Smart Water Network and IoT Systems

Adelaide
South Australia

Dr Mark Stephens

Government of South Australia

SA Water

Example Value Proposition:

Acoustic Alerts for Proactive Main Break Repair

Government of South Australia

SA Water

Adelaide CBD Water Network IoT – why and what?

Transient/hydrophone logger

Water quality logger

Acoustic (accelerometer) loggers

Smart customer meter

IoT framework

Smart City Sensor Grid

DATA CONNECTIVITY

- LPWan
- 3G/4G

DATA STORAGE

- Operational Data Store (ODS)
- Enterprise Data Warehouse (EDW)

DASHBOARD AND REPORTING

- Microsoft BI
- Geospatial Services
- Smart Water Analytics

ANALYSIS

- Smart Water Analytics
- Machine Learning

PREDICTIVE

- Smart Water Analytics

TAKE ACTION

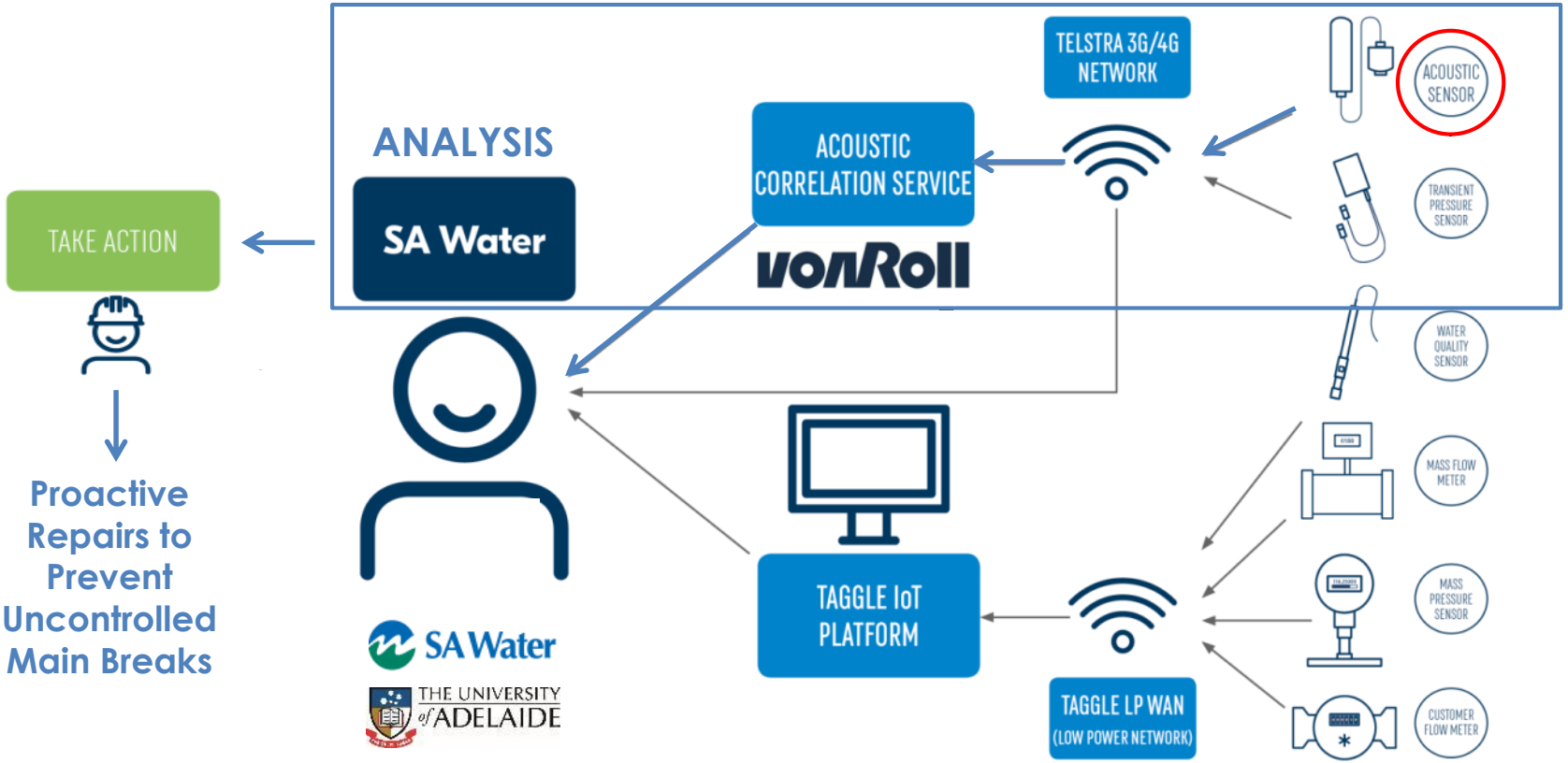
- Acoustics
- Smart Meters
- MicroSpiders
- Water Quality

NB-IoT

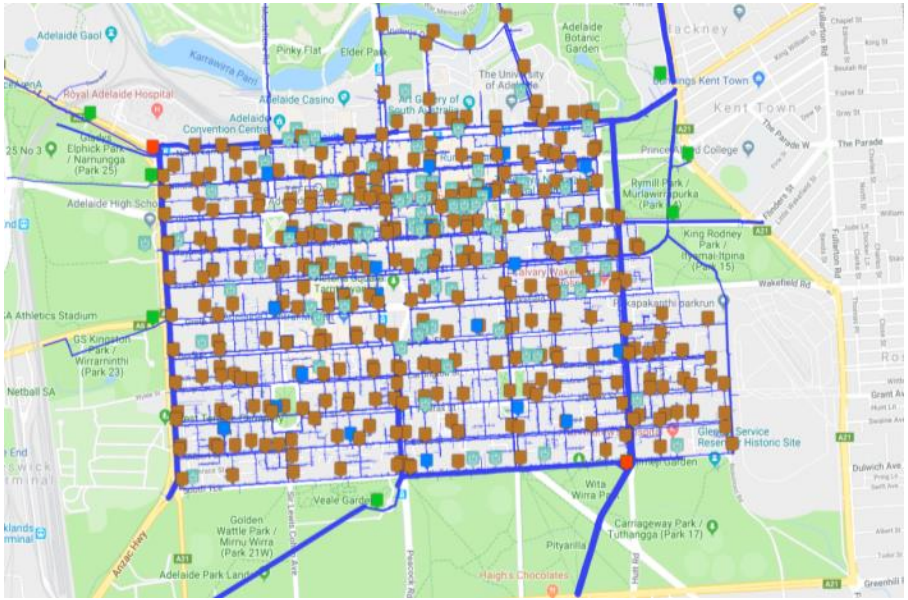
sigfox

WizeAlliance

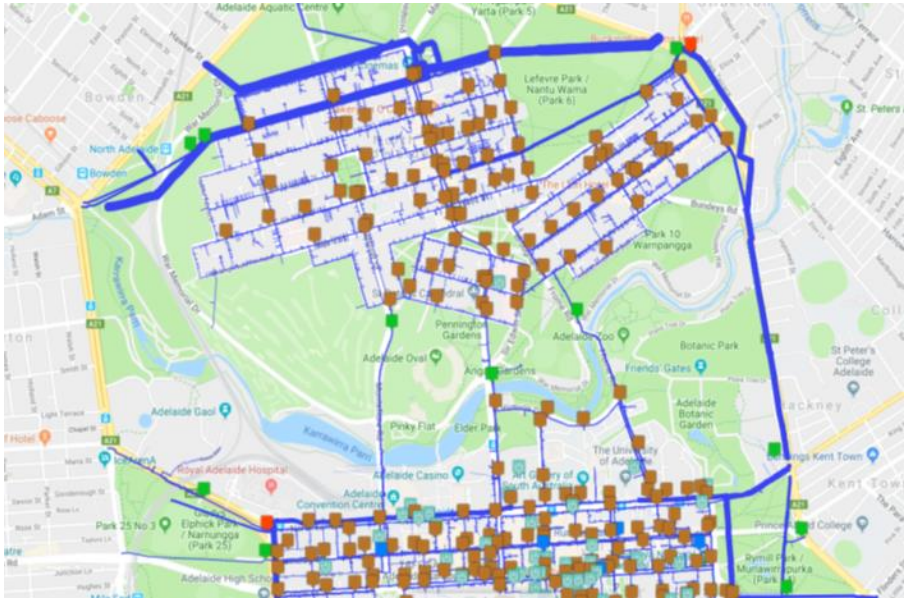
Detecting main breaks



The sensor network: current and future



Adelaide CBD Smart Network Sensors

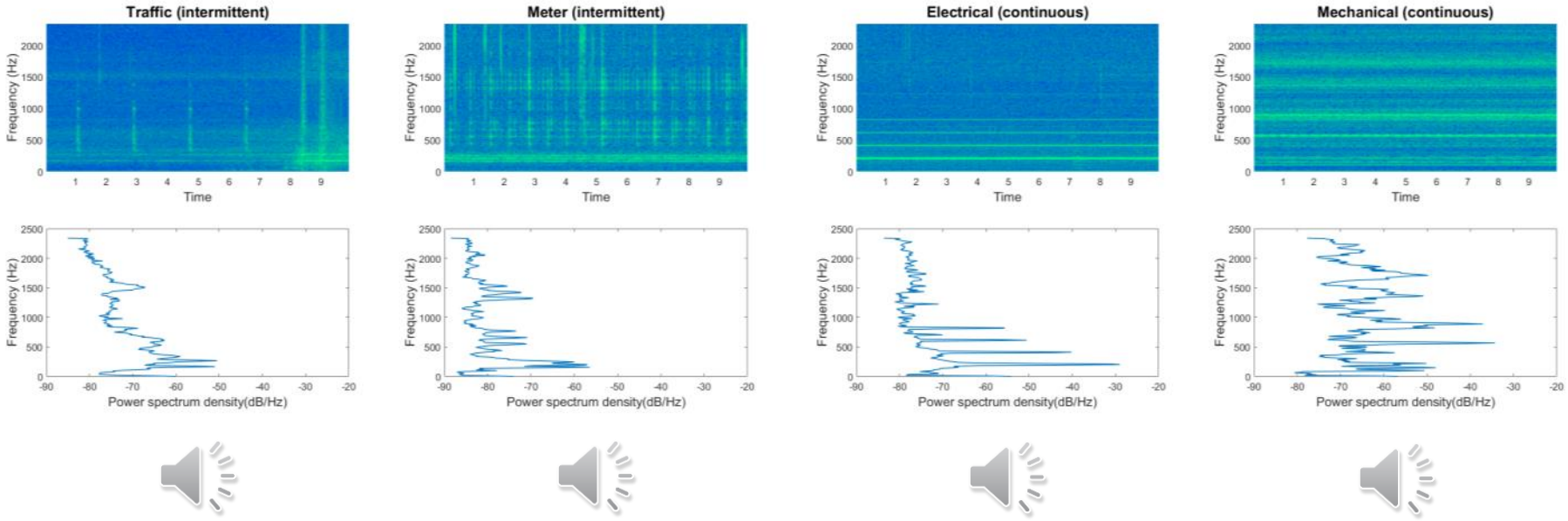


North Adelaide Smart Network Sensors

300 active acoustic loggers in the Adelaide CBD.

Out of 126km of pipes, loggers concentrate on those with a higher failure risk and impact.

Understanding environmental noise



We hear many forms of significant and ongoing environmental noise.

Understanding what ‘typical’ acoustic signatures look like, and noises sound like, is key.

Identifying faults

Fault patterns and features are being identified, including for cracked pipes, leaking valves, leaking water meters and/or leaks on the customer side of water meters.

