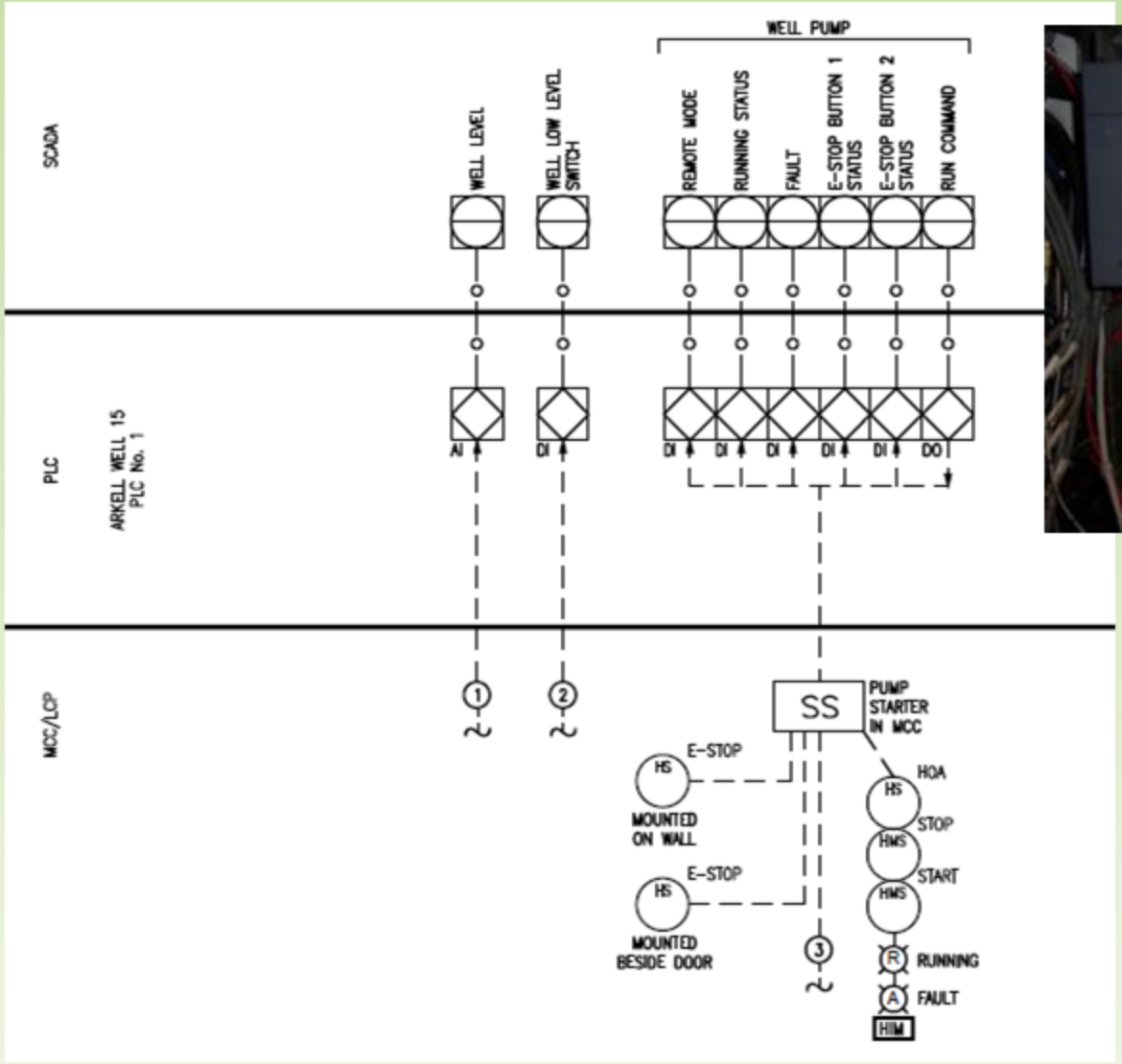
SCADA View Terminal

More Heavily Used SCADA View Terminals

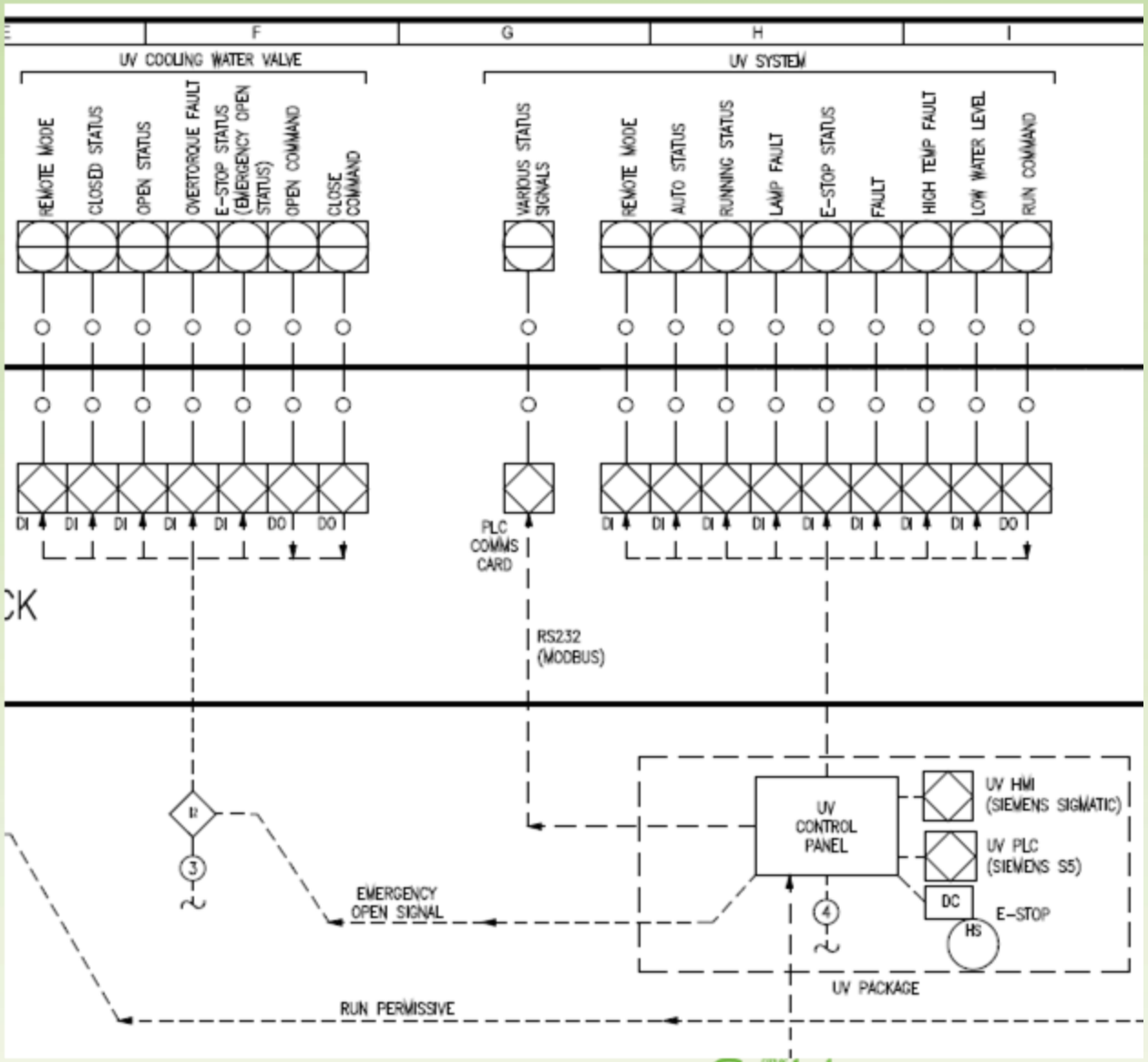
I/O Level - Instrumentation



I/O Level - Pumps



I/O Level – a more complicated example

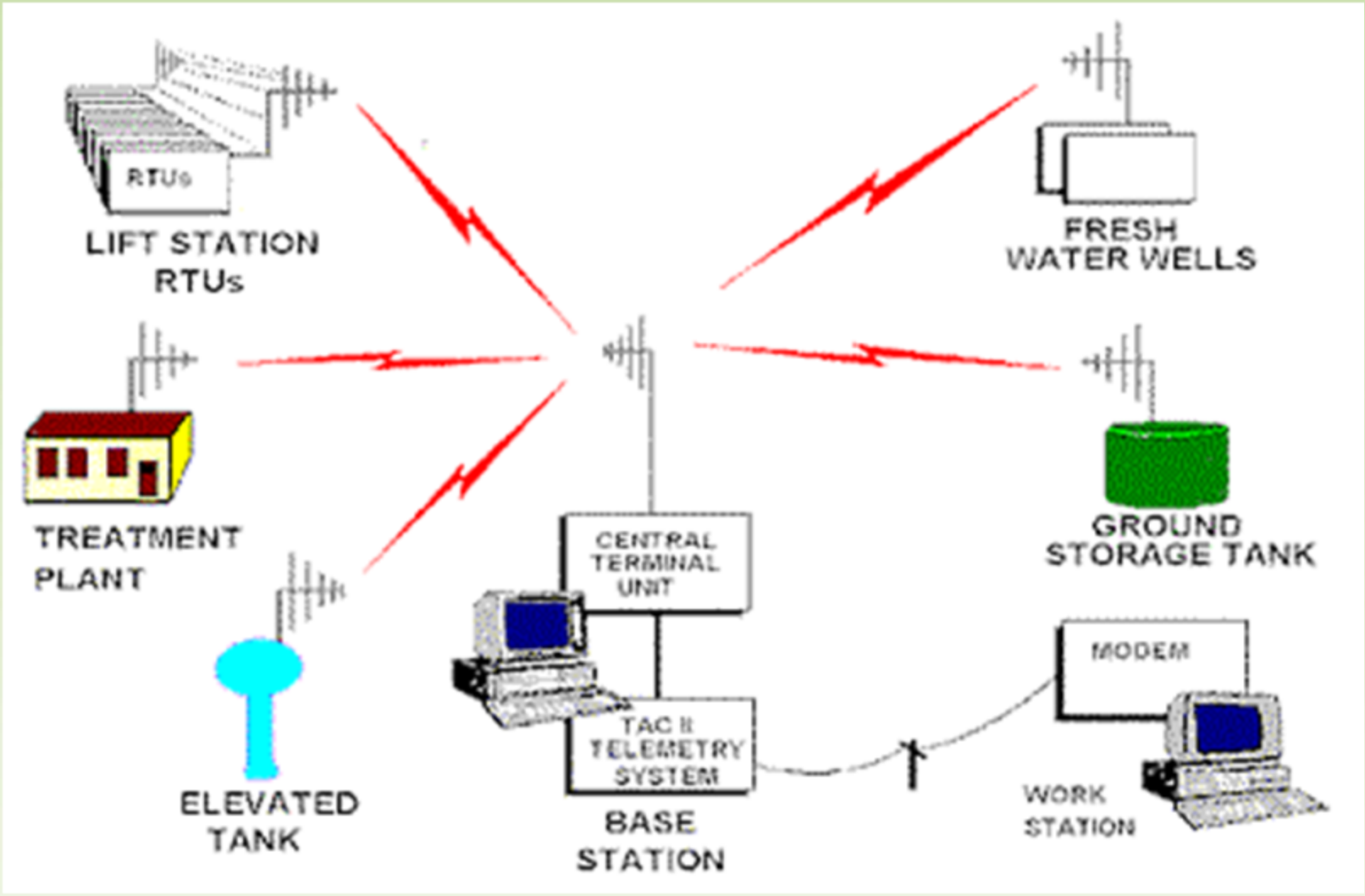


UV Reactor

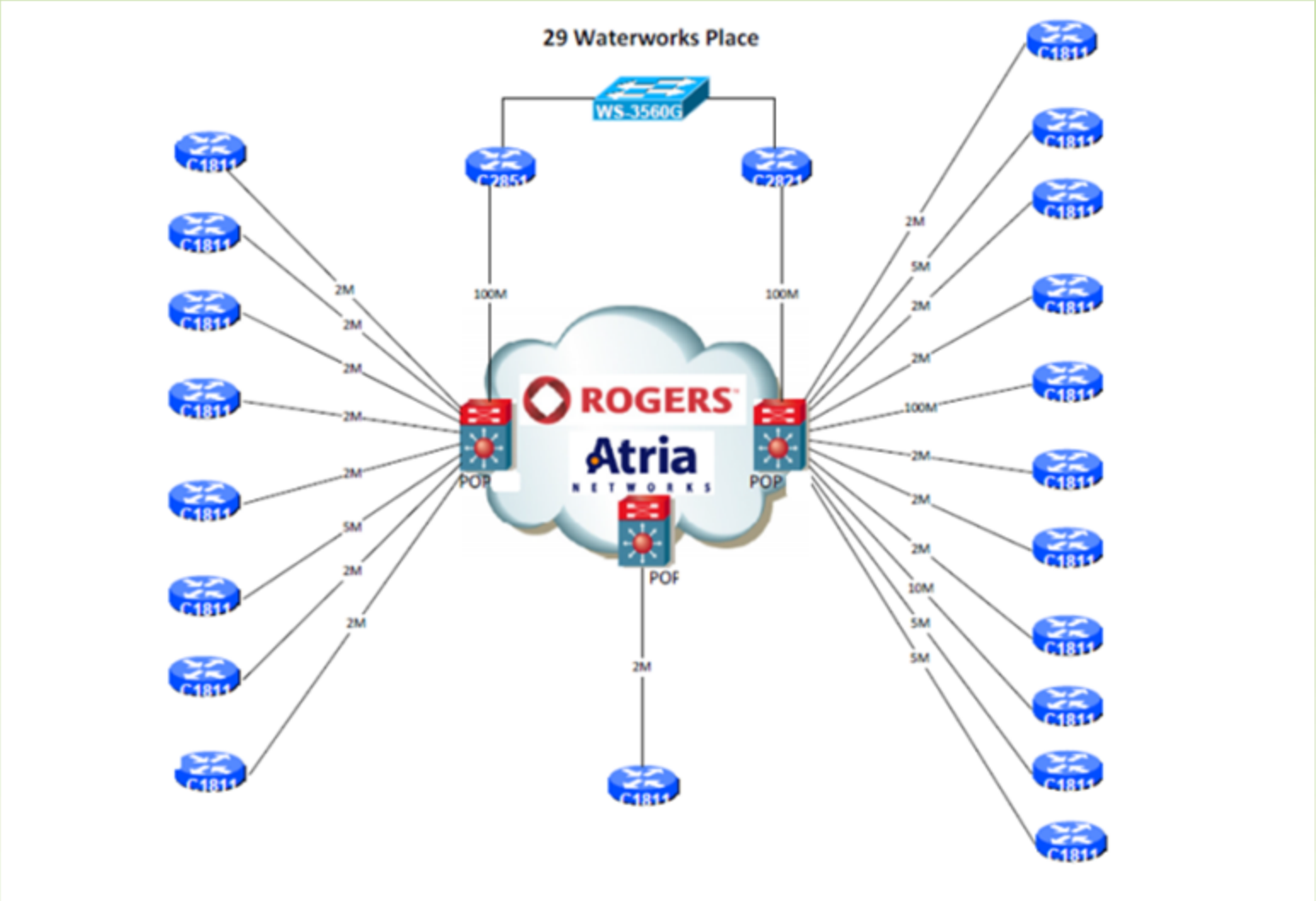
PLC Control Panel

PLCs

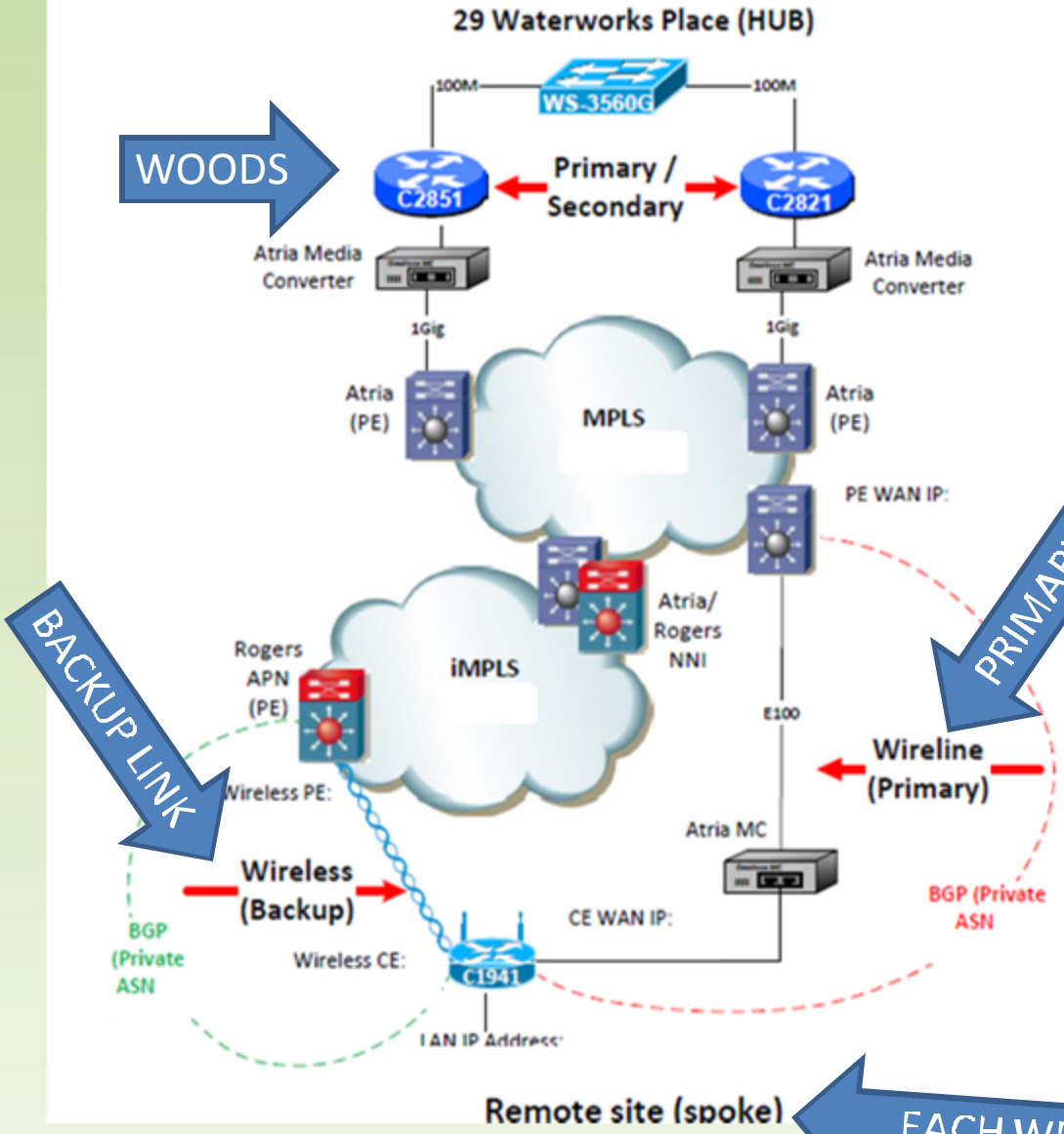
SCADA Network



SCADA Network (Fibre optic)



Guelph Water SCADA Network: Fibre optic with automatic secure wireless backup



Main site objectives:

- Maintain status quo with existing Primary / Secondary (standby) routers (no config. changes)
- Both Primary and Secondary routers will continue to handle traffic via existing Atria MPLS network
- Rogers will extend a connection from Atria network to Rogers EON network via a new inter-as bridge specific to the customer's VRF
