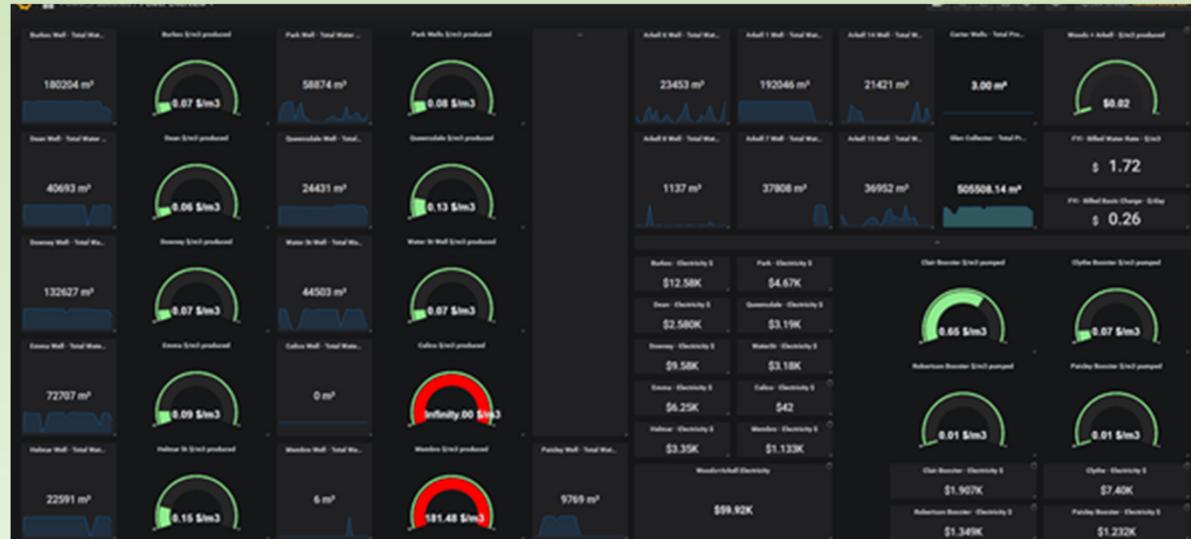


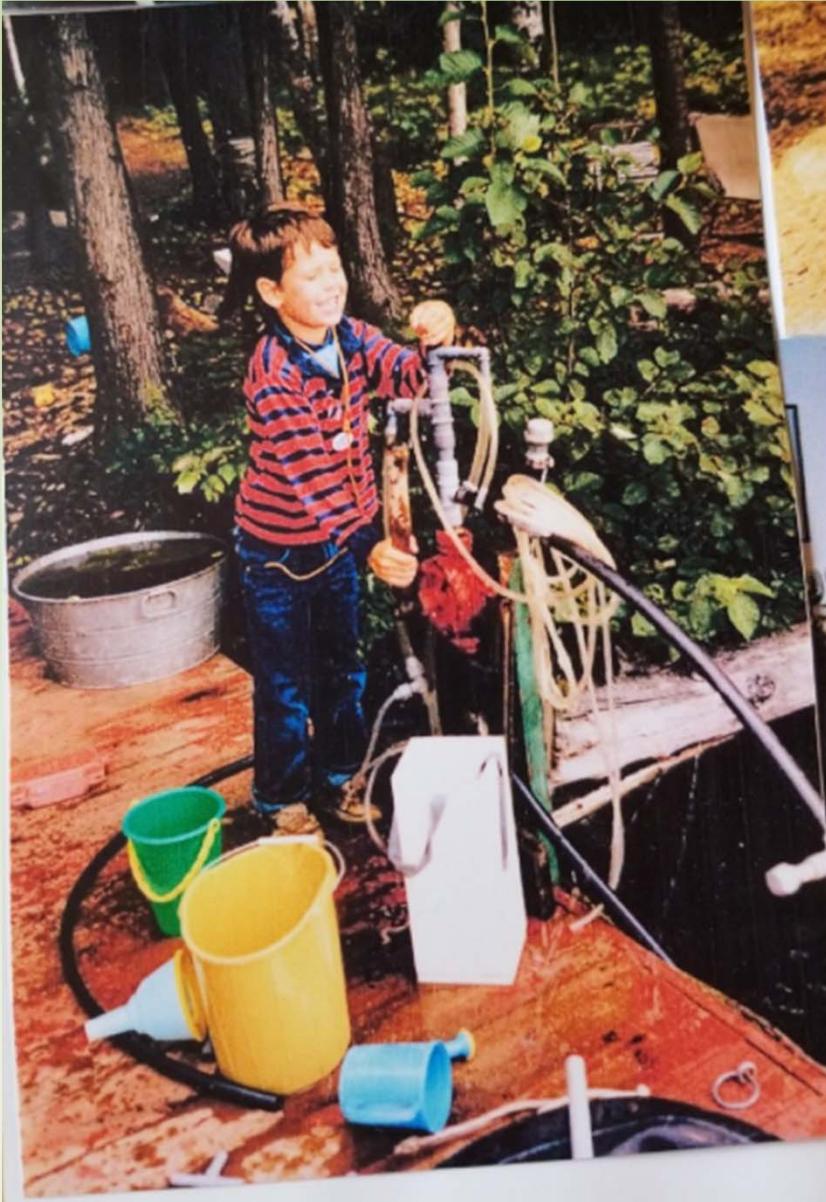
Operational Dashboards for monitoring Water Main Flow Patterns, Tower Levels, and Realtime Pumping Energy Costs per m3



Speaker: Graham Nasby, Water SCADA & Security Specialist, Guelph Water Services

Making Complicated Computer Screens of Squiggly Lines that no one Understands





I wanna be a
Water Guy
when I grow up!

So I got to live
the dream!



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

- Guest instructor at McMaster University, Conestoga College and Mohawk College
- Has published over 40 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.

- Contact: graham.nasby@guelph.ca

City of Guelph Water Services

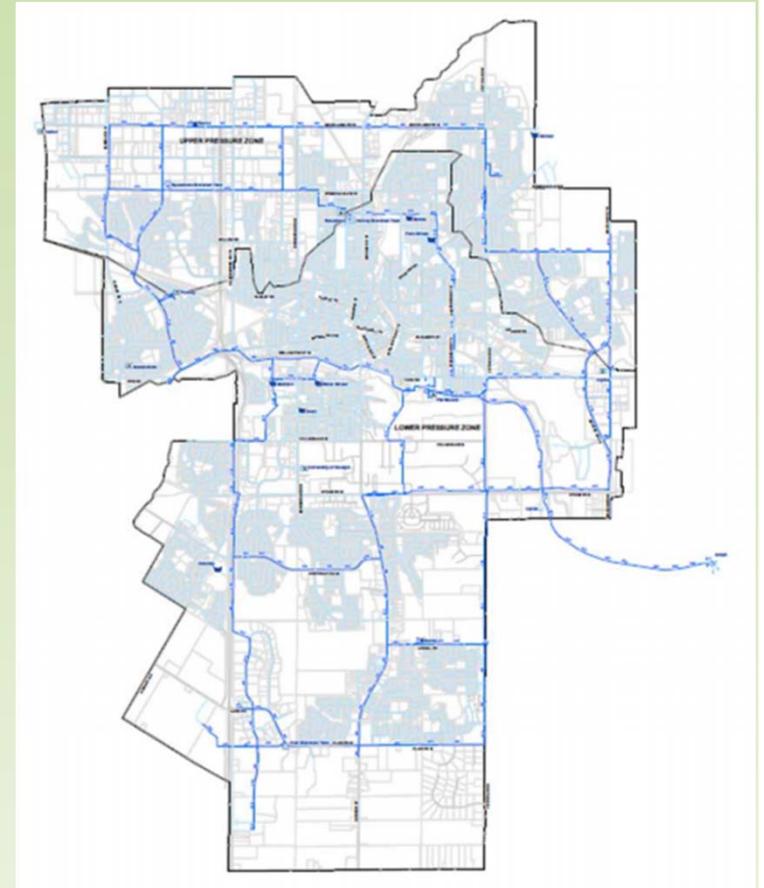


- Guelph, Ontario, Canada
- 130,000 residents
- 21 groundwater wells
- 3 water towers
- 549 km of water mains
- 49,000 service connections
- 2,750 fire hydrants
- 46,000 m³/day [12 MGD]



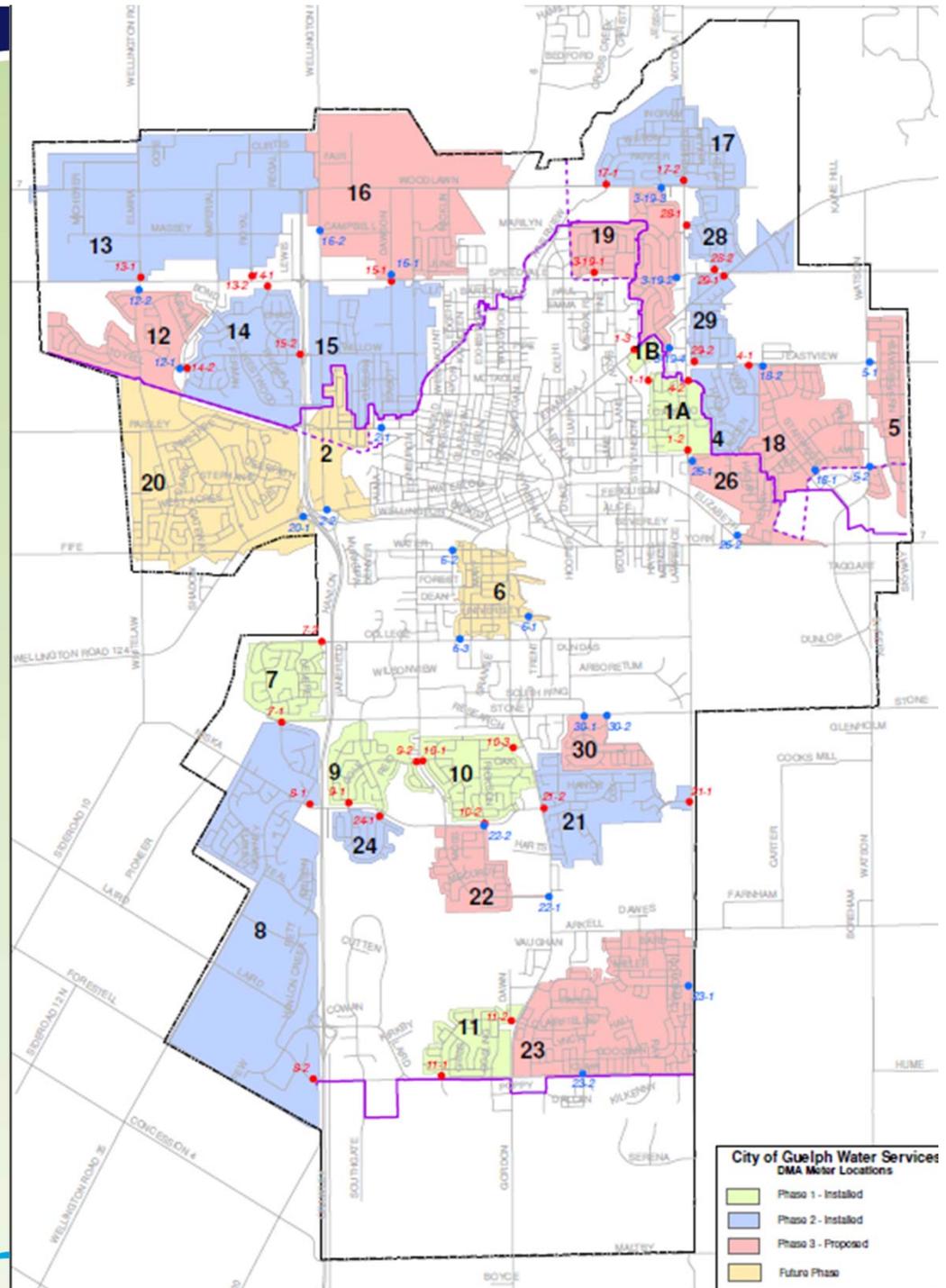
Guelph Water Facilities

- Approx. 15km x 15km area
- 35 Facilities
 - 4 booster stations
 - 21 wells
 - 2 valve chambers
 - 3 water towers
 - 5 monitoring sites
- 40 PLCs plus 2 data centers
- Redundant Datalogging
 - Realtime datalogging
 - QuickPanels with store/forward
 - DNP3 Dataloggers with store/forward
 - Raspberry PI Dataloggers with store/forward
- High availability SCADA network
 - Primary: private fibre optic
 - Secondary: private wireless, with 45 second auto-failover



District Metered Areas

- Segments Water Distribution into DMA Areas with 1-3 connections on borders
- Put flowmeters on the DMA's border connections
- What this give us:
 - Water in/out of DMAs
 - Compare to Customer Meters
 - Compare to Wells & Pumping Station meters
 - Calibrate Water Models



The Challenge

We are a water utility = a lot of what we do involves pumping water

- How much electricity do we use to pump water?
- How much is this electricity costing us?
- How can we get good/timely data about how we use electricity?
- **Waiting until we get power bills at the end of each month is not that helpful**
- The gold standard is to create an automated reporting tool to give us:
 - kWh per m3 produced
 - \$ of electricity per m3 produced
 - Ability to compare one facility to another
 - Ability to compare one operating strategy vs. another
 - Timely information for the operations team
 - Long term reporting to measure performance over time
 - Something that looks nice!

Prior Work

Smart Water Initiative (2013)

- Grant money was used to install building digital power meters at all water facilities
- Custom daily power reports created by a system integrator
- Reports stopped working in mid-2015 due to software/data-feed issues

Hydro Bill Analysis Company, online services (available since 2015)

- Service the city uses to analyze power bills
- Web-based tool for downloading and analyzing power bills
- Data is available at the end of each month, **monthly power totals only**

Online Power Reports 2.0 (2016-2017)

- SCADA Group was asked to work with system integrator to fix online power reports
- Conventional SCADA software was used
- After a year of work with the integrator, the power reports were working again
- Reports provided daily totals (cost, kWh, m3 pumped), **data available “next day”**

But could we do better?

Better granularity, more timely data, better reports, ability to self-edit....

Skunkworks



A **Skunkworks project** is a project developed by a small and loosely structured group of people who research and develop a project primarily for the sake of radical innovation.

The term originated with Lockheed's World War II *Skunk Works* project.

Let's see if we can use Open Source software to build something using IIoT...