‘Faults of interest’ are based on noise:

- Persistency
- Magnitude
- Frequency
- Changes
- Rate of change

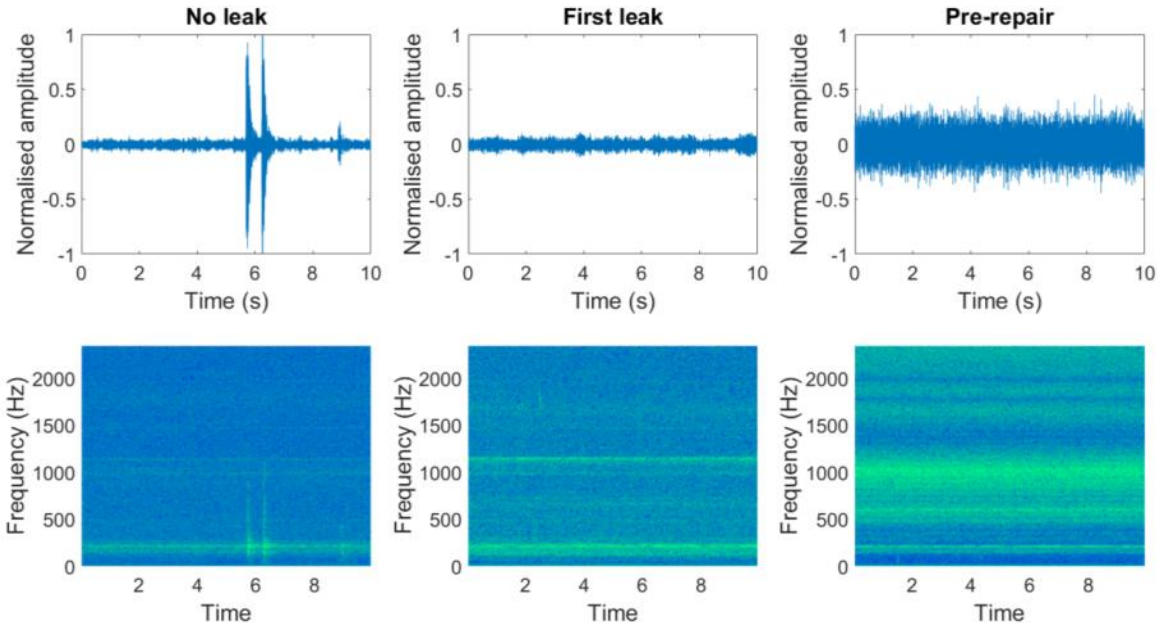
Circumferential Crack

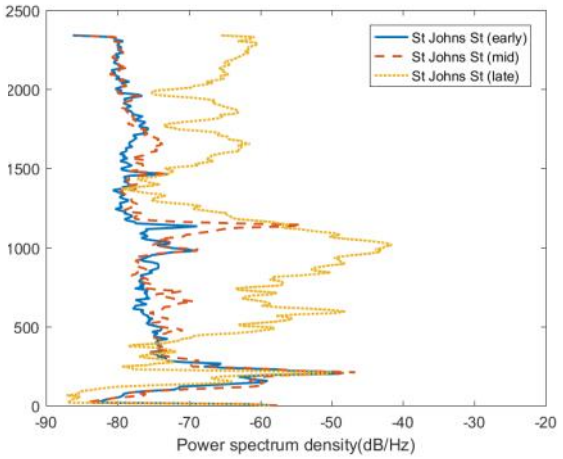
Longitudinal Crack

Type and status of a crack can now be identified in a number of cases.

Helps us assign the urgency for repairing it.

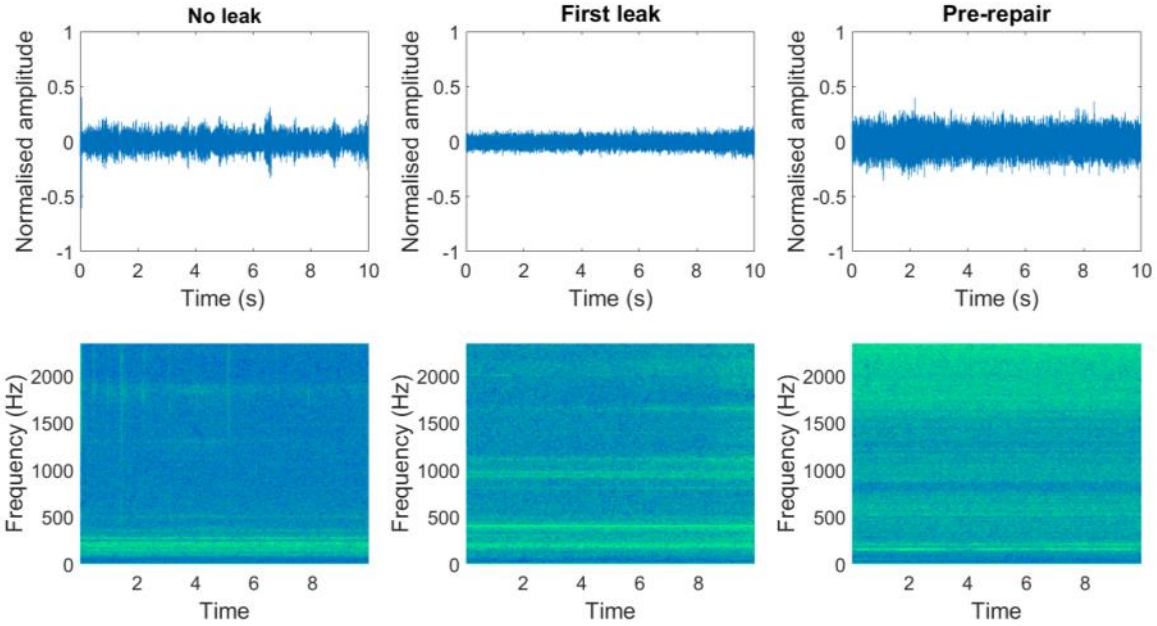
Circumferential cracks

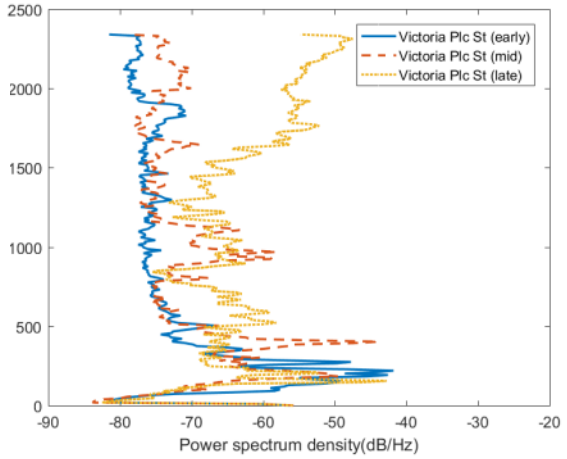




Typical: significant initial magnitude which remains relatively stable until repair.

Longitudinal cracks





Typical: small initial magnitude which increases in an unstable manner until repair.

Proactive versus reactive repairs

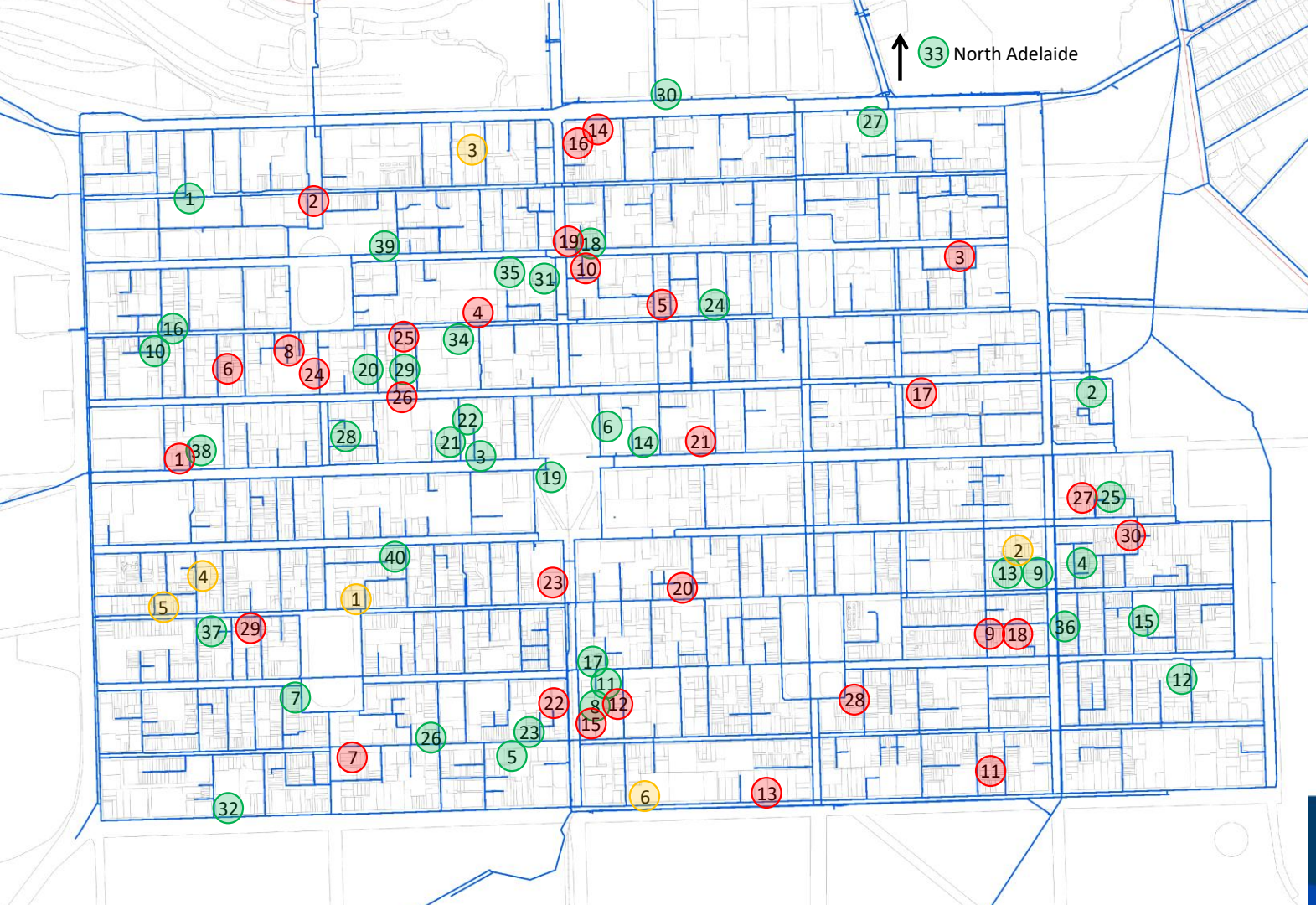
Proactive night repair King William

Reactive day repair Grenfell St

Third party services

Completed with less cost and customer disruption.

Enable third party infrastructure to be better managed.



July 2017 to March 2019

36 reactive repairs

40 proactive repairs

Based on an audit of all 76 events there has been a 24% repair cost and 35% supply interruption time reductions for the proactive repairs.

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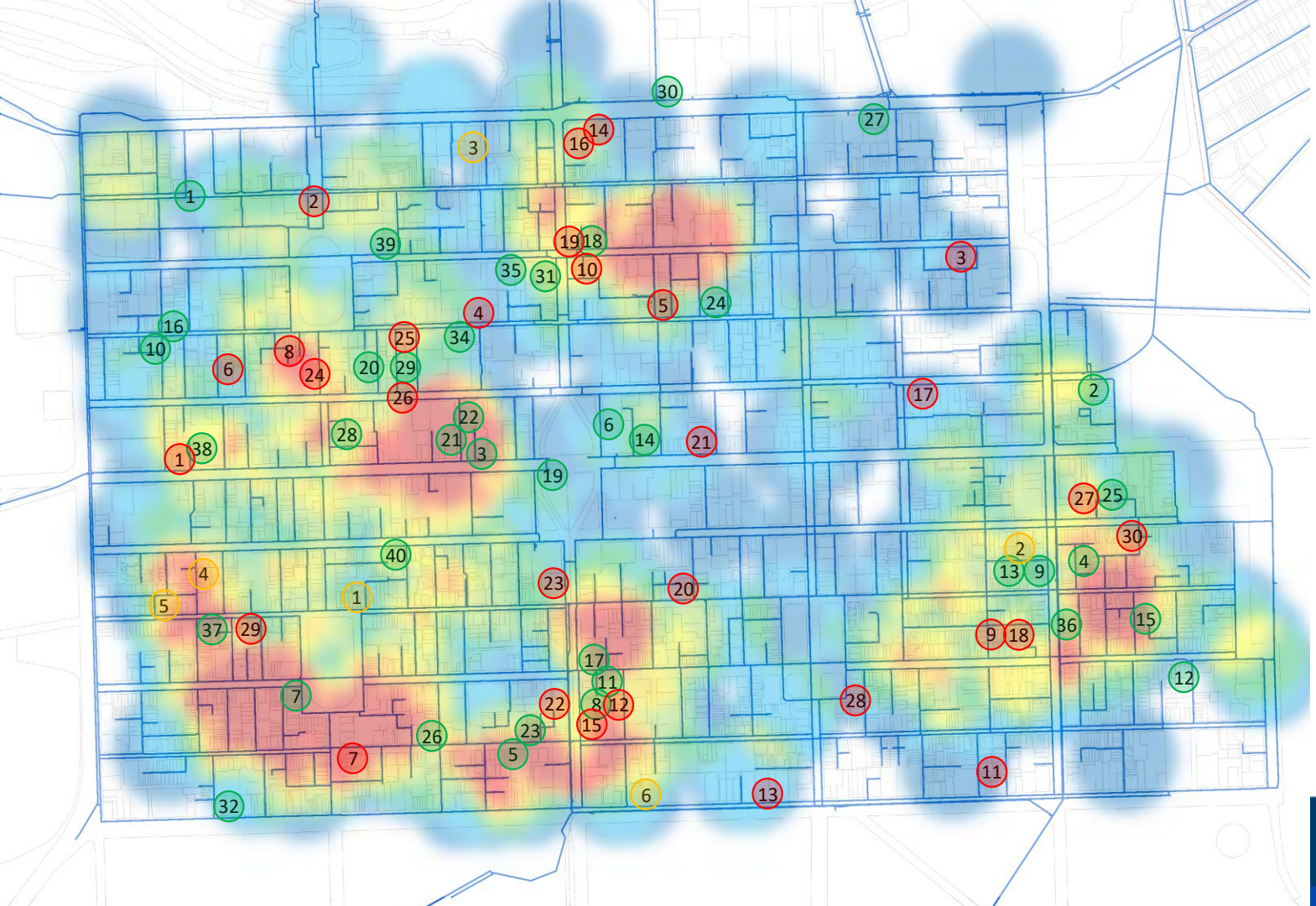