- Both Primary / Secondary routers will communicate to new Wireless backup accesses over this bridge via the existing Atria MPLS network over BGP

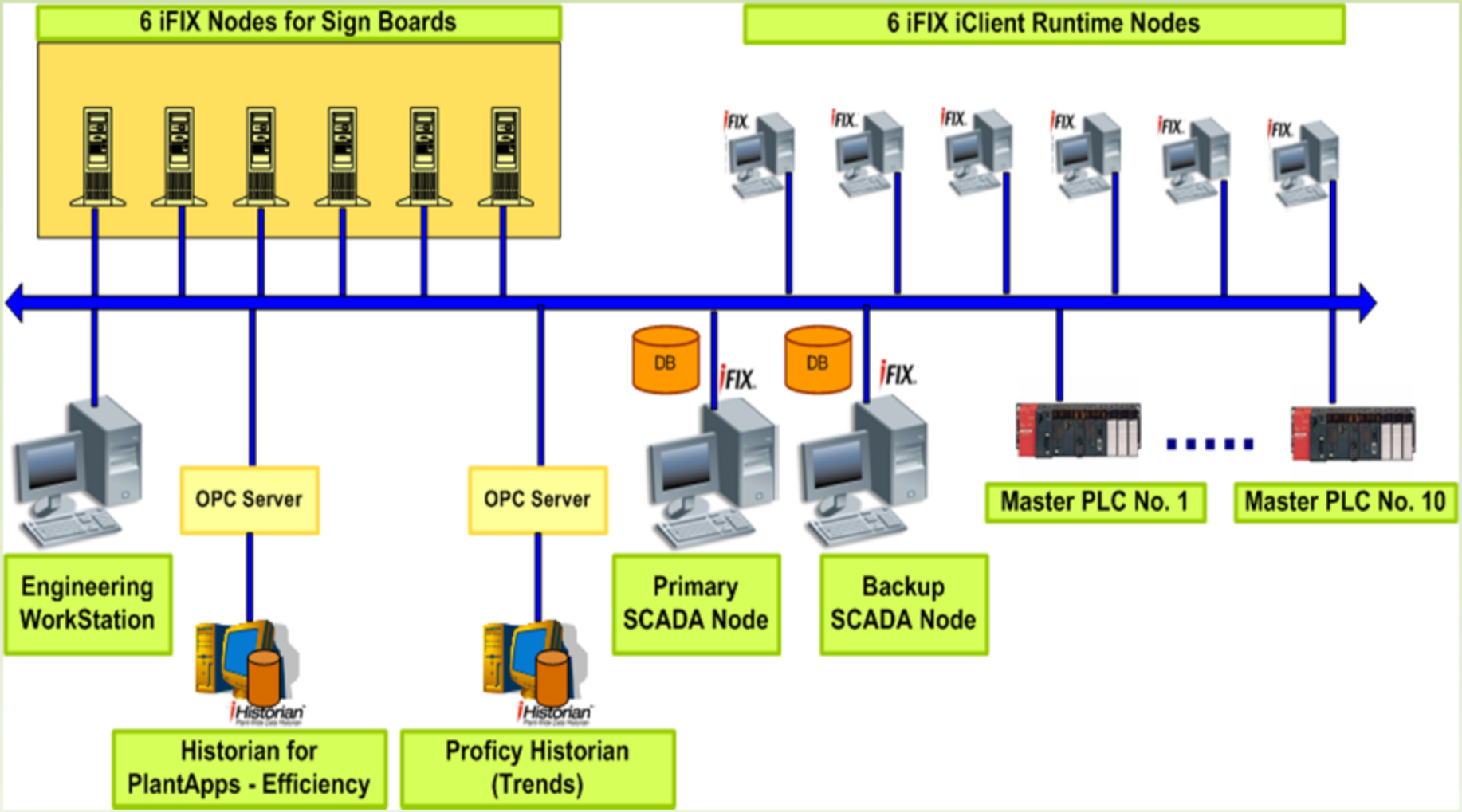
Remote sites objectives:

- Maintain current Atria access via Fiber/MC
- Replace current Atria Router with a Rogers Managed Cisco 1941 router w/HSPA+ wireless backup module & antenna
- Rogers will build a new MPLS customer VRF on the EON platform and inter-connect this with the Atria MPLS customer VRF
- Wireless backup will be via Rogers EON network back to Atria MPLS via inter-as bridge
- Wireline primary access will be direct from 1941 to Atria MPLS core via BGP
- Wireless will use AS Prepend inbound and local pref outbound for Wireline
- Assumptions:

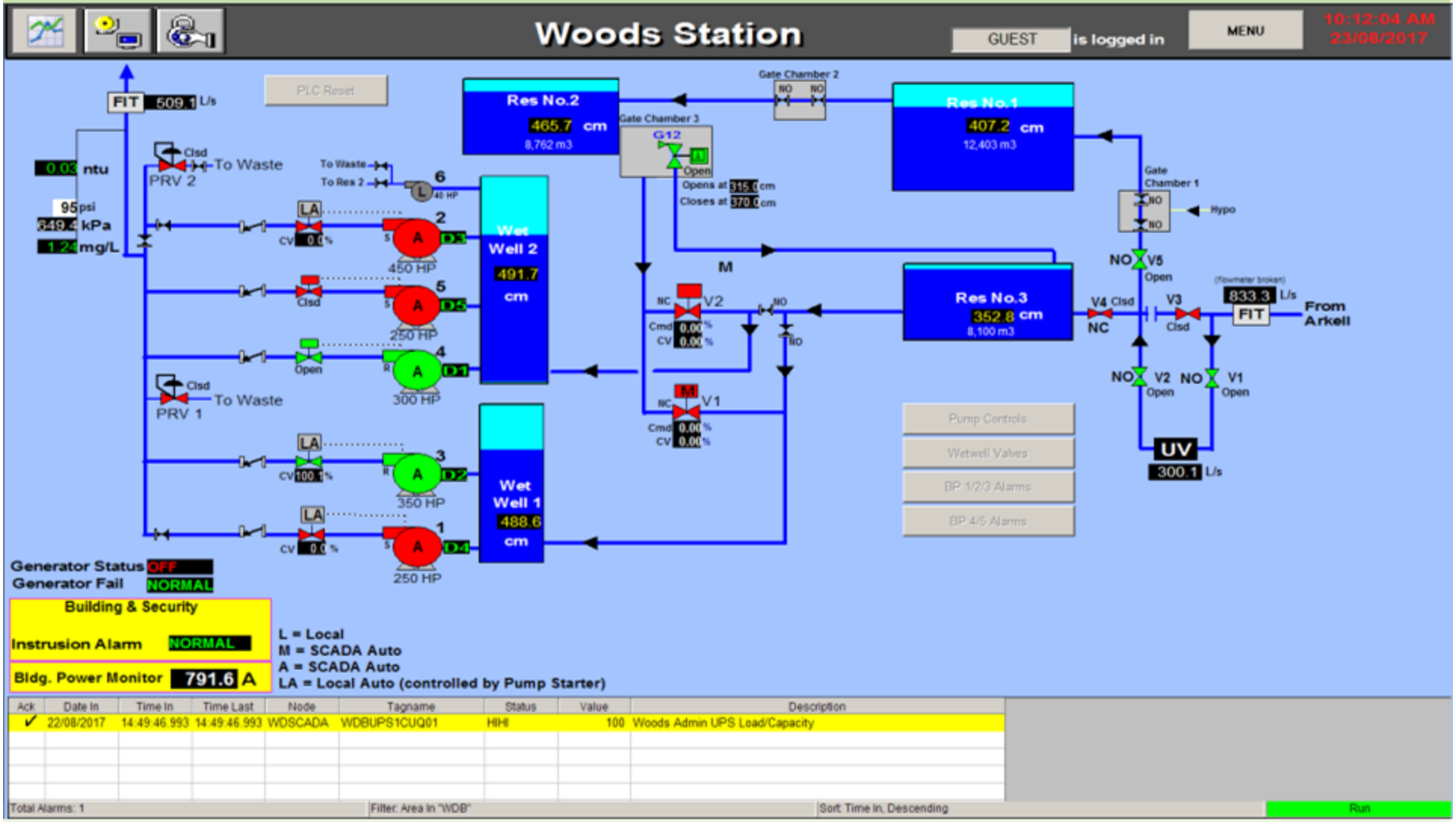
1. Private AS different from Host AS (no AS-Override Required)
2. Hub and Spoke will be maintained and each spoke will re-use the same Private-As (not required but can be done)