IIoT = Industrial Internet of Things

Skunkworks SCADA Team

Goal: Make a better power reporting tool

Kick-off: Met at May 2017 OWWA conference

Graham Nasby

- Water SCADA & Security Specialist

Jason Little

- Open Source Software Developer
- Day job is a SCADA specialist at a nearby utility

Noah Clark

- SCADA co-op student (Jan-Apr 2018)
- Had a previous co-op at an energy management firm

Travis Murray

- SCADA Specialist (Nov`18-Jun`19)



This is what we built



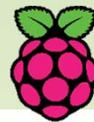
How it works



Plant PLC's
(Flow Data)



Digital Power Monitors



Raspberry Pi



Single Board Computer < \$35
(Neptune Cluster software)

Logs data every 5min
Logs changes on 1 sec intervals

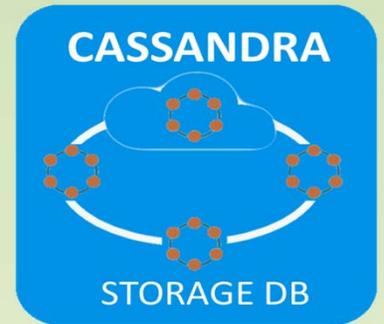


Pump Motor Starters

Web-based
Dashboard
& Reporting
Tool



Distributed
Open
Source
Database
(no licensing fees)



Pushes to
Historizer
Server



Pushes to
Time Series
Database

Power Calculations

- Measuring Electricity Usage is EASY...
- Calculating Power Costs is HARD!
- Ontario has one of the most complicated electricity pricing schemes in the world
- Connection Charges
- Transmission Charges
- Distribution Charges
- Transformer Factors
- Energy Usage
- Peak Charges
- Ontario Hourly Energy Prices
- Time of Day Adjustments
- Global Adjustment
- Global Adjustment Estimates
- End of the Month Balancing
- Debt Retirement Charges
- Rebates
- Etc.

hydro one Service address: CUSTOMER NAME: CUSTOMER NAME ADDRESS FIELD ADDRESS NOTES
 Your account number: 4331-56129456 Bill Cycle (MCI)
 Billing date: August 9, 2017 Page 1 of 2

Customer service
 Hydro One Toronto Inc.
 40 King Street
 Toronto, Ontario L4Y 1G1
 www.hydroone.com
 For billing and service inquiries, call 1-800-481-1070 Monday to Friday 7:00 a.m. - 6:30 p.m.
 For all other general inquiries, call 1-800-481-1070 or visit us online at hydroone.com
 Ontario Service supplied by Hydro One

Here's what you owe

PowerStream | alectra utilities

Account Number: 1234567890
 Please reference this number when making a payment.

Statement Date: November 20, 2018
 Amount Due: \$127.33
 Due Date: December 16, 2018
 A 1% monthly late payment interest charge will be applied if payment received after due date.

Bill #: 3485797553
 JONATHAN DOE
 1 SERVICE ADDRESS
 MARKHAM ON L3L 5L5
 Service Location: 1 SERVICE ADDRESS MARKHAM ON L3L 5L5
 Premise #: 1234512345

Service	Meter	From	To	# Days	Previous Reading	Current Reading	Read Type	Multipier	Usage	Adjustment Factor	Adjusted Usage
Electric	ABC123123	10/17/2018	11/16/2018	29	55213.80	55213.80	Act.	1.0	300,000 kWh	1.00000	311,076
Water	123123123123	10/17/2018	11/16/2018	29	55213.80	55213.80	Act.	1.06	300.00 M3		

Your Previous Charges

Amount of Last Bill: \$132.54
 Payment Received: \$132.54 CR
 Balance Forward: \$0.00
 Your Electricity Charges - Residential

Electricity provided by Alectra Utilities Corporation (a Standard Supply Service)

Time of Use

Summer On-Peak 50 kWh @ \$0.132	\$6.60
Summer Mid-Peak 20 kWh @ \$0.095	\$1.90
Summer Off-Peak 30 kWh @ 0.065	\$1.95
Winter On-Peak 100 kWh @ \$0.132	\$13.20
Winter Mid-Peak 40 kWh @ \$0.095	\$3.80
Winter Off-Peak 60 kWh @ \$0.095	\$5.70

Delivery: \$26.97
 Regulatory: \$1.48
 Debt Retirement Charge: \$0.00
 Ontario Electricity Support Program: \$45.00 CR
 Your Total Electricity Charges: \$14.78

Your Water/Wastewater Charges - Residential

Water Charges: \$53.55
 Wastewater Charges: \$56.26
 Your Total Water & Wastewater/Storm Charges: \$111.81

Your Other Charges/Credits

H.S.T. (H.S.T. Registration 726054299): \$1.92
 8% Provincial Rebate: \$1.18 CR
 Total Amount Due by December 16, 2018: \$127.33

Daily Average Electricity Usage

Daily Average Water Usage

Electricity Rates have changed effective November 1, 2018, go to www.alectrautilities.com for information.

Power Calculations

Hydro One – General Service -Energy Hydro One – General Service -Demand

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>First Rate (<750kWh)	
>>Remaining Rate (>750kWh)	
>>Debt Retirement Charge	
>>Service Charge	
>>Distribution Volumetric Rate	
>>Transmission Network Charge	
>>Transmission Connection Charge	
>>Loss Factor	
>>Wholesale Market Rate	
>>Rural Rate Assistance	
>>SS Admin Charge	

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>Debt Retirement Charge	
>>Wholesale Market Rate	
>>Rural Rate Assistance	
>>Service Charge	
>>SS Admin Charge	
>>Loss Factor	
Instantaneous Power	
>>Distribution Volumetric Rate	
>>Transmission Connection Charge	
>>Transmission Connection Charge	
>>Transformer Allowance	

Guelph Hydro – Time of Use

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>On Peak Rate	
>>Off Peak Rate	
>>Mid Peak Rate	
>>Distribution Volumetric Rate	
>>Transmission Network Charge	
>>Transmission Connection Charge	
>>Debt Retirement Charge	
>>Loss Factor	
>>Wholesale Market Rate	
>>Rural Rate Assistance	
>>Monthly Service Charge	
>>SS Admin Charge	
>>OEP Charge	
>>Loss Factor Rate	

Guelph Hydro – General Service

Hydro Cost	
Energy Cost Today	
Accumulating kWh	
>>Debt Retirement Charge	
>>Wholesale Market Rate	
>>GA Rate Rider	
>>Service Charge	
>>SS Admin Charge	
>>Loss Factor	
Power Cost Today	
Instantaneous Power	
>>Distribution Volumetric Rate	
>>Transmission Connection Charge	
>>Transmission Connection Charge	
>>Transformer Allowance	

Hydro One	
<50kW	>50kW
General Service – Energy (aka Two Tiered)	General Service – Demand
Arkell 08	Arkell 06
Arkell 14	Arkell 07
Arkell 15	
Guelph Hydro	
<50kW	>50kW
Time of Use	General Service
Calico	Burke Well
Carter	Clythe Creek
Clair Booster	Downey
Dean	Emma
Helmar	Membro
Queensdale	Paisley
Robertson	Park
	Univeristy
	Water Street
	Woods

Power Calcs



Live Feed of Hourly Global Adjustment Hourly Energy Prices



Web-based Dashboard & Reporting Tool



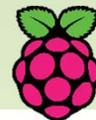
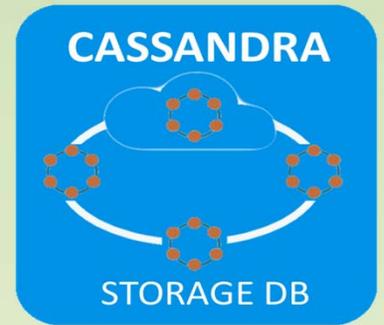
Digital Power Monitors



Plant PLC's (Flow Data)



Distributed Open Source Database



Calculates Live Energy Costs every 5 mins

RaspberryPi



Single Board Computer < \$35 (Neptune Cluster software)

Logs data every 5min
Logs changes on 1 sec intervals



Pushes to Historizer Server



Pushes to Time Series Database

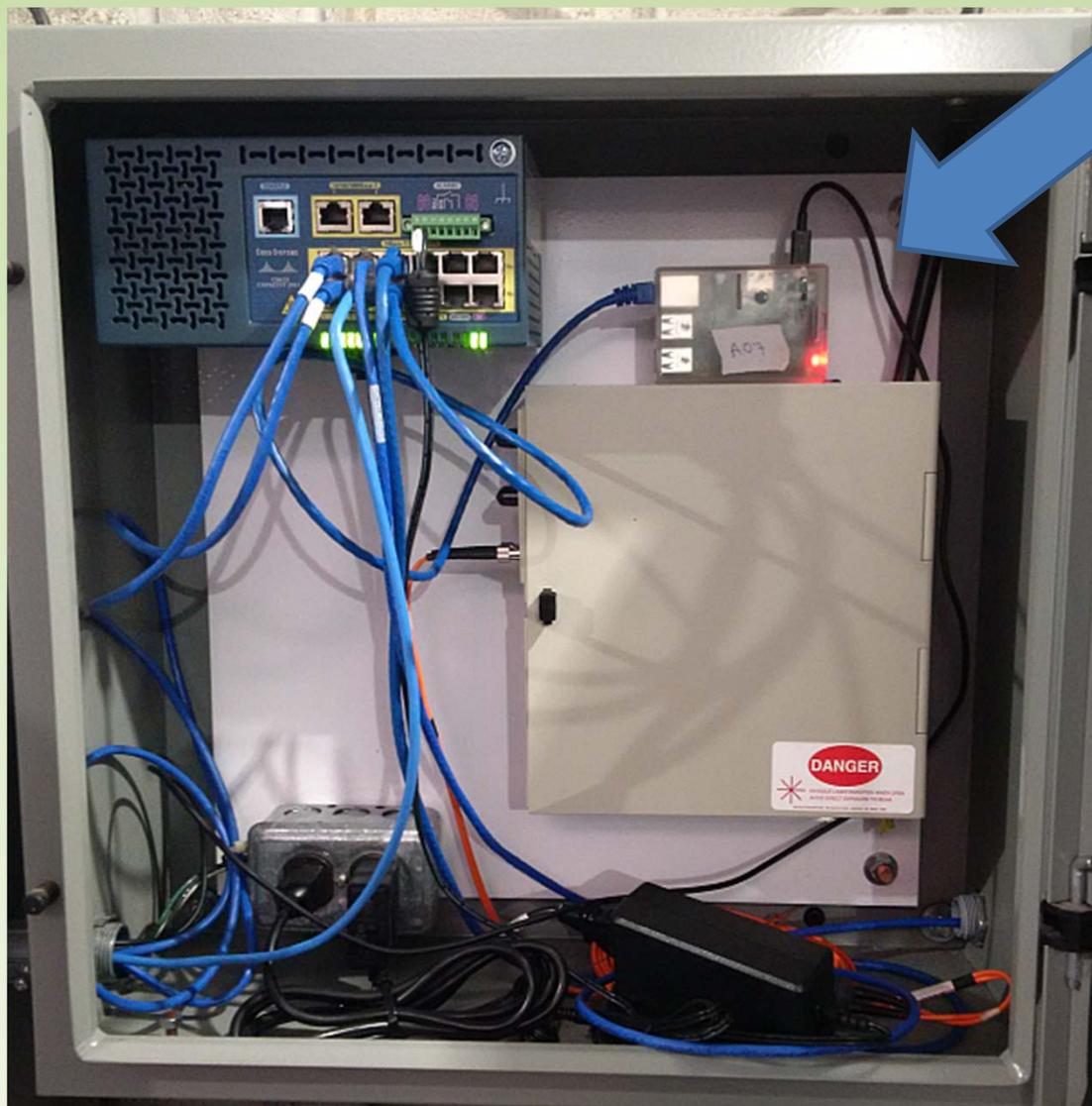


Pump Motor Starters

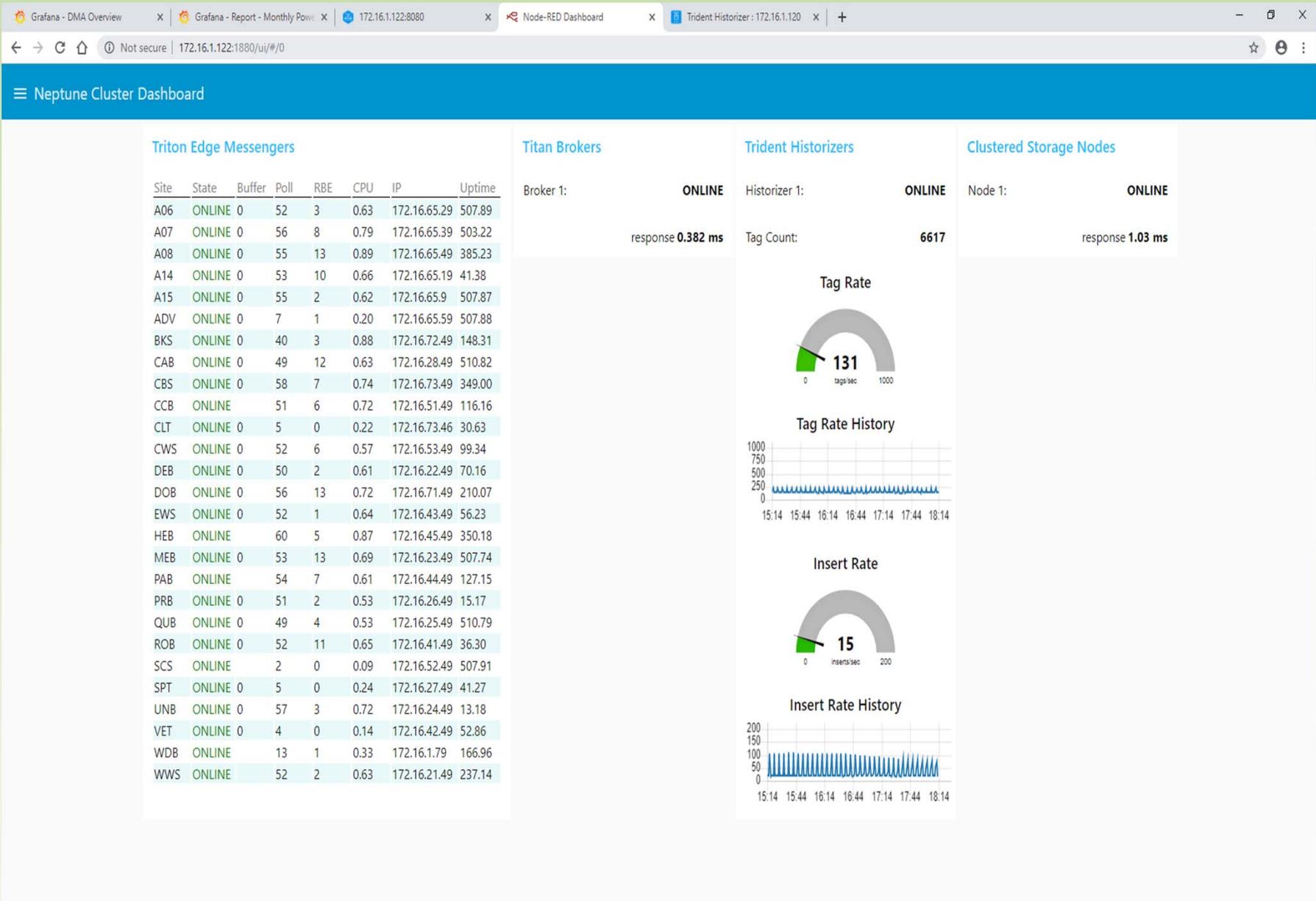
Polls Data Every Second



Raspberry Pi Installed



Collecting the Data



Pulling Data from Digital Power Monitors

The screenshot displays a Node-RED dashboard for Triton Edge Messenger. The main workspace shows a flow for 'PM3000' with the following components:

- Input:** A 'timestamp' node followed by a script node `/home/pi/lab_pm3000.py` (pid: 18628) and a 'delay 10s' node.
- Analytics:** The flow branches into multiple parallel paths, each leading to an 'Analytics' node. The nodes are labeled with various power monitor parameters:
 - F15_L1Current, F15_L2Current, F15_L3Current, F15_AvgCurrent
 - F15_L1-NVoltage, F15_L2-NVoltage, F15_L3-NVoltage, F15_AvgL-NVoltage
 - F15_L1-L2Voltage, F15_L2-L3Voltage, F15_L3-L1Voltage, F15_AvgL-LVoltage
 - F15_Frequency, F16_L4Current, F16_PositiveSequenceCurrent, F16_NegativeSequenceCurrent, F16_%CurrentUnbalance, F16_PositiveSequenceVoltage, F16_NegativeSequenceVoltage, F16_%VoltageUnbalance, F16_PhaseRotation, F16_AverageFrequency, F17_L1RealPower, F17_L2RealPower

The right sidebar shows flow information:

- Information:** Flow ID: "40d8bdad.c63914", Name: PM3000, Status: Enabled.
- Flow Description:** None.

At the bottom of the sidebar, there are instructions: "Show the Info tab with `ctrl-g` i or the Debug tab with `ctrl-g` d".

Pulling Data from Water Supply Site PLCs

The screenshot displays the Node-RED interface within the Triton Edge Messenger application. The browser address bar shows the URL `172.16.22.49:1881/#flow/6a20adf9.255594`. The interface includes a left sidebar with a 'filter nodes' search bar and a 'Deploy' button. The main workspace shows a flow diagram with the following components:

- Input:** A 'timestamp' node followed by a '/home/pi/ab_slc.py' node (ID: 467).
- Processing:** A 'json' node and a 'split' node.
- Output:** Five parallel paths, each consisting of a specific PLC data node (e.g., 'PLC1/Well1_FlowRate', 'PLC1/POE_FlowRate', 'PLC1/POE_Pressure', 'PLC1/POE_ChlorineResidual', 'PLC1/Reservoir1_Level') followed by an 'Analytics' node.

On the right, the 'Info' tab is active, showing the following details:

Information	
Flow	"6a20adf9.255594"
Name	SLC Read
Status	Enabled

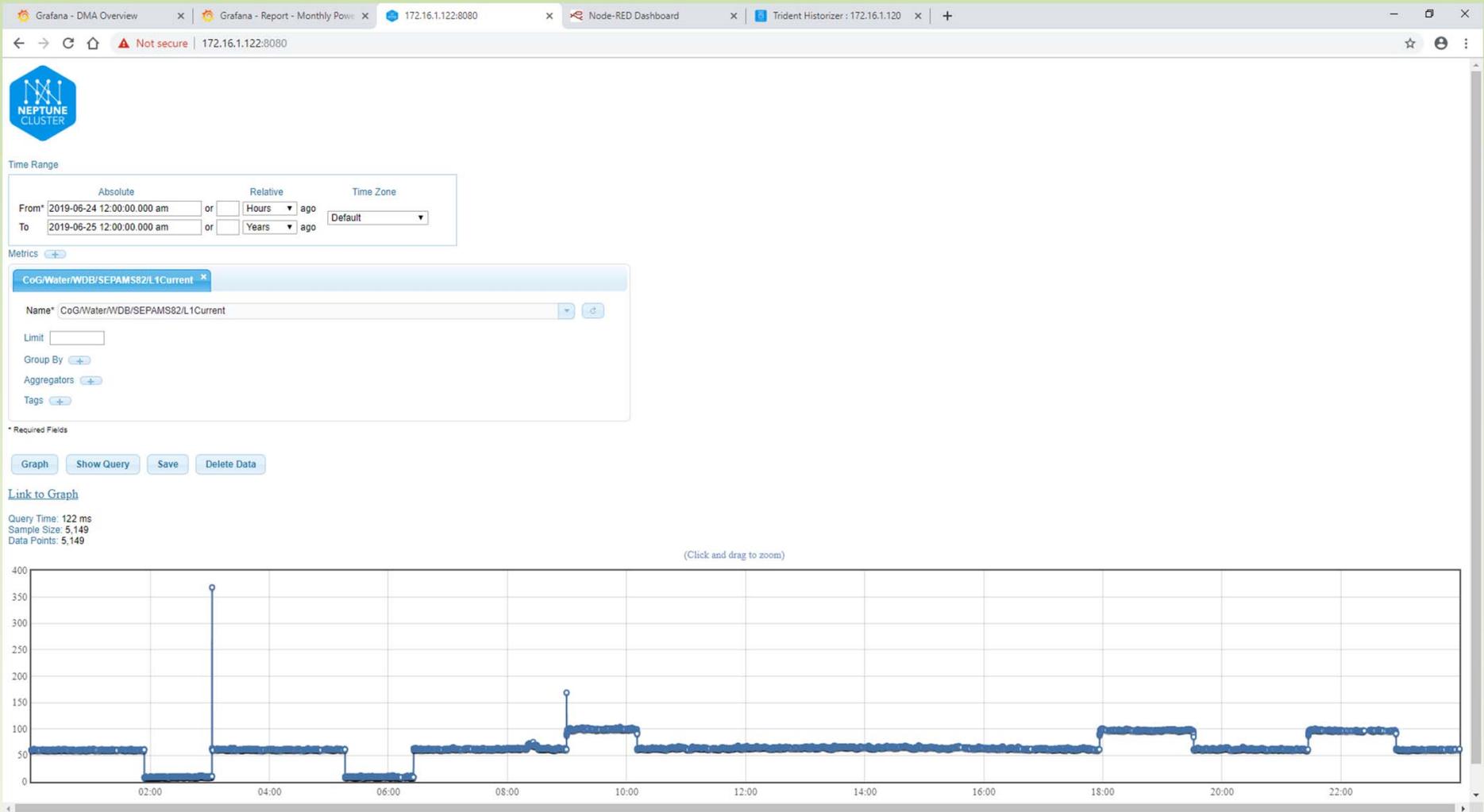
Below the 'Info' tab, the 'Flow Description' is currently 'None'. At the bottom of the right sidebar, there are instructions: 'Show the Info tab with `ctrl-g i` or the Debug tab with `ctrl-g d`'.

Buffering Data in the Raspberry Pi's

The screenshot shows a Grafana dashboard titled "Current Tag Values". At the top, there is a "Tag Filter" input field and a "REFRESH" button. Below this, there is a toggle for "auto refresh" (which is turned off) and a "Tag Filter Results Count: 67". The main content is a table with three columns: "Tag", "Value", and "Age (s)". The table lists various tags such as "PLC1/Booster1_Running" with a value of 1.00 and an age of 3 seconds, and "PM3000/F15_AvgCurrent" with a value of 38.78 and an age of 1 second. The table is scrollable, and a vertical scrollbar is visible on the right side.

Tag	Value	Age (s)
PLC1/Booster1_Running	1.00	3
PLC1/POE_ChlorineResidual	0.82	3
PLC1/POE_FlowDayTotal	1,083.04	3
PLC1/POE_FlowRate	16.64	3
PLC1/POE_FlowYesterdayTotal	1,418.97	3
PLC1/POE_Pressure	505.83	3
PLC1/Reservoir1_Level	1.77	3
PLC1/Well1_FlowDayTotal	1,092.94	3
PLC1/Well1_FlowRate	19.06	3
PLC1/Well1_FlowYesterdayTotal	1,395.55	3
PLC1/Well1_Running	1.00	3
PM3000/F15_AvgCurrent	38.78	1
PM3000/F15_AvgL-LVoltage	584.20	1
PM3000/F15_AvgL-NVoltage	0.00	1
PM3000/F15_Frequency	59.96	1
PM3000/F15_L1-L2Voltage	585.42	1
PM3000/F15_L1-NVoltage	0.00	1
PM3000/F15_L1Current	33.84	1
PM3000/F15_L2-L3Voltage	584.32	1
PM3000/F15_L2-NVoltage	0.00	1
PM3000/F15_L2Current	40.06	1
PM3000/F15_L3-L1Voltage	582.87	1
PM3000/F15_L3-NVoltage	0.00	1

Direct Query Tool for Cassandra Database



Direct Query Tool for Cassandra Database

The screenshot displays the Neptune Cluster Direct Query Tool interface. The browser address bar shows the URL 172.16.1.122:8080. The interface includes a sidebar with the Neptune Cluster logo and a main configuration area. The 'Time Range' section is set to 'Absolute' with 'From' and 'To' dates of 2019-06-24 12:00:00.000 am and 2019-06-25 12:00:00.000 am, respectively. The 'Metrics' section is set to 'CoG/Water/ROB/PM3000/F17_L1RealPower'. The 'Time Zone' is set to 'Default'. The 'Required Fields' section is empty. The 'Graph' section shows a line chart with a y-axis from 0 to 400 and an x-axis from 02:00 to 22:00. The chart shows a sharp spike in power at approximately 03:00. The interface also includes buttons for 'Graph', 'Show Query', 'Save', and 'Delete Data'.

Time Range

Absolute Relative

From* 2019-06-24 12:00:00.000 am or Hours

To 2019-06-25 12:00:00.000 am or Years

Time Zone

From* 2019-06-24 12:00:00.000 am or Hours ago

To 2019-06-25 12:00:00.000 am or Years ago

Default

Metrics

CoG/Water/ROB/PM3000/F17_L1RealPower

Name* CoG/Water/ROB/PM3000/F17_L1RealPower

Limit

Group By

Aggregators

Tags

* Required Fields

Graph Show Query Save Delete Data

Graph

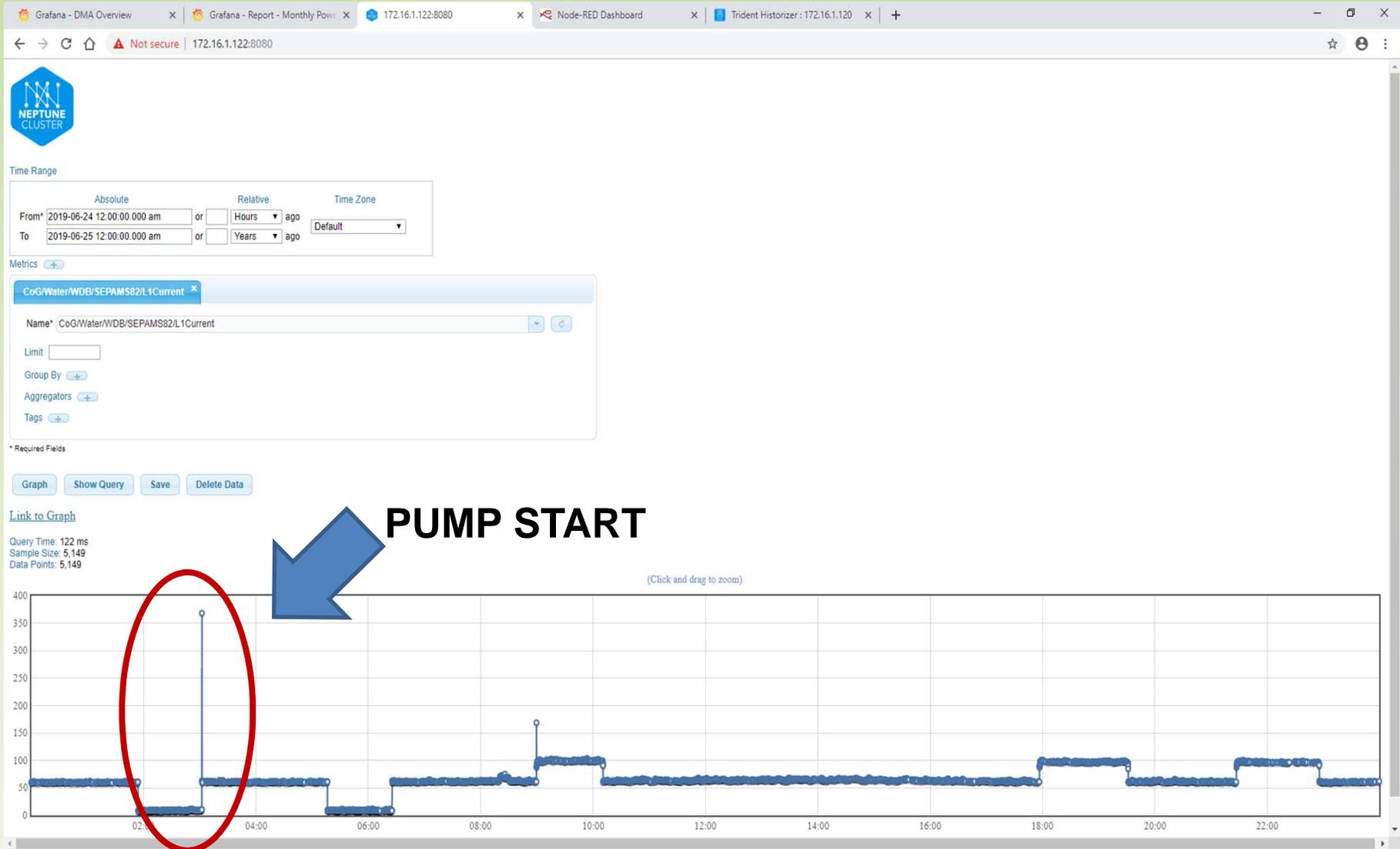
Show Query

Save

Delete Data

Query Time: 122 ms
Sample Size: 5,149
Data Points: 5,149

Direct Query Tool: Woods Pump Starts



Direct Query Tool: Woods Pump Starts

Grafana - DMA Overview x Grafana - Report - Monthly Powe x 172.16.1.122:8080 x Node-RED Dashboard x Trident Historizer : 172.16.1.120 x +