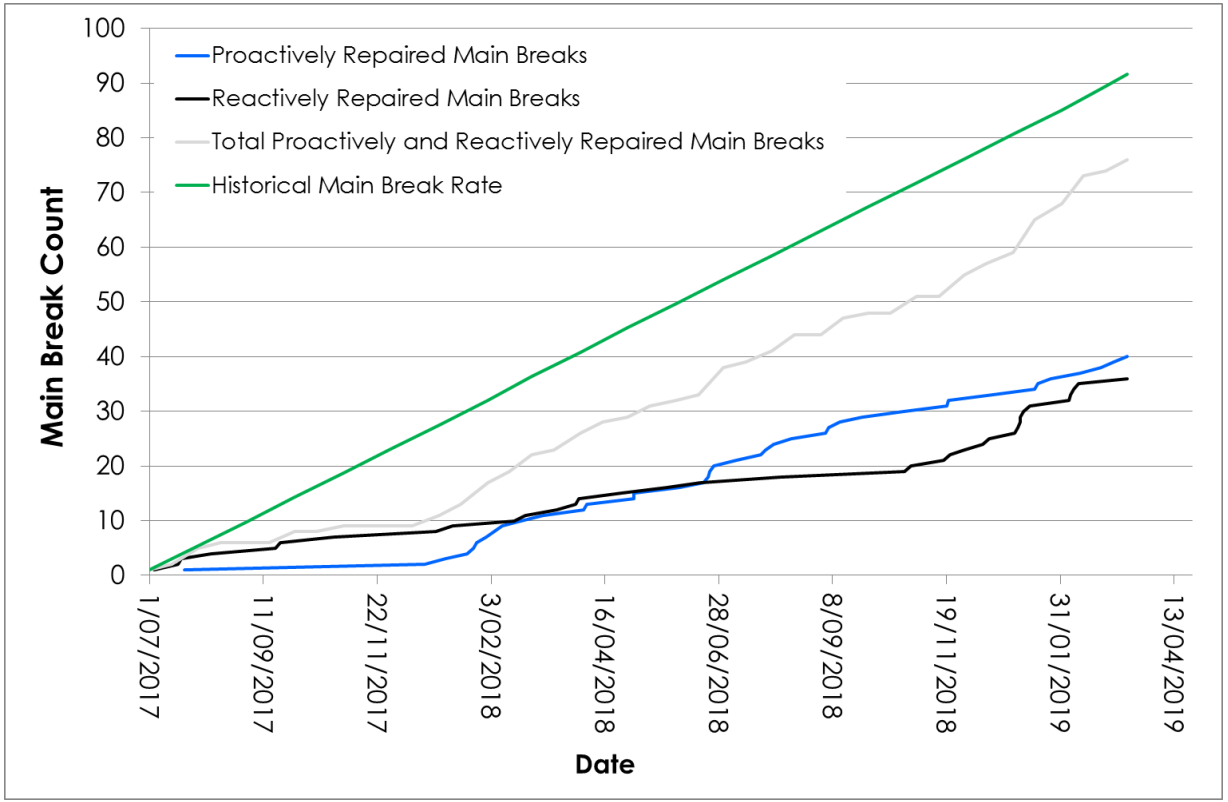
July 2017 to March 2019

Total 76 repairs

10 year main break heat map

SA Water

Results – main breaks



Ten year main break average for the Adelaide CBD varies from four – five per month.

Total main breaks since 1 July 2017 follows the ten year main break rate.

Proactive repairs (currently 52 per cent, at end March 2019) exceed reactive.

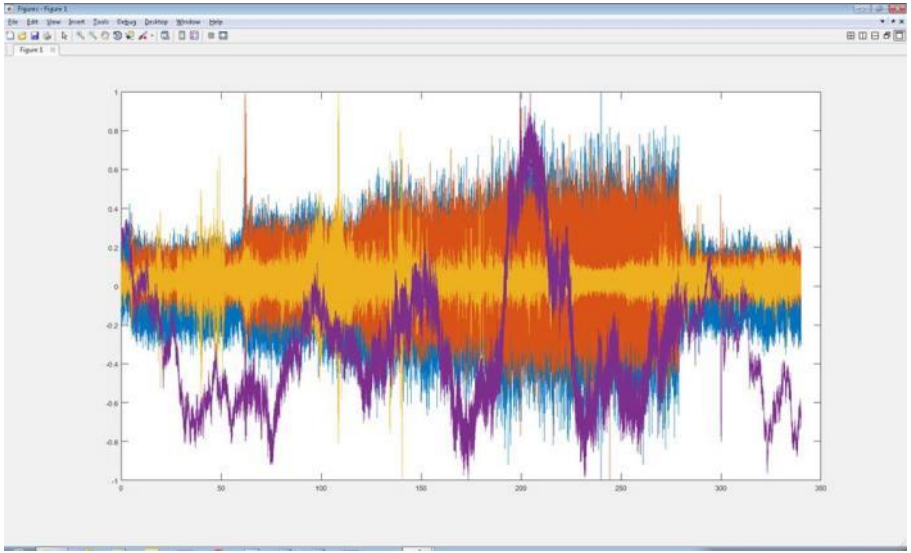
More data & analytics?

Future goals:

- more accurate alerts (in terms of leak location and identification of fault type)
- extending sensor cover and optimising placement (system risk profile)
- issue alerts as near to real time as possible (by separating environmental noise)

Improvements:

- fully test next generation sensors/DAQ
- complete noise filtering systems
- complete fully automated analytic algorithms



IoT (Internet of Things) Acoustic Alerts Analytics

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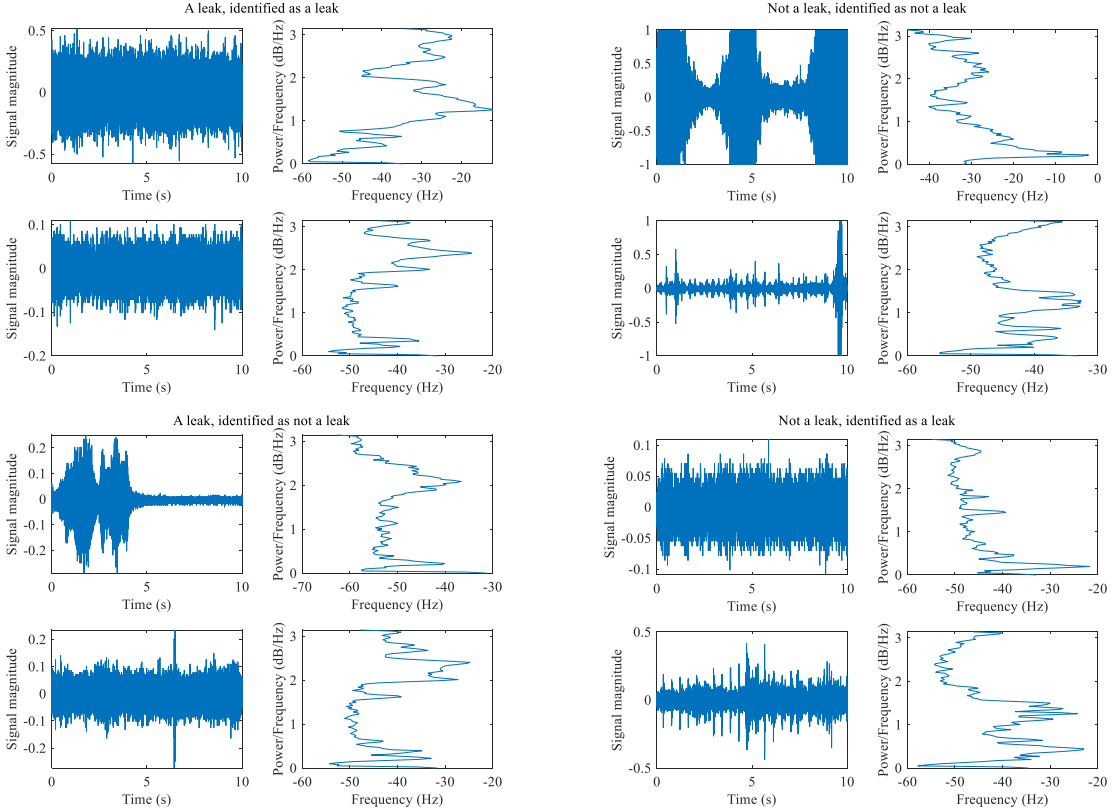
Noise Classification – Leaks (and non-leaks)

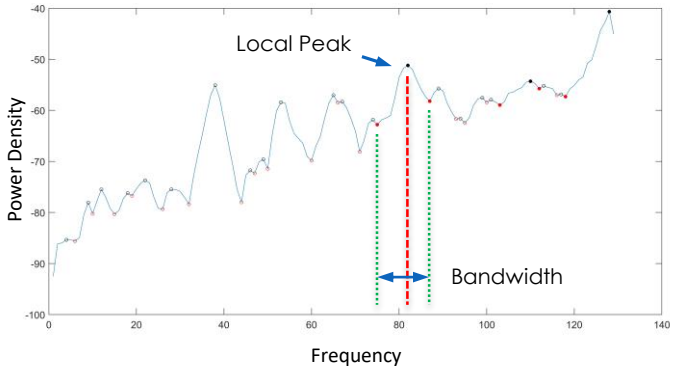


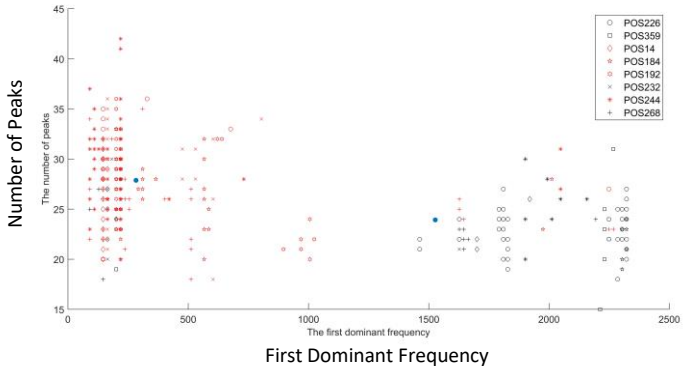
In the case of the SA Water Adelaide CBD Smart Water Network, over 200,000 noise files have been captured.

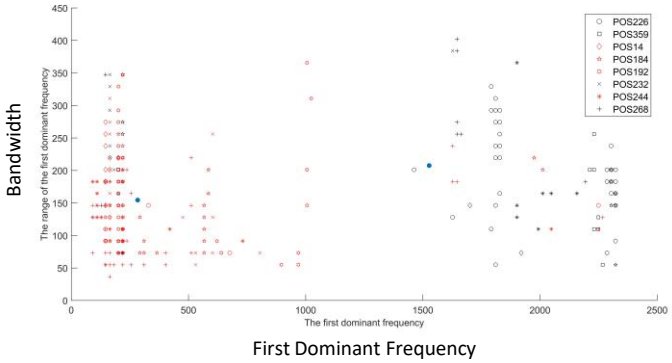
Many examples of noises not associated with cracked pipes are available for training.