SCADA Servers

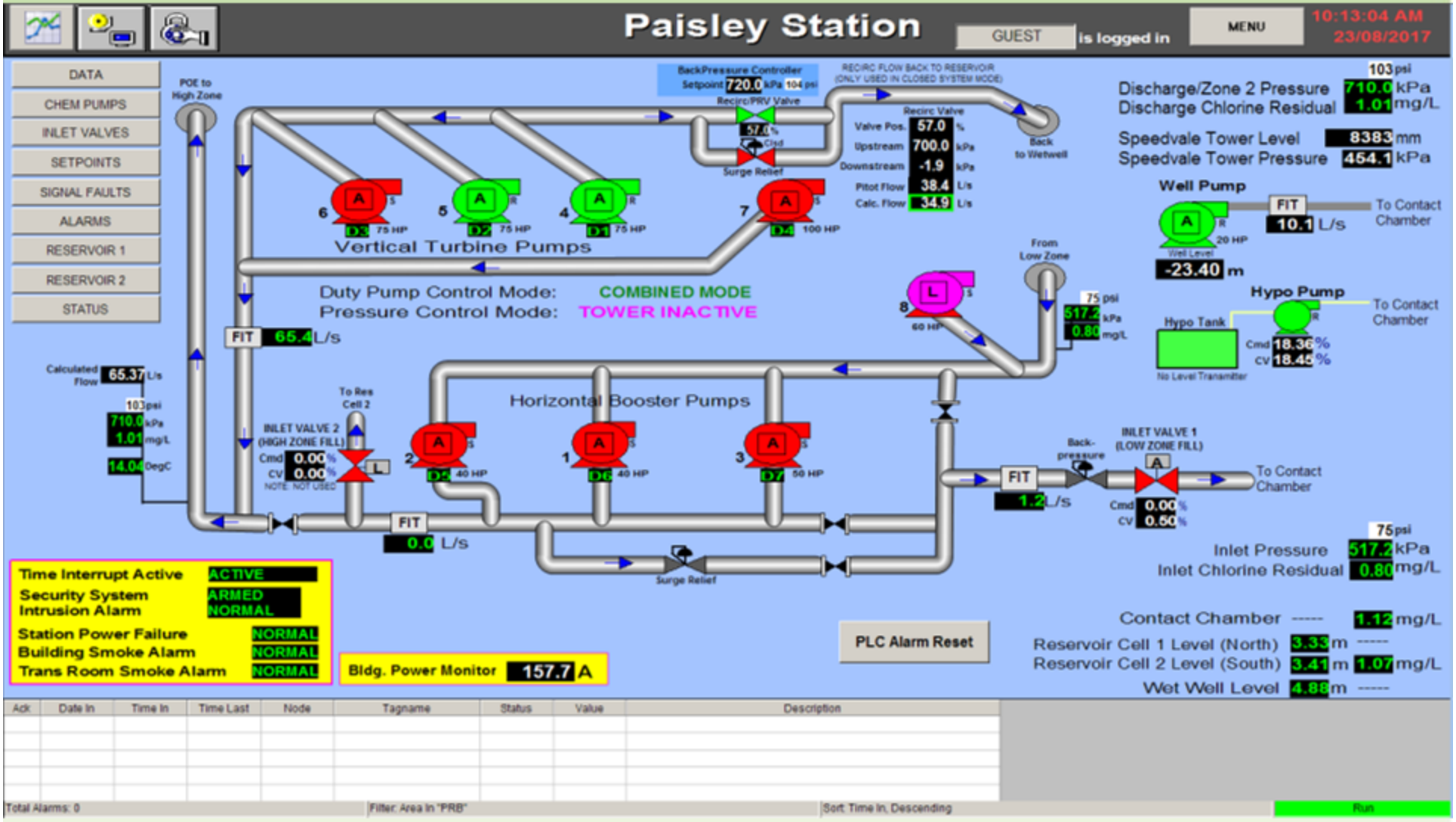
SCADA Servers - Example



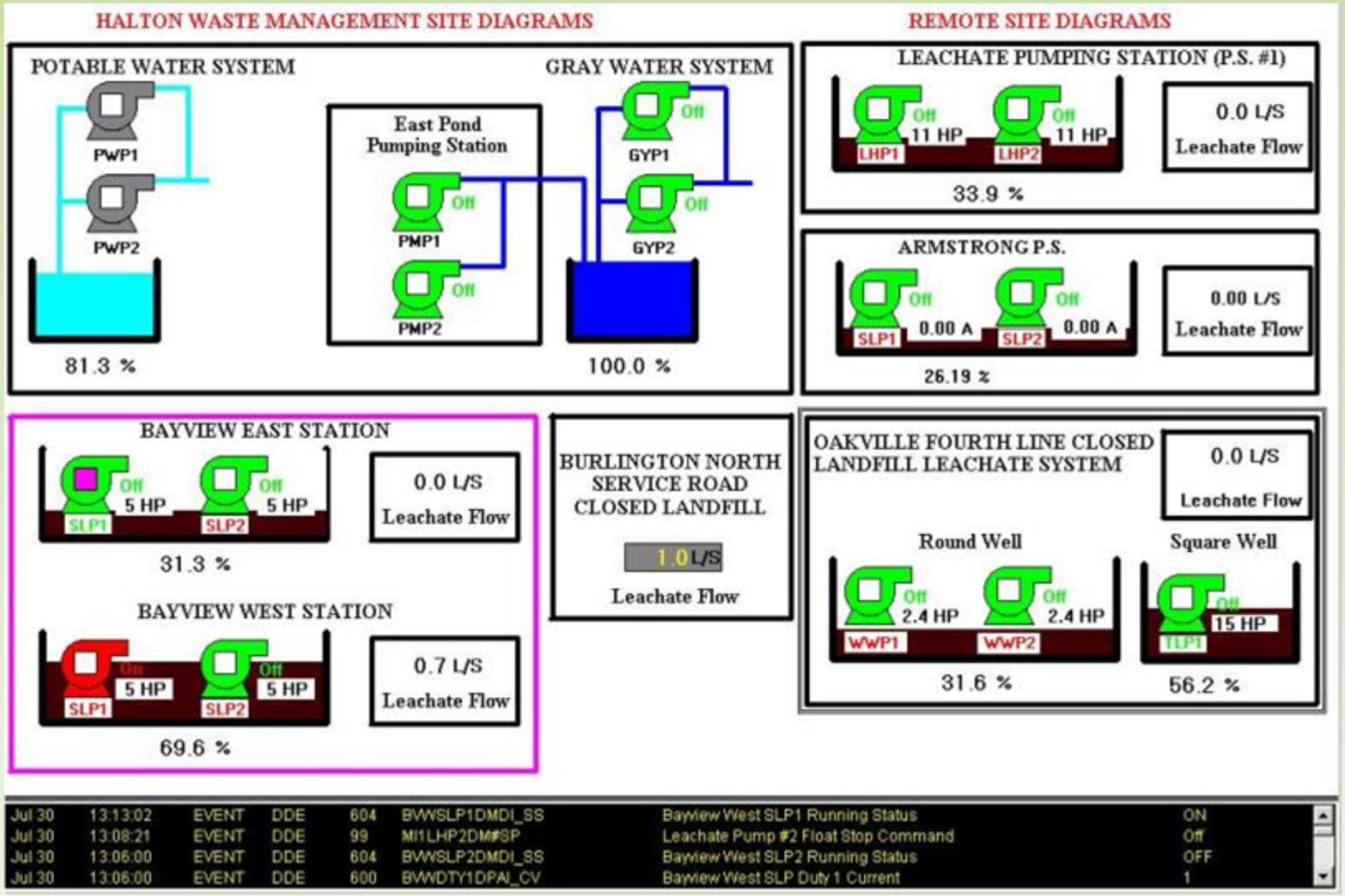
Screens


Woods Station
GUEST is logged in
MENU
10:12:04 AM
23/08/2017
PLC Reset
FIT 509.1 L/s
0.03 ntu
95 psi
649.4 kPa
1.24 mg/L
Clsd To Waste PRV 2
To Waste
To Res 2
Res No.2
465.7 cm
8,762 m3
Gate Chamber 2
Gate Chamber 3
G12
Open
Opens at 315.0 cm
Closes at 370.0 cm
Res No.1
407.2 cm
12,403 m3
Gate Chamber 1
Hypo
Wet Well 2
491.7 cm
Wet Well 1
488.6 cm
450 HP
250 HP
300 HP
350 HP
250 HP
Clsd To Waste PRV 1
Open
M
V2
V1
Res No.3
352.8 cm
8,100 m3
V4 Clsd
V3 Clsd
V5 Open
V2 Open
V1 Open
833.3 L/s
FIT
From Arkell
UV
300.1 L/s
Pump Controls
Wetwell Valves
BP 1/2/3 Alarms
BP 4/5 Alarms
Generator Status OFF
Generator Fail NORMAL
Building & Security
Instrusion Alarm NORMAL
Bldg. Power Monitor 791.6 A
L = Local
M = SCADA Auto
A = SCADA Auto
LA = Local Auto (controlled by Pump Starter)
Ack | Date In | Time In | Time Last | Node | Tagname | Status | Value | Description
✓ | 22/08/2017 | 14:49:46.993 | 14:49:46.993 | WDSCADA | WDBUPS1CUQ01 | HiHi | 100 | Woods Admin UPS Load/Capacity
Total Alarms: 1
Filter: Area In "WDB"
Sort: Time In, Descending
Run

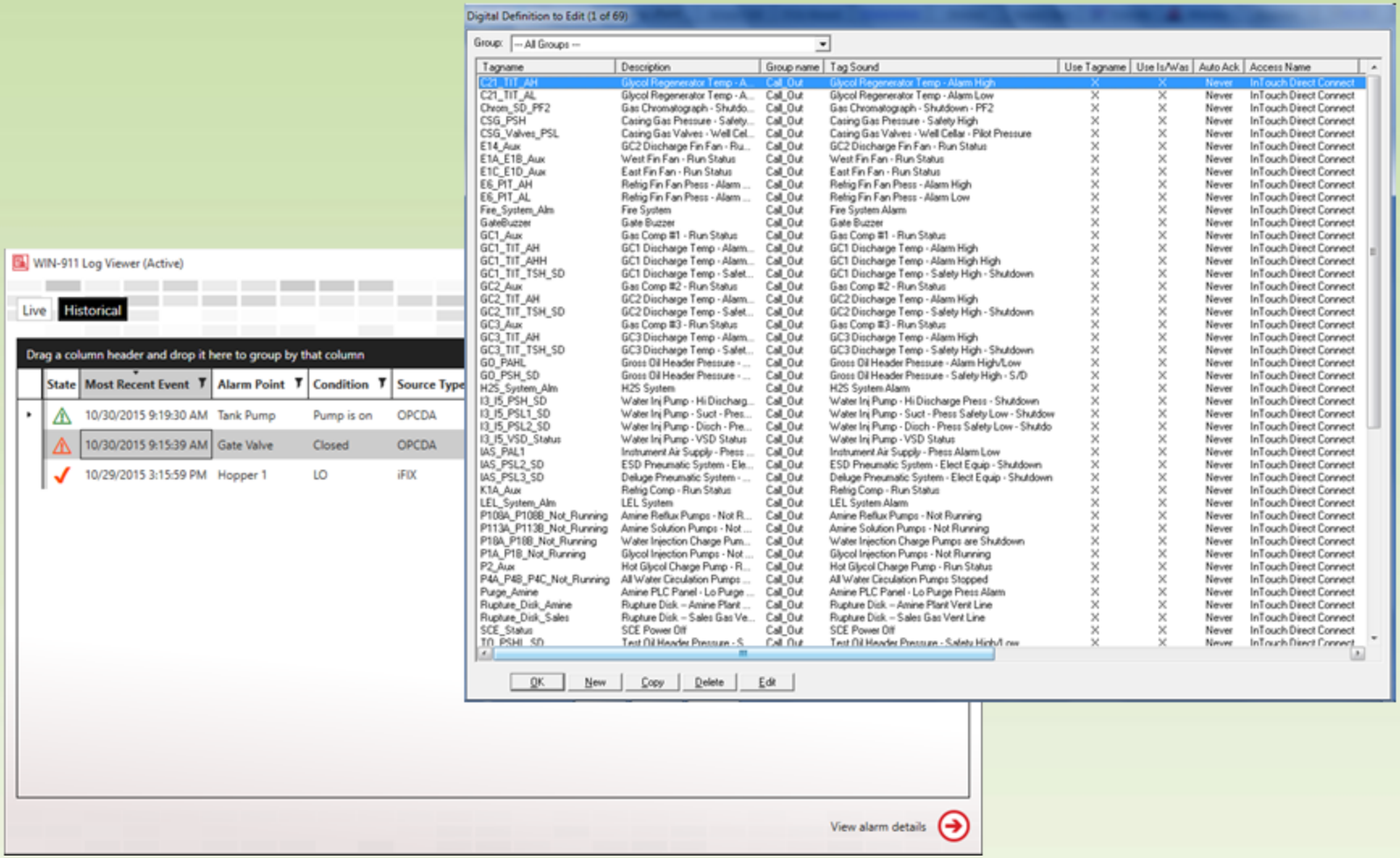
Screens


Paisley Station
GUEST
is logged in
MENU
10:13:04 AM
23/08/2017
DATA
CHEM PUMPS
INLET VALVES
SETPOINTS
SIGNAL FAULTS
ALARMS
RESERVOIR 1
RESERVOIR 2
STATUS
POE to High Zone
BackPressure Controller
Setpoint 720.0 kPa 104 psi
Recirc/PRV Valve
Surge Relief
RECIRC FLOW BACK TO RESERVOIR (ONLY USED IN CLOSED SYSTEM MODE)
Recirc Valve
Valve Pos. 57.0 %
Upstream 700.0 kPa
Downstream -1.9 kPa
Pitot Flow 38.4 L/s
Calc. Flow -14.9 L/s
Back to Wetwell
Vertical Turbine Pumps
6 D3 75 HP
5 D2 75 HP
4 D1 75 HP
7 D4 100 HP
Duty Pump Control Mode: COMBINED MODE
Pressure Control Mode: TOWER INACTIVE
FIT 65.4 L/s
Calculated Flow 65.37 L/s
103 psi
710.0 kPa
1.01 mg/L
14.04 DegC
To Res Cell 2
INLET VALVE 2 (HIGH ZONE FILL)
Cmd 0.00 %
CV 0.00 %
NOTE: NOT USED
Horizontal Booster Pumps
2 D5 40 HP
1 D6 40 HP
3 D7 50 HP
FIT 0.0 L/s
Surge Relief
From Low Zone
8 60 HP
75 psi
517.2 kPa
0.80 mg/L
Back-pressure
INLET VALVE 1 (LOW ZONE FILL)
Cmd 0.00 %
CV 0.50 %
FIT 1.2 L/s
To Contact Chamber
Discharge/Zone 2 Pressure 103 psi 710.0 kPa
Discharge Chlorine Residual 1.01 mg/L
Speedvale Tower Level 8383 mm
Speedvale Tower Pressure 454.1 kPa
Well Pump
20 HP
Well Level
-23.40 m
FIT 10.1 L/s
To Contact Chamber
Hypo Pump
Hypo Tank
No Level Transmitter
Cmd 18.36 %
CV 18.45 %
To Contact Chamber
Inlet Pressure 75 psi 517.2 kPa
Inlet Chlorine Residual 0.80 mg/L
Contact Chamber ----- 1.12 mg/L
Reservoir Cell 1 Level (North) 3.33 m -----
Reservoir Cell 2 Level (South) 3.41 m 1.07 mg/L
Wet Well Level 4.88 m -----
Time Interrupt Active ACTIVE
Security System Intrusion Alarm ARMED NORMAL
Station Power Failure NORMAL
Building Smoke Alarm NORMAL
Trans Room Smoke Alarm NORMAL
Bldg. Power Monitor 157.7 A
PLC Alarm Reset
Ack
Date In
Time In
Time Last
Node
Tagname
Status
Value
Description
Total Alarms: 0
Filter: Area In "PRB"
Sort: Time In, Descending
Run

Screens – another example

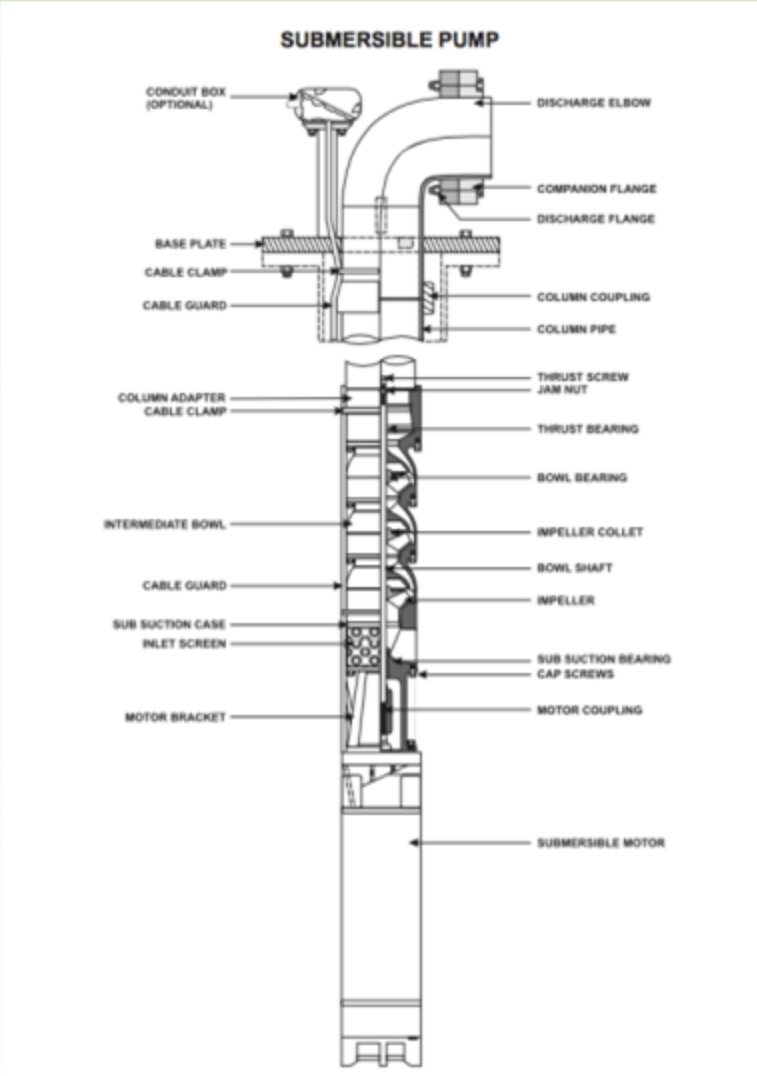


Alarm System & Call Out Alarms



Instrumentation for Groundwater Wells

Typical Groundwater Wells

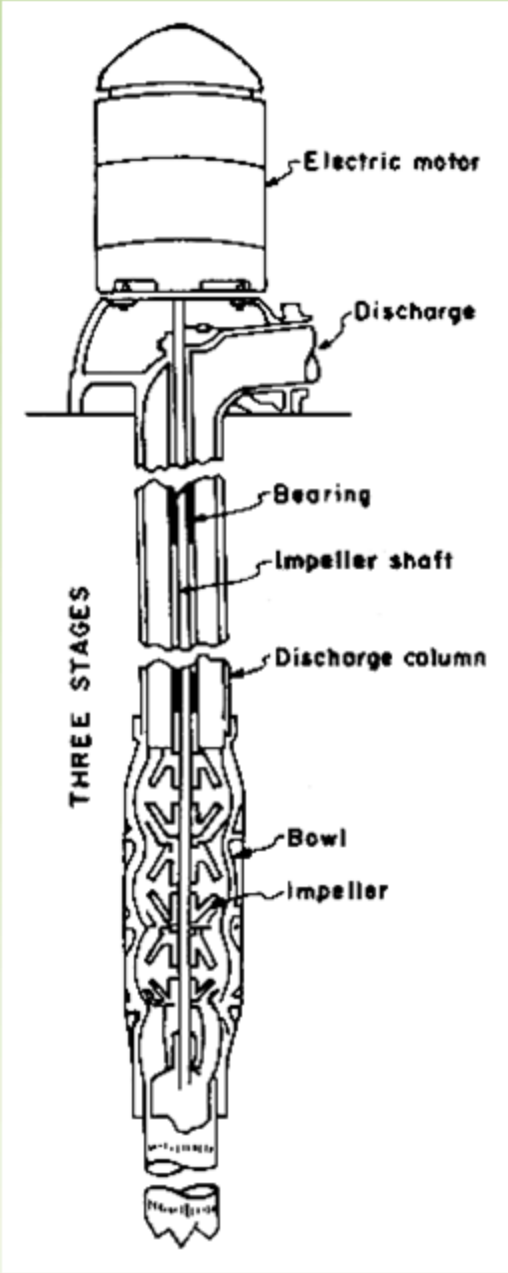


Submersible Pump

Vertical Turbine Pump

Well Instrumentation

- Well Flow Rate & Totalization
  - All flow from well (for permit)
  - Flow to Treatment System
  - Flow to Waste
- Well Level (Water Level)
- Well Pump Motor Electrical Power
- Pump Discharge Pressure
- Down-hole instrumentation
- Raw Water Analyzers for Studies