← → ↻ 🏠 ⚠ Not secure | 172.16.1.122:8080 ☆ ⚙



Time Range

Absolute Relative Time Zone

From* 2019-06-24 12:00:00.000 am or Hours ago

To 2019-06-25 12:00:00.000 am or Years ago Default

Metrics +

CoG/Water/WDB/SEPAMS82/L1Current

Name* CoG/Water/WDB/SEPAMS82/L1Current

Limit

Group By +

Aggregators +

Tags +

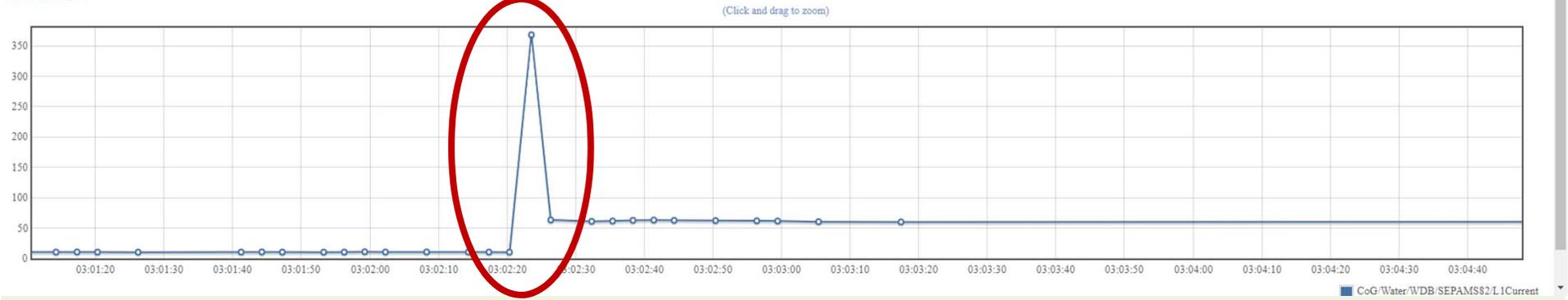
* Required Fields

Graph Show Query Save Delete Data

[Link to Graph](#)

Query Time: 122 ms
Sample Size: 5,149
Data Points: 5,149

In-Rush Current of Pump Starting



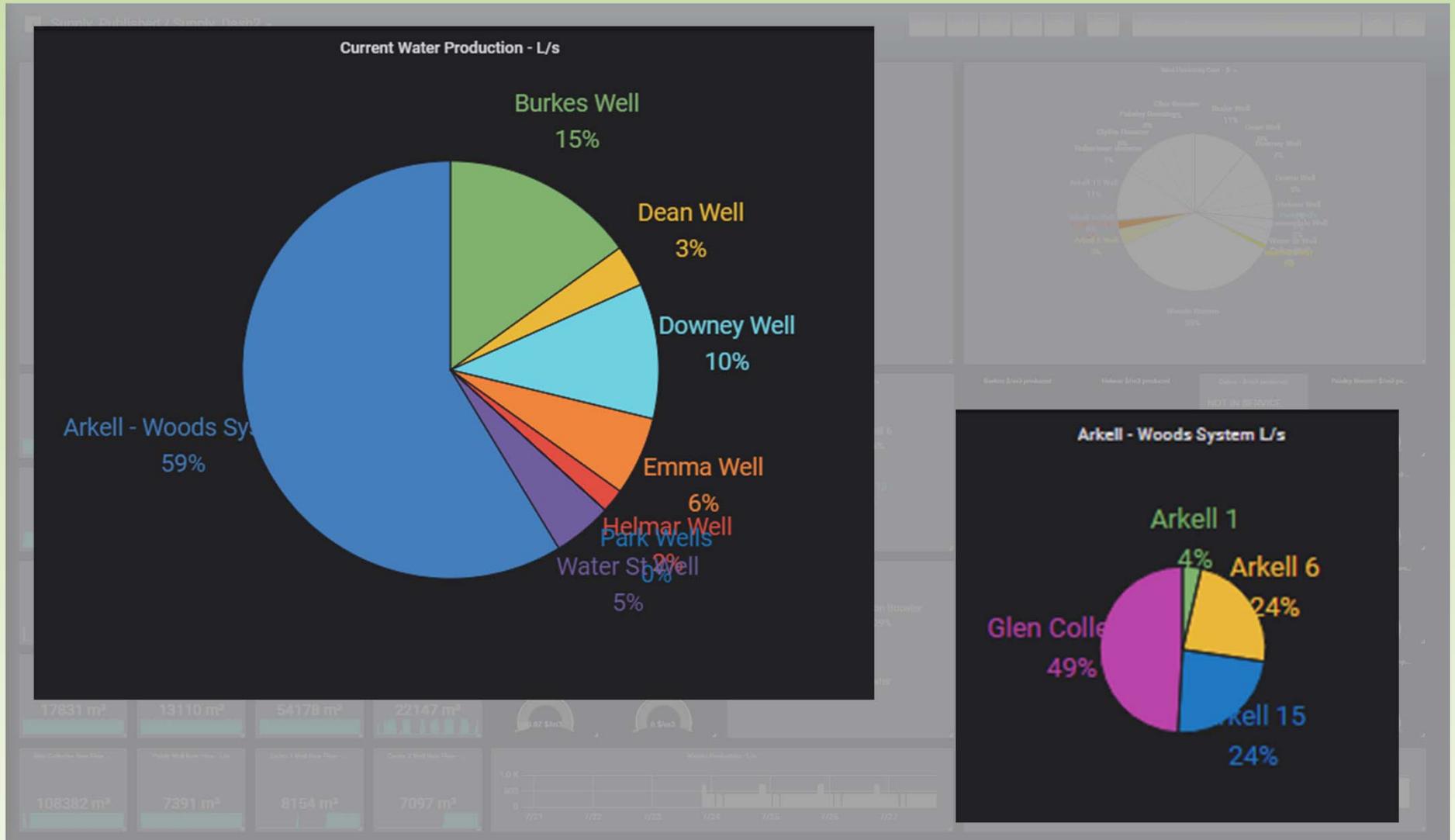
Grafana web-based Dashboarding Tool

The screenshot displays the Grafana web-based dashboarding tool interface. On the left, a sidebar shows a search bar and a list of dashboards categorized by folders: 'DMA', 'DMA_Published', 'Power_Published', and 'General'. A 'Filter by:' dropdown menu is open, showing options like 'Tags'. The main area displays several time-series charts, including 'Energy Cost (5min Intervals)' and 'Well & Booster Flow Rates (L/s)'. The charts show data points over time, with the x-axis labeled with dates like 6/28 00:00 and 6/29 00:00.

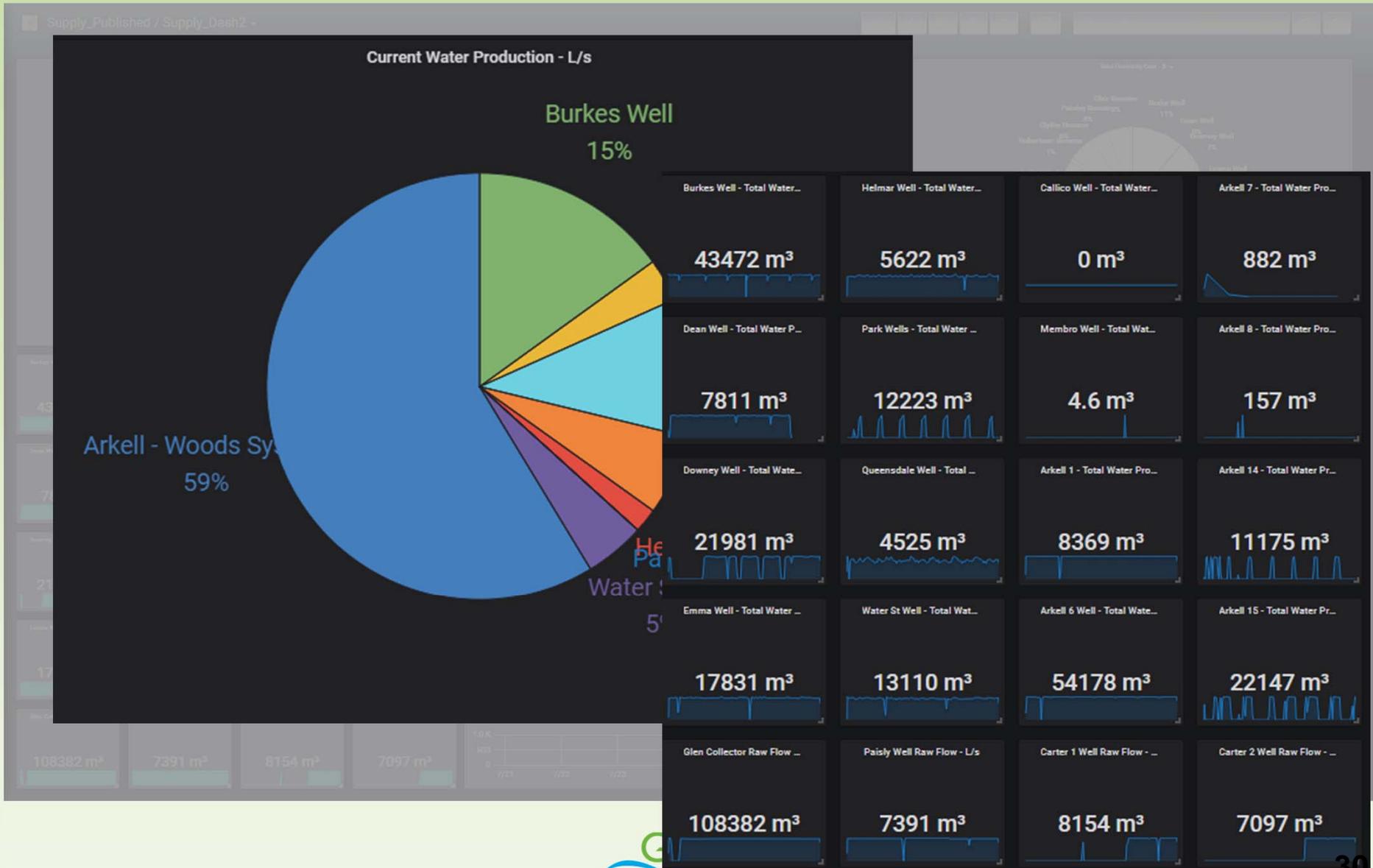
Power Dashboard (in our Treatment Ops Area)