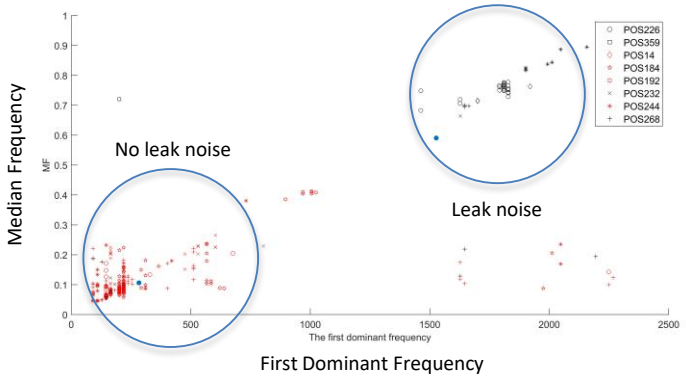
Similarly, many examples of noises that are associated with cracked pipes are available for training.

Noise Classification – Feature Identification







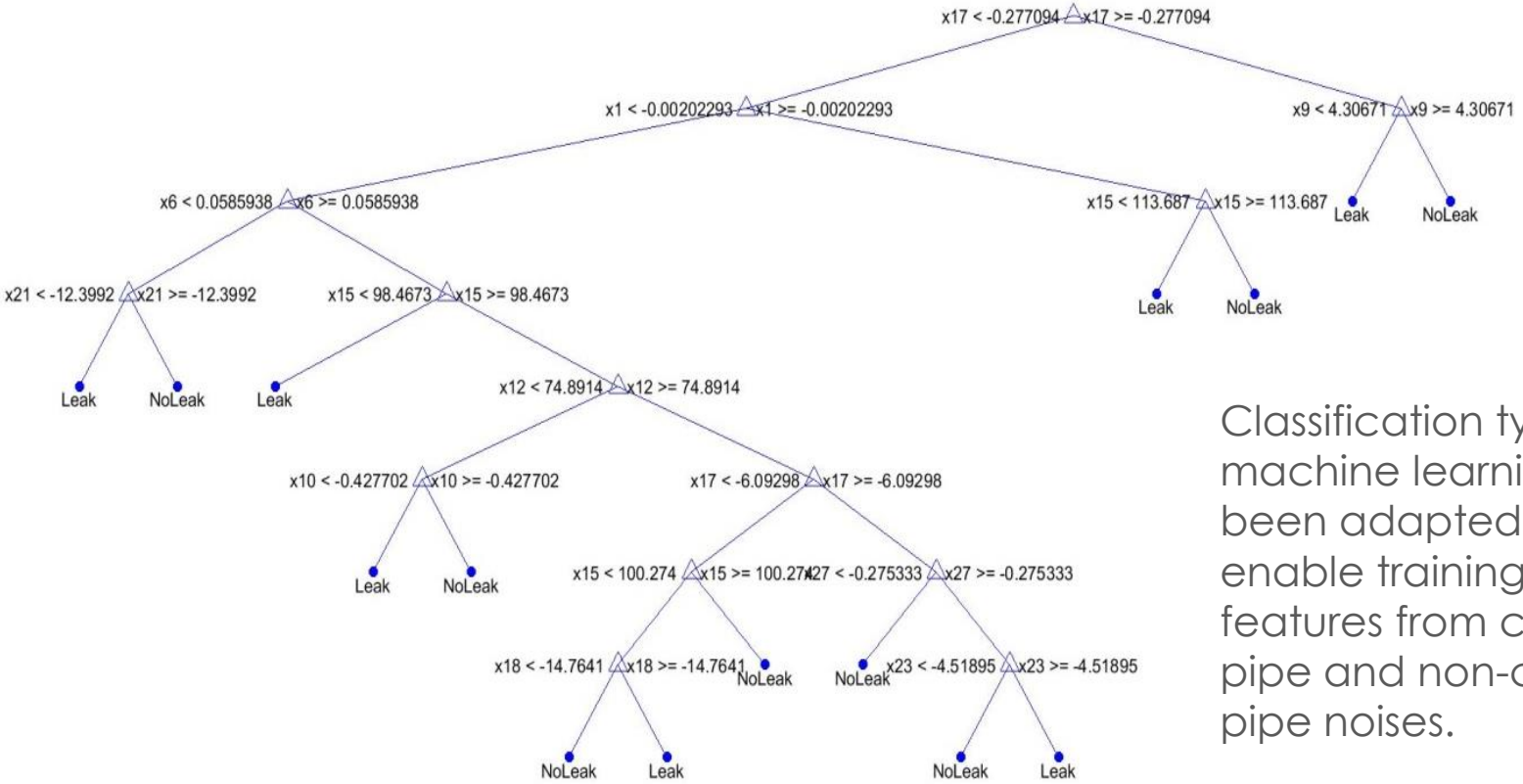


Customised features have been identified in the noise which are indicative of leaks and other forms of noise.

Features include:

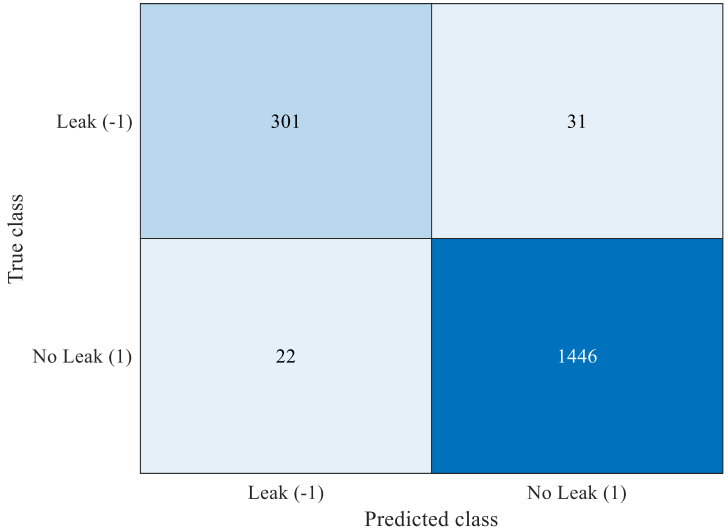
- Number of peaks
- Bandwidths
- Median frequency (MF)

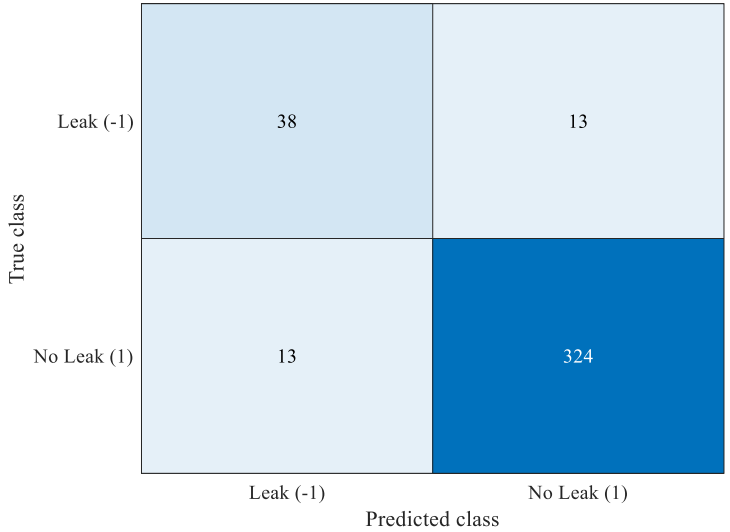
Classifier – Machine Learning the Noises



Classification type machine learning has been adapted to enable training to key features from cracked pipe and non-cracked pipe noises.

Results of Training (and then Testing)

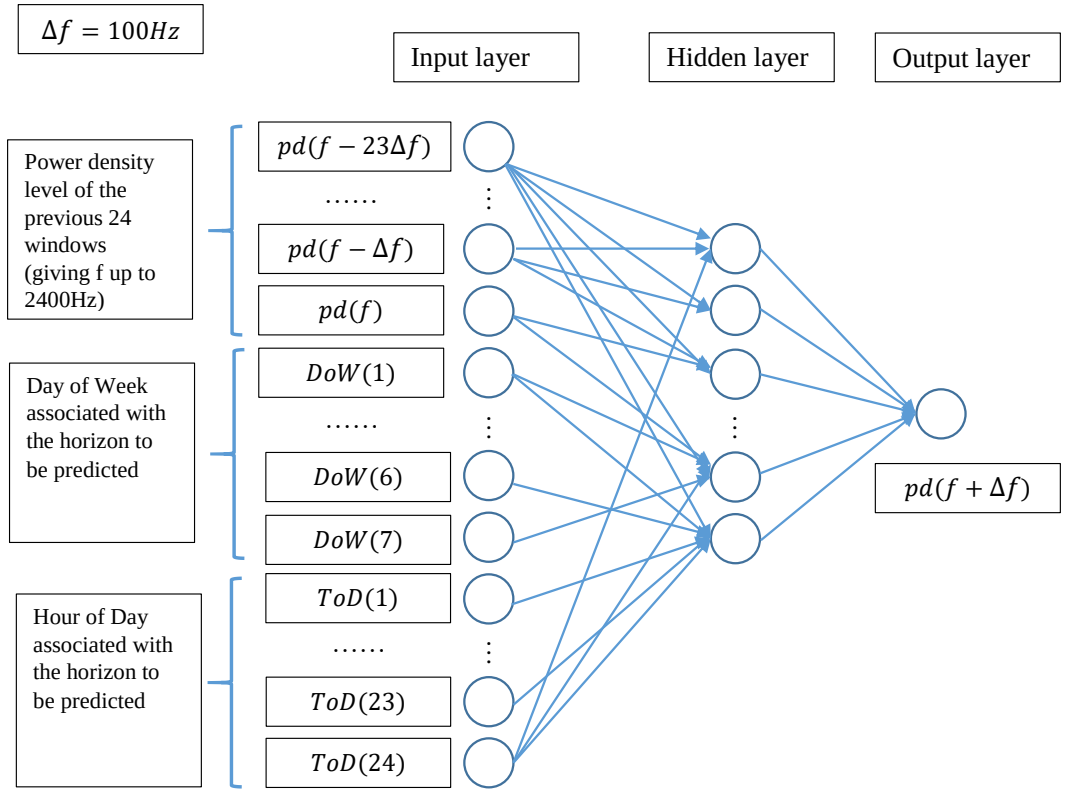




The left hand side confusion map shows a 90.7% true leak and 98.5% true no-leak training outcome.

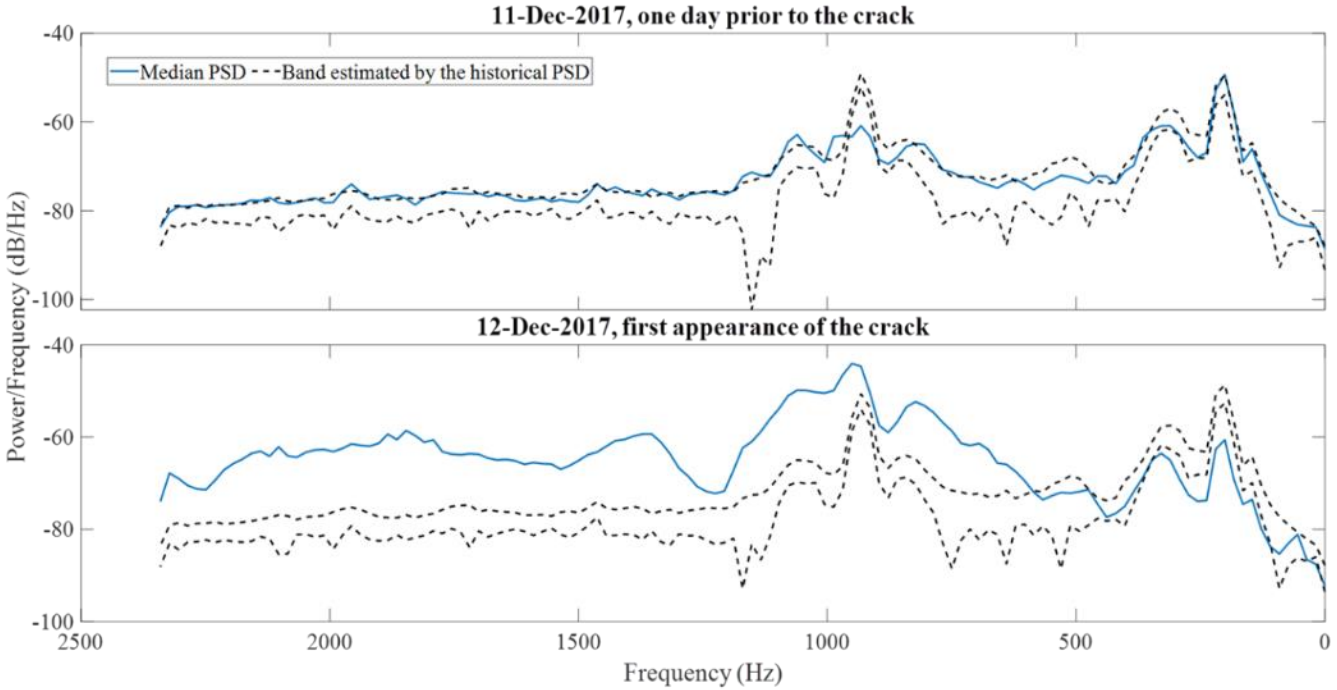
The right hand side confusion map shows a 74.5% true leak and 96.1% true no-leak test outcome using the training learner.