Well Discharge Flow

- Two Options
  - Periodic Manual Measurement
    - Standalone totalizing meter (water meter)
  - Continuous Measurement
    - Magnetic Flowmeters
    - Other technologies

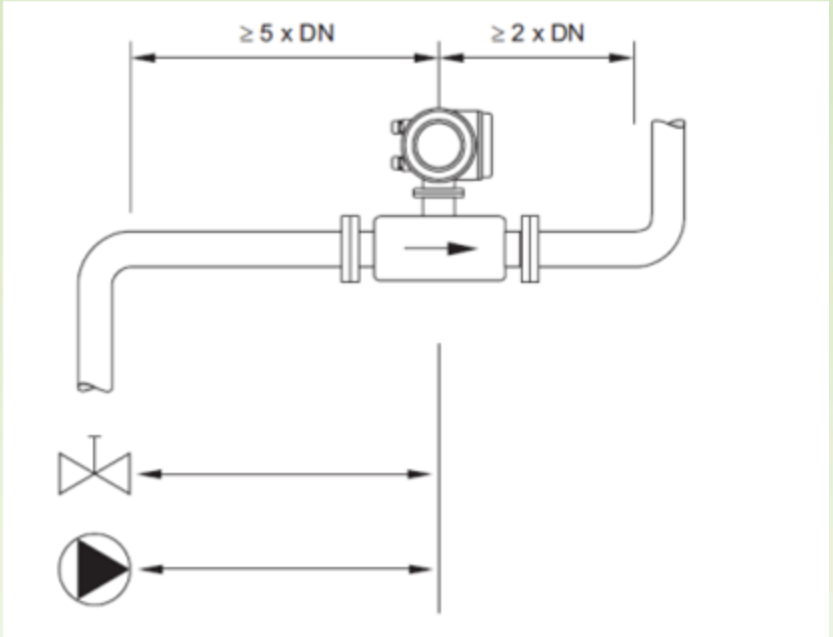
Well Discharge Flow: Best Practices

- <u>Best Practices for Magnetic Flowmeters</u>
- Size flowmeter based on “flow rate envelope” – not pipe size!
- Install with straight-pipe before/after: 5 diameters before, 2 diameters after
- If mounting vertical, have flow go “up” (not down)
- Air Release valve to let out air

- Think about how you measure:
  All flow, Flow to treatment, Flow to waste

- Use SCADA to calculate daily flow totals
- “Empty pipe” at meter is ok
  if pipe fills when pump runs
  (disable the empty pipe alarm)

- Program low flow alarms to only
  be enabled when pump is running!



Well Level (Water Level)

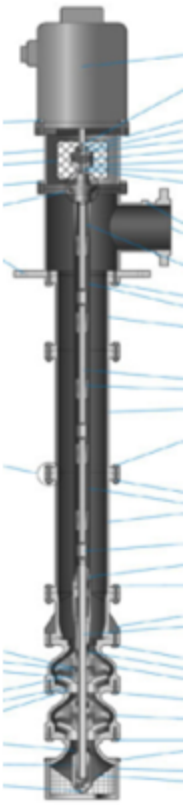
- Two Options
  - Periodic Manual Measurement
    - Well Level Tape
  - Continuous Measurement
    - Hydrostatic (pressure-based) probe

- Pressure reading must be converted to a measurement of "weight of water above the probe" (e.g. 0-100 psi = -70.39 to 0.00 m of Water)

- Best Practices
- Do not hang naked probe in well, put it in a tube
- Have two tubes: (a) for probe, (b) for well tape
- Use standard pressure range for probes

Well Level Probe Calculations

Well Water Level			LEVEL PROBE VALUES				Remember well level is down from baseplate, not stick-up tubes
			100.00 psi	*+0.00m*	+21.39m		
							0.34m
0.00m	Well Baseplate				0.00m		
	-36.00	Normal operating range of well level					
	-42.00						
-48.00m	MPL Level						
			0.00 psi	*-70.39m*	-49.00m		
-50.00m	Pump Intake Level		Raw Pressure Range	Raw Level Range	Corrected Level Range *(depth of probe is -49.00m)*		
			(4-20mA)	(4-20mA)	(4-20mA)		



Well Discharge Pressure

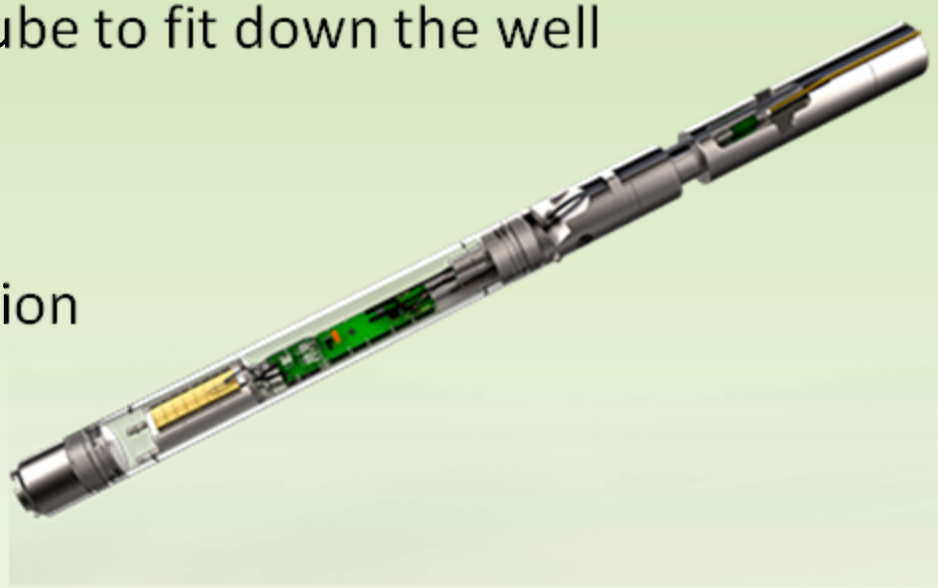
- Two Options
  - Periodic Manual Measurement
    - Pressure Gauge
  - Continuous Measurement
    - Pressure Transmitter

Downhole Instrumentation

- Could be useful for studies (or may not be worth it)
- Usually temporary when used (other than level probes)

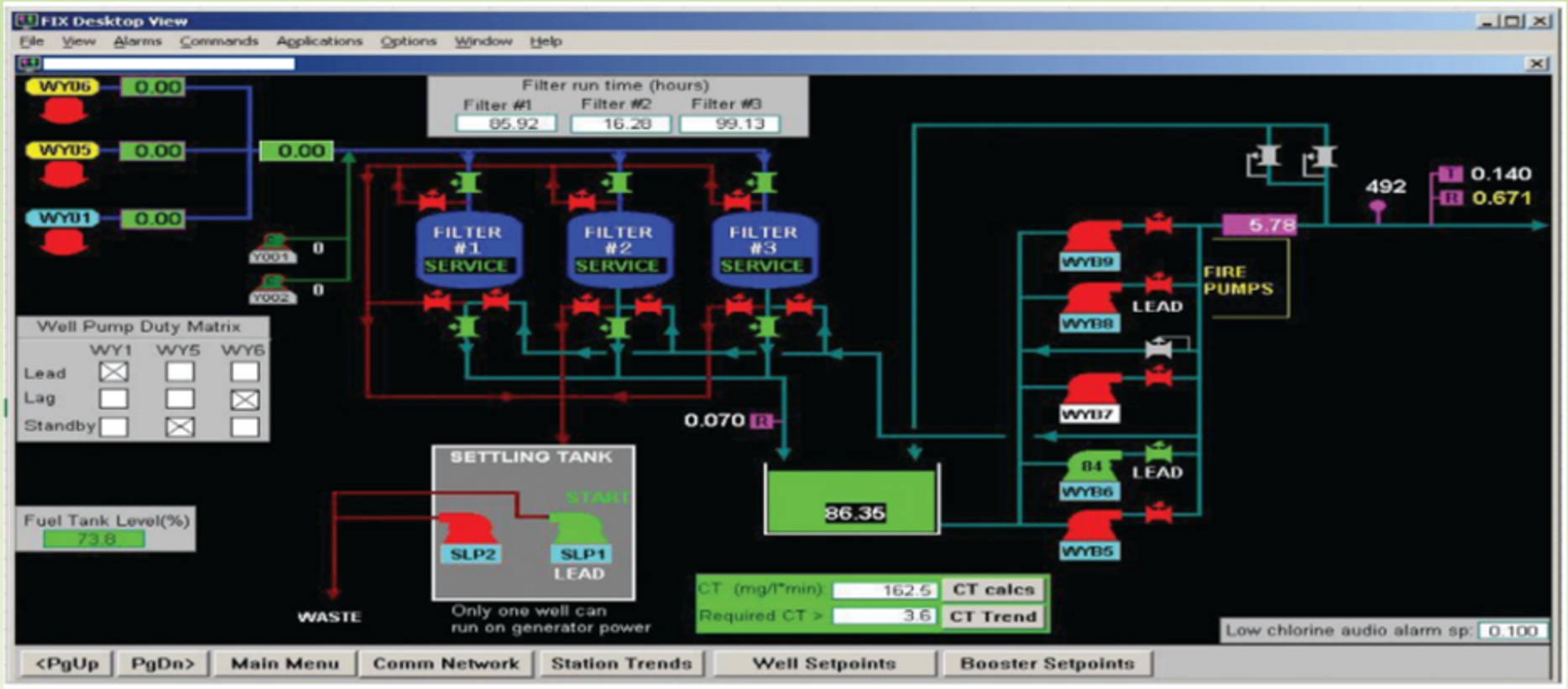
- Look the well instrumentation tube diameters
- Most downhole instrumentation needs minimum 1” or larger inside diameter tube to fit down the well
- Can be very expensive

- Downhole instrumentation
  - Conductivity
  - Temperature
  - Etc.



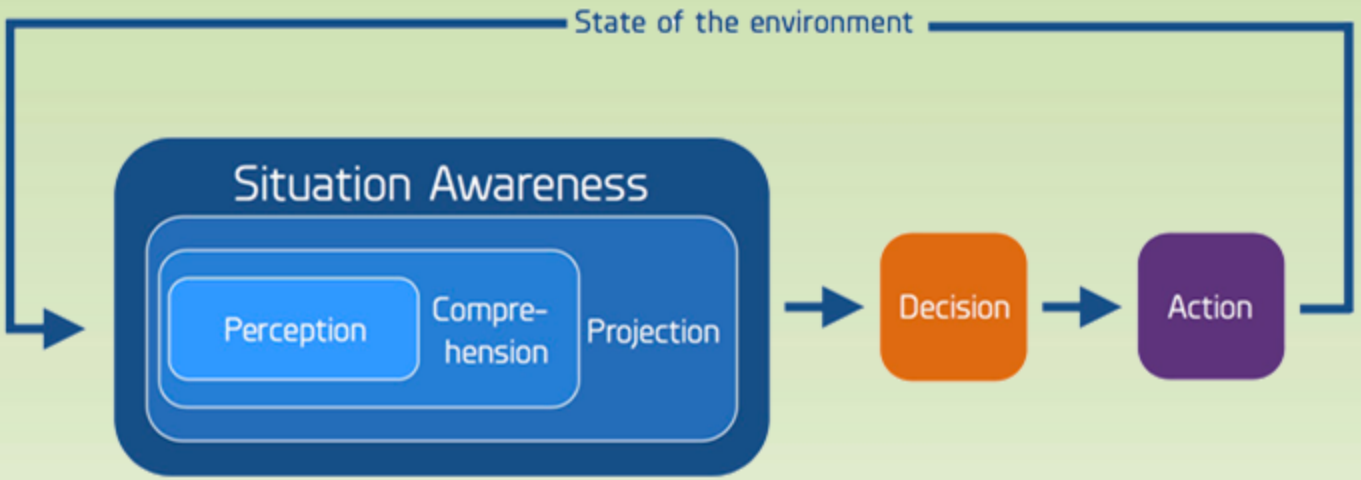
What's New in SCADA?

What's new in SCADA?



- What is running?
  - What if your are colour blind?
- Is the process running well?
- Is anything abnormal?

