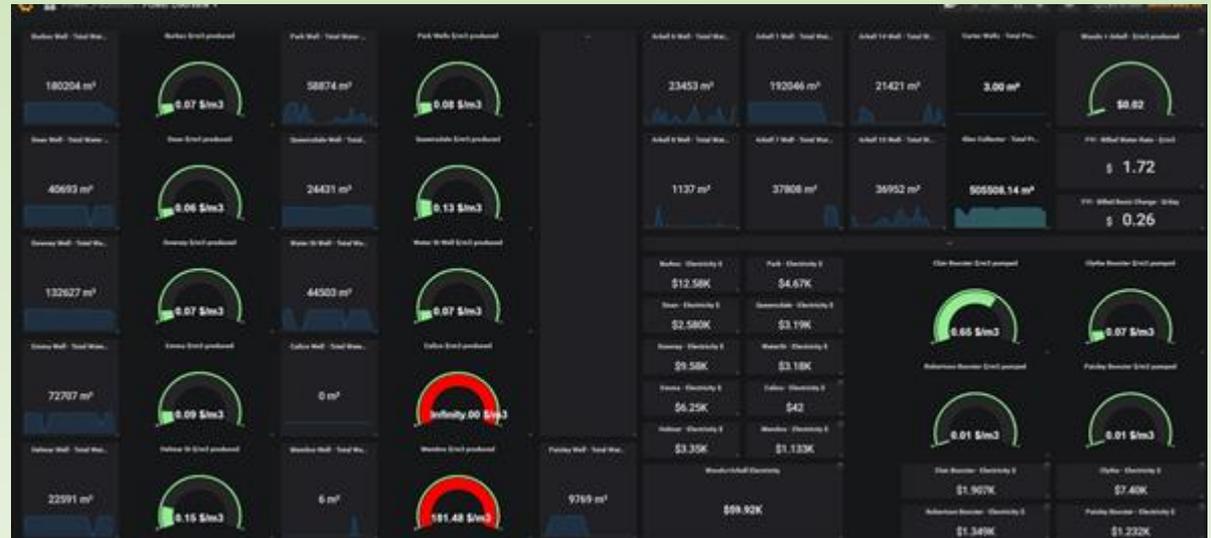


Guelph Water Services – SCADA Update

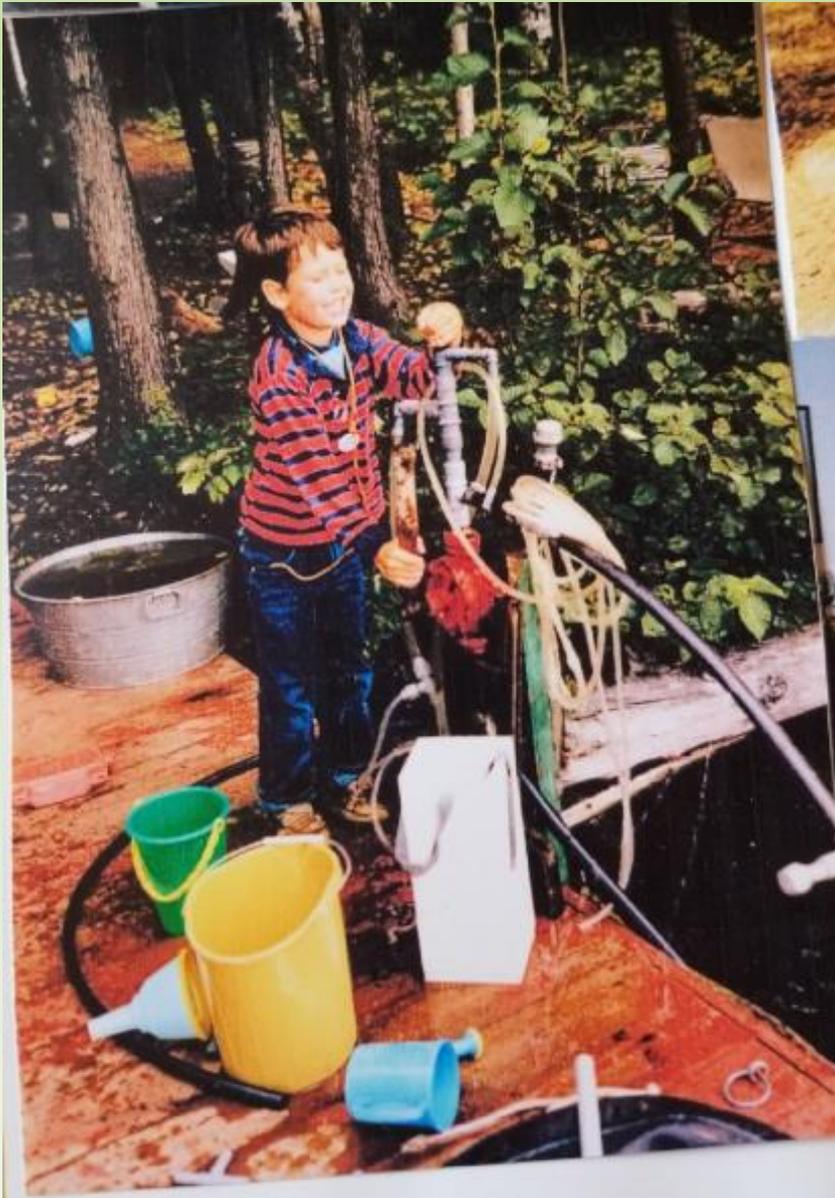
Power Usage Dashboards

DMA District Flowmeter Dashboards



Speaker: Graham Nasby, Water SCADA & Security Specialist

July 3, 2019 – Guelph, Ontario, Canada



**I wanna be a
Water Guy
when I grow up!**

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 programming/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 only 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
- After a year of work by the integrator, the power reports were working again
- Reports only provide 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 better!

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

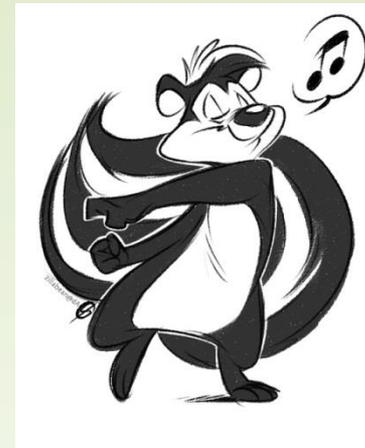
- Open Source Software Developer
- Day job is a SCADA specialist at a nearby utility

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



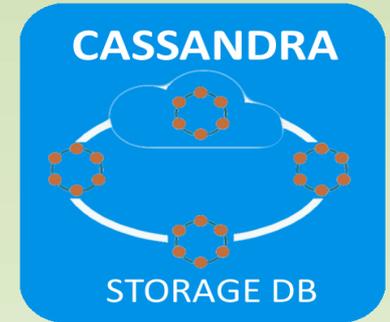
How it works



Web-based
Dashboard
& Reporting
Tool



Distributed
Open
Source
Database
(no licensing fees)



Pushes to
Historizer
Server



Pushes to
Time Series
Database

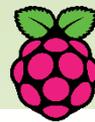


Digital Power Monitors

Polls Data Every
Second



Pump Motor Starters



RaspberryPi



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

Logs data every 5min
Logs changes on 1 sec intervals

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**
- **Energy Usage**
- **Peak Charges**
- **Ontario Hourly Energy Prices**
- **Time of Day Adjustments**
- **Global Adjustment**
- **Global Adjustment Estimates**
- **End of the Month Balancing**
- **Etc.**

Power Calculations

Hydro One – General Service -Energy

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 One – General Service -Demand

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



Web-based Dashboard & Reporting Tool



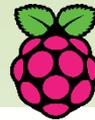
Live Feed of Hourly Global Adjustment Hourly Energy Prices



Plant PLC's (Flow Data)