Custom Coded ANN for Cracked Pipe Detection



Matlab, R and Python scripted Artificial Neural Networks (ANNs) have been used to analyse noise magnitude and frequency data.

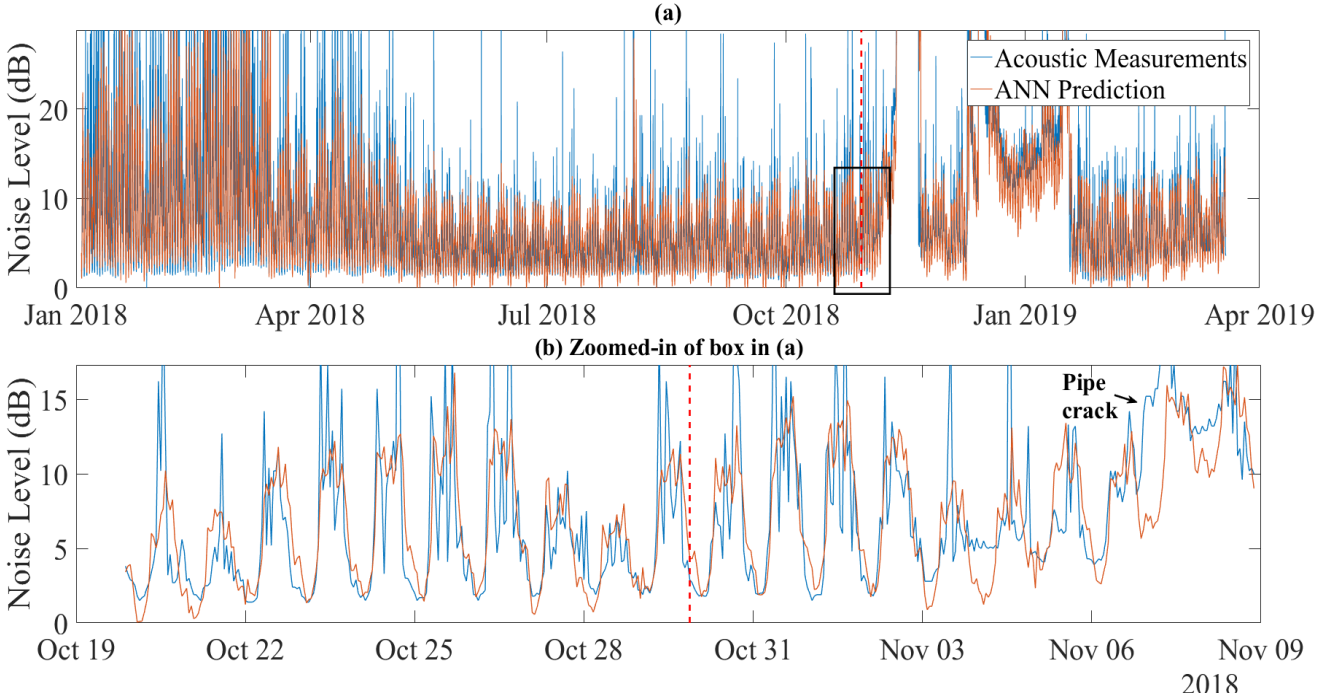
Custom Coded ANN – Using PSD Patterns



The application of the previous custom coded ANN to a series of Power Spectrum Density (PSD) measurements (for a particular logger).

Bands are established for the expected behaviour and deviation from them can indicate a new leak.

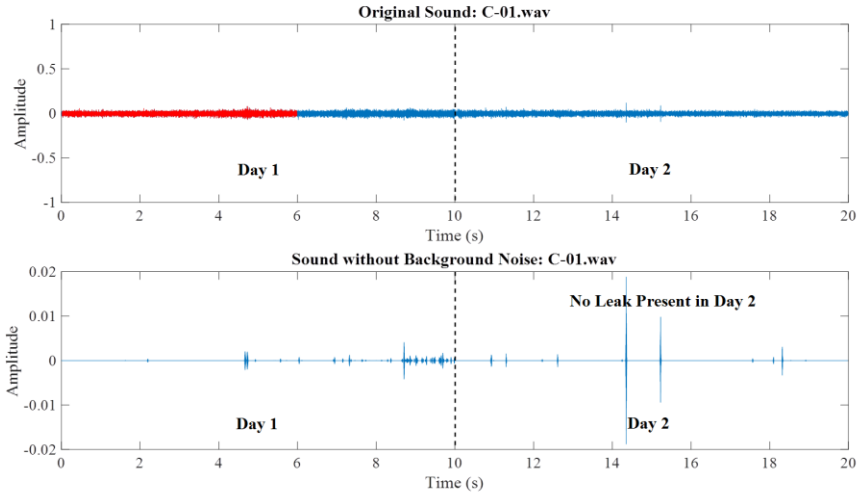
Custom Coded ANN – Using Magnitude Data

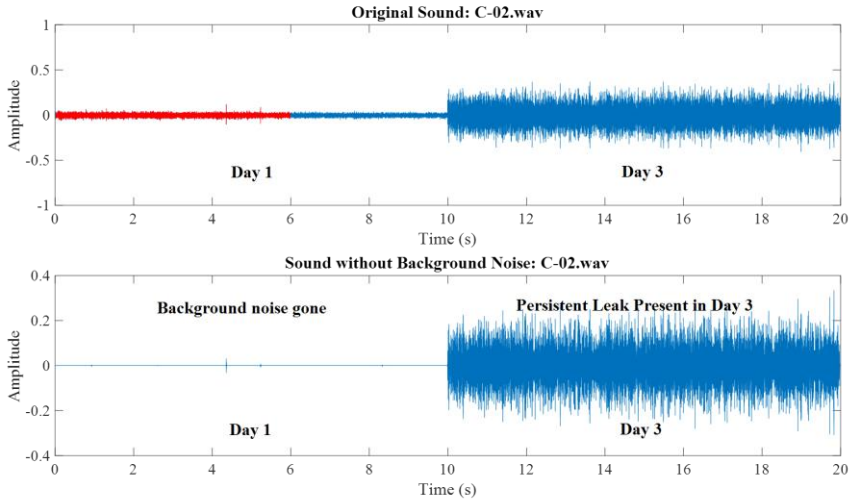


Modification of the customised ANN enables it to be trained to historical noise magnitude data.

Deviations from the ANN predicted pattern can indicate a new leak.

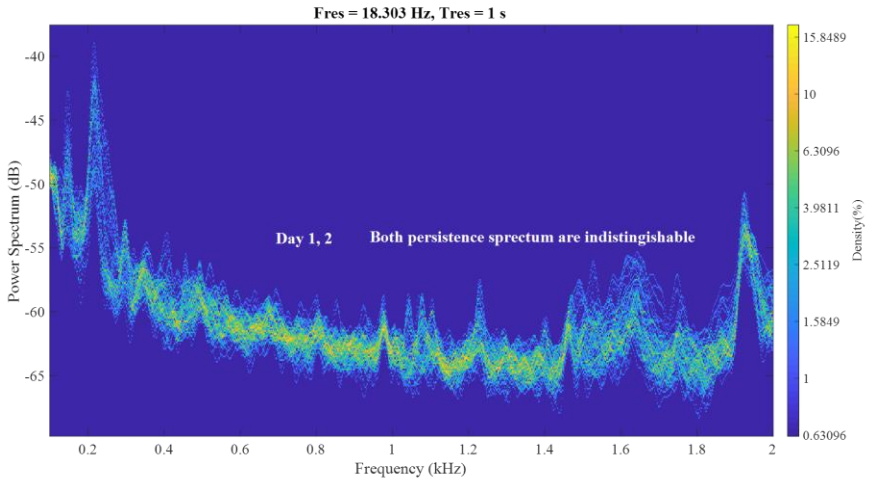
New Sensor Based Analysis - Filtering

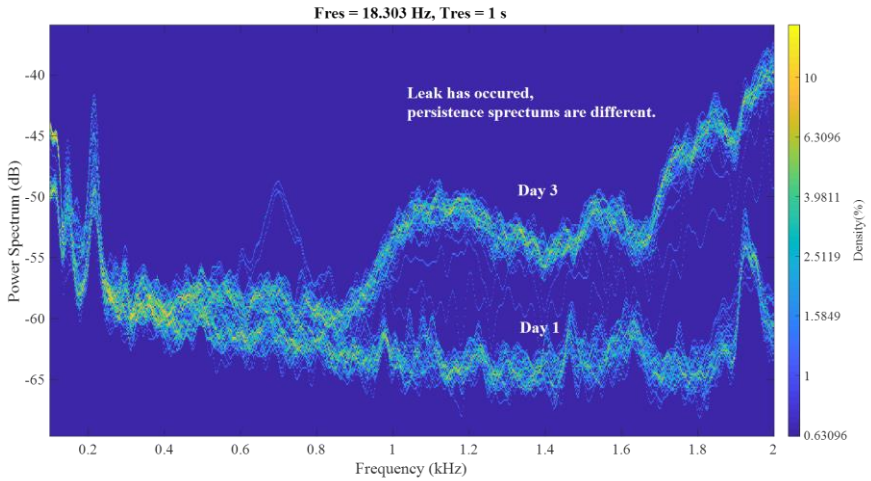




Distinct from the analytics illustrated above, sensor based filtering of noise measurements using historical data, at either individual loggers or across groups of loggers, is undertaken to identify initial noise level changes and any on-going change.

Leak Identification – Persistence Spectrums





The occurrence of a leak (and other noise sources) can also be detected using persistence spectrums (for the day 1, 2 and 3 noise measurements presented on the previous slide).