SCADA: Situational Awareness



To be an effective operator

–

you have to be aware of what your plant is doing

Common SCADA problem

In some SCADA systems….
You can't see the whole picture

Common SCADA problem

What your SCADA system may not be showing you

CAN

YOU

FIND

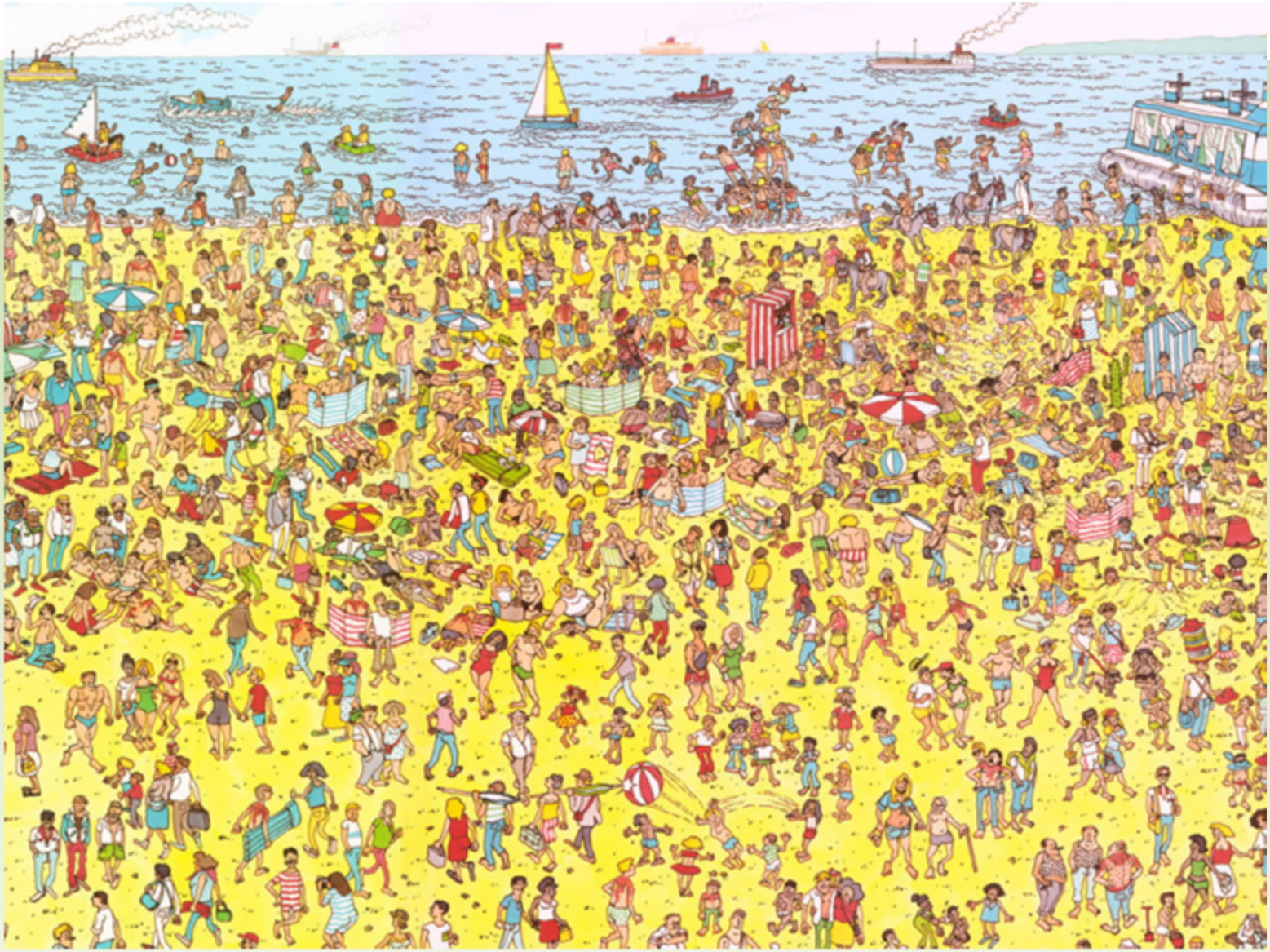
THE

PROBLEM

ON THE

SCADA

SCREEN?



Friendly
SCADA Guy

Situational Awareness

- **To be able to react to a problem,**
  Operators need to be aware of the problem

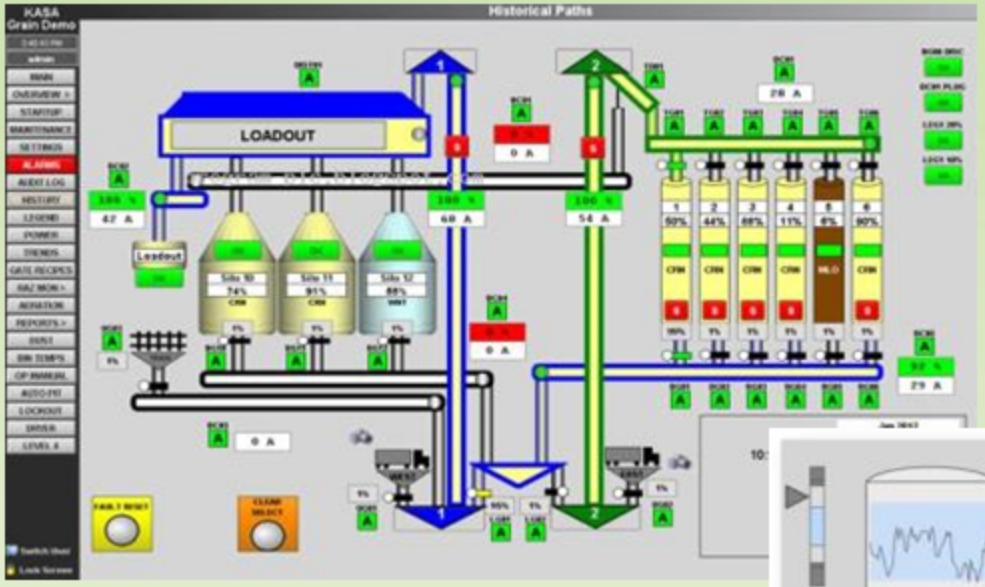
- Old way operating “by alarm” (reactively)
- New approach: Present data to operators so they can proactively respond to problems as they develop
- Reserve alarms only for events that require immediate action

- High Performance HMIs (Human Machine Interfaces)
- Alarm Management (better designed alarm systems)
- Understanding your operating envelope (know your plant’s limits)

High Performance HMIs

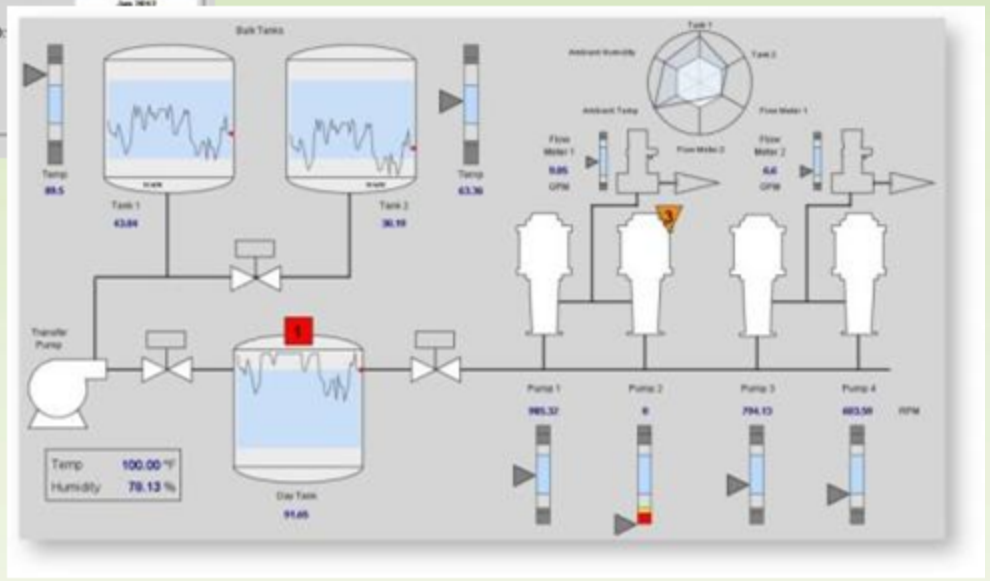
High Performance HMIs

HMI = Human Machine Interface (computer screen)