Calculates Live Energy Costs every 5 mins



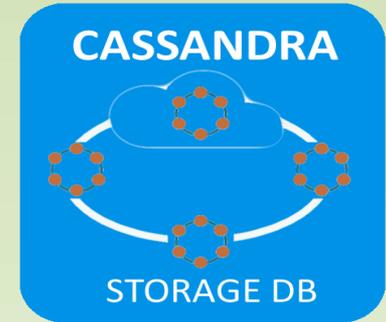
RaspberryPi



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

Logs data every 5min
Logs changes on 1 sec intervals

Distributed Open Source Database



Pushes to Historizer Server



Pushes to Time Series Database



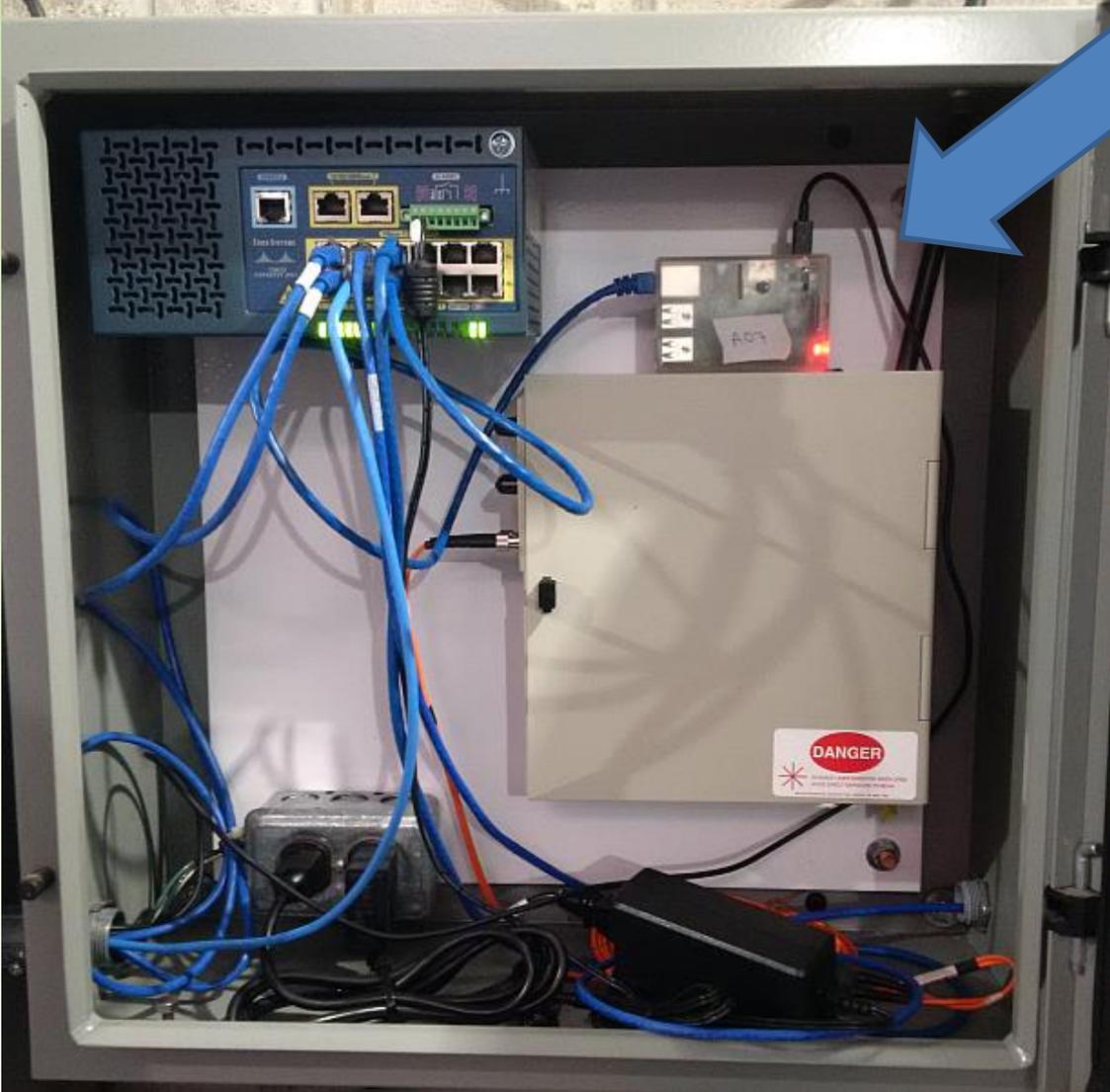
Digital Power Monitors

Polls Data Every Second



Pump Motor Starters

Raspberry Pi Installed



Collecting the Data

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

Not secure | 172.16.1.122:1880/ui/#/0

Neptune Cluster Dashboard

Triton Edge Messengers

Site	State	Buffer	Poll	RBE	CPU	IP	Uptime
A06	ONLINE	0	52	3	0.63	172.16.65.29	507.89
A07	ONLINE	0	56	8	0.79	172.16.65.39	503.22
A08	ONLINE	0	55	13	0.89	172.16.65.49	385.23
A14	ONLINE	0	53	10	0.66	172.16.65.19	41.38
A15	ONLINE	0	55	2	0.62	172.16.65.9	507.87
ADV	ONLINE	0	7	1	0.20	172.16.65.59	507.88
BKS	ONLINE	0	40	3	0.88	172.16.72.49	148.31
CAB	ONLINE	0	49	12	0.63	172.16.28.49	510.82
CBS	ONLINE	0	58	7	0.74	172.16.73.49	349.00
CCB	ONLINE	0	51	6	0.72	172.16.51.49	116.16
CLT	ONLINE	0	5	0	0.22	172.16.73.46	30.63
CWS	ONLINE	0	52	6	0.57	172.16.53.49	99.34
DEB	ONLINE	0	50	2	0.61	172.16.22.49	70.16
DOB	ONLINE	0	56	13	0.72	172.16.71.49	210.07
EWS	ONLINE	0	52	1	0.64	172.16.43.49	56.23
HEB	ONLINE	0	60	5	0.87	172.16.45.49	350.18
MEB	ONLINE	0	53	13	0.69	172.16.23.49	507.74
PAB	ONLINE	0	54	7	0.61	172.16.44.49	127.15
PRB	ONLINE	0	51	2	0.53	172.16.26.49	15.17
QUB	ONLINE	0	49	4	0.53	172.16.25.49	510.79
ROB	ONLINE	0	52	11	0.65	172.16.41.49	36.30
SCS	ONLINE	0	2	0	0.09	172.16.52.49	507.91
SPT	ONLINE	0	5	0	0.24	172.16.27.49	41.27
UNB	ONLINE	0	57	3	0.72	172.16.24.49	13.18
VET	ONLINE	0	4	0	0.14	172.16.42.49	52.86
WDB	ONLINE	0	13	1	0.33	172.16.1.79	166.96
WWS	ONLINE	0	52	2	0.63	172.16.21.49	237.14

Titan Brokers

Broker 1: **ONLINE**
response **0.382 ms**

Trident Historizers

Historizer 1: **ONLINE**
Tag Count: **6617**

Tag Rate
131 tags/sec

Insert Rate
15 inserts/sec

Clustered Storage Nodes

Node 1: **ONLINE**
response **1.03 ms**

Pulling Data from Digital Power Monitors

The screenshot displays a Node-RED dashboard for Triton Edge Messenger. The main workspace shows a flow starting with a 'timestamp' node, followed by a function node '/home/pi/lab_pm3000.py' with a 'pid:18628' property. This is connected to a 'delay 10s' node. The output of the delay node is connected to a large array of nodes, each representing a specific data point from the PM3000 device. These nodes are organized into two columns: the left column contains nodes for current and voltage measurements (e.g., 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), and the right column contains 'Analytics' nodes for each corresponding data point. The flow is deployed to the Triton Edge Messenger device.

Information

Flow	"40d8bdad.c63914"
Name	PM3000
Status	Enabled

Flow Description

None

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 Triton Edge Messenger interface with a Node-RED flow. The browser tabs include Grafana - DMA Overview, Grafana - Report - Monthly Power, 172.16.1.122:8080, Node-RED Dashboard, Trident Historizer: 172.16.1.120, and Triton Edge Messenger: 172.16.1.120. The URL is 172.16.22.49:1881/#flow/6a20adf9.255594. The interface shows a flow with the following components:

- timestamp** node
- /home/pi/ab_slc.py** node (script)
- delay 10s** node
- json** node
- split** node
- Five **PLC1/...** nodes: *Well1_FlowRate*, *POE_FlowRate*, *POE_Pressure*, *POE_ChlorineResidual*, and *Reservoir1_Level*
- Five **Analytics** nodes

The right sidebar contains the following information:

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

Below the information is a section for **Flow Description** with the text "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`".

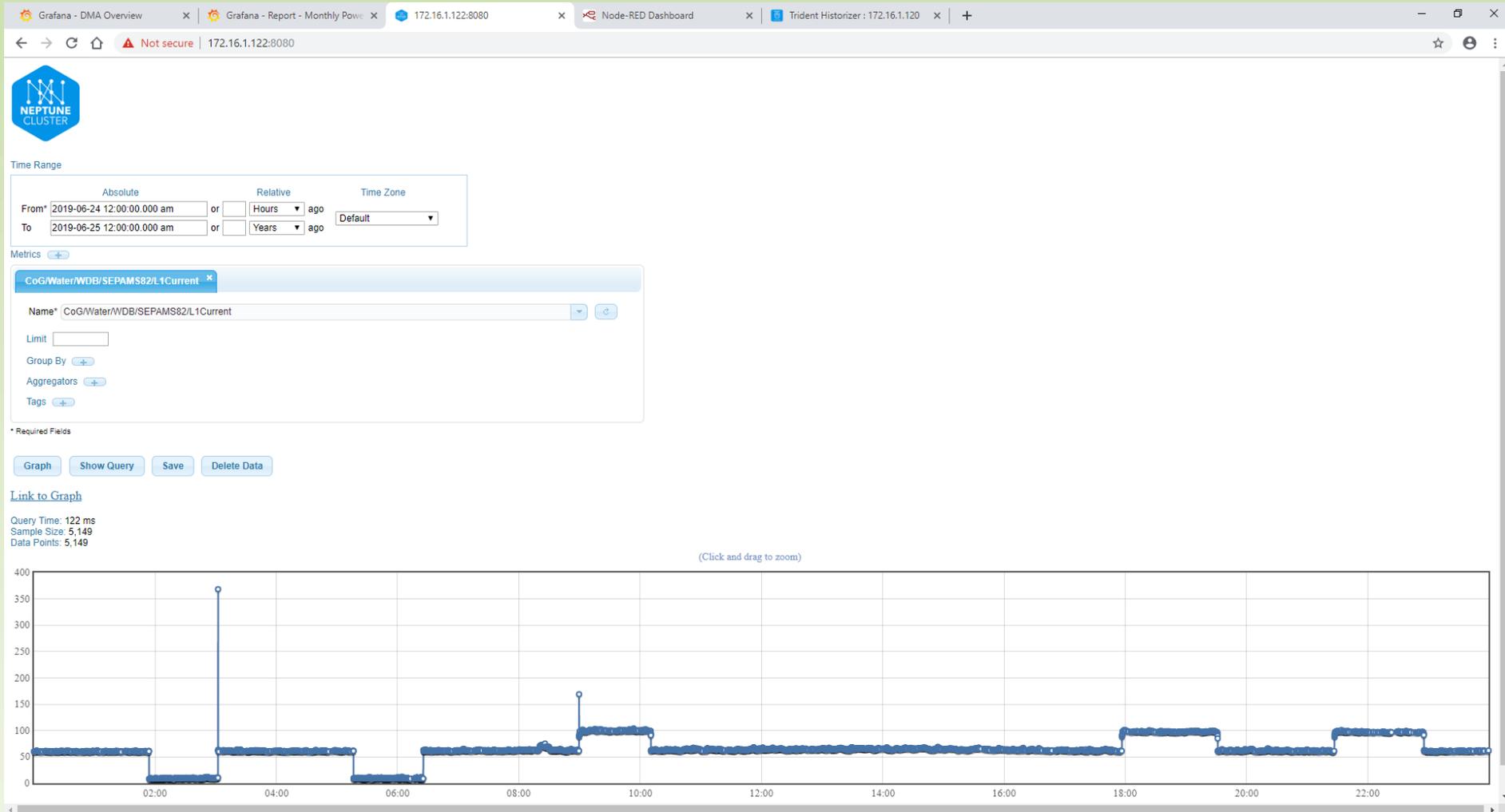
Buffering Data in the Raspberry Pi's

The screenshot shows a web browser window displaying a Grafana dashboard titled "Current Tag Values". The browser tabs include "Grafana - DMA Overview", "Grafana - Report - Monthly Power", "172.16.1.122:8080", "Node-RED Dashboard", "Trident Historizer - 172.16.1.120", and another "Node-RED Dashboard". The address bar shows "Not secure | 172.16.22.49:1880/ui/#/0".