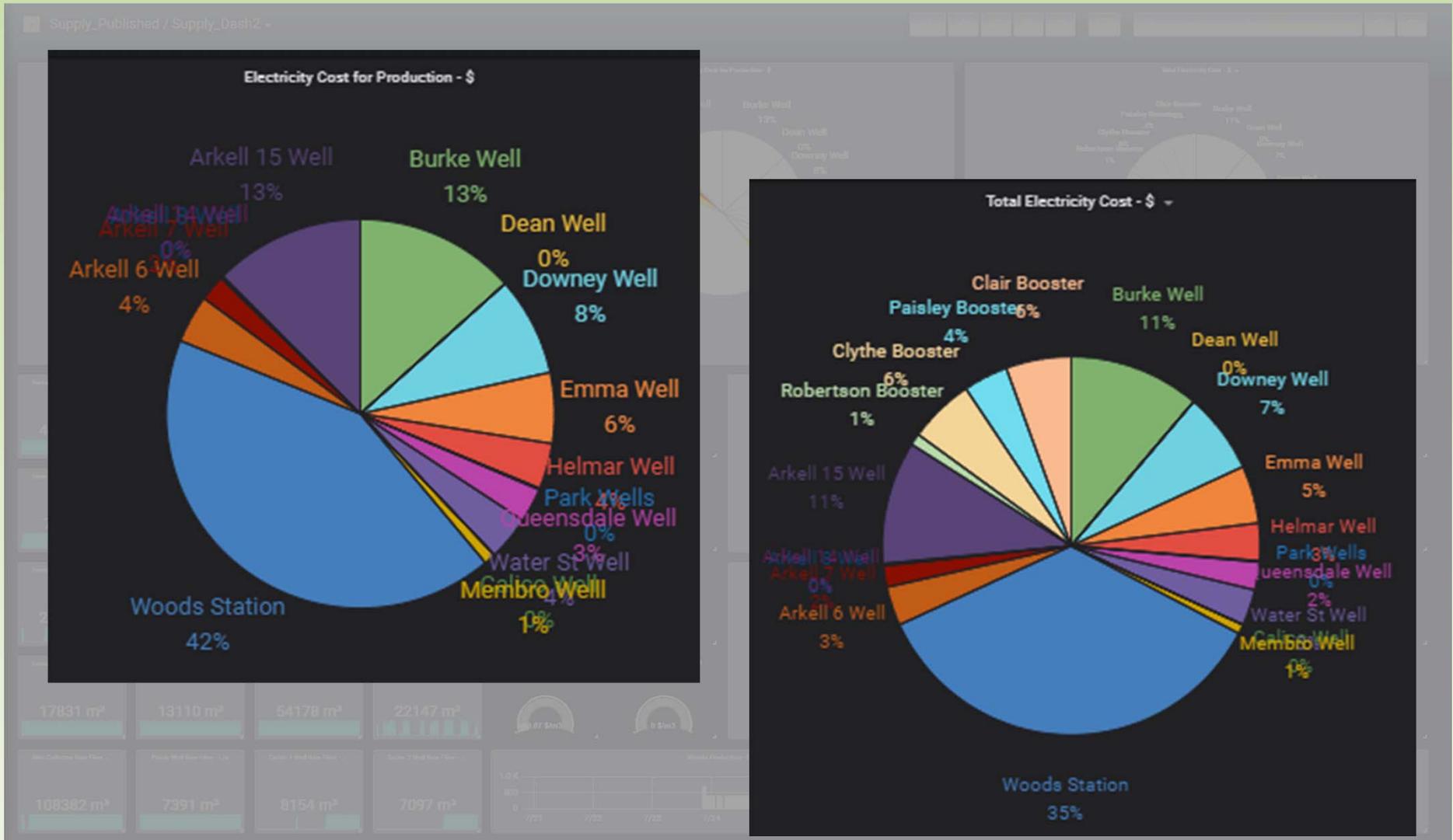
Where the water comes from



Where the water comes from



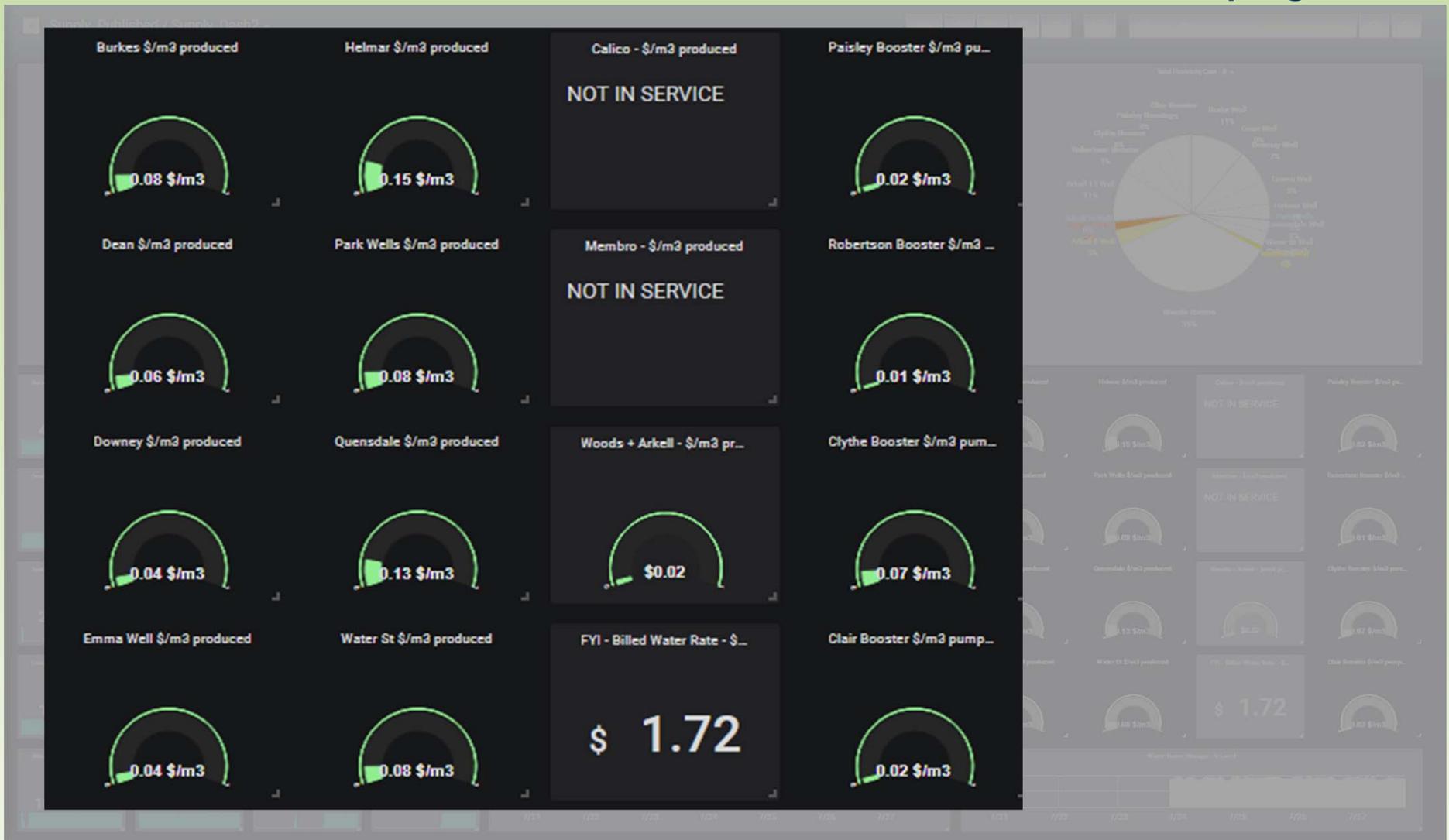
Live Breakdown of Electricity Costs for Water Utility



Electricity cost to Produce Water: \$/m3



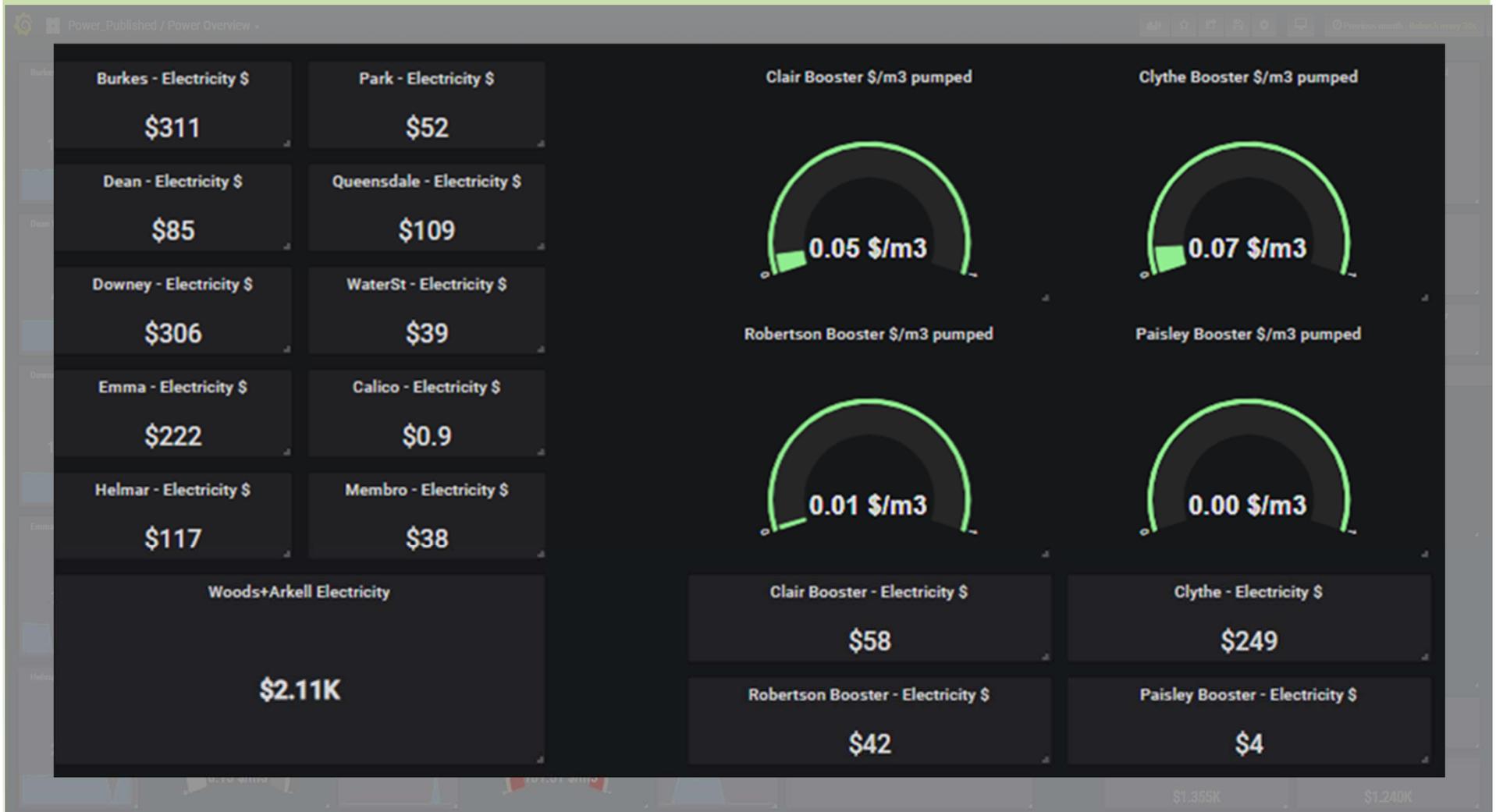
Putting Electricity Costs in Perspective: Water Production & Booster Pumping



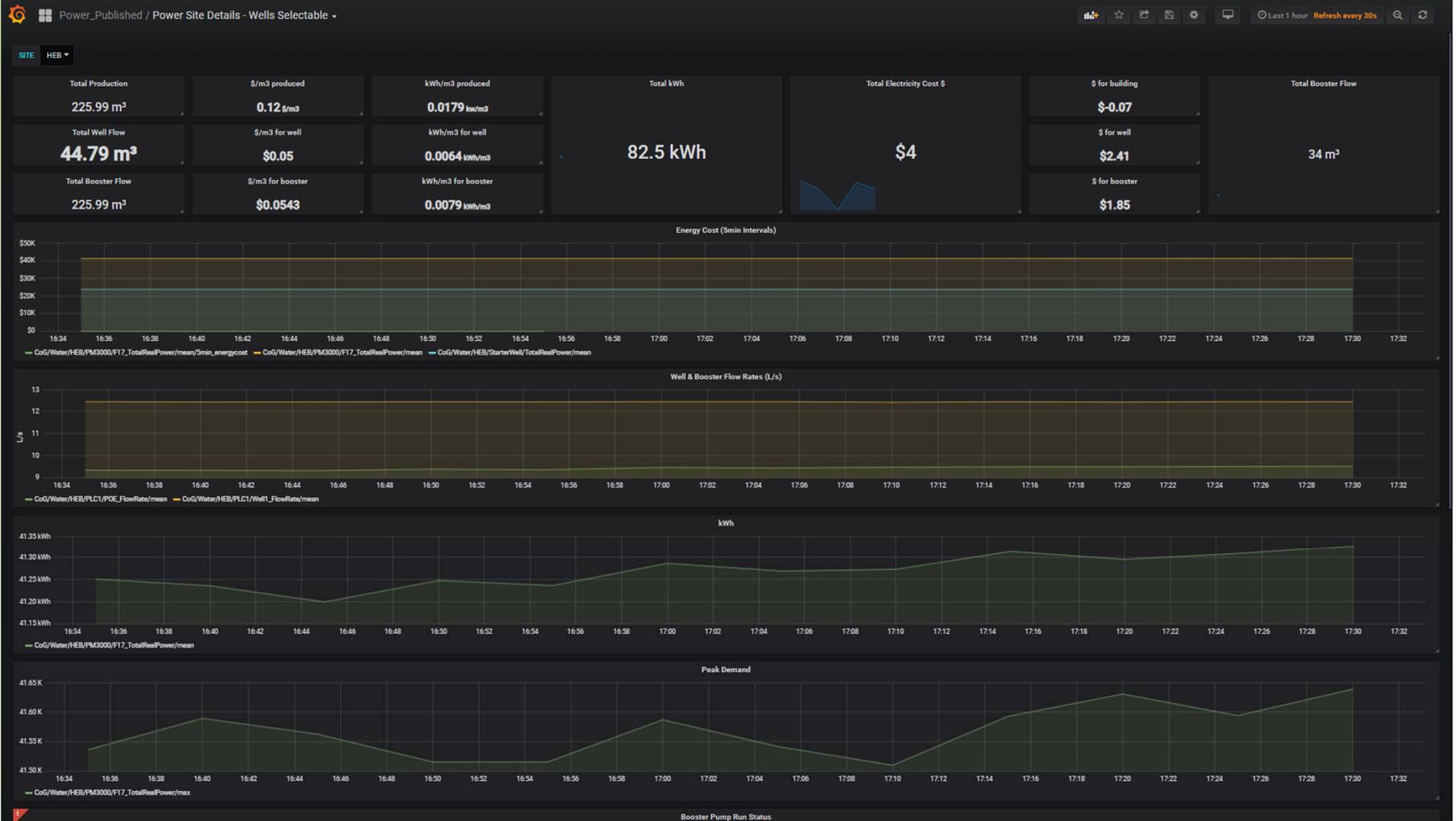
Power Operational Dashboard



Power Operational Dashboard: Daily Electricity Costs



Site Detail - Helmar Well (1hour)



Site Detail– Robertson Booster (2 days)



Site Detail– Robertson Booster (30 days)

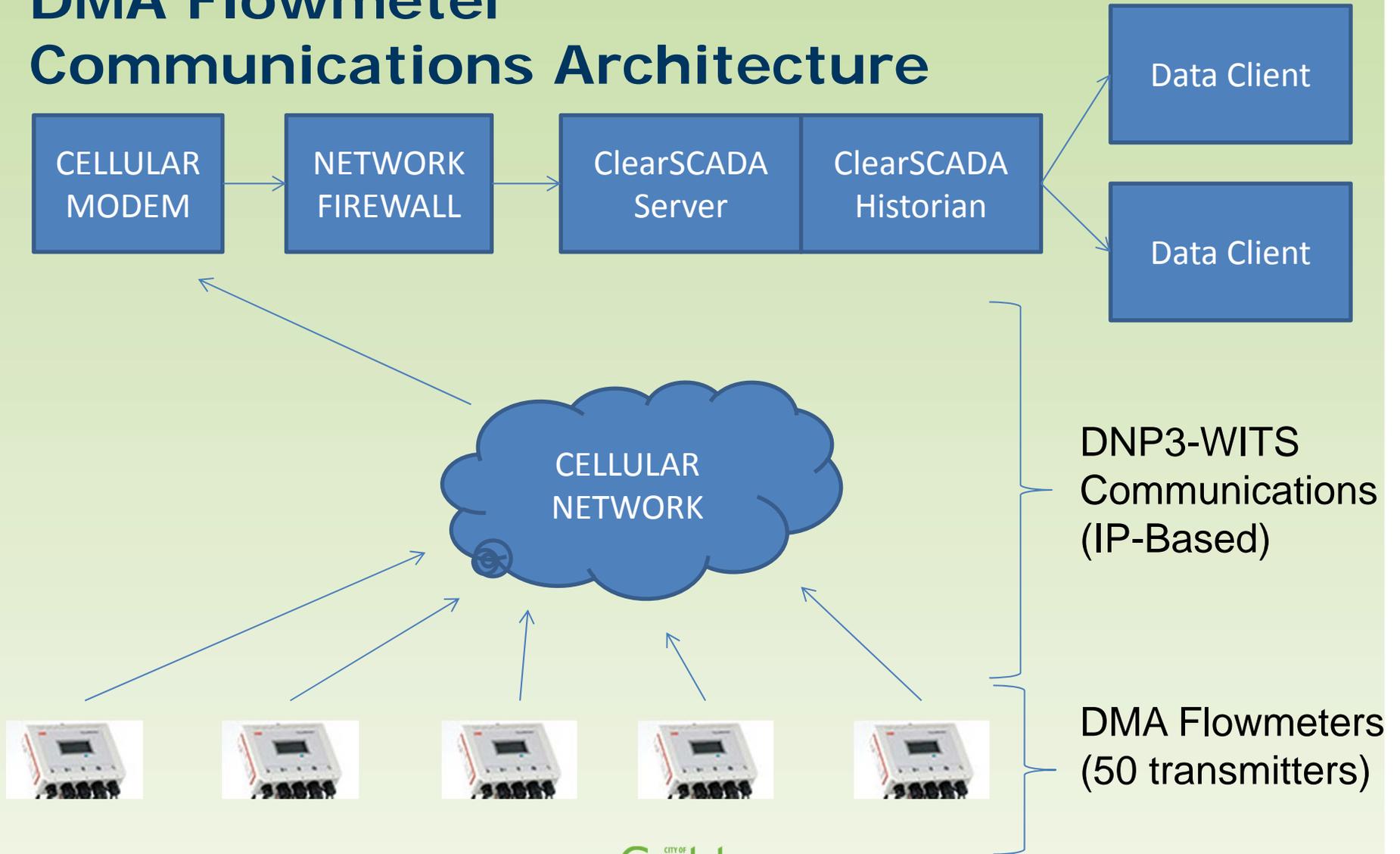


Let's use Neptune to manage our DMA Flowmeter Data...