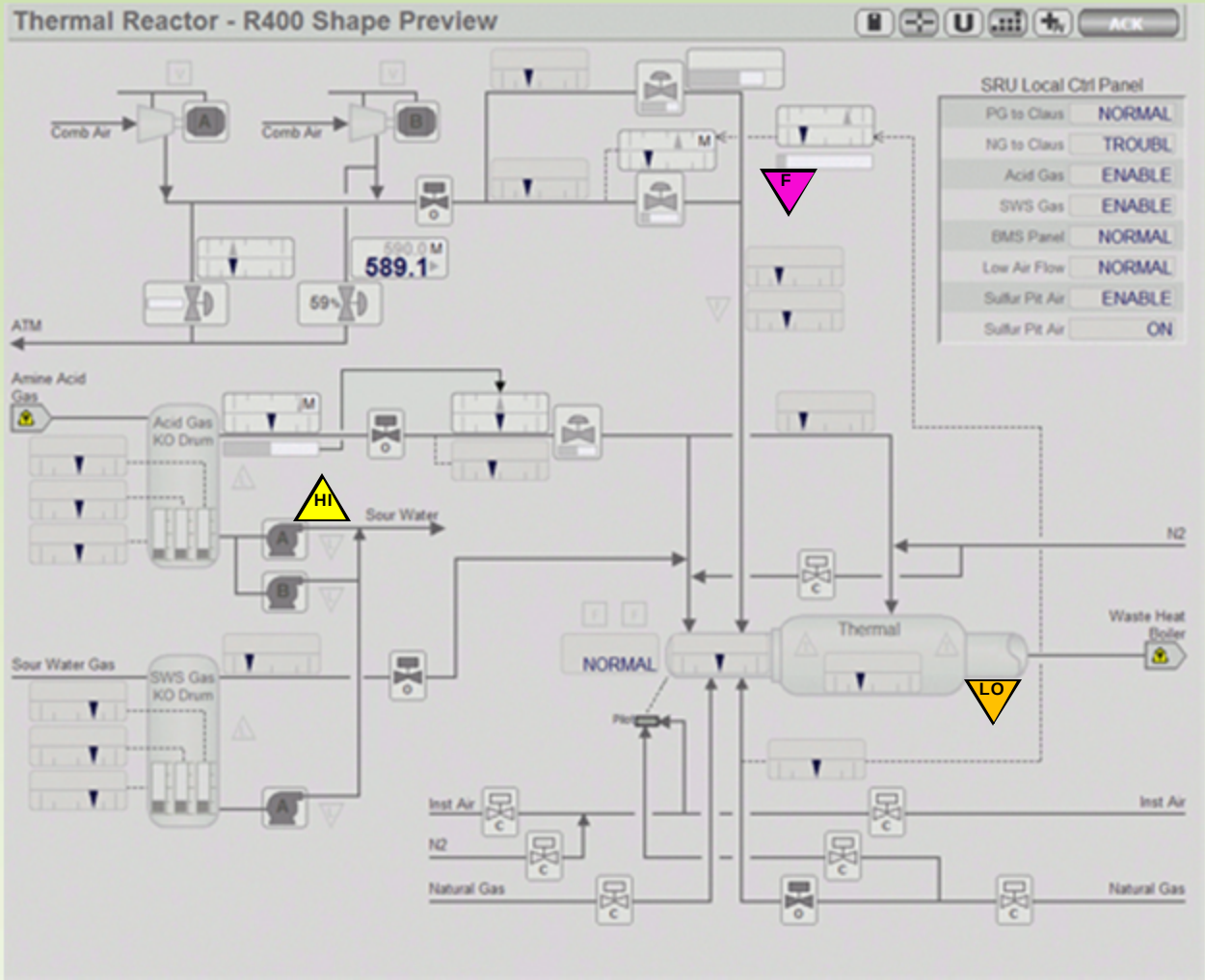


Poor Colour Scheme

High Performance HMI
Colour scheme



High Performance HMI – Plant Running Normally



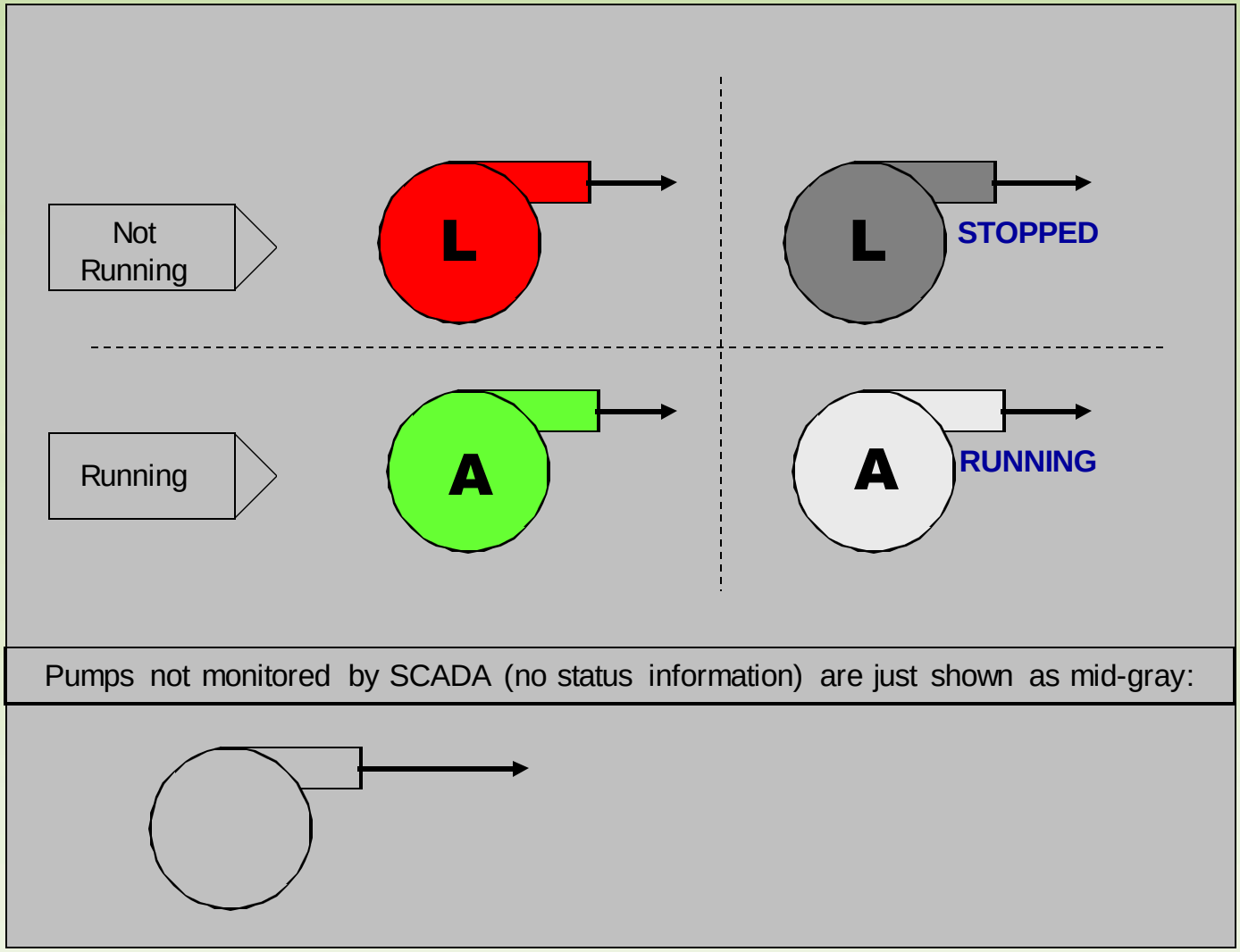
Notice the
Lack of Colour

High Performance HMI – Showing Pump Statuses

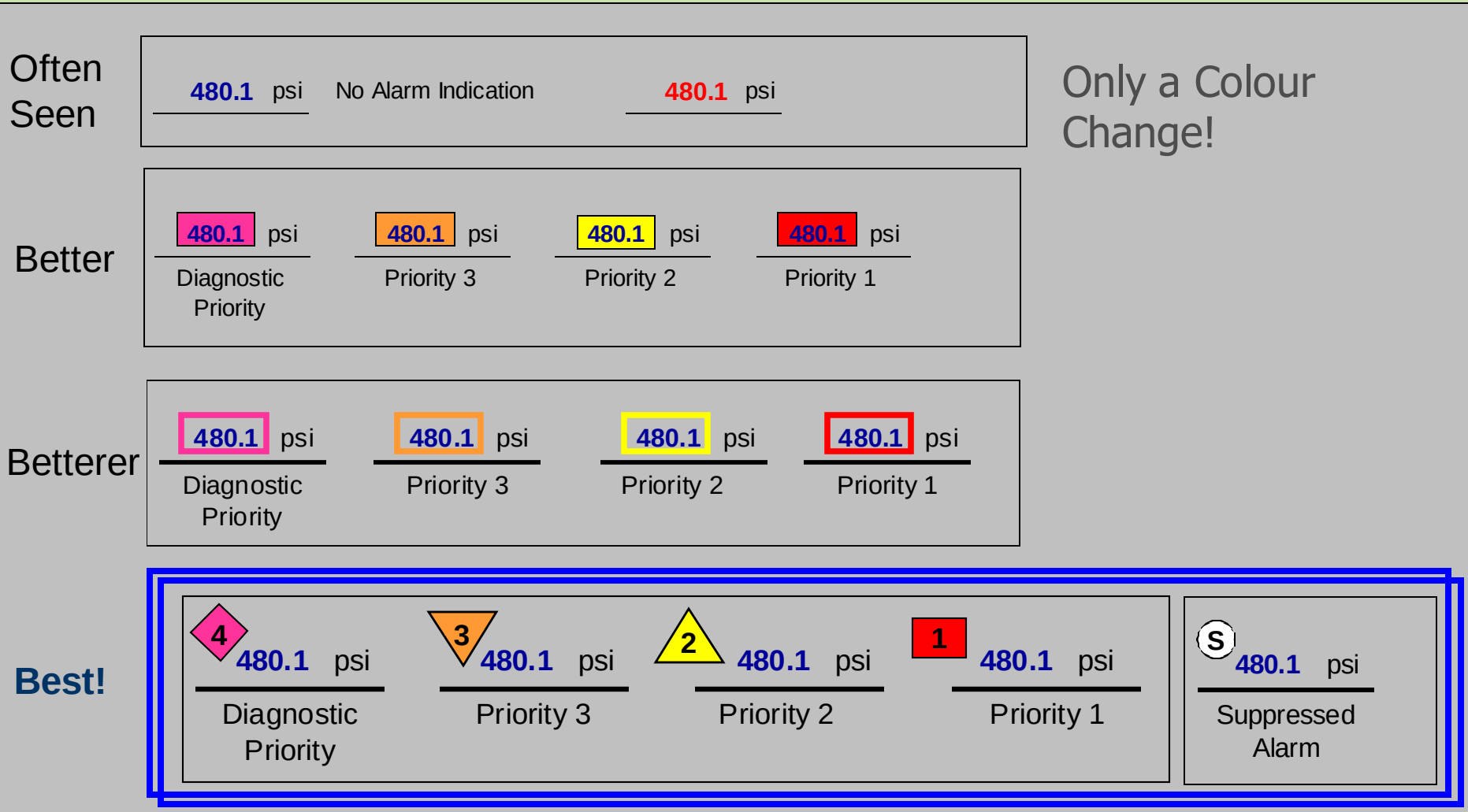
Red/Green for status

vs.

Greyscale & redundant coding

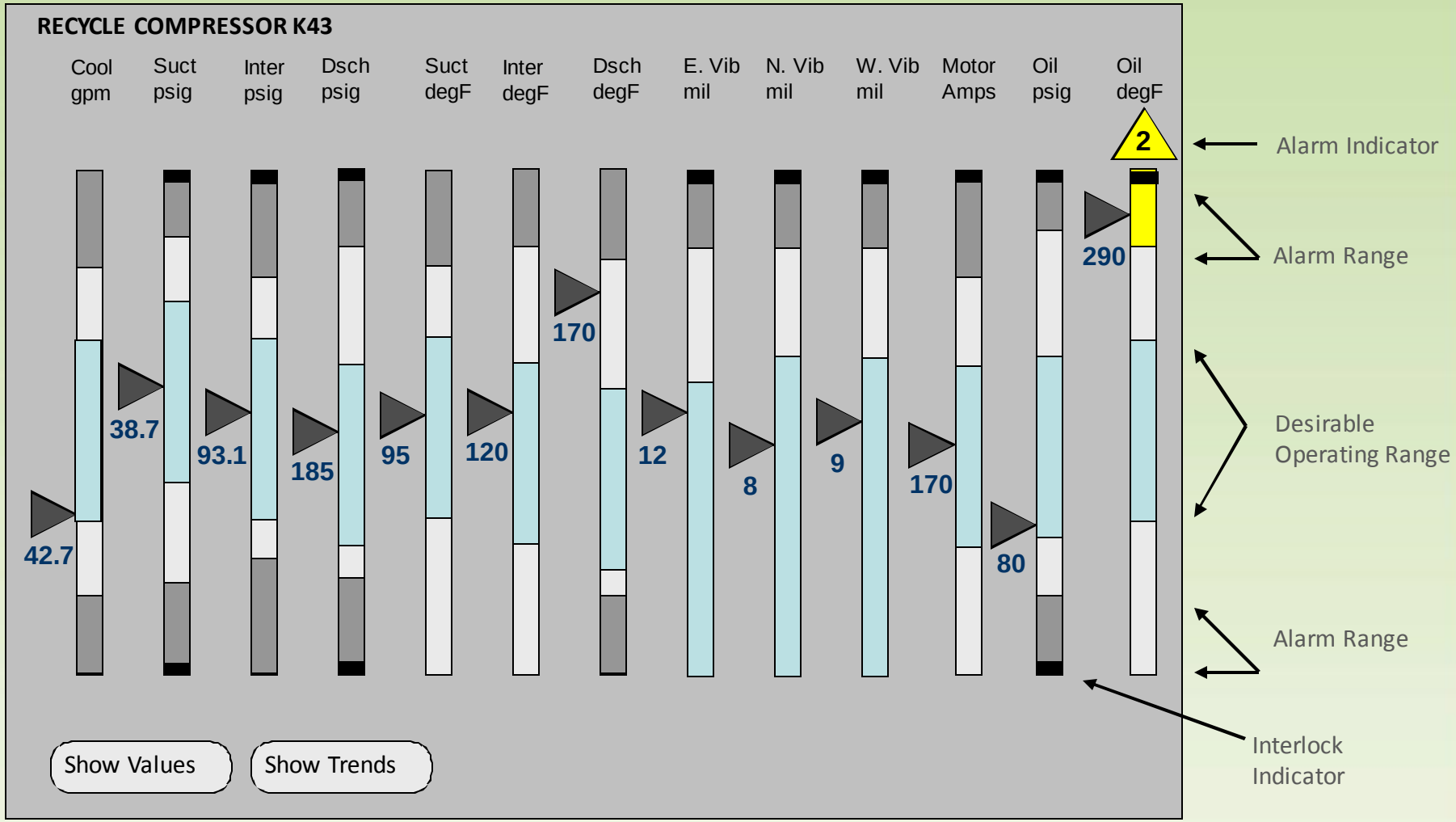


High Performance HMI – Analog Values



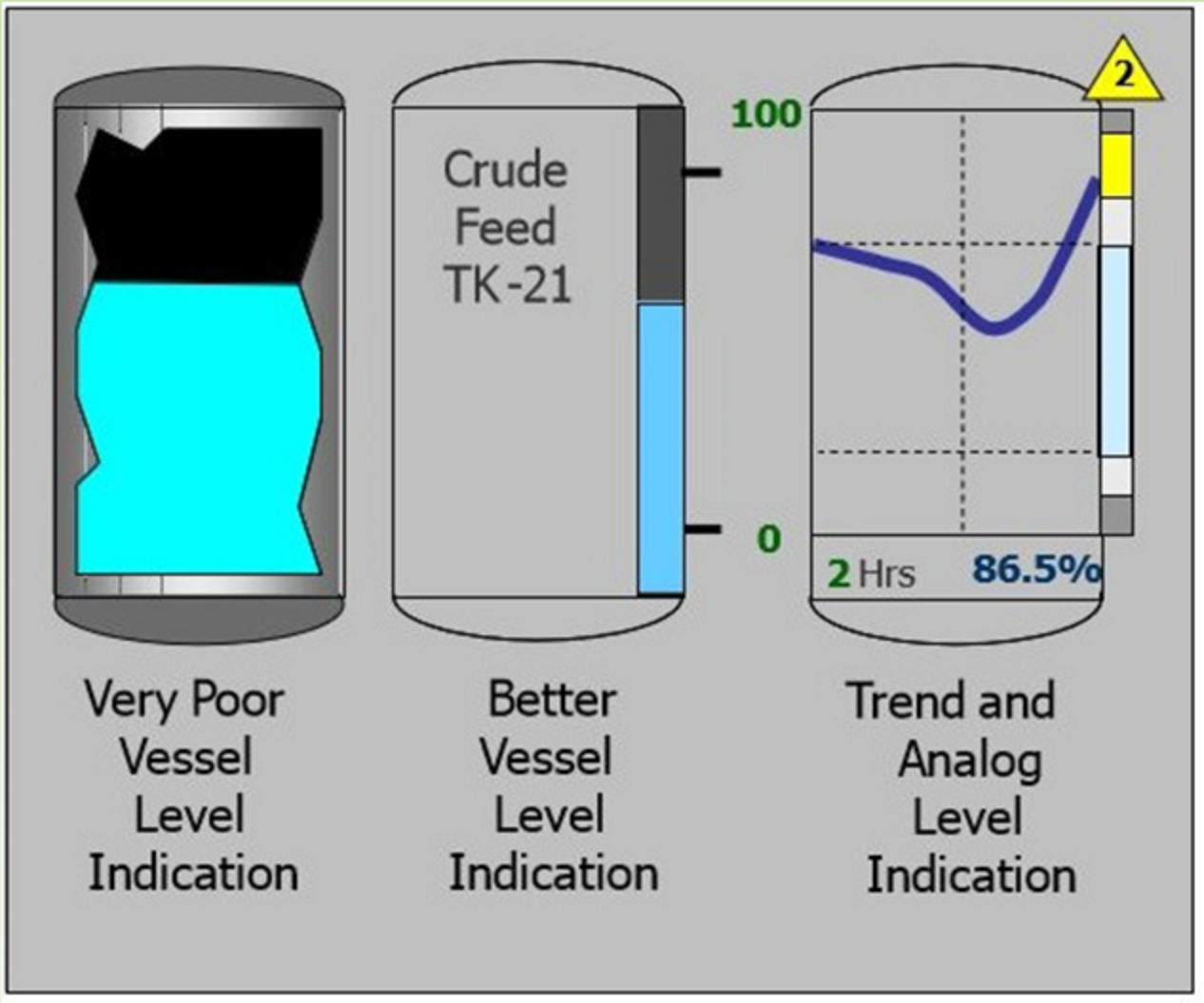
Show alarms in multiple ways: Colour, Shape, Text ("redundant coding")