The dashboard features a "Tag Filter" section with a "REFRESH" button and a "Tag Filter Results Count: 67" indicator. Below this is a table with columns for "Tag", "Value", and "Age (s)". The table lists various tags such as "PLC1/Booster1_Running", "PLC1/POE_ChlorineResidual", and "PM3000/F15_AvgCurrent", each with a numerical value and an age in seconds.

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 tabs include Grafana - DMA Overview, Grafana - Report - Monthly Power, 172.16.1.122:8080, Node-RED Dashboard, and Trident Historizer - 172.16.1.120. The address bar shows the URL 172.16.1.122:8080.

The interface features a sidebar on the left with the Neptune Cluster logo and a 'Time Range' section. The main content area is titled 'NEPTUNE CLUSTER' and contains a 'Time Range' section with the following configuration:

- Time Range:** Absolute. From: 2019-06-24 12:00:00.000 am, To: 2019-06-25 12:00:00.000 am. Time Zone: Default.
- Relative:** From: Hours ago, To: Years ago.

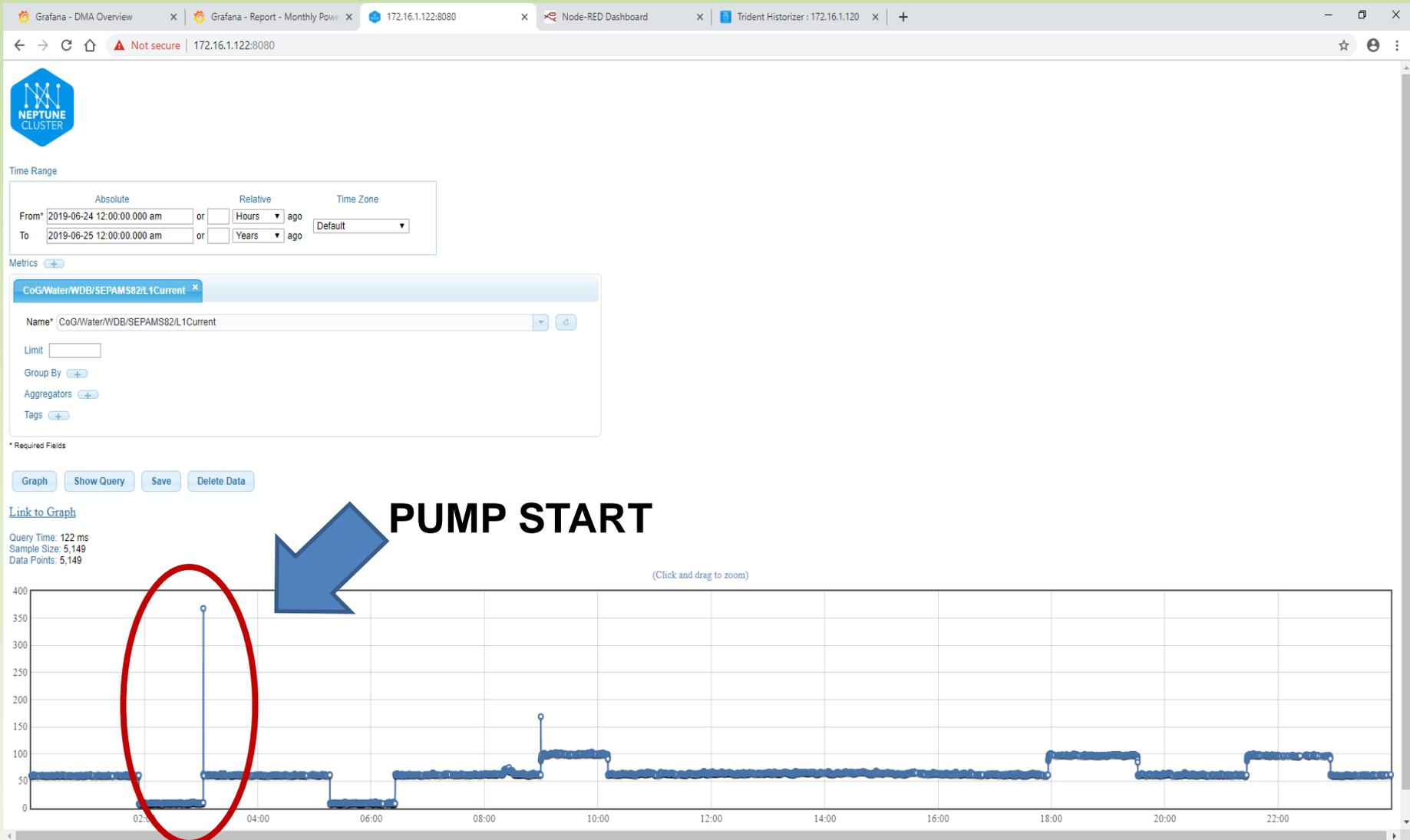
The 'Metrics' section is expanded to show the following configuration:

- Metrics:** CoG/Water/ROB/PM3000/F17_L1RealPower
- Name:** CoG/Water/ROB/PM3000/F17_L1RealPower
- Limit:** [Empty field]
- Group By:** [Empty field]
- Aggregators:** [Empty field]
- Tags:** [Empty field]

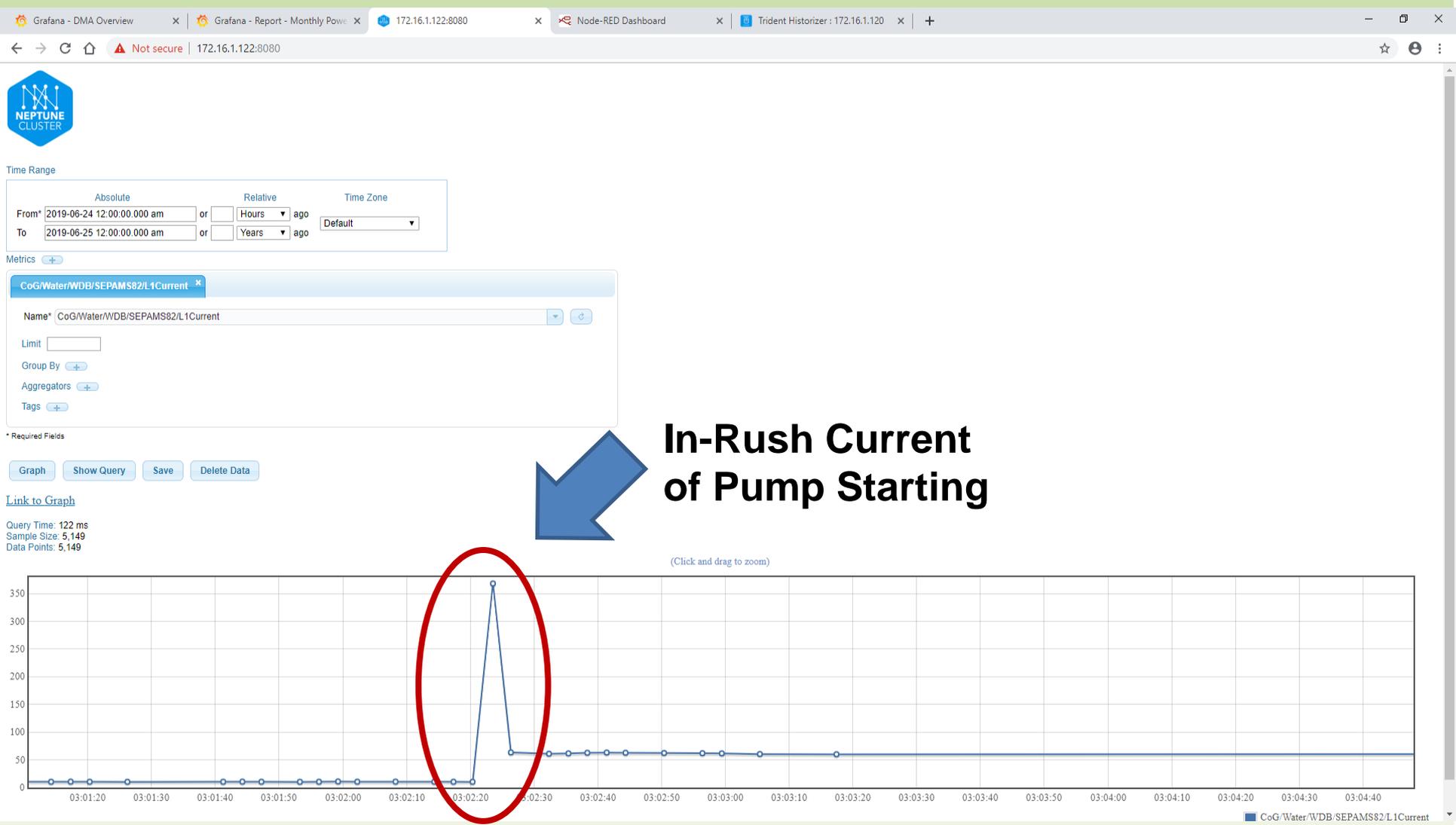
At the bottom of the metrics section, there are buttons for 'Graph', 'Show Query', 'Save', and 'Delete Data'. A 'Required Fields' section is also visible below the metrics configuration.

In the background, a line graph is visible with a y-axis ranging from 0 to 400 and an x-axis showing time from 02:00 to 22:00. The graph shows a sharp spike in power consumption around 03:00.