SCADA and IoT – PI and Azure

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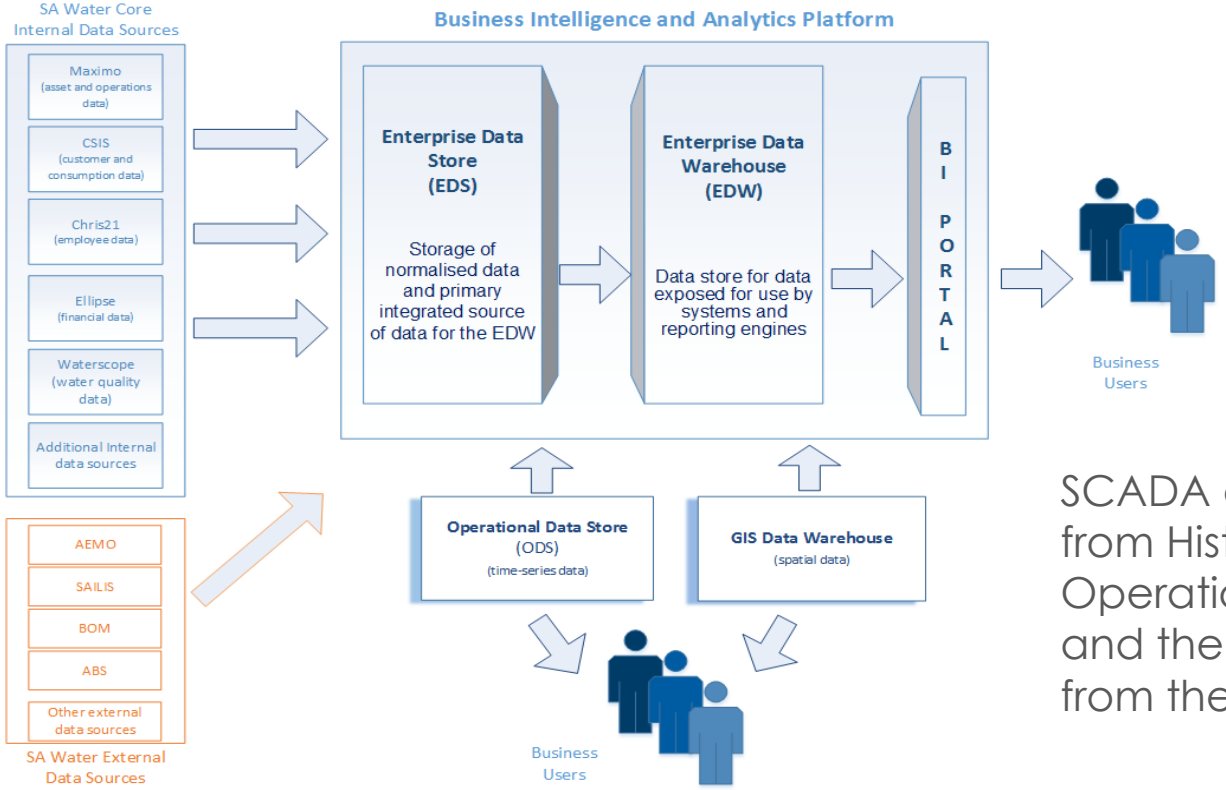
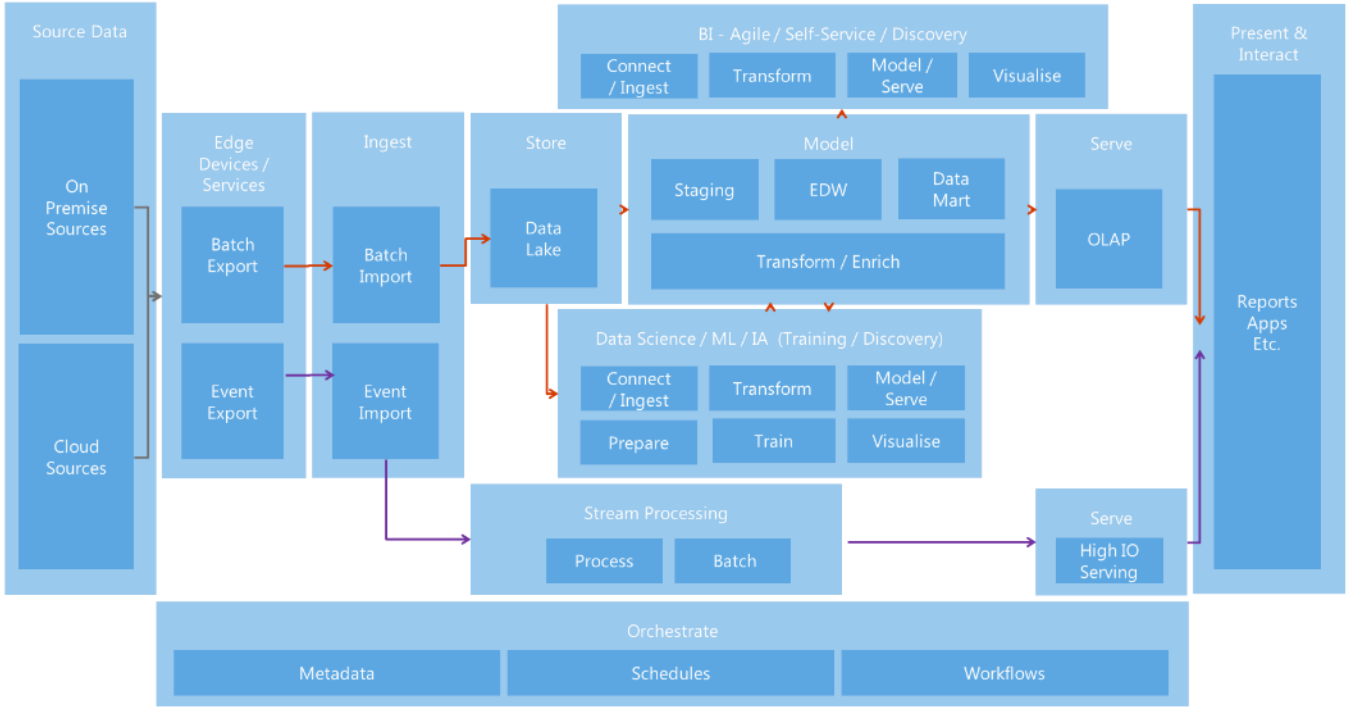
Current Primary SA Water Data Storage Structure



The SA Water main data wharehouses include an EDS and EDW which become accessible to all SA Water users.

SCADA data can be directed from Historian to a SA Water Operational Data Store (ODS) and then extracted to the EDS from the ODS (see below).

Developing Data Framework(s)

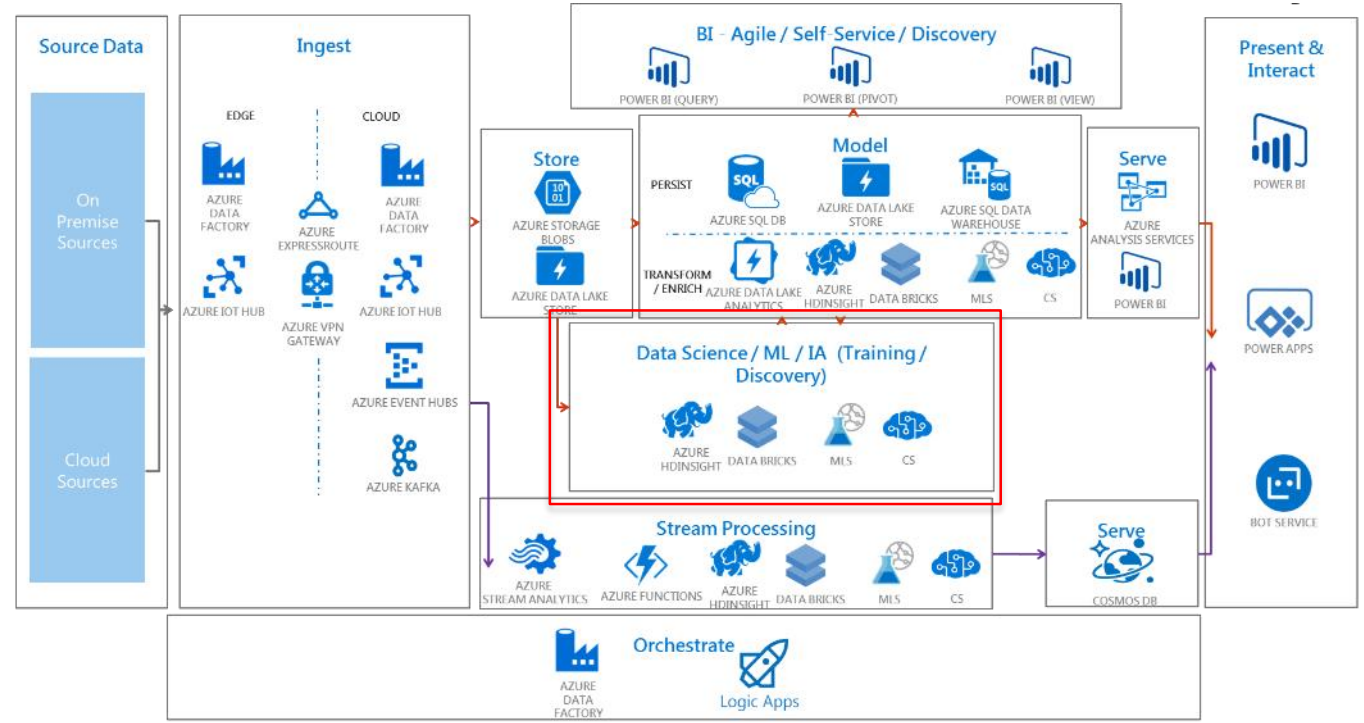


DATA ---------- INTELLIGENCE ---------- ACTION

SA Water is aware of changes to data and information frameworks.

Within the framework shown IoT stream (calculation level) and more complicated mathematical analysis of data can be undertaken.

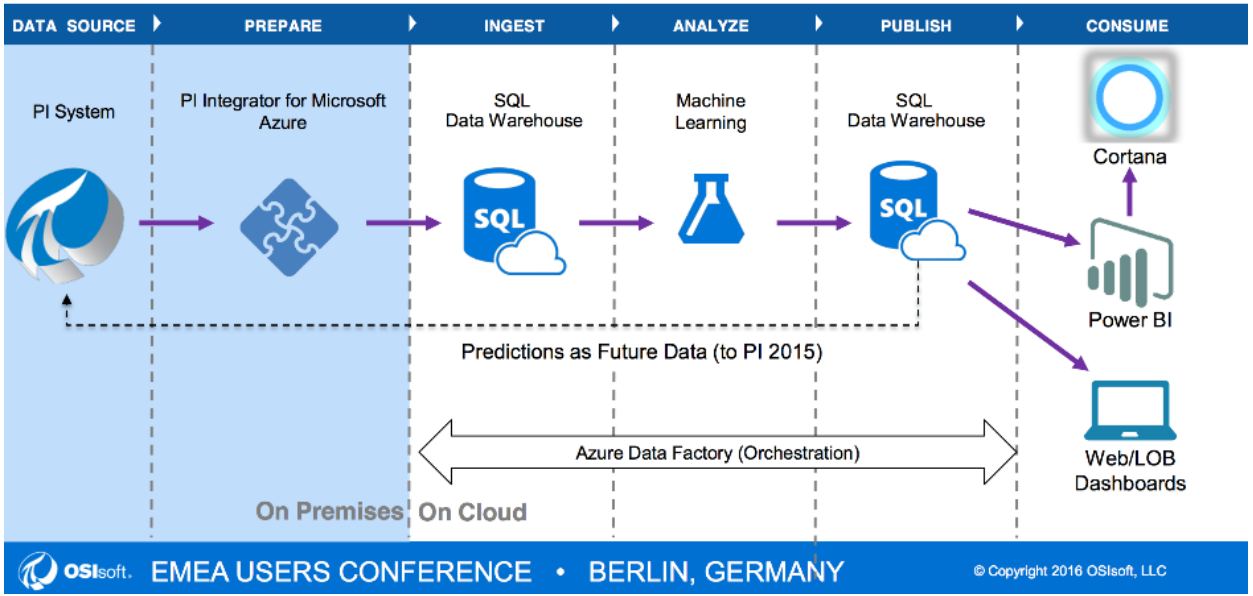
Developing Data Framework(s)



Data and information framework including Azure machine learning environment (and data exchange into and out of it).