High Performance HMI – Analog Values Another Way

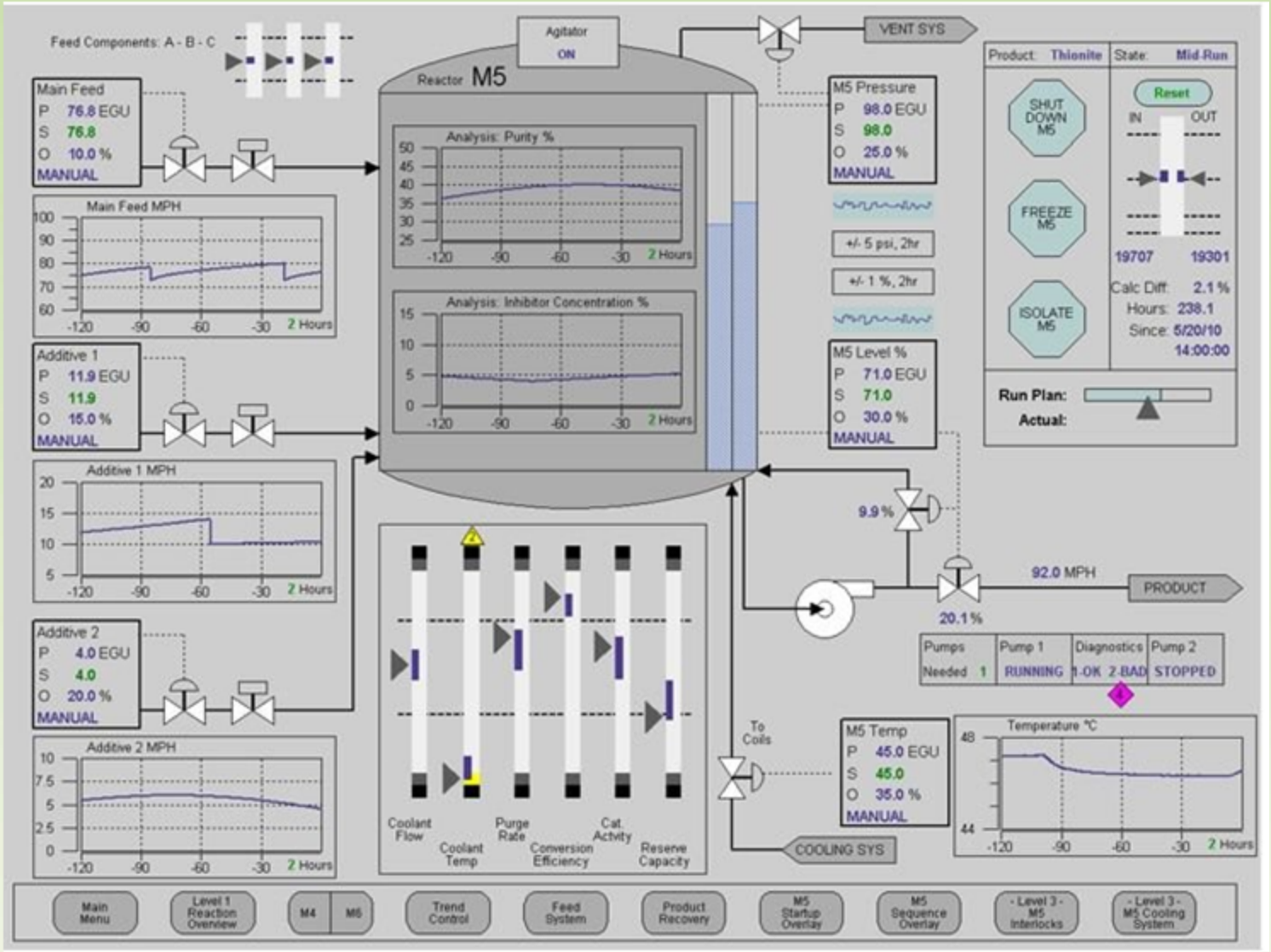


Buttons for additional functionality

High Performance HMI – Tank Levels Depiction



High Performance HMI – Embedding Trends



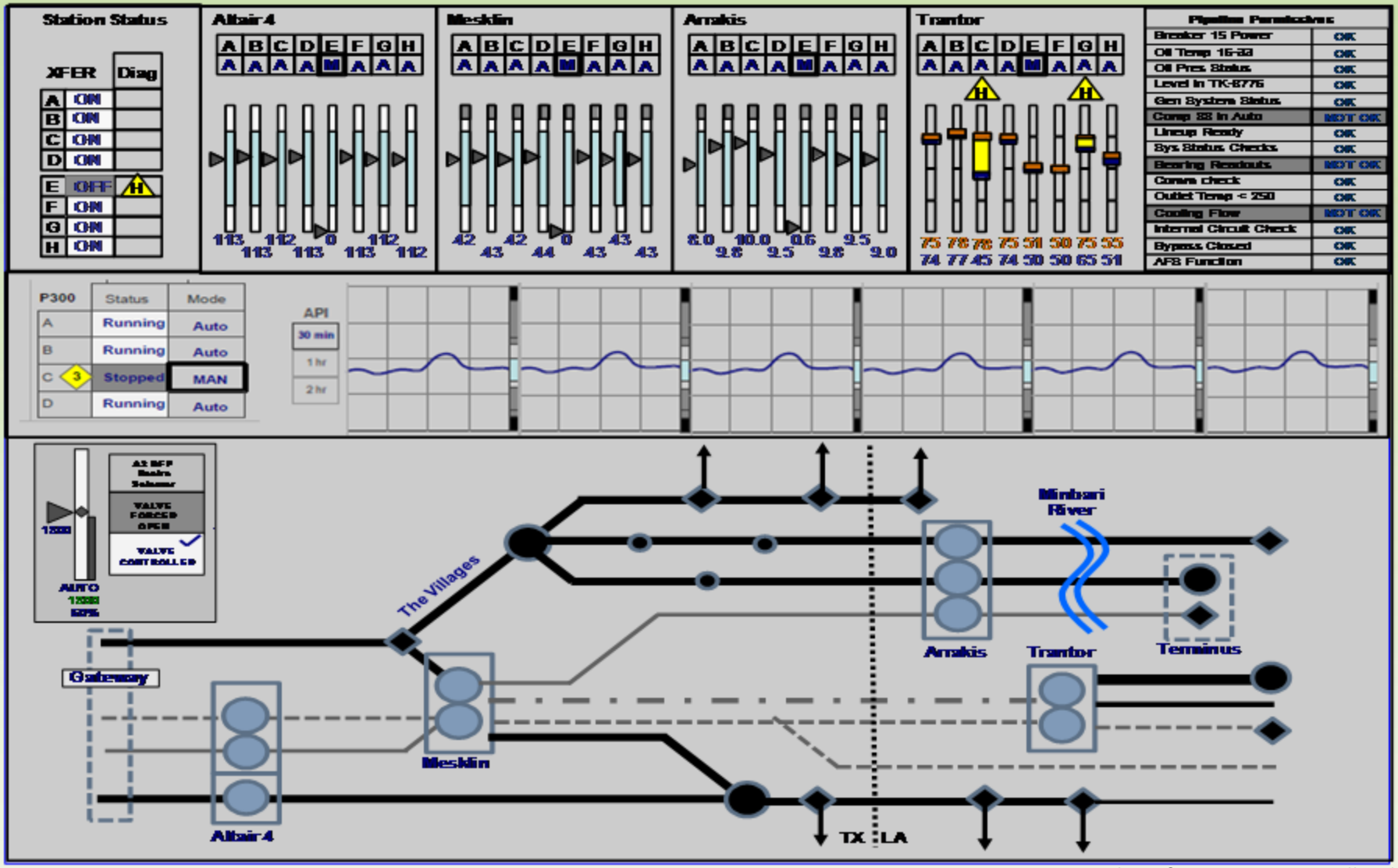
Source: High Performance HMI Handbook

High Performance HMI – Display Hierarchy

- HIERARCHY for Displays:
- Level 1 – Plant or Entire System Overview
  - Entire Operator Span of Control. “Single-Glance”
- Level 2 – Sub-Process Overview
  - More details than a Level 1 display, smaller area
- Level 3 – Equipment or Details Screen
  - Specific details about part of the process or control
- Level 4 – Specific Task or Diagnostic Screen
  - Very detailed screen, only used for diagnostics

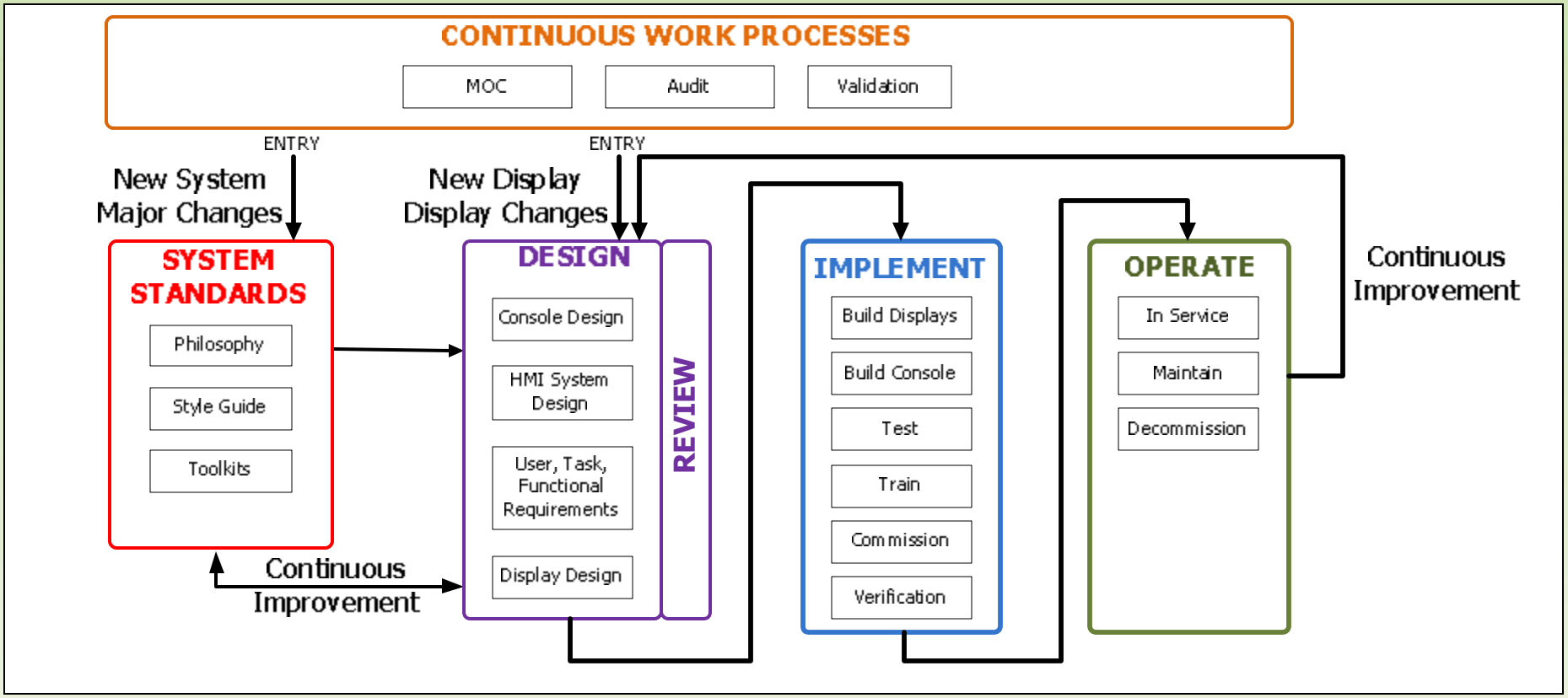
High Performance HMI – The old way

High Performance HMI – Level 1 Display



Source: High Performance HMI Handbook

High Performance HMI – ISA101 Standard



Alarm Management

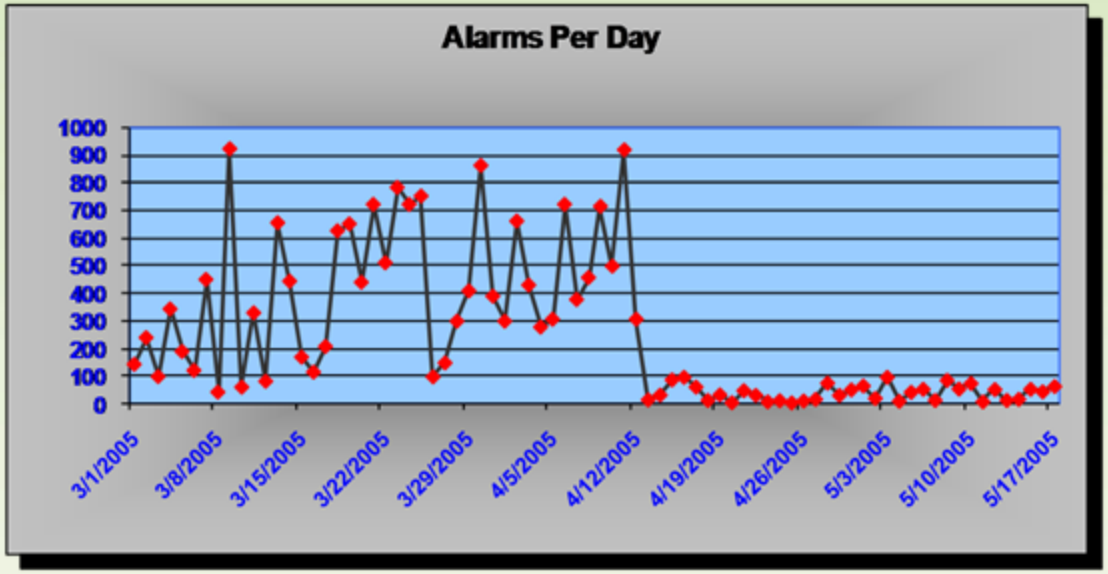
Alarm Management: ISA18.2

ANSI/ISA-18.2-2016 *

Management of Alarm Systems for the Process Industries

> **Alarm:** *An audible and/or visible means of indicating to the operator an equipment malfunction, process deviation or abnormal condition requiring a timely response.*

Methodology for identifying, rationalizing and designing alarms to be a powerful tool for operations, and eliminating non-useful alarms



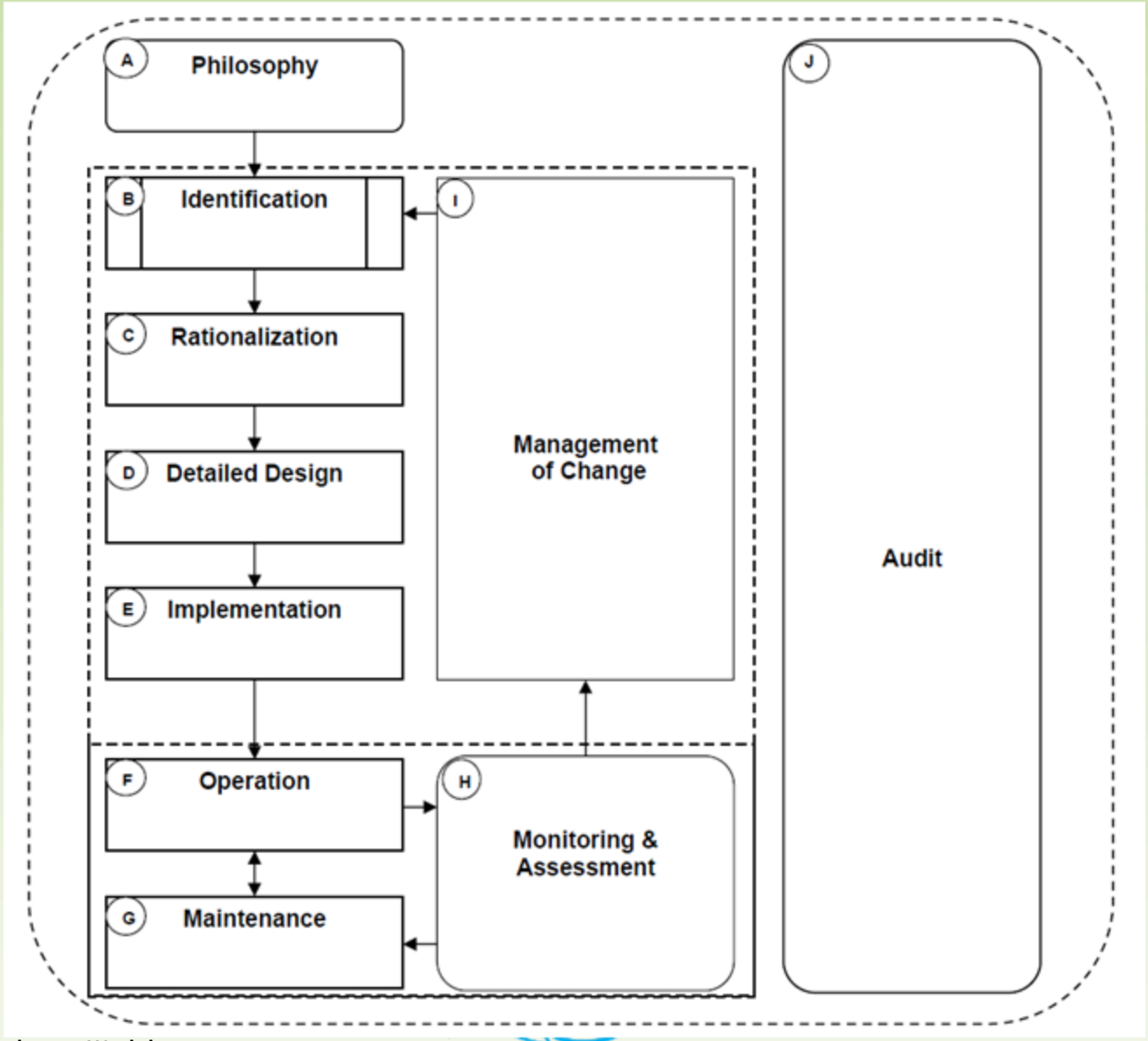
Typical example of results of 18.2 being implemented (showing before/after)

*originally published as ISA-18.2-2009, now also IEC-62682

Alarm Management: ISA18.2

- **ANSI/ISA-18.2-2016,**
  Management of Alarm Systems for the Process Industries
- **Addresses the development, design, installation, and management of alarm systems in the process industries**
- **Defines terminology and models to develop alarm system – and the work processes to effectively maintain it throughout its lifecycle**
- **Seven technical reports available to explain application in detail**
- **Based on work by the ISA18 committee, active since 2003.**
- **First version of ISA18.2 standard published in 2009, became IEC-62682 in 2015, and updated version published in 2016.**

Alarm Management: ISA18.2 Alarm Mgmt. Lifecycle



Alarm Management: Master Alarm Database

- MADB
  - Central repository of approved alarms and their configuration (below is a wastewater example)

Tag	Priority	Desc.	Condition	Consequence If Ignored	Consequence Severity	Expected Operator Response	Time to Respond
P1-380-LAH-201	LOW	Aeration 1 High Level	High Level Switch Activated for 10sec	Overflows in Secondary clarifiers.	MINOR	Check Level Controller	2 hours
P1-380-AAL-102	MED	Aeration 1 Low DO	DO below 3ppm for 30min	Loss of Biological Action, Risk of Damage to Biological Mass	MAJOR	Investigate and turn on additional blowers	1 hour
P1-380-PALL-456A	LOW	Aeration 1 Air Pres. Low Low	Less than 15psi for 5min	Loss of Energy if Air Leak, Poor Aeration (Note: there is a low DO alarm)	MINOR	Check pressures in air distribution system via HMI, check valves in field	4 hrs

Alarm Management: Master Alarm Database

- **Alarm Tag**
- **Alarm Description** (full description & what is shown on HMI)
- **Identification:** Trigger Condition, Purpose
- **Rationalization**:
  - Consequence & Severity if Ignored
  - Expected Operator Response, Time to Respond
  - Alarm Priority & Alarm Class
  - Justification for having this alarm configured!
- **Design:** Trigger Condition, On/Off Delays, Additional Filtering Logic, Setpoints, Routing/grouping information for the HMI
- **Operation:** When put into service, If Periodic Testing is required

Alarm Management: Key SCADA Features

- Master Alarm Database
- Ability to create non-alarm messages and logged events
- Support for Alerts, Prompts, and Maintenance Messages
- HMI Alarm Summary Display Screen
- Alarm Sorting, Filtering, Routing
- Alarm Areas/Grouping
- Alarm Priorities
- Alarm Classes

Alarm Management: Key SCADA Features cont'd

- Standardizing Alarm Features with Function Blocks
- On-Delay, Off-Delay, Deadband
- Conditional Alarming: base condition plus additional logic
- Alarm Shelving Method with Authorization / Logging
- Alarm Out of Service
- Change Control – Permissions, Setpoints, Configuration
- Configuration Change Logging
- Alarm Setpoint/Attribute verification & enforcement