Direct Query Tool: Woods Pump Starts

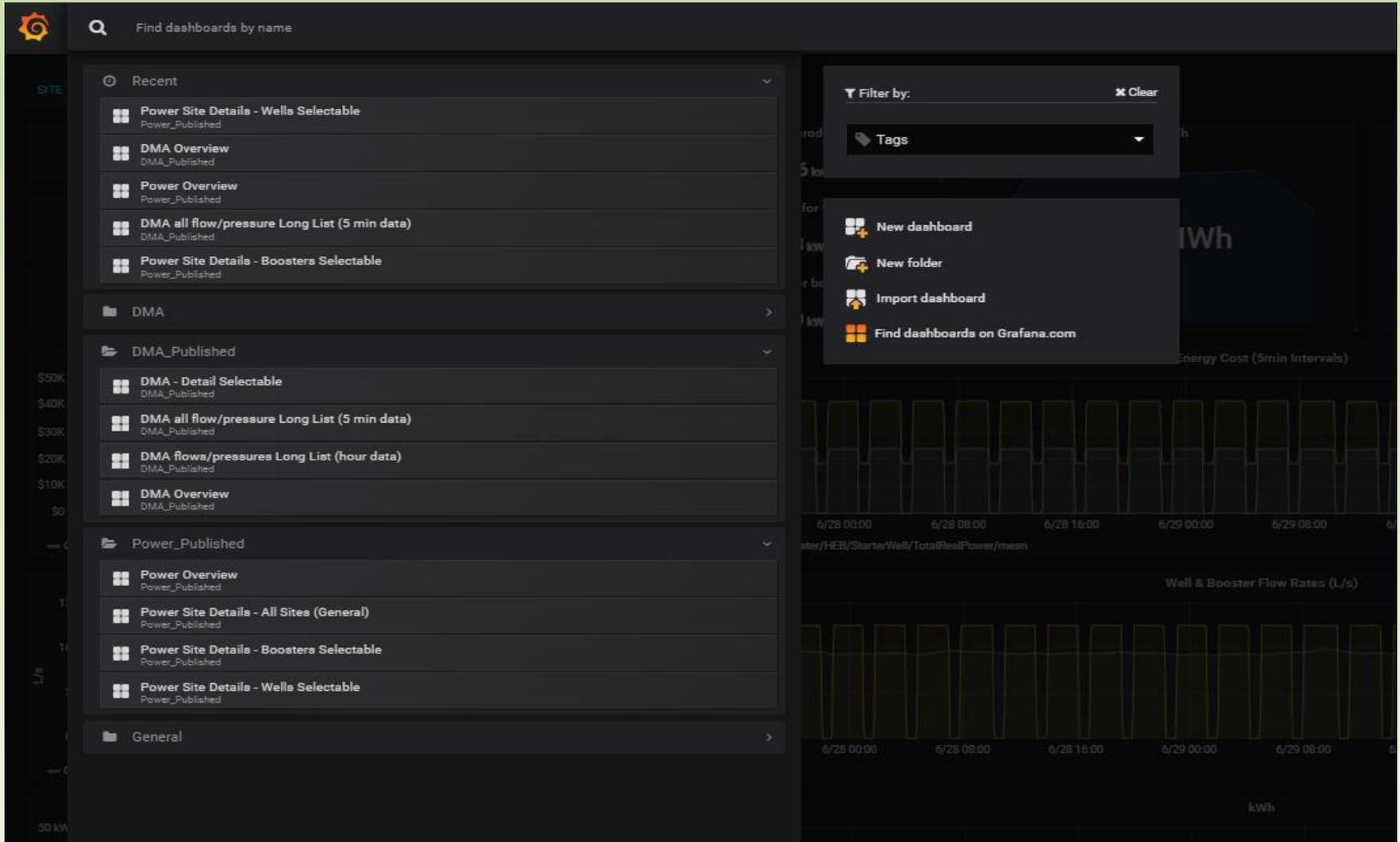


Direct Query Tool: Woods Pump Starts



**In-Rush Current
of Pump Starting**

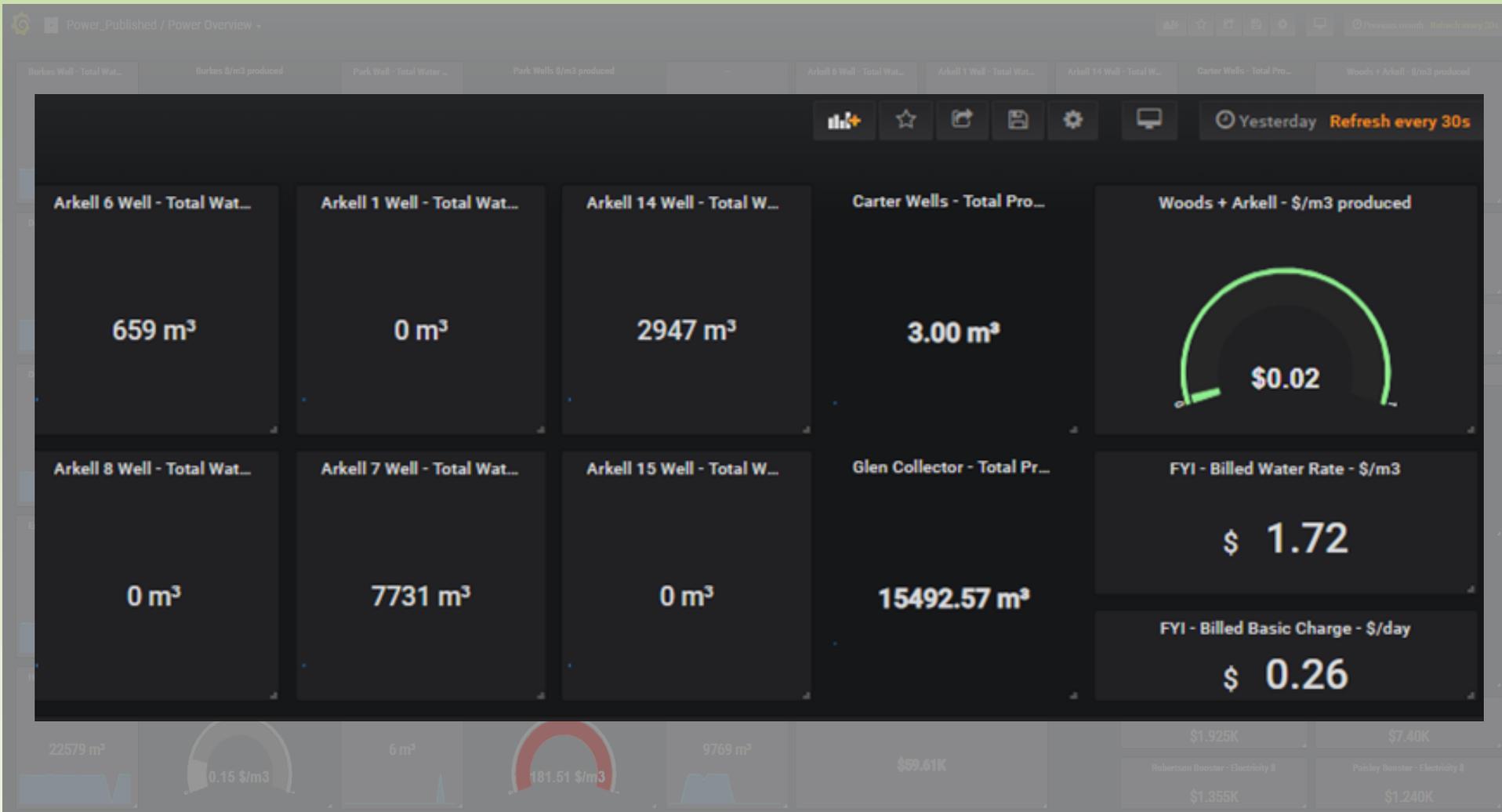
Grafana web-based Dashboarding Tool



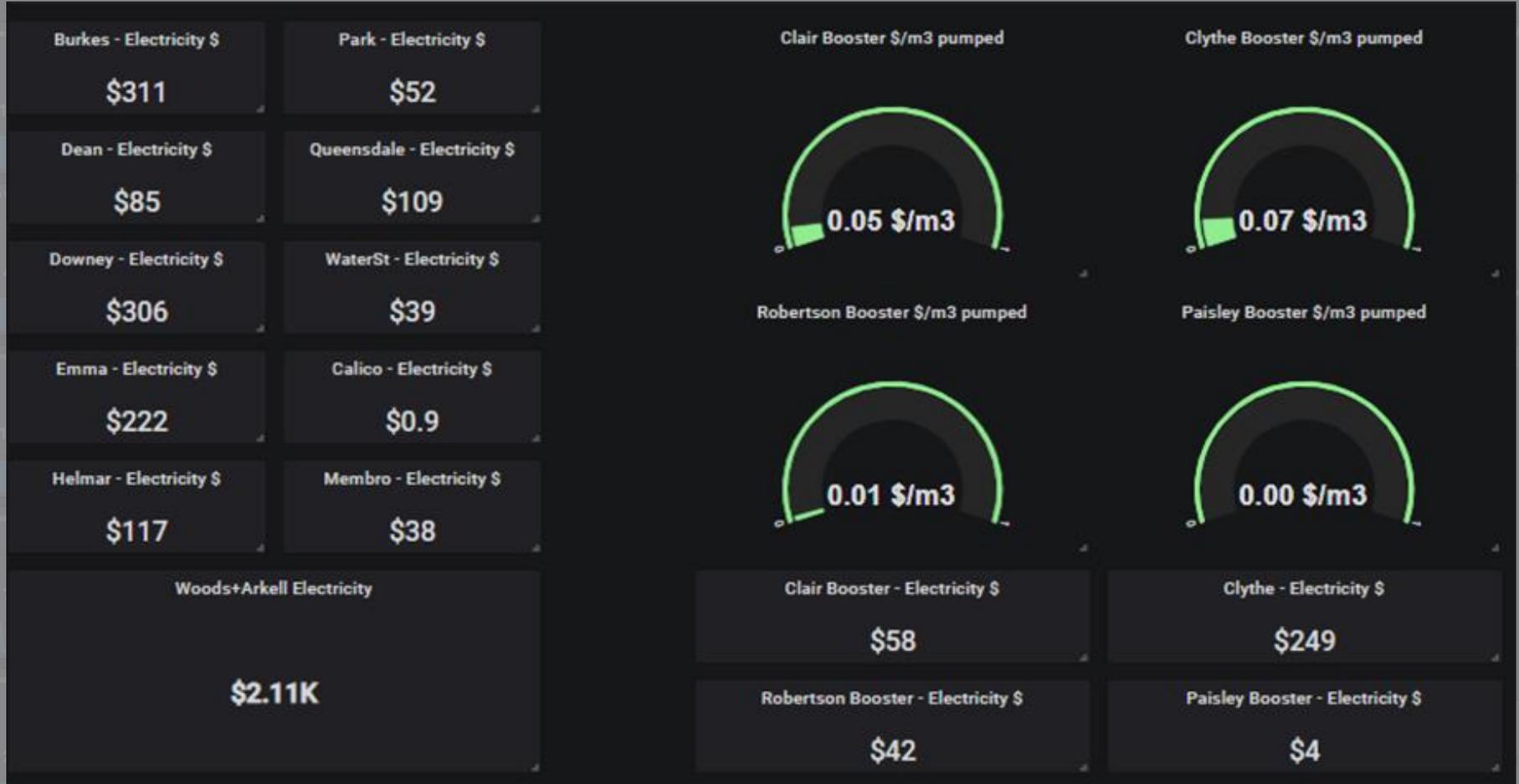