**DMA = District Metered Area
Flow/Pressure Monitoring
in Water Distribution System**

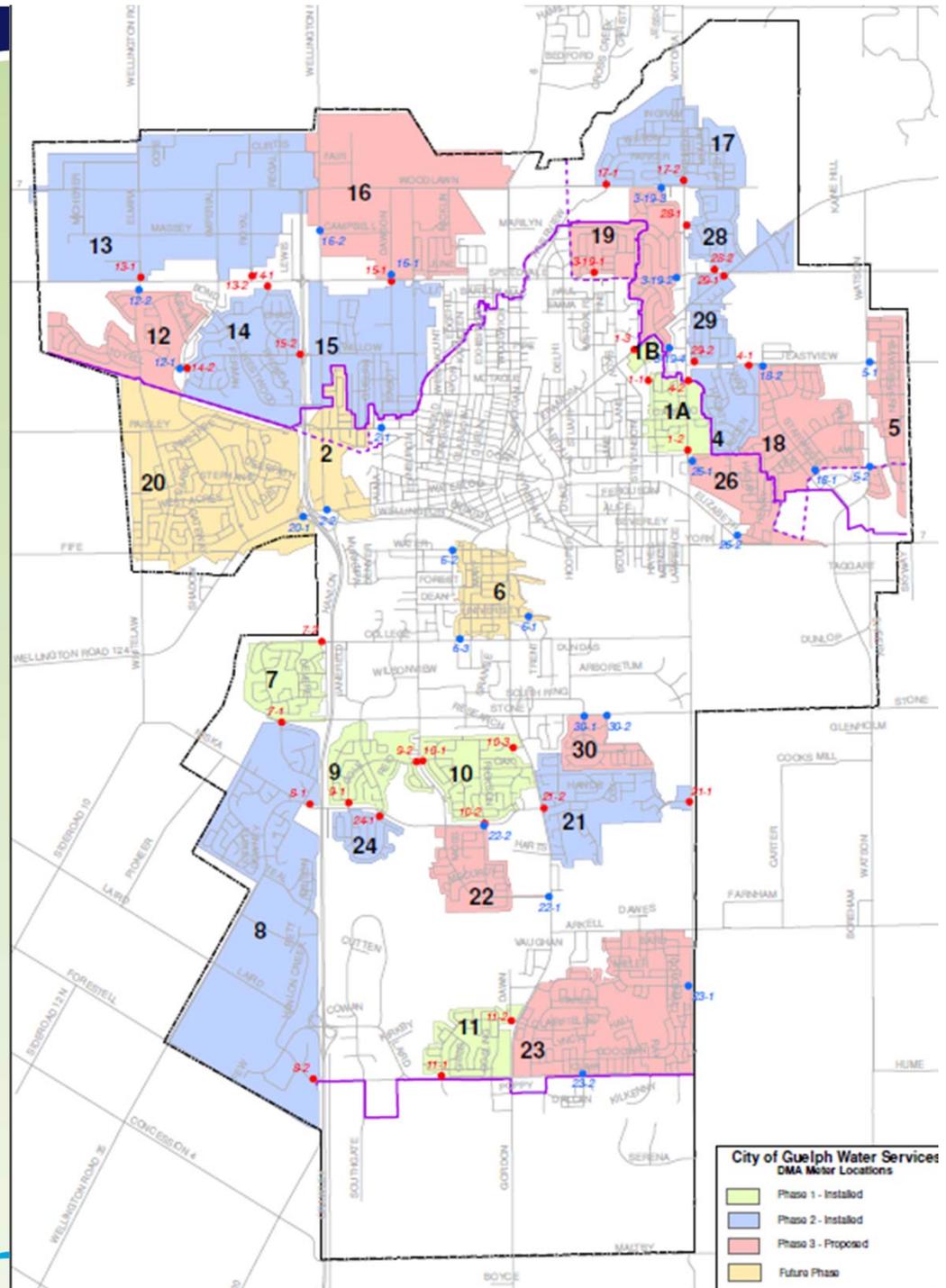


DMA Flowmeter Communications Architecture



District Metered Areas

- Segments Water Distribution into DMA Areas with 1-3 connections on borders
- Put flowmeters on the DMA's border connections
- What this give us:
 - Water in/out of DMAs
 - Compare to Customer Meters
 - Compare to Wells & Pumping Station meters
 - Calibrate Water Models



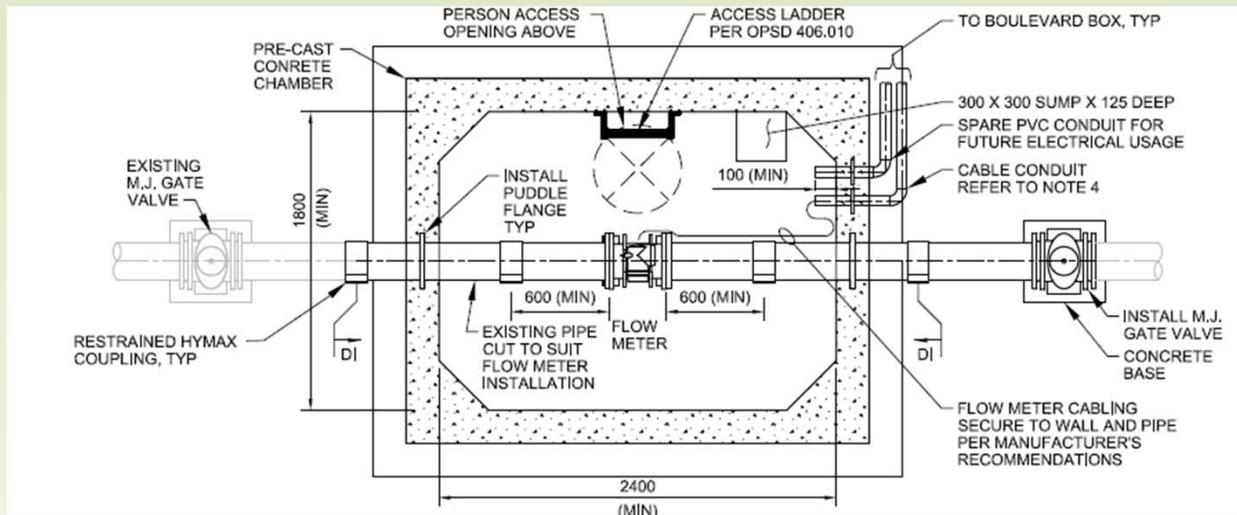
District Flow Meters

- Magnetic Flowmeter
- Integrated Remote Transmitter
 - Transmitter
 - Data Logger
 - Cellular Modem & Antenna
 - Built-in DNP3-WITS Protocol
 - IP 68 Submersion Rated
 - Long Life Battery
- Flow Tube
 - IP68 Submersion Rated



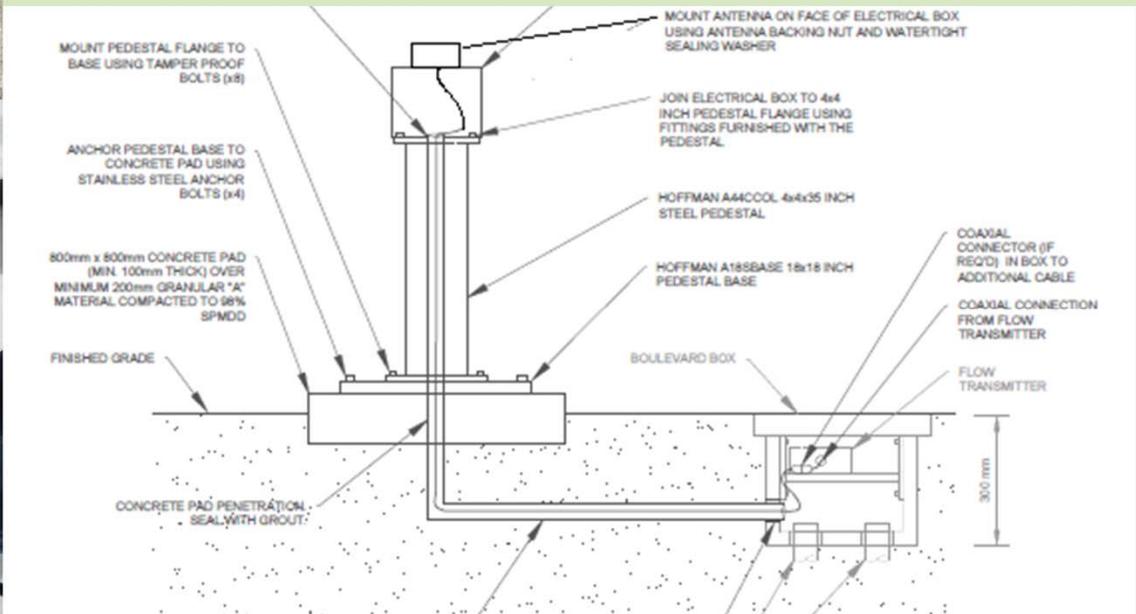
Flowmeter Chambers

- Each DMA is enabled by closing valves, so only 2-3 entry points
- Put Flowmeter chamber on each of DMA's entry points
 - Chamber contains the Flowmeter “flow tube”
 - Pressure sensor (also monitored by flowmeter electronics)
 - Upstream and downstream isolation valves



Flowmeter Transmitters

- Flowmeters installed into boulevard boxes
- Antenna pedestals to mount cellular antennas on

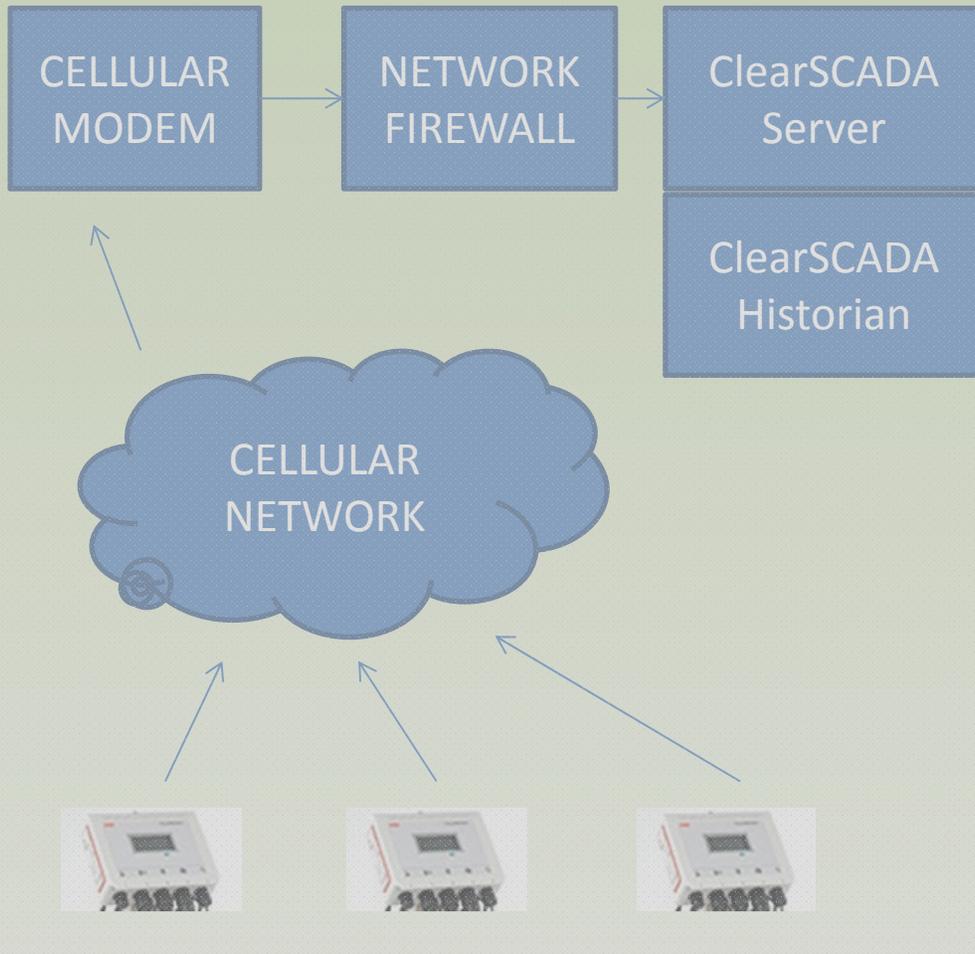






Applying Neptune to DMAs

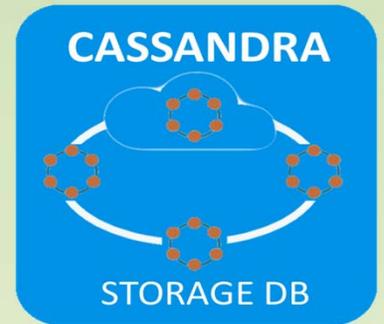
Existing SCADA Infrastructure



Web-based
Dashboard
& Reporting
Tool



Distributed
Open
Source
Database
(no licensing fees)