Alarm Management: Non-Alarms

HMI: Alarms, Events and Notifications

- SCADA Systems can have multiple types of notifications

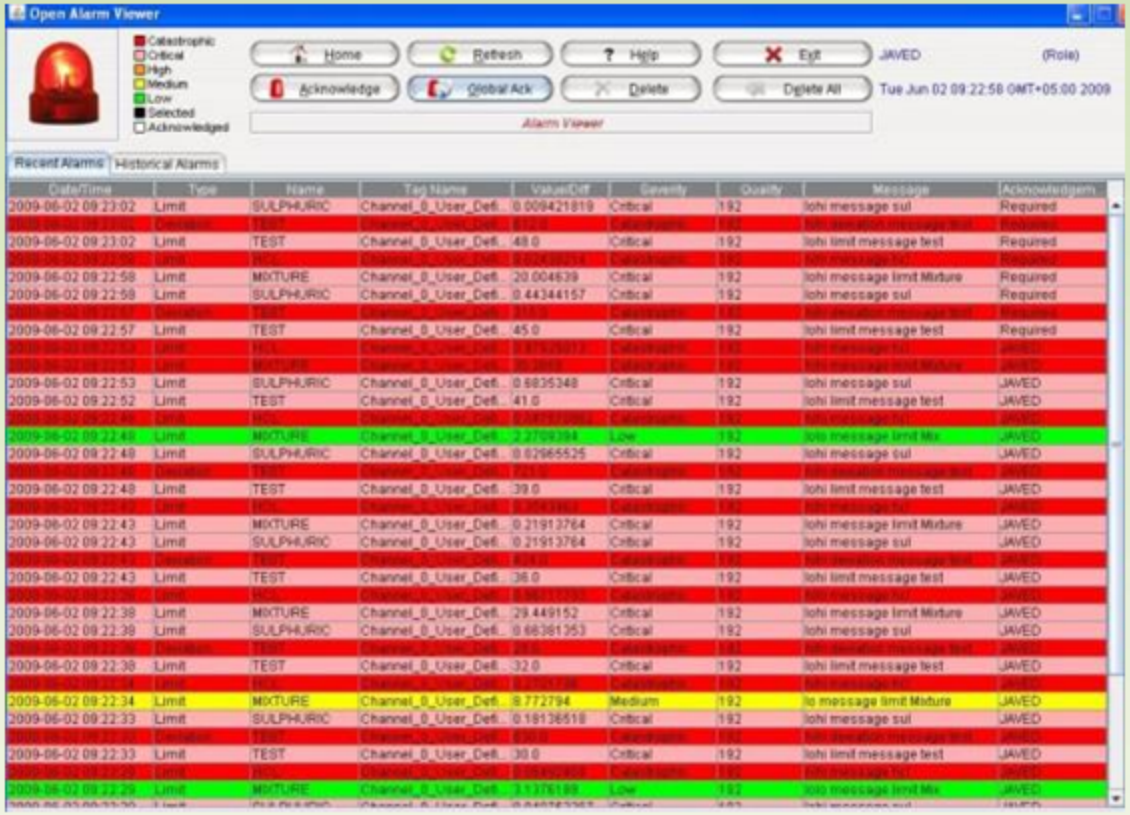
Operator notification types	Operator is expected to take an action	Operator might need to be aware but is not required to take action *(Action might be expected from someone other than the operator.)*
Arises from an abnormal process or equipment situation	Alarm	Alert
Arises from a normal situation	Prompt	Status

Figure 6 – Sample criteria for notification types from an alarm philosophy

- SCADA systems should have support for:
  - Alarms
  - Other notifications: alerts, prompts, maintenance messages
  - Event messages
  - Logged-only events

Alarm Management: Dedicated Alarm Display

- Dedicated screen for displays alarms – only alarms
- Ideally on its own dedicated monitor in multi-monitor setup



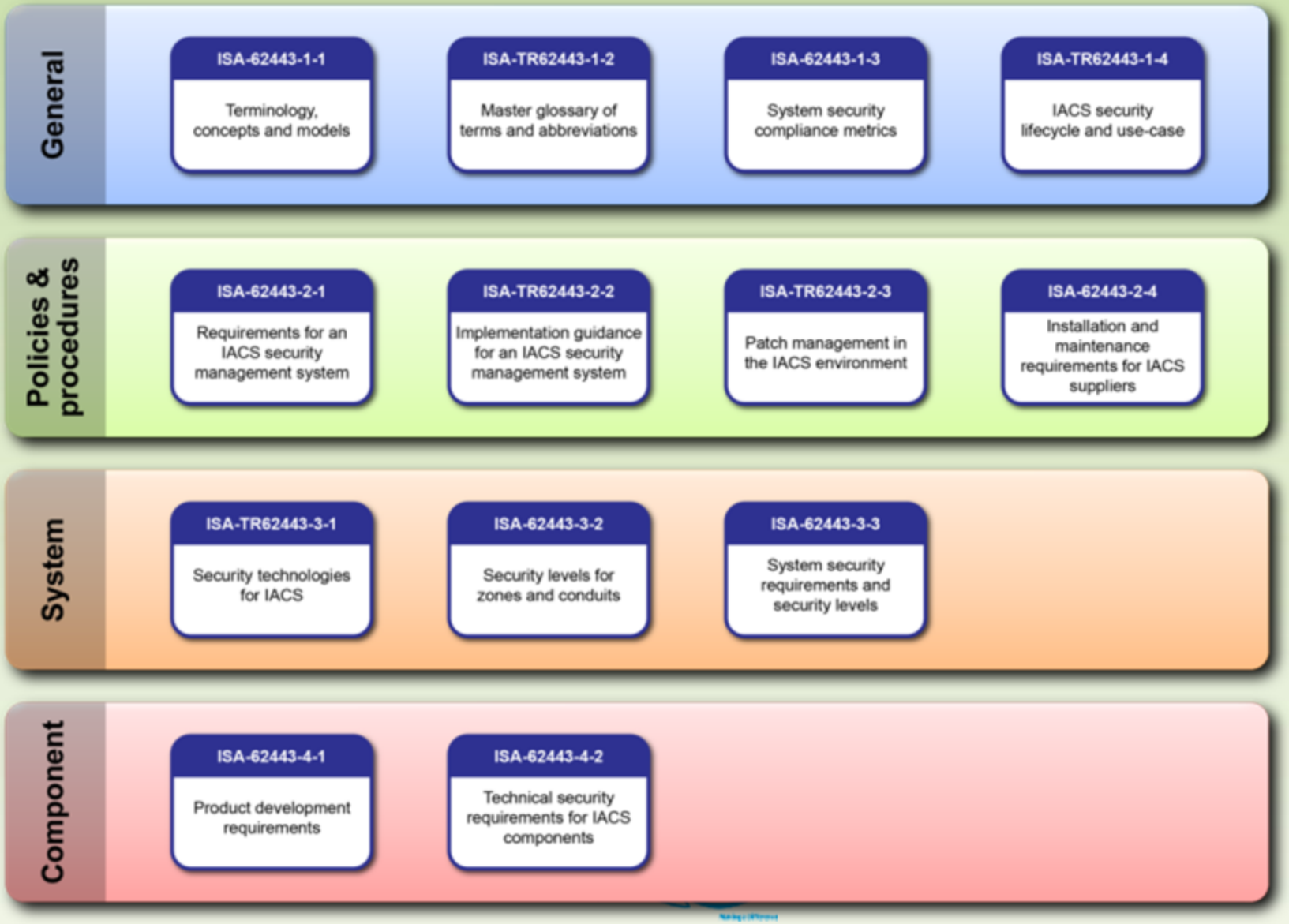
Last of All: Cyber Security

SCADA Cyber Security

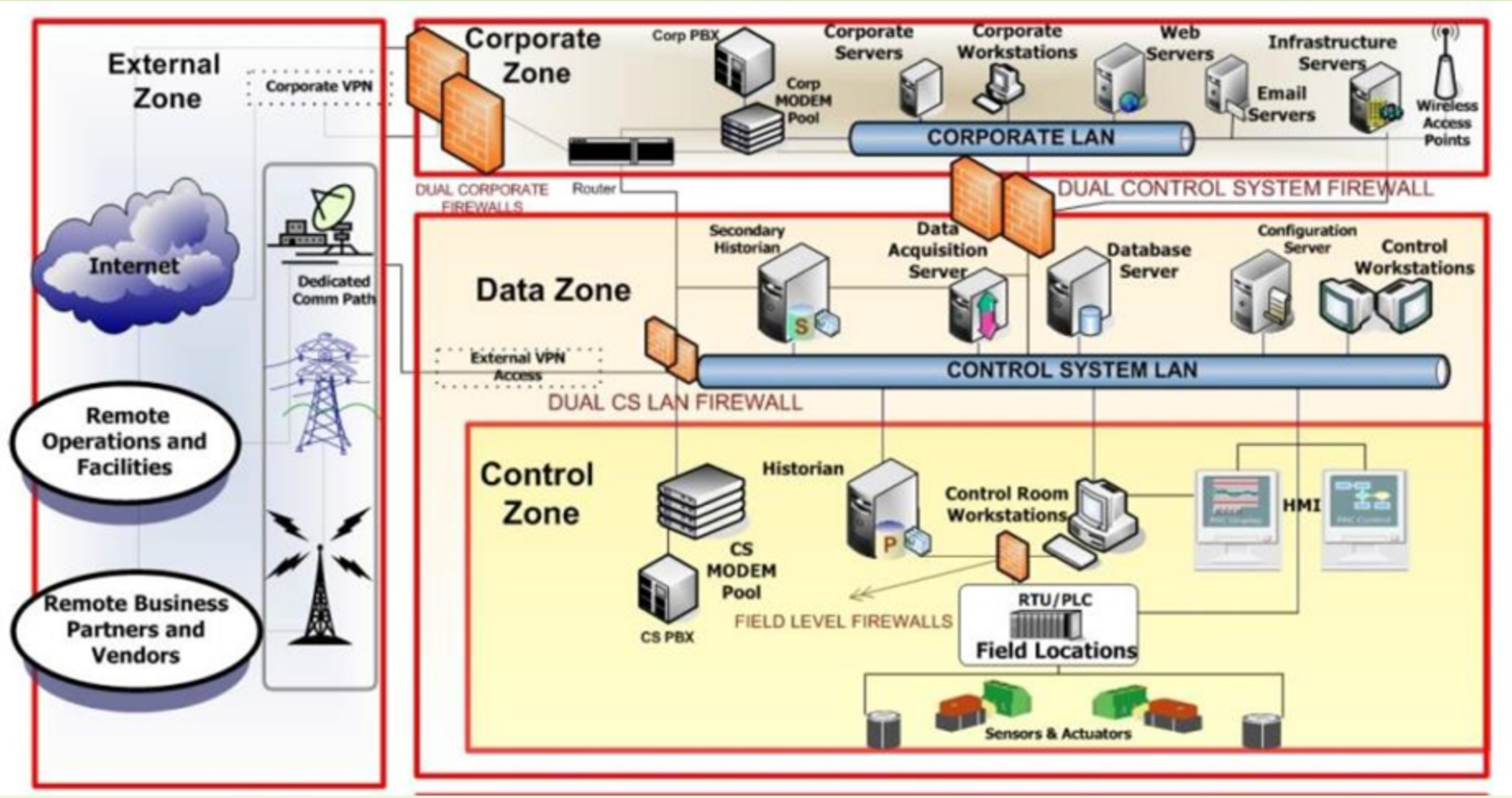
- You need to protect your SCADA system for unauthorized access
- In the past this was difficult to do
- Requires multipronged approach
  - People
  - Process
  - Technology

- There is guidance now available on how to do this
  - ISA/IEC-62443 (formerly known as ISA-99)
  - AWWA GW430
  - NIST Cyber Security Framework

SCADA Cyber Security: ISA/IEC-62443



SCADA Cyber Security: ISA/IEC-62443



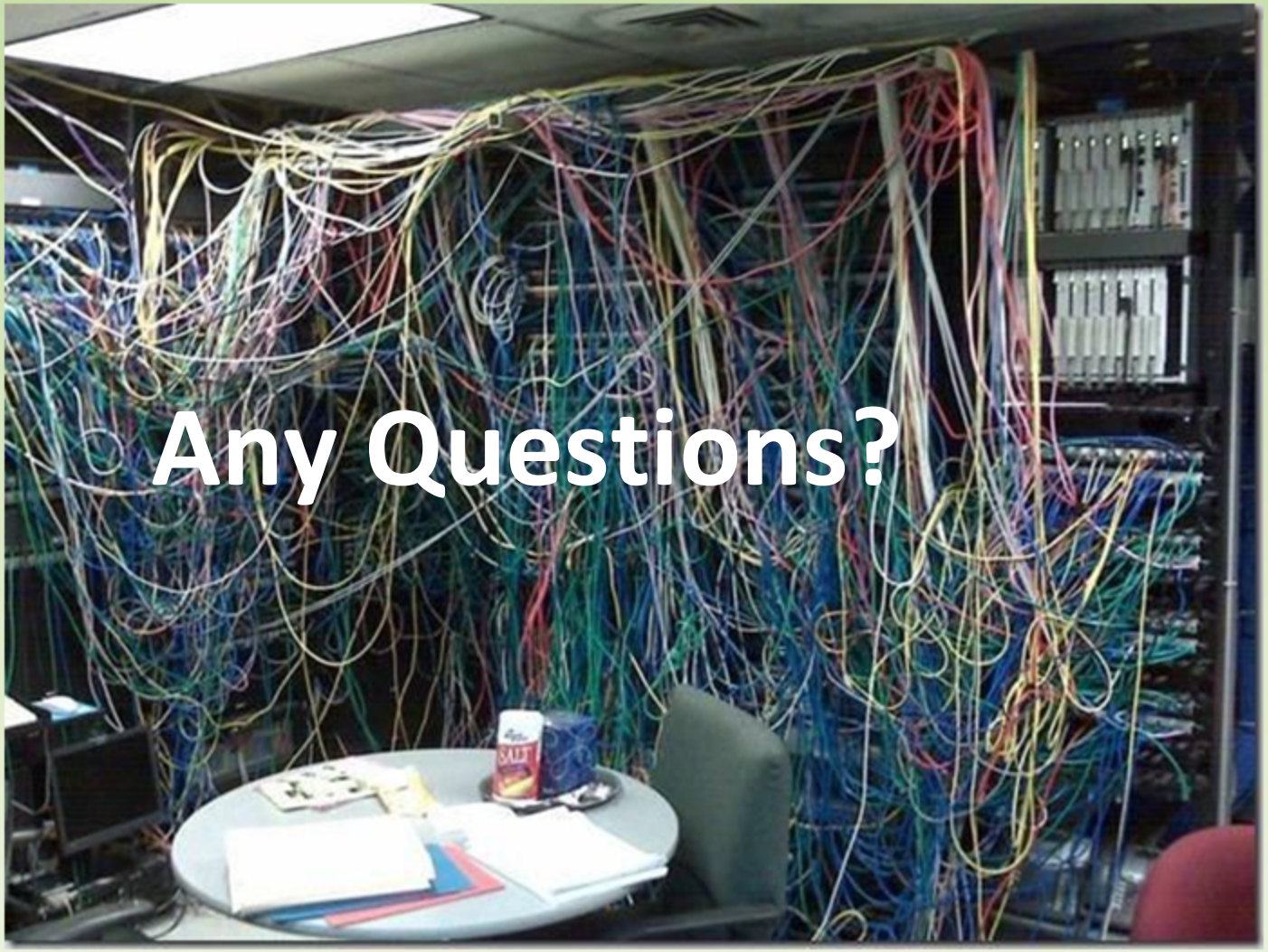
Wrapping Up

- Typical SCADA Architecture
- Best Practices for Groundwater Well Instrumentation

- SCADA is essential for both Operations and Compliance

- Operators Need Situational Awareness to Operate Effectively
- Use the SCADA HMI to show the whole picture to operators
- SCADA Alarms systems must be rationalized/documented
- Cyber Security is requires a multi-pronged approach

- Remember the SCADA System is a tool: put it work for you



* Not a High Performance SCADA System