Power Overview Dashboard



Power Overview Dashboard



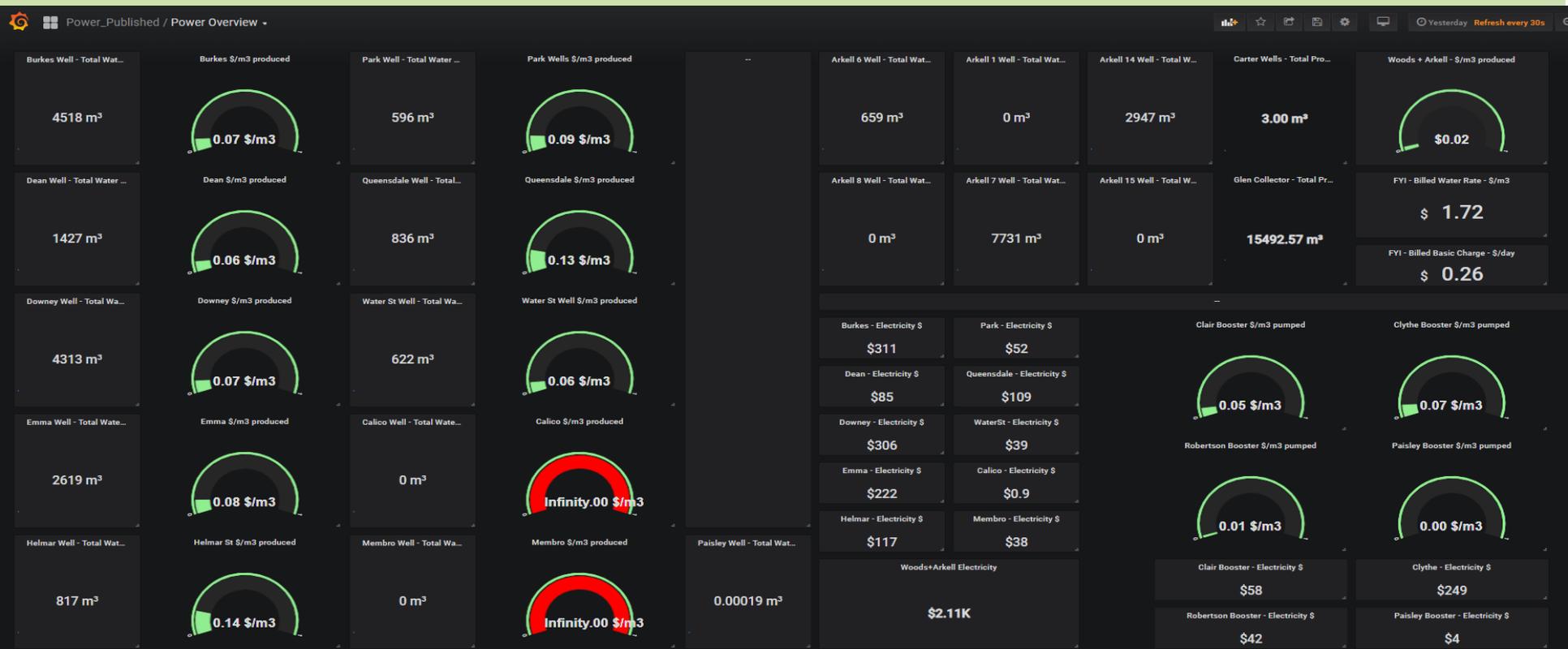
Power Overview Dashboard



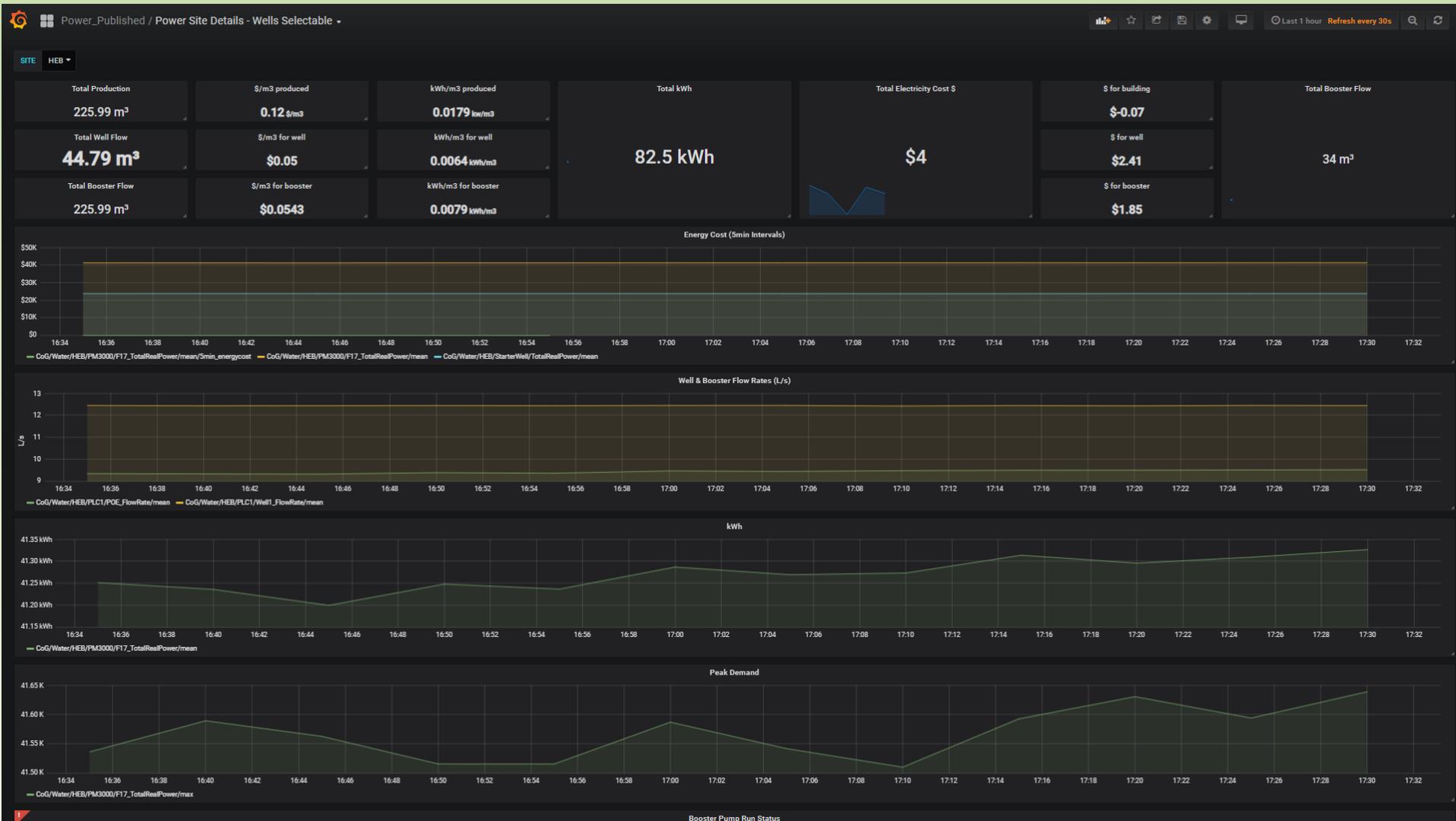
Power Overview Dashboard



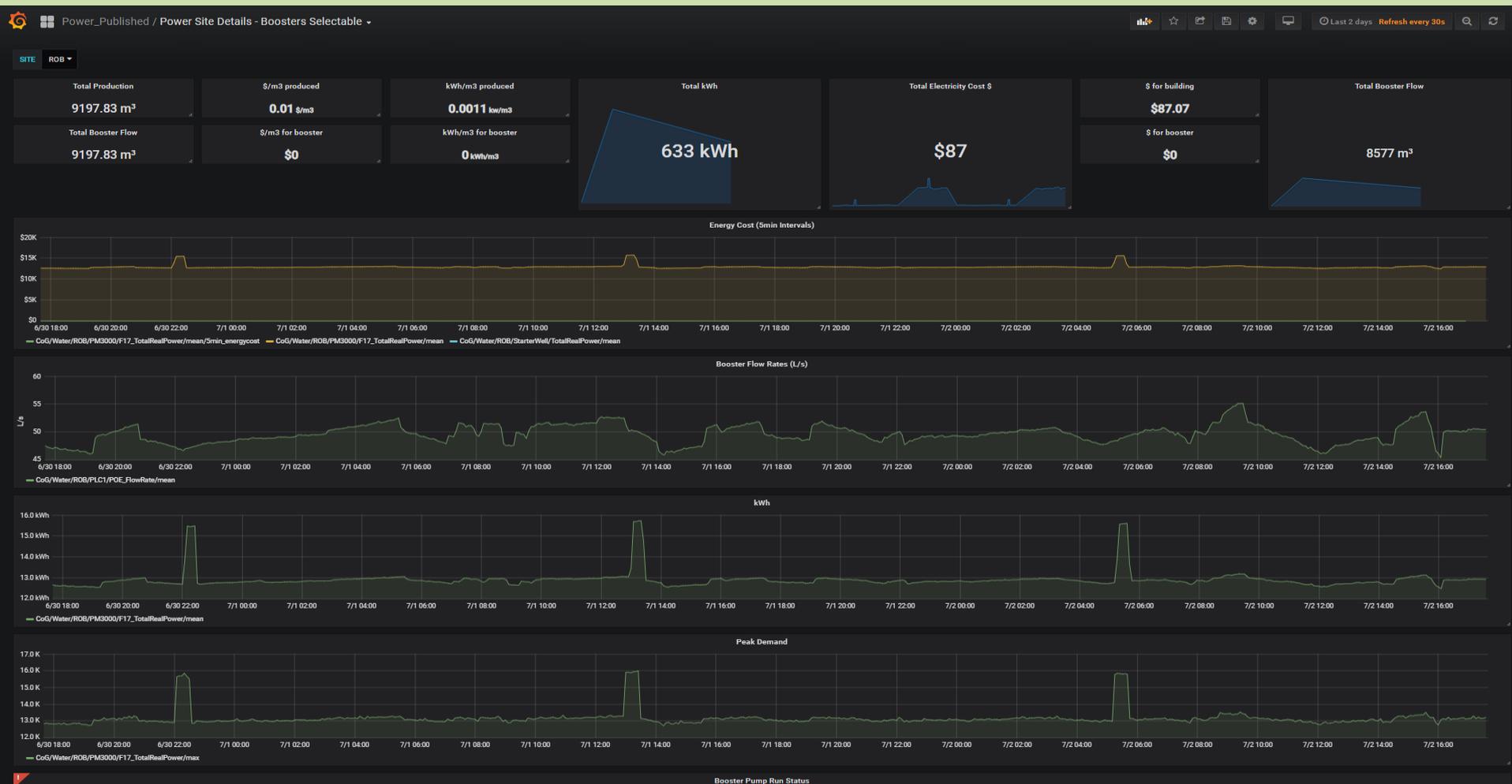
Power Overview Dashboard



Site Detail - Helmar Well (1hour)