Hourly
Data Sync
Script



Pushes to
Historizer
Server

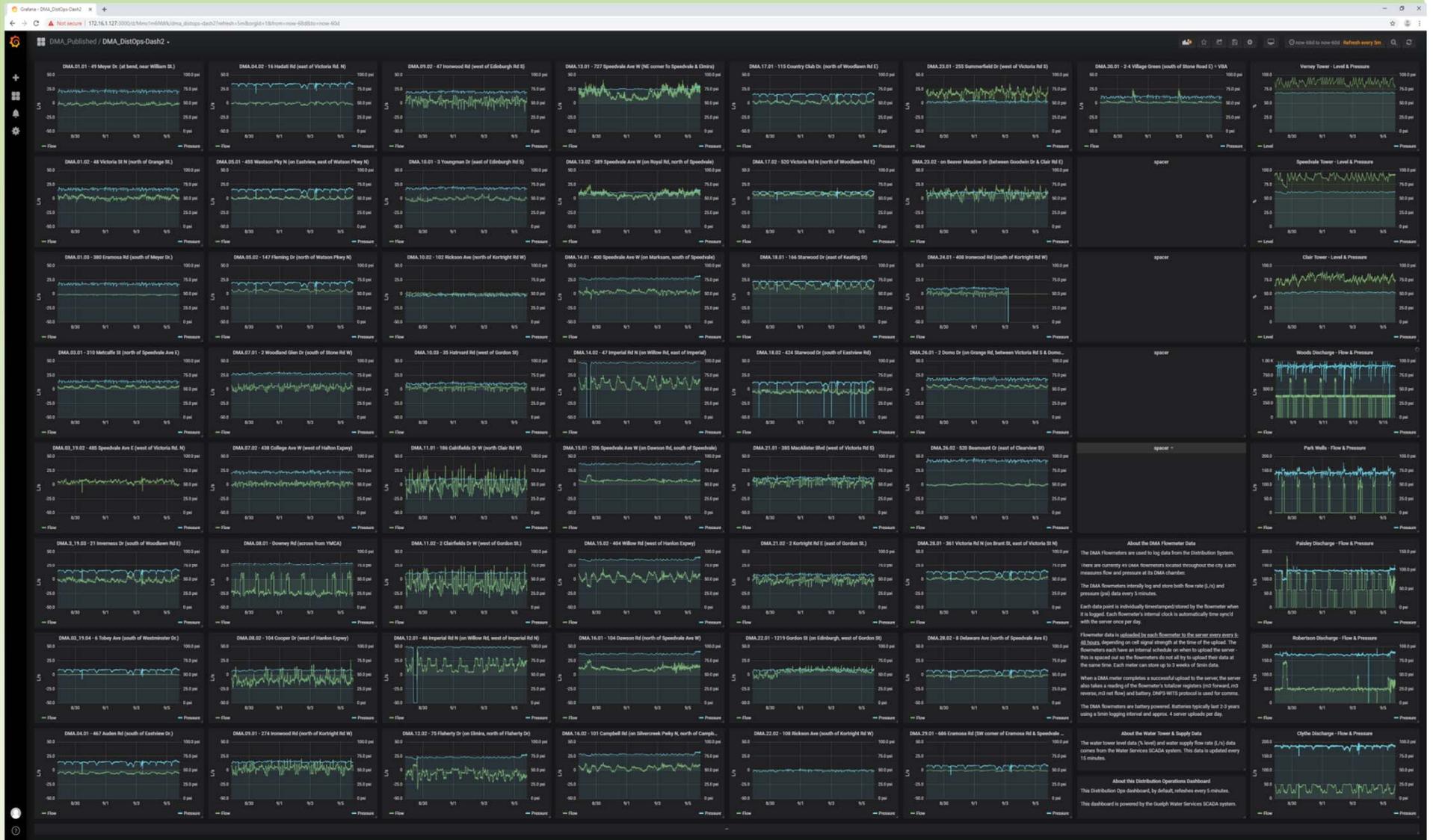


Pushes to
Time Series
Database

Neptune Hourly Data Sync Scripting

The screenshot displays a Node-RED flow titled "ClearSCADA ETL" within a browser window. The flow is designed to sync hourly data from SCADA systems. It begins with an "inject" node followed by a "Runs Every Hour" trigger. The data path includes an "http request" node, a "json" node, and a "change: 2 rules" node. A "query historical data for specific tag and time range (returns max 40000 records)" node is connected to a "change: 4 rules" node. A "delay 500ms" node is placed before a "parse data" node. A "timestamp" node is connected to a "get all the tags to pull data for" node, which then feeds into a "change: 3 rules" node. A "catch (1)" node is also present. The flow concludes with a "set msg.payload" node, a "change: 2 rules" node, and an "msg" node. A "Midnight backfill" trigger is connected to a "change: 2 rules" node. A note at the bottom states: "Auto Backfill Data at Midnight for two weeks (Runs @ 12:30am so hourly is done by 12:15am, no collisions)". The browser tabs include "Grafana - DMA Overview", "Grafana - Report - Monthly Powe...", "172.16.1.122:8080", "Node-RED Dashboard", and "Trident Historizer : 172.16.1.120". The right sidebar shows the "Info" tab for the flow, with details: Name: ClearSCADA ETL, ID: "3786ddf3.2ca782", Status: Enabled. The "Information" section is empty. The bottom right of the sidebar contains instructions: "Show the Info tab with ctrl-g i or the Debug tab with ctrl-g d".

DMA Dashboard Display (in our Distribution Ops Area)



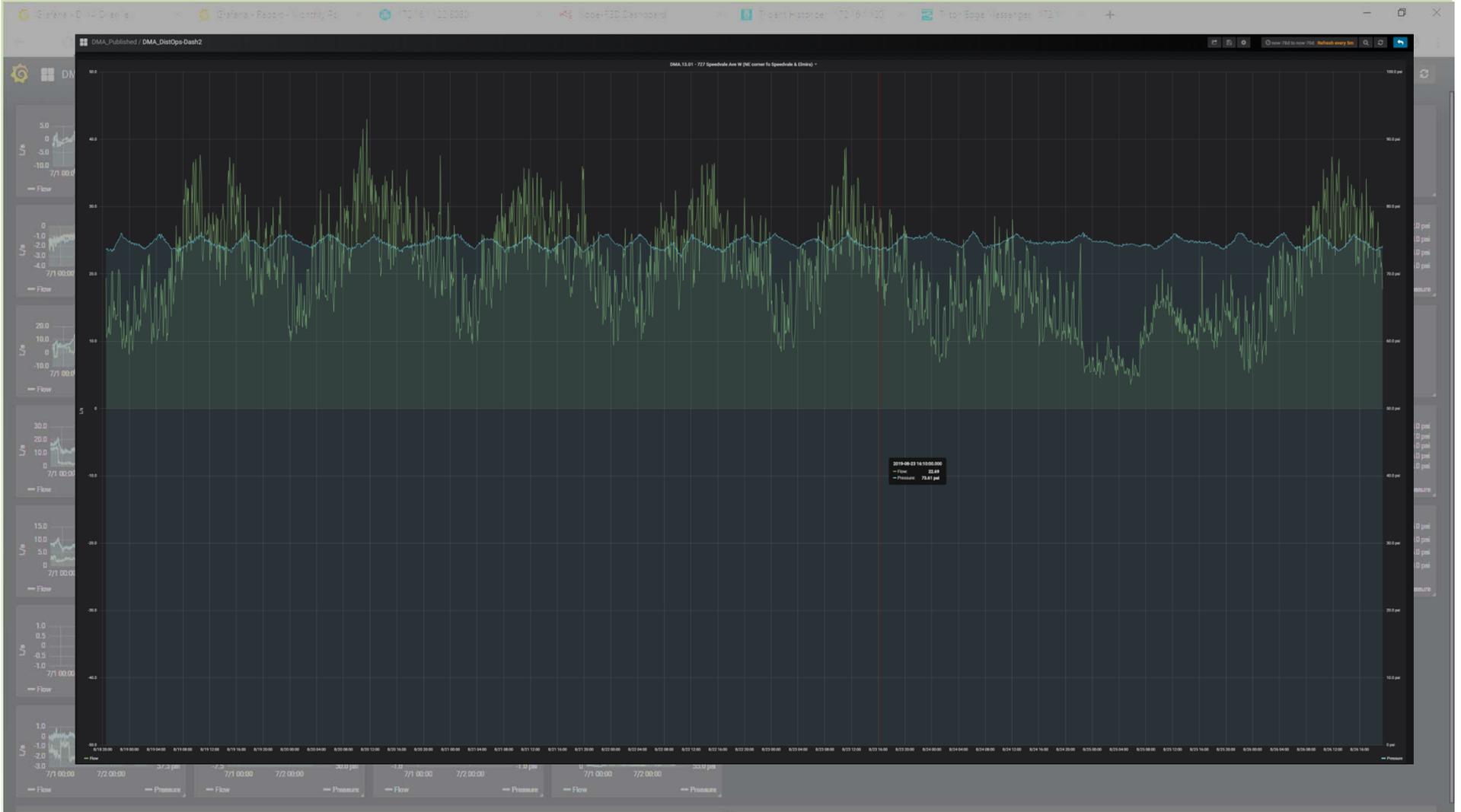
DMA Dashboard – showing last 7 days



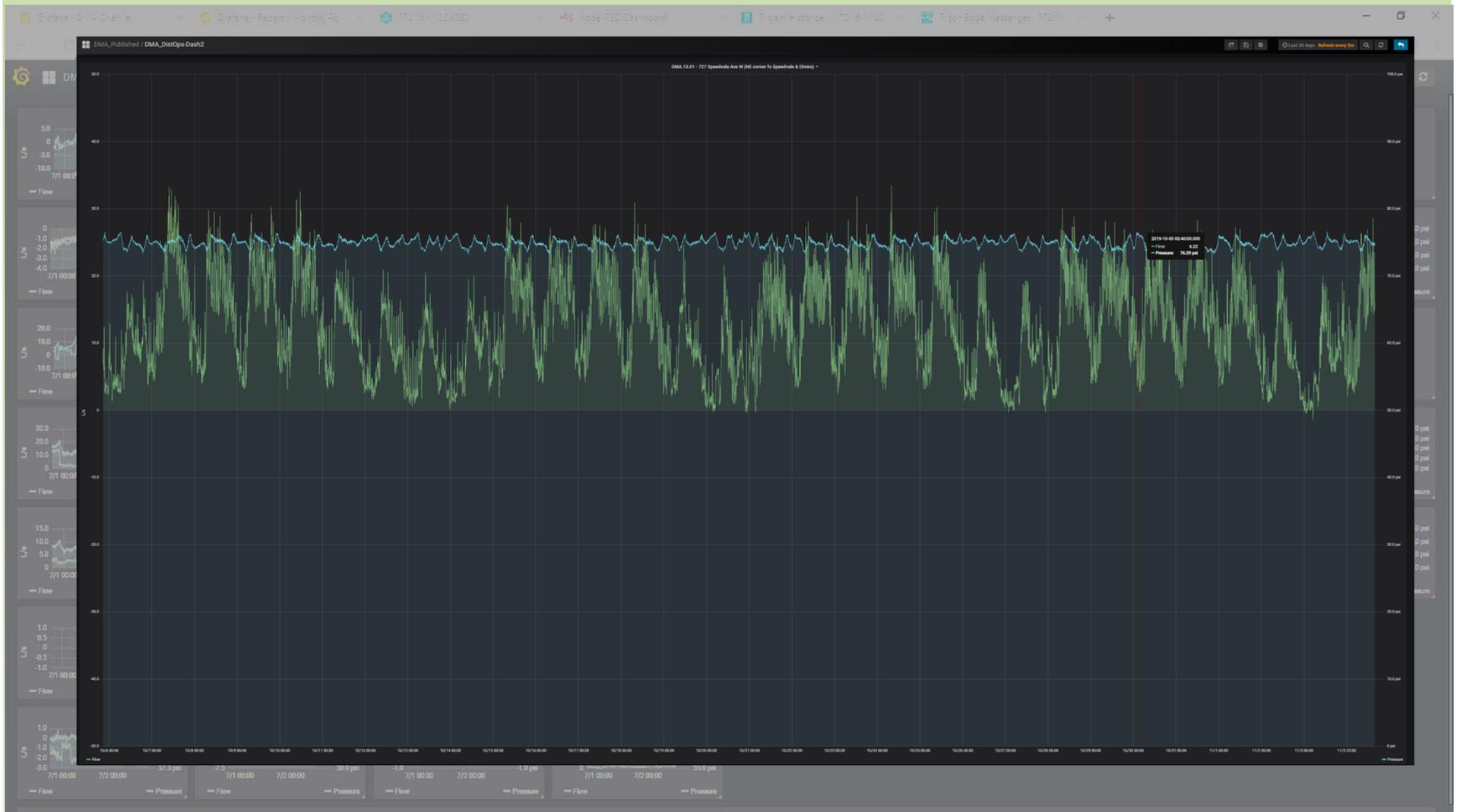
DMA Dashboard – showing last 30 days (auto-scaled to show variations)



DMA Dashboard – detail view (7 days)



DMA Dashboard – detail view (30 days)