Analytics in OSI Soft PI and Azure

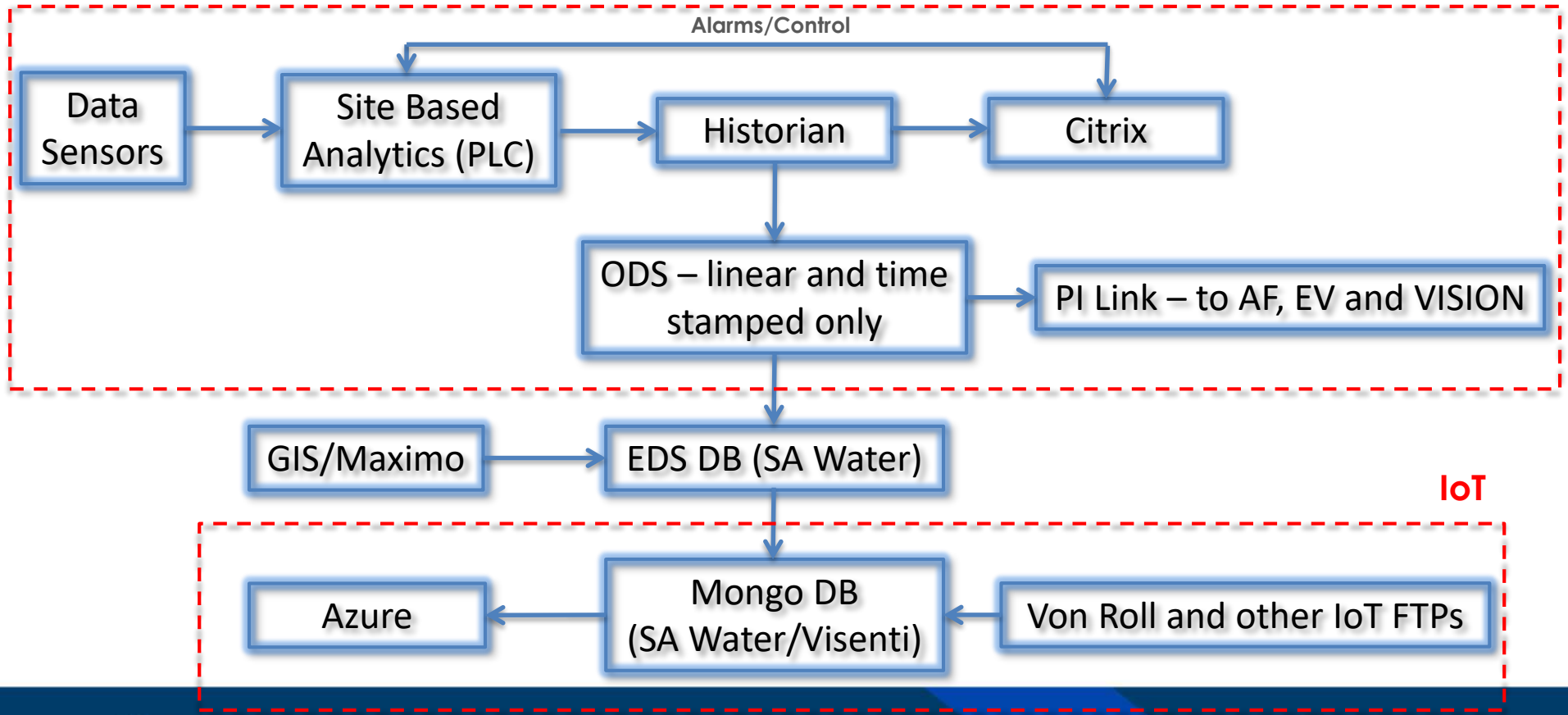
How to Operationalize Predictions



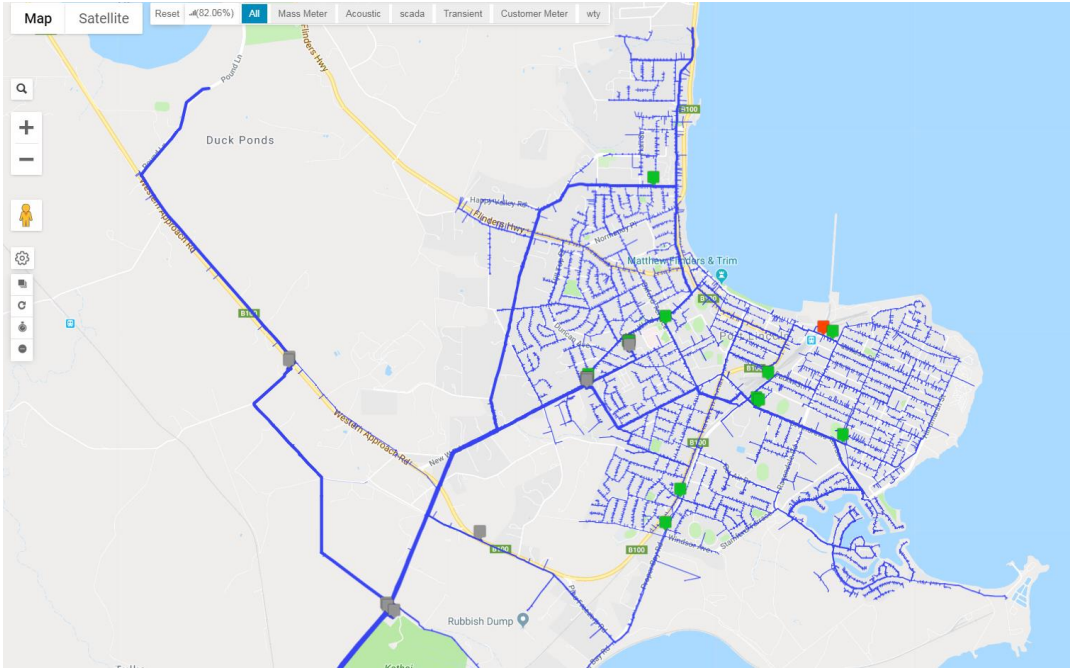
One version (high level) of an operationalisation pathway for OSIsoft PI data (from SCADA) through Azure of relatively more complex analytics (including machine learning).

SA Water has implemented a similar pathway for IoT data in Azure but not from OSIsoft PI (yet).

Framework for use of SCADA and IoT Data



SCADA and IoT – Port Lincoln SA



Port Lincoln Township Flow, Tank Level and Water Quality Sensors (new in green/red and existing in grey)

A combination of new (IoT) and existing (SCADA) flow and other sensors being used together.

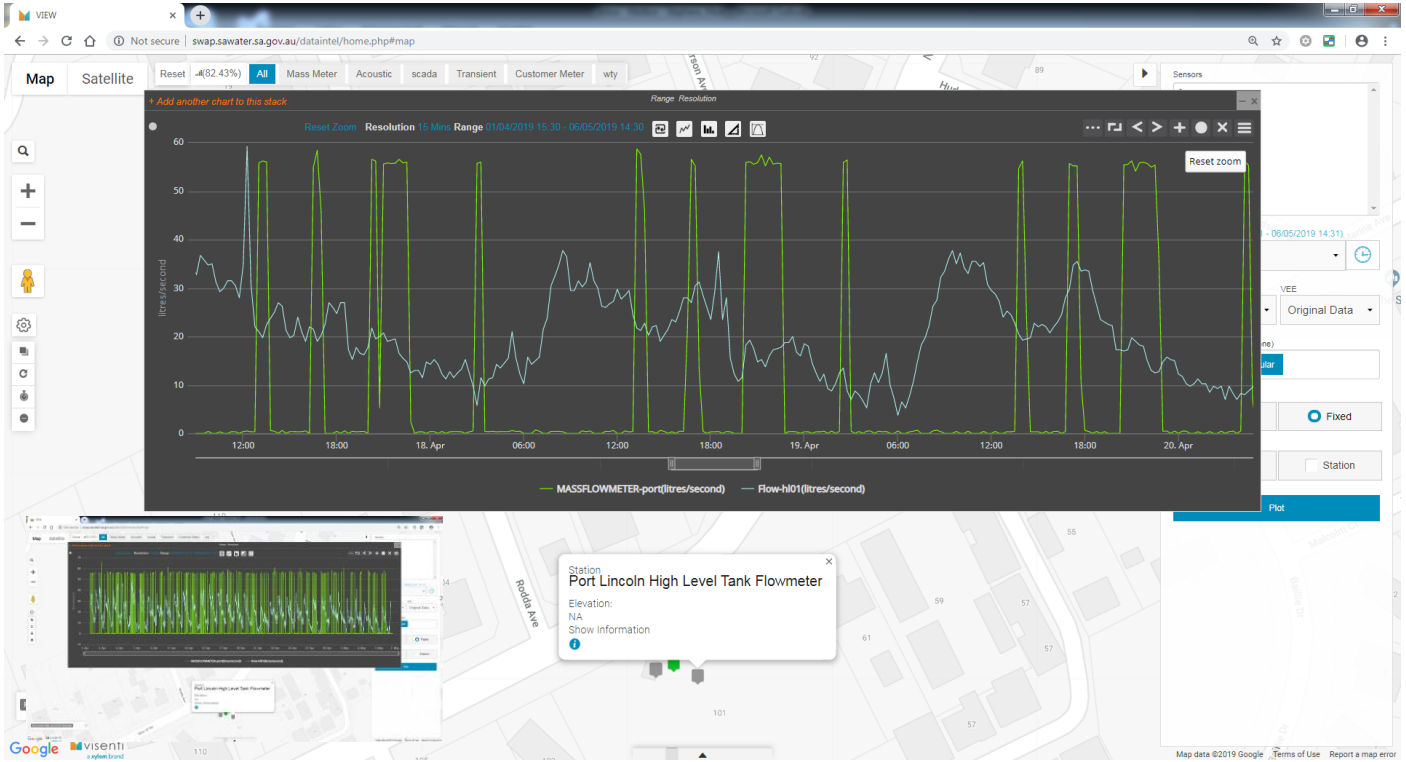
Objectives include the creation of virtual metered areas for the assessment of water loss and quality.

Delivery efficiency improved by utilising new (IoT) and existing (SCADA) sensors and systems.

SCADA and (to) IoT – Port Lincoln SA

Visualisation of flow data from different IoT (green) and SCADA (blue) sensors.

Data able to be directed to analytics for flow balance and loss determination.

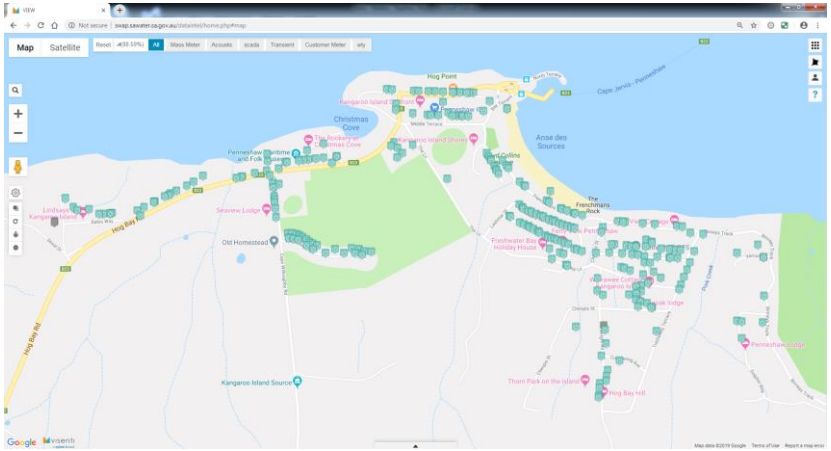


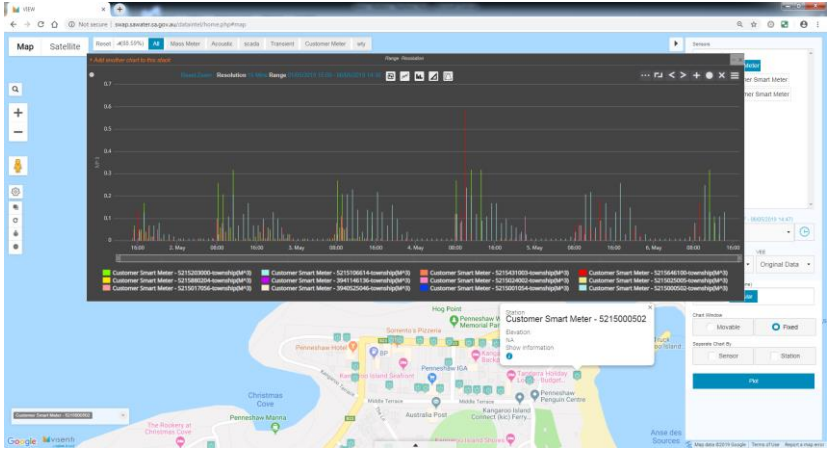
Penneshaw Smart Meters

300 smart meters have been installed on all customer connections in the township of Penneshaw SA.

These smart meters transmit consumption data back to SA Water's IoT analytics platform via Taggle radio communication infrastructure.

A mixture of IoT and SCADA flow and tank level information is also transmitted back to the IoT analytics platform where a range of native flow balancing calculations are undertaken.



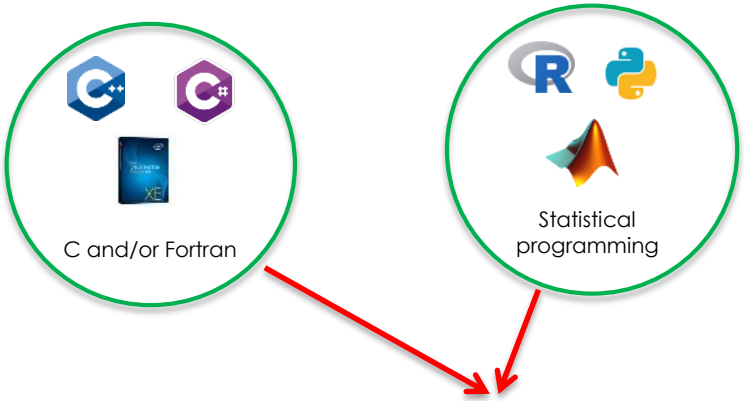


Operationalising Alert Analytics

Government of South Australia

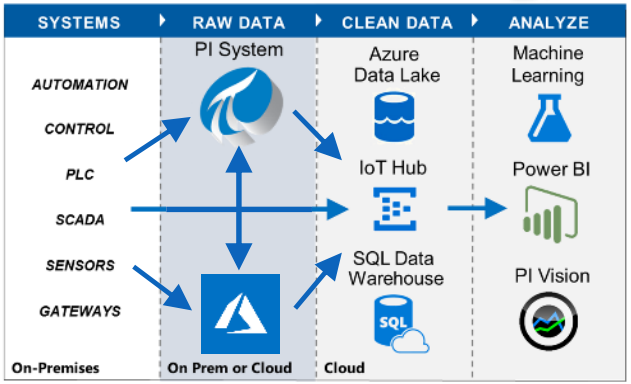
SA Water

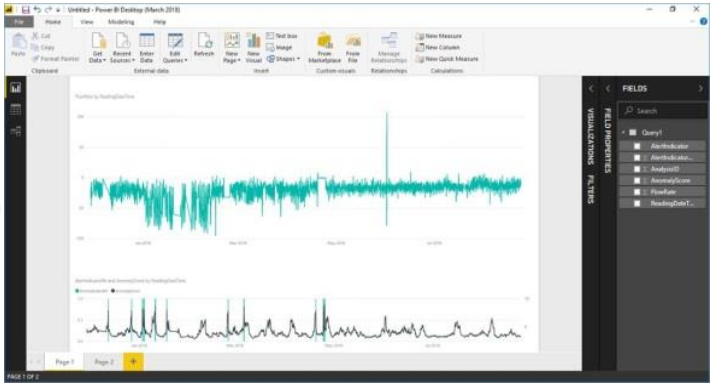
Implementing Analytics



SA Water has not yet established an IT framework in which relatively more complex analytics can be executed with SCADA data.