Site Detail– Robertson Booster (2 days)



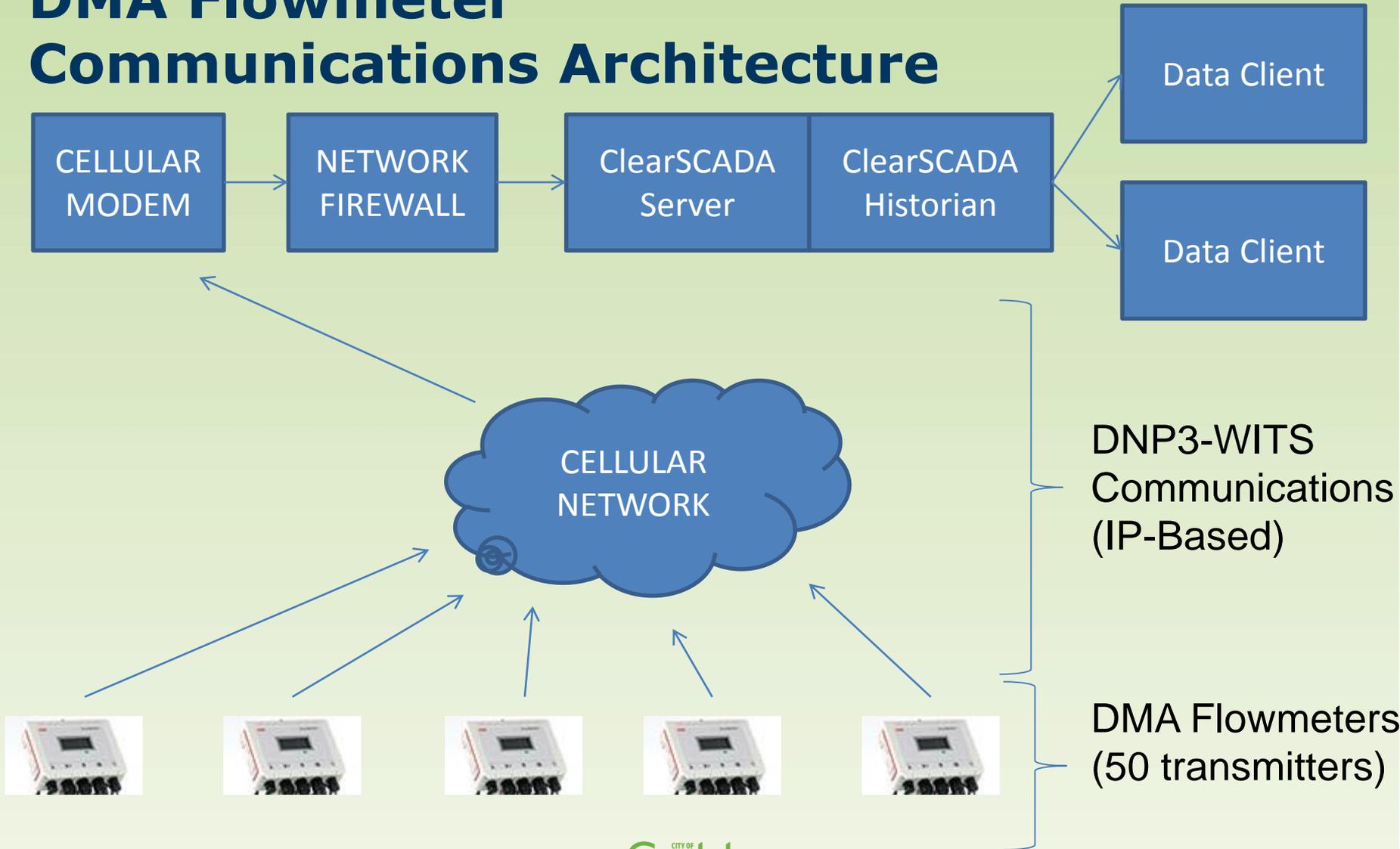
Site Detail– Robertson Booster (30 days)