DMA Dashboard – Another Detail View



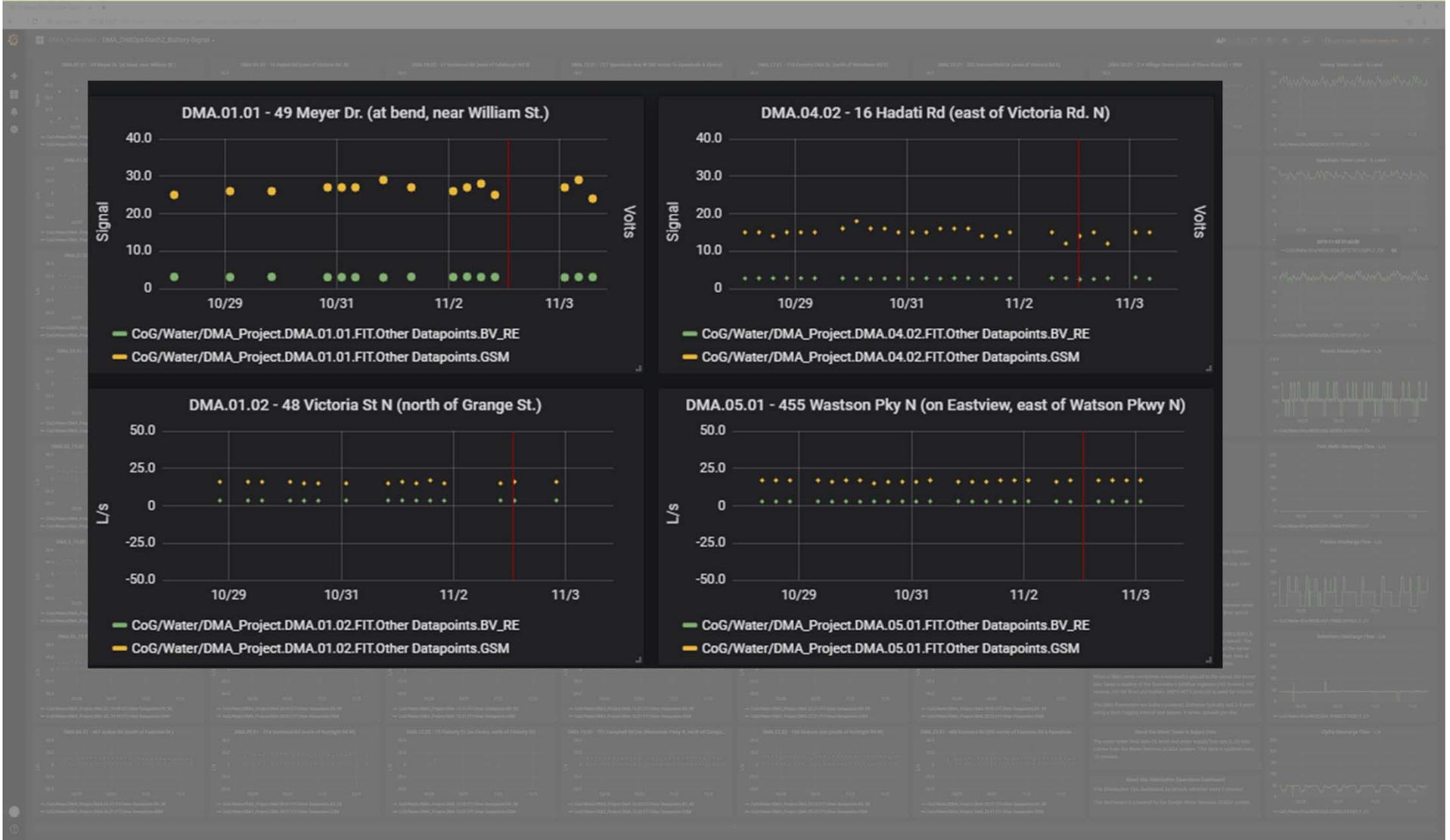
DMA Dashboard – DMA Flowmeter Health & Performance



DMA Dashboard – Tracking Battery Life & Cell Signal Strength



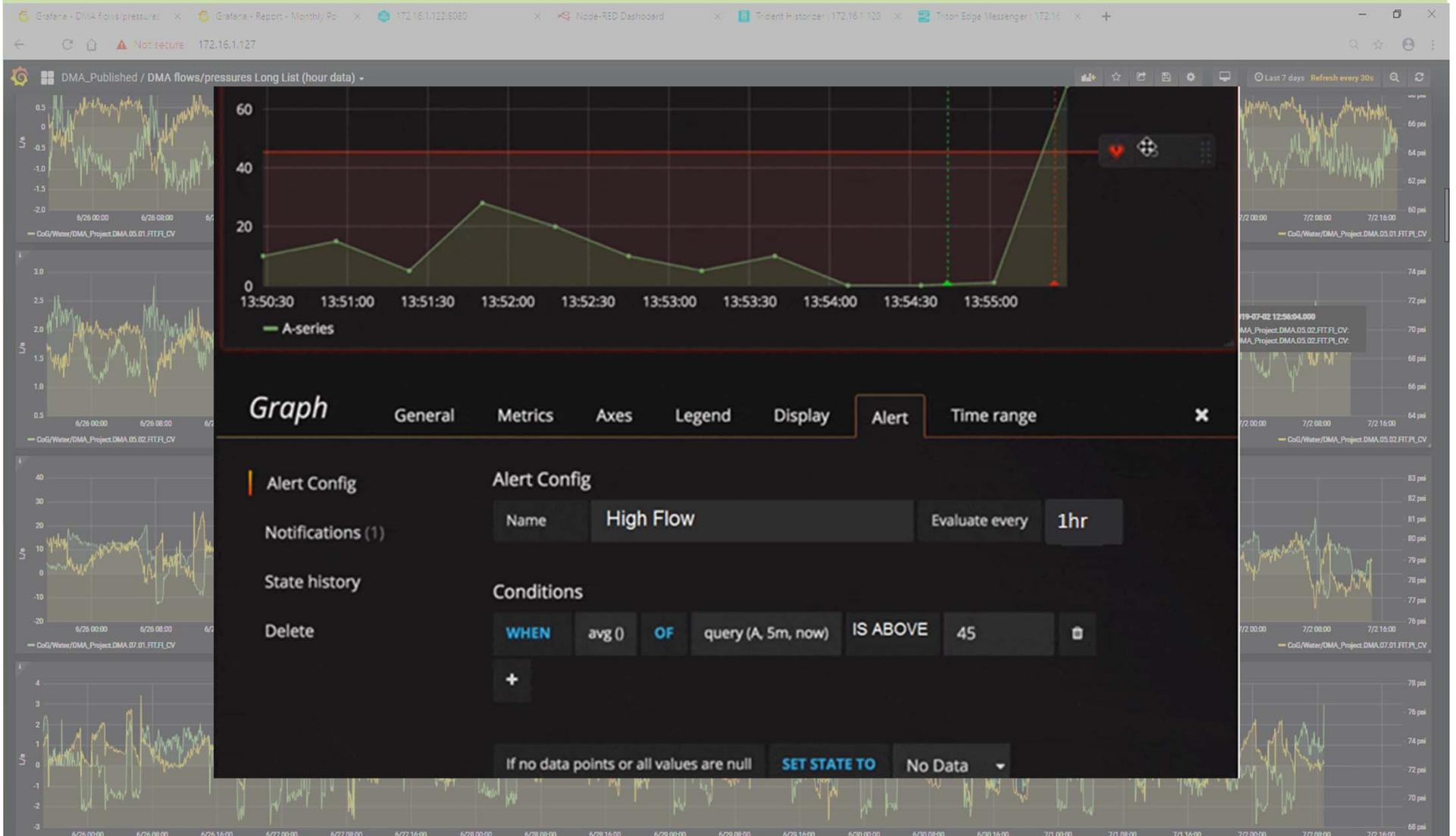
DMA Dashboard – Tracking Battery Life & Cell Signals



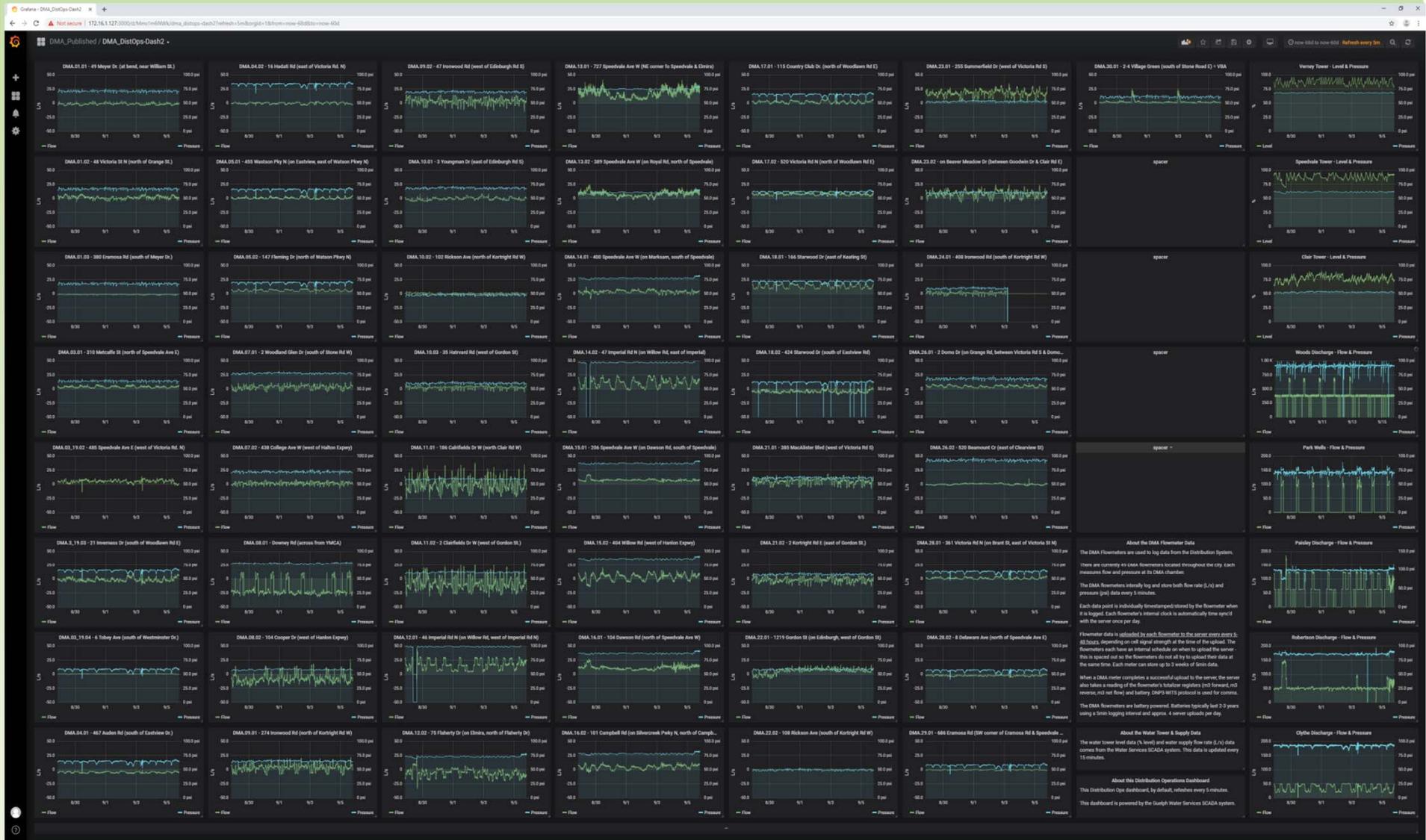
Live displays of Water Towers & Key Station Flows



DMA Dashboard – Setting up Email Alerts

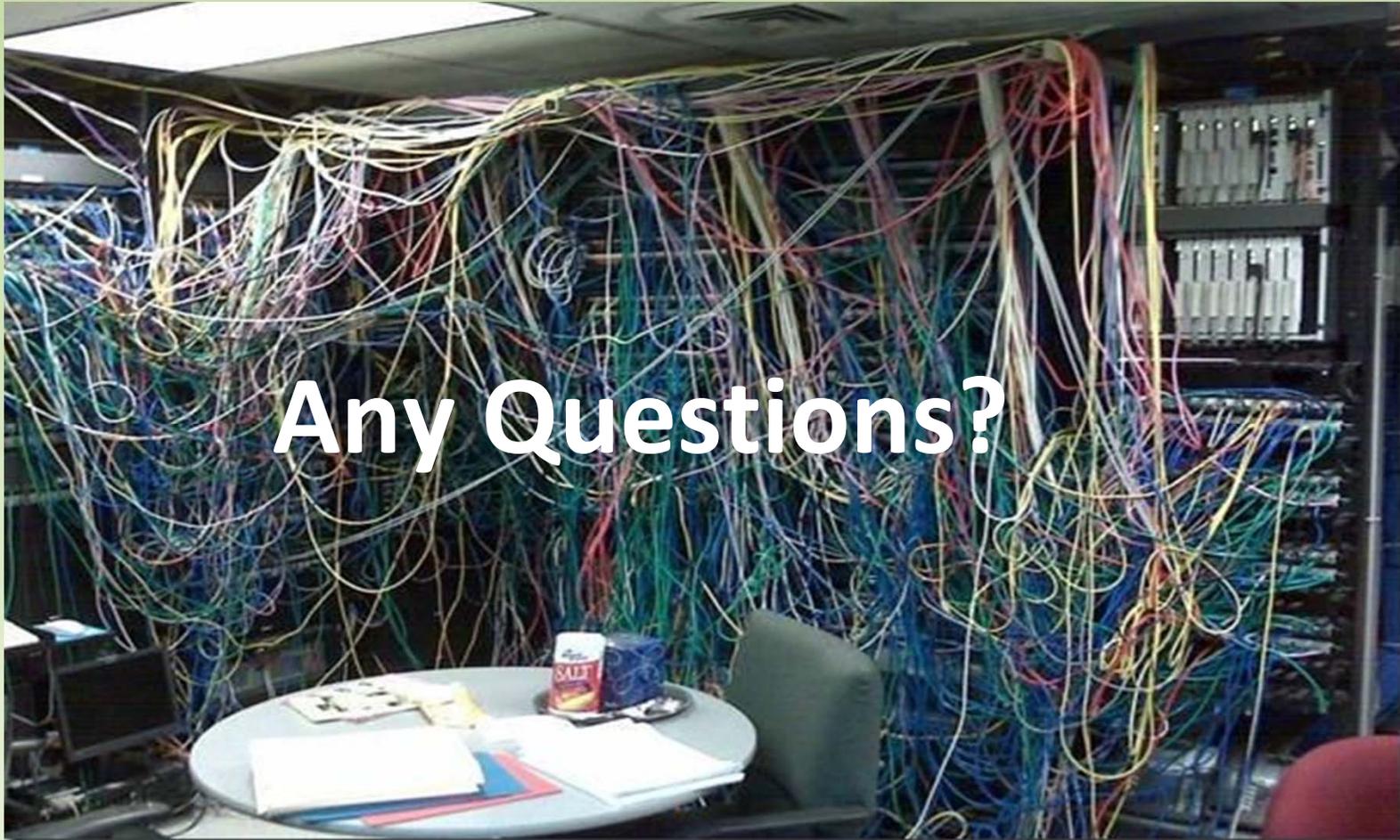


DMA Dashboard



Power Overview Dashboard





Any Questions?

* Not a High Performance SCADA System

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Special thanks to Jason Little and Triple Point Solutions for helping us develop our Power and DMA Dashboards with their Neptune Cluster system.