However, SA Water believe that the IoT analytics it has developed and operationalised in Azure will be able to be modified for use with OSIsoft PI (if useful).





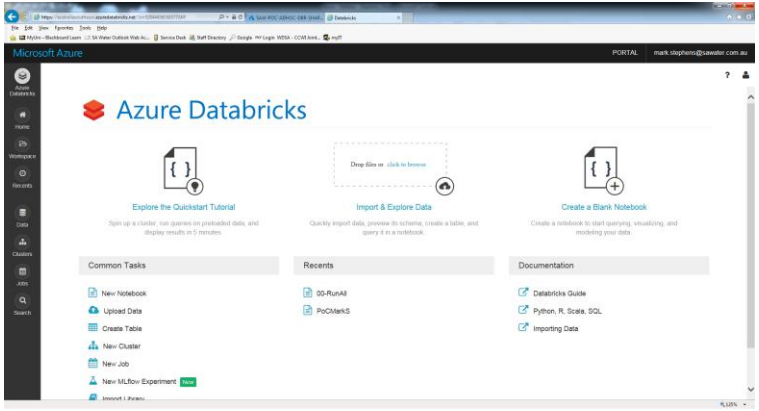
Azure Operationalisation

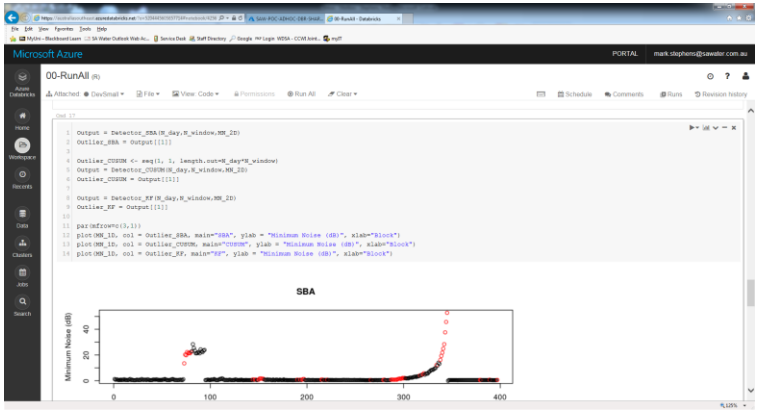
SA Water has operationalised a number of analytics involving relatively more complex mathematics:

- iterative solving
- matrix handling
- integration/differentiation
- transforms (e.g., Fourier)
- customised and classification based machine learning)

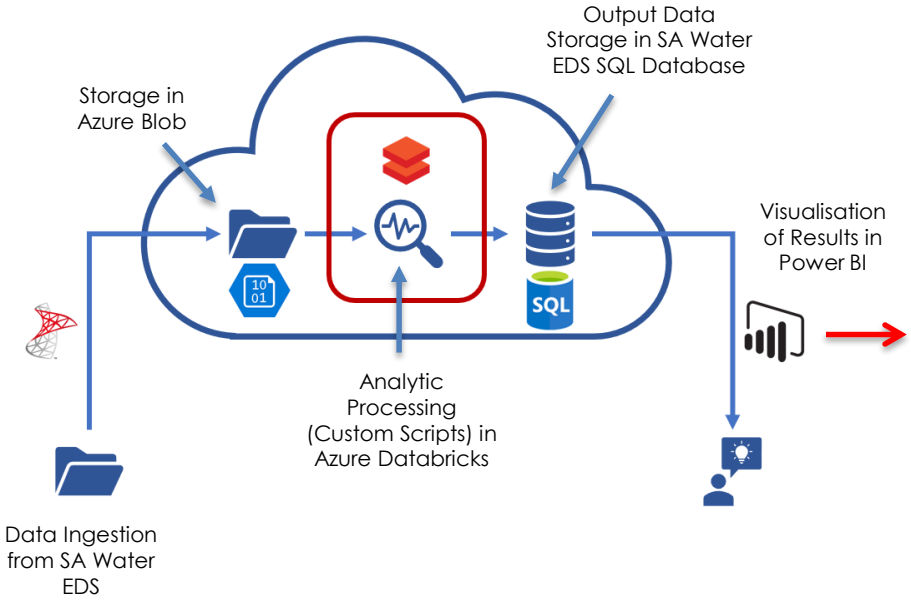
in the Azure Environment (Databricks) using R and Python program scripts.

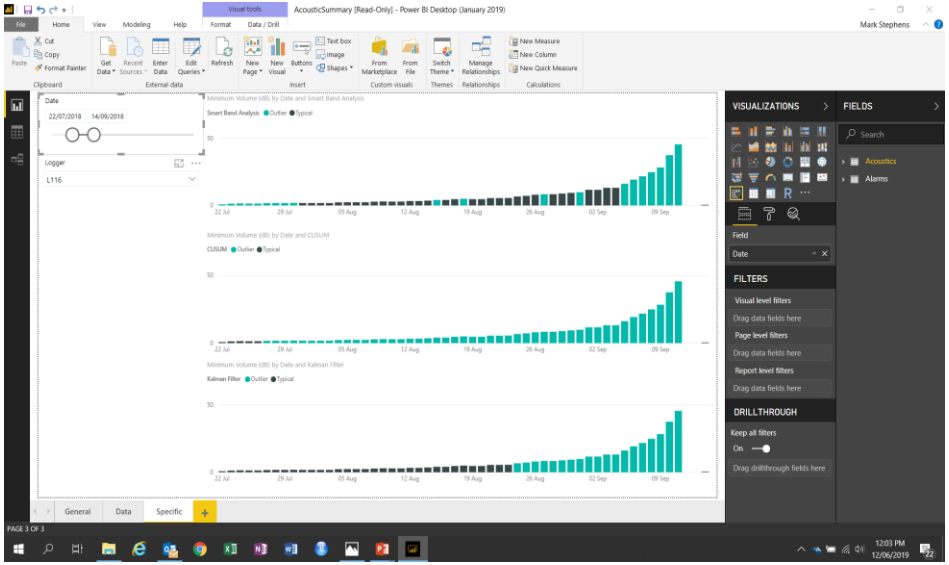
It is anticipated that similar analytics can be created for application to SCADA data.





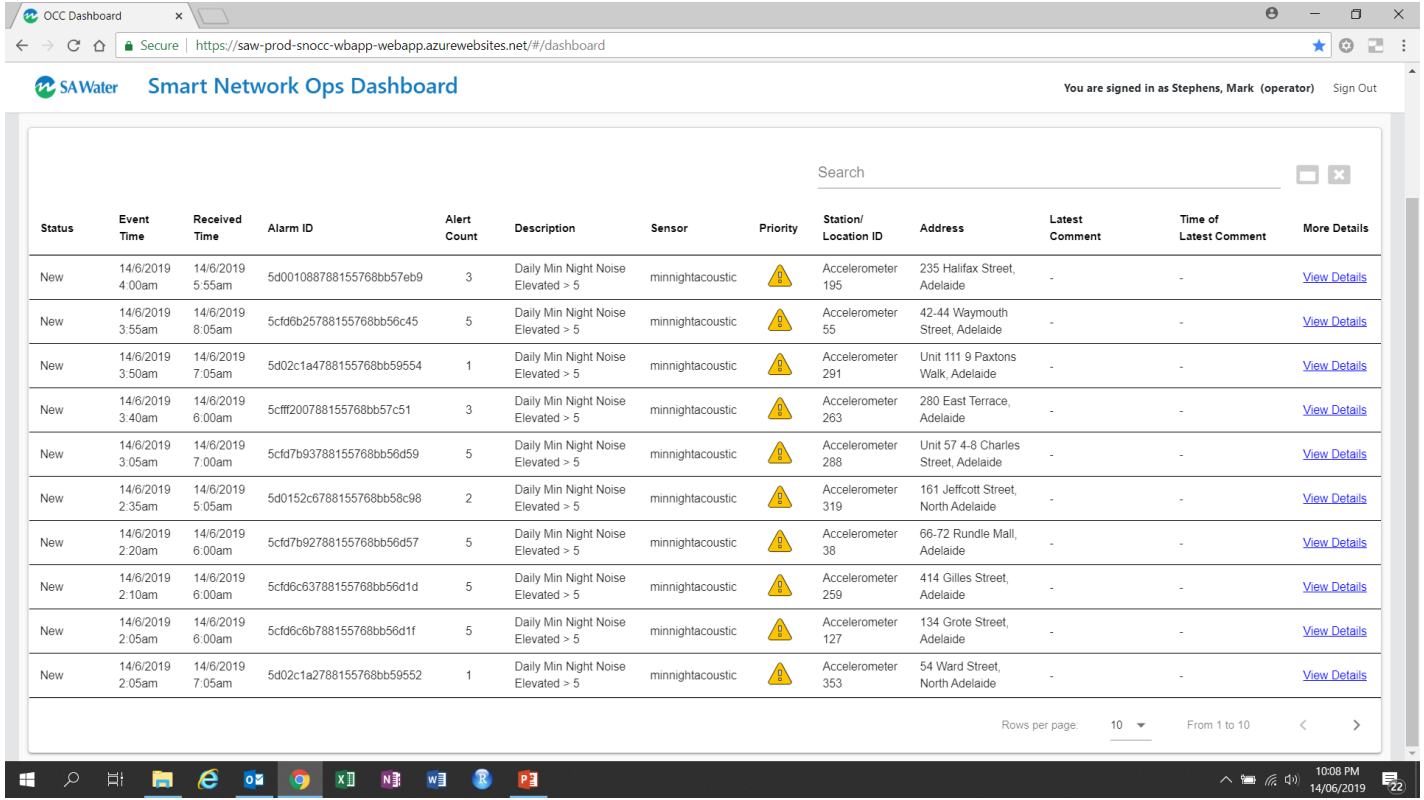
Azure Operationalisation continued ….





Customised test operationalisation of SA Water developed noise magnitude change detection analytics and visualisation in Power BI.

Operationalisation – Alert Dashboards



Status	Event Time	Received Time	Alarm ID	Alert Count	Description	Sensor	Priority	Station/ Location ID	Address	Latest Comment	Time of Latest Comment	More Details
New	14/6/2019 4:00am	14/6/2019 5:55am	5d00108878815576 8bb57eb9	3	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 195	235 Halifax Street, Adelaide	-	-	View Details
New	14/6/2019 3:55am	14/6/2019 8:05am	5cfd6b25788155768bb56c45	5	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 55	42-44 Waymouth Street, Adelaide	-	-	View Details
New	14/6/2019 3:50am	14/6/2019 7:05am	5d02c1a4788155768bb59554	1	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 291	Unit 111 9 Paxtons Walk, Adelaide	-	-	View Details
New	14/6/2019 3:40am	14/6/2019 6:00am	5cfff200788155768bb57c51	3	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 263	280 East Terrace, Adelaide	-	-	View Details
New	14/6/2019 3:05am	14/6/2019 7:00am	5cfd7b93788155768bb56d59	5	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 288	Unit 57 4-8 Charles Street, Adelaide	-	-	View Details
New	14/6/2019 2:35am	14/6/2019 5:05am	5d0152c6788155768bb58c98	2	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 319	161 Jeffcott Street, North Adelaide