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

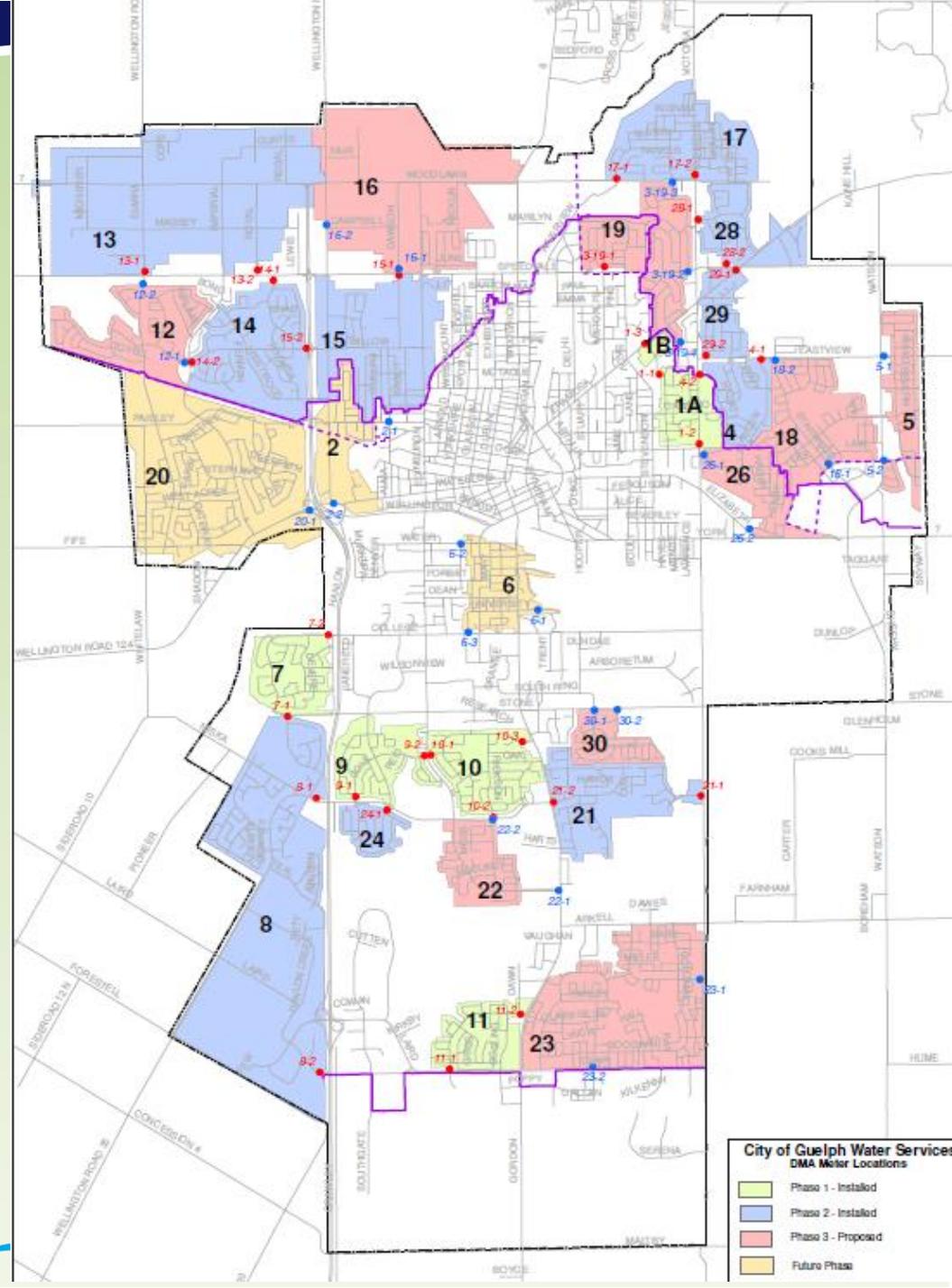


DMA Flowmeter Communications Architecture



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



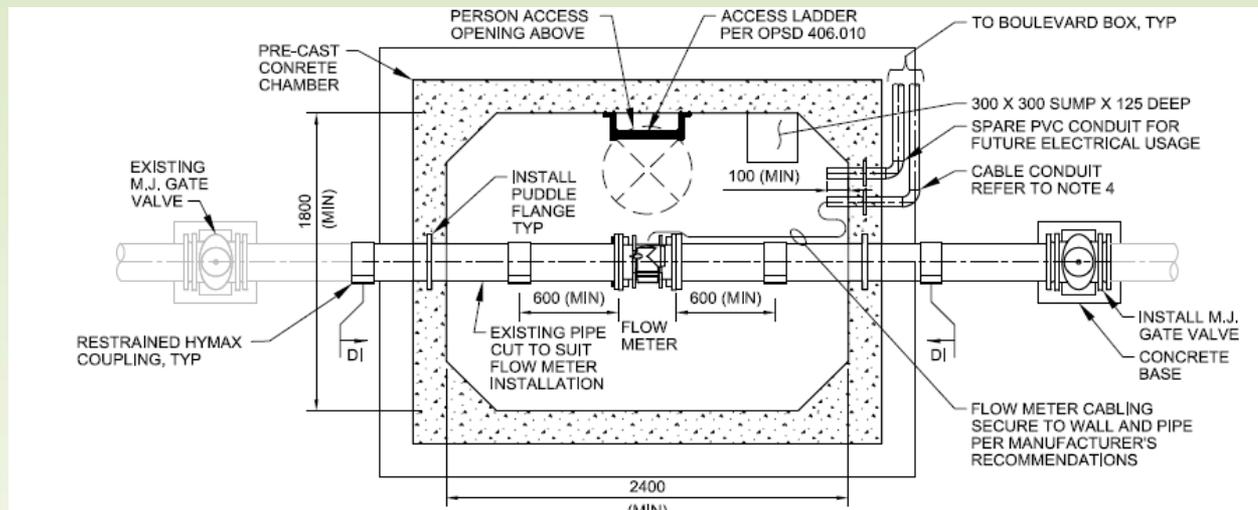
District Flow Meters

- 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



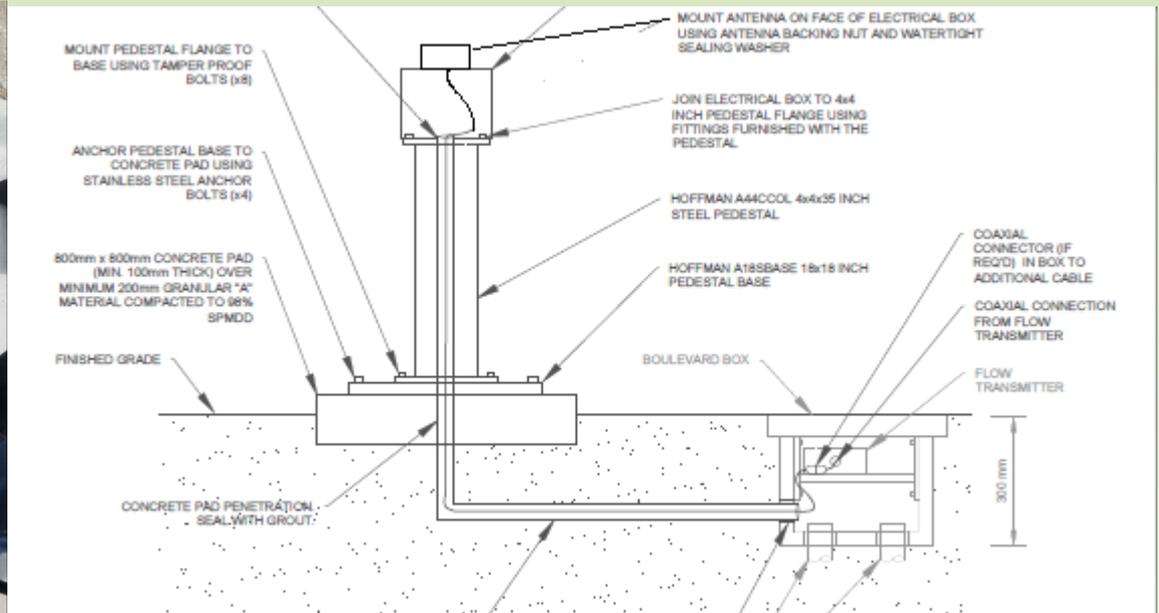
Flowmeter Chambers

- 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

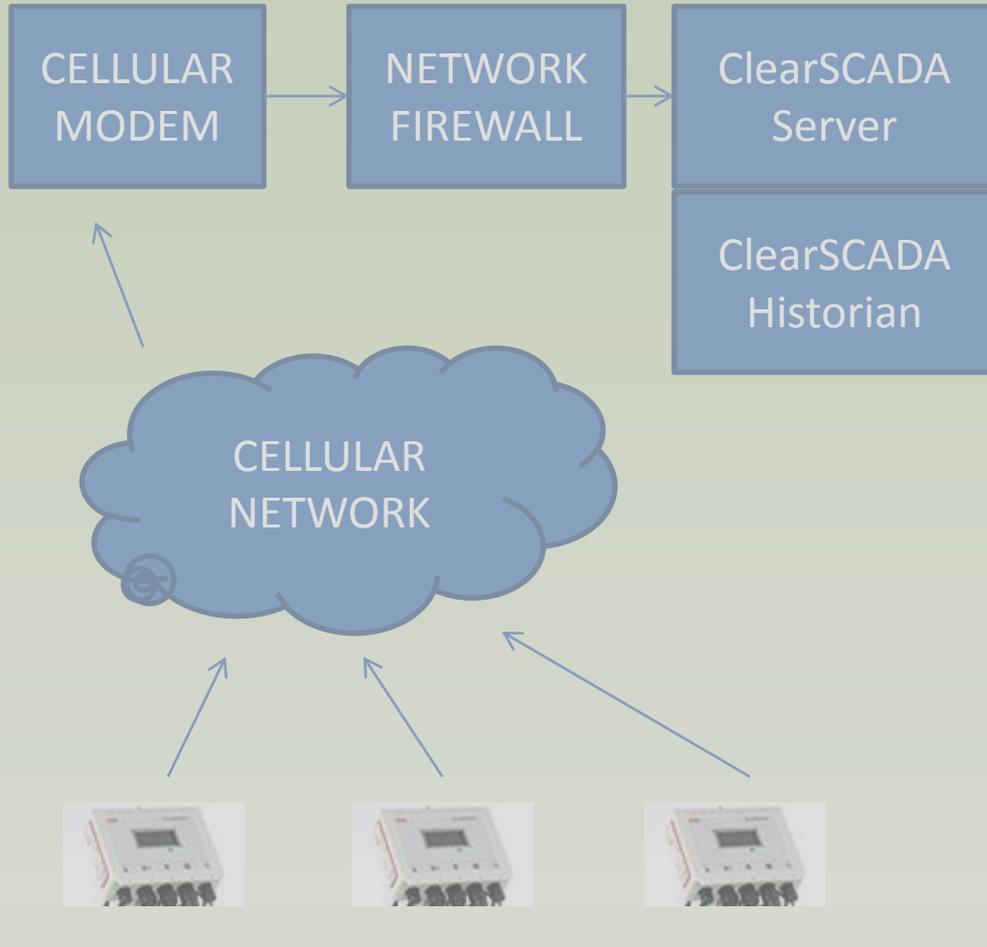
- Flowmeters installed into boulevard boxes
- Antenna pedestals to mount cellular antennas on





Applying Neptune to DMAs

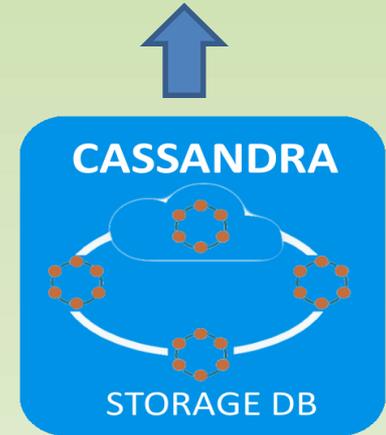
Existing SCADA Infrastructure



Web-based
Dashboard
& Reporting
Tool



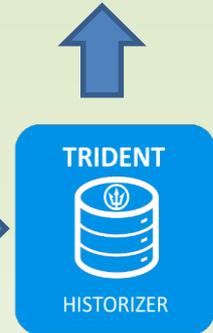
Distributed
Open
Source
Database
(no licensing fees)



Hourly
Data Sync
Script



Pushes to
Historizer
Server



Pushes to
Time Series
Database

Neptune Hourly Data Sync Scripting

The screenshot displays a Node-RED dashboard for a flow named "ClearSCADA ETL". The flow starts with an "inject" node, followed by an "http request" node, a "json" node, and a "change: 2 rules" node. A "Runs Every Hour" trigger is connected to the inject node. The flow then branches into two paths. The upper path includes a "query historical data for specific tag and time range (returns max 40000 records)" node, a "delay 500ms" node, and a "parse data" node. The lower path includes a "timestamp" node, a "get all the tags to pull data for" node, a "change: 3 rules" node, and a "catch (1)" node. Both paths converge at a function node "f". From the function node, the flow goes to a "set msg.payload" node and a "change: 2 rules" node. A "Midnight backfill" trigger is connected to the "timestamp" node. The flow ends with a "msg" node and 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)".

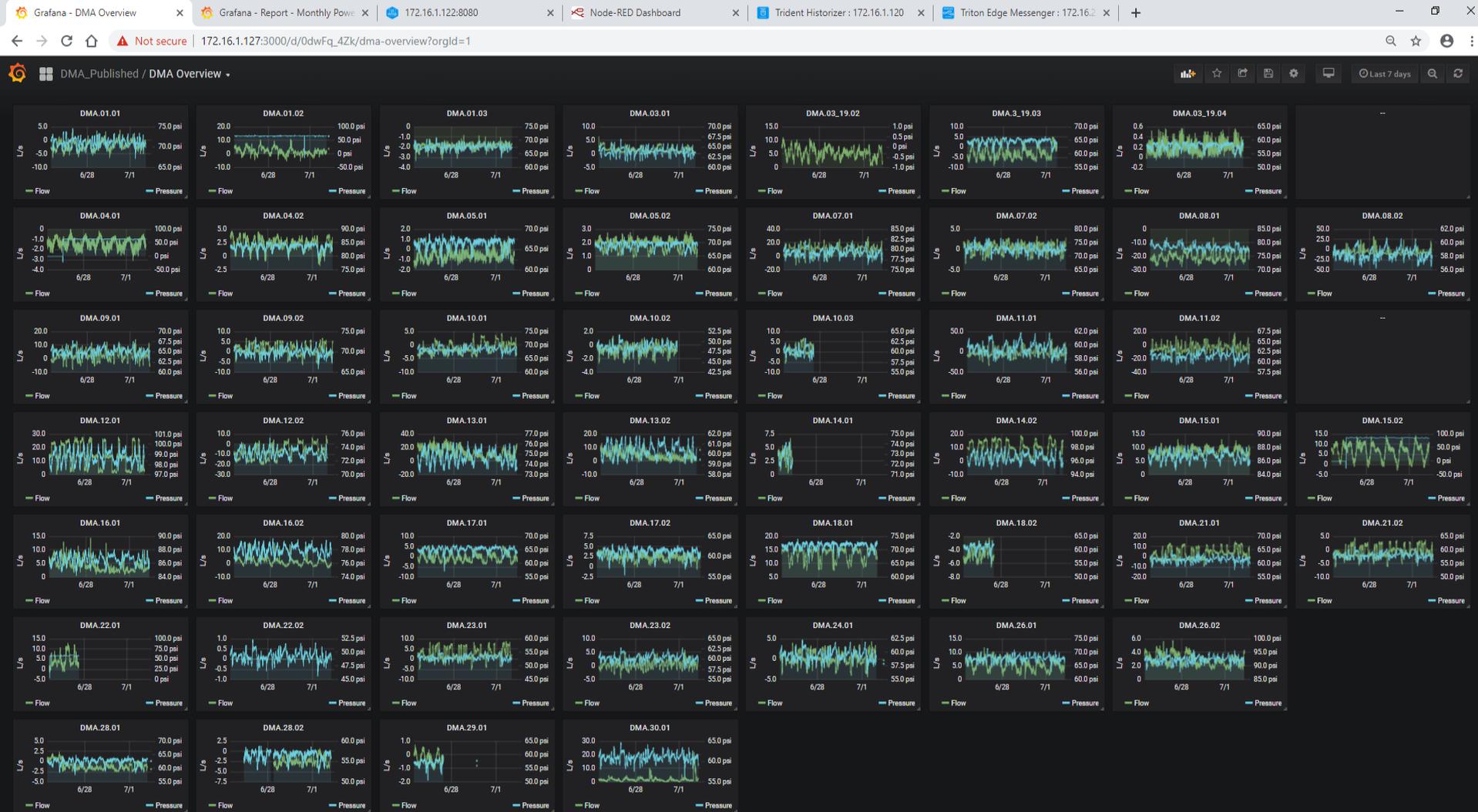
Flow Information:

Property	Value
Name	ClearSCADA ETL
ID	"3786ddf3.2ca782"
Status	Enabled

Information

Show the Info tab with `ctrl-g i` or the Debug tab with `ctrl-g d`

DMA Dashboard



DMA Dashboard – showing last 7 days



DMA Dashboard – showing last 30 days



DMA Dashboard – or last 2 days



DMA Dashboard – Detail View



DMA Dashboard – Individual Flowmeter



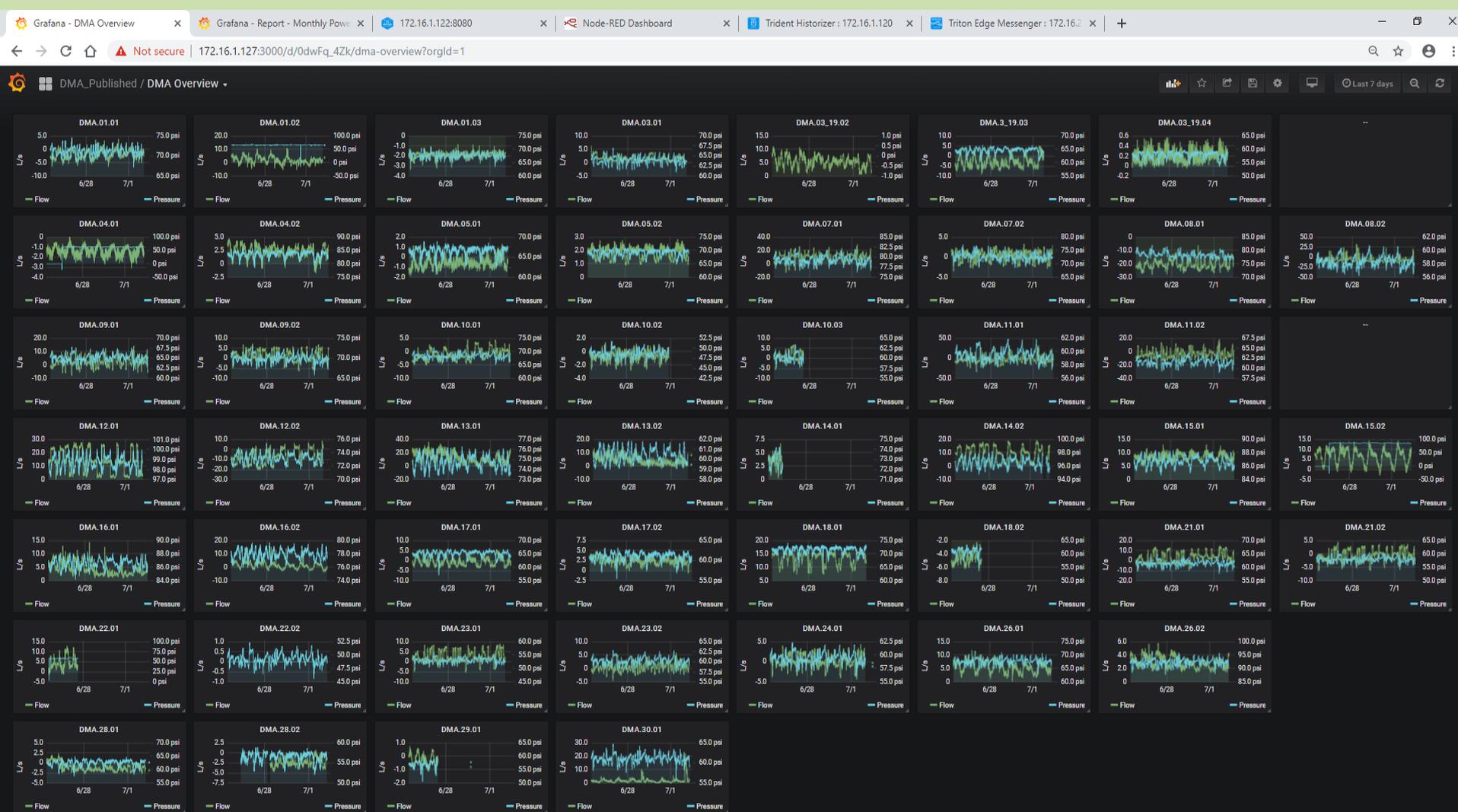
DMA Dashboard – Setting up Email Alerts

The screenshot displays a Grafana dashboard titled "DMA_Published / DMA flows/pressures Long List (hour data)". The main chart shows a line graph for "A-series" with a red horizontal threshold line at 45. The x-axis represents time from 13:50:30 to 13:55:00. The y-axis represents flow/pressure values from 0 to 60. An alert configuration panel is overlaid on the chart, showing the following settings:

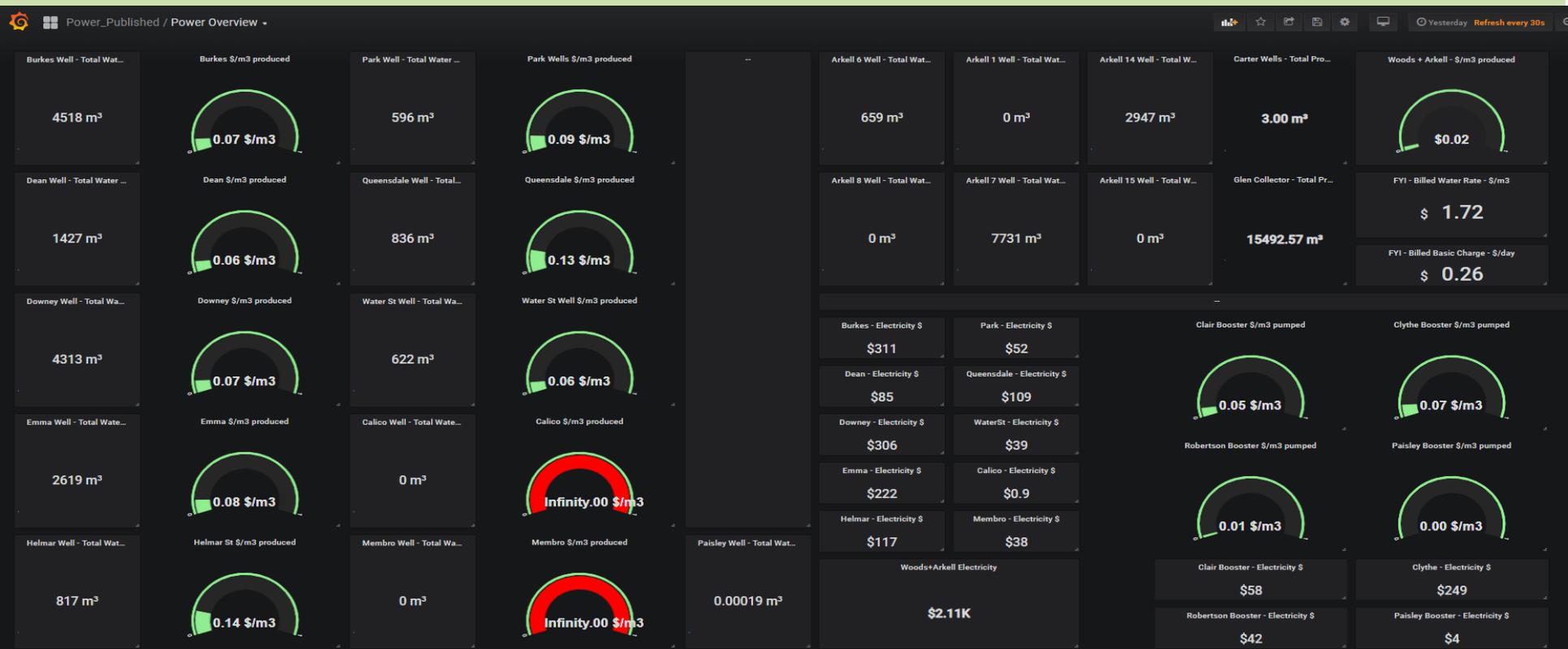
- Alert Config:** Name: High Flow, Evaluate every: 1hr
- Notifications (1):** (One notification is listed)
- State history:** (History is visible)
- Delete:** (Delete button)
- Conditions:** WHEN avg () OF query (A, 5m, now) IS ABOVE 45
- SET STATE TO:** No Data

The dashboard also features several smaller line graphs on the left and right sides, each showing different DMA flow/pressure data over time.

DMA Dashboard



Power Overview Dashboard



Next Steps

Power Usage Dashboards

- Has been gathering data for past 12 months
- Final testing and adjustments in progress
 - Some tweaking still left to do
 - Automatic PDF email reports feature still under development (initial testing done)
 - Install work for network connections to existing Pump Motor Starters is in progress
- Next Steps
 - Mount display in Woods hallway as a realtime energy dashboard
 - Making Data-query web-interface accessible to Water Services staff (via desktop)
 - Making Grafana web-interface available to make dashboards for Water Serv. staff

DMA Flow & Pressure Dashboards

- All DMA flowmeter flow/pressure hardware issues resolved as of Jun 28, 2019
- Each flowmeter pushes data to server very approx. 6 hrs, longer if poor weather/signal
- Five meters need site visits every 2 weeks to push data (upgrades in 2020 should fix)
- Final testing and adjustments in progress
 - Some tweaking of dashboards & reporting tool still left to do
 - Selecting criteria to test out email alert feature (e.g. high flow rates) and testing
- Next Steps
 - Mount display in Woods hallway near Distribution Ops as a realtime dashboard
 - Making Data-query and Grafana web-interface available to Water Services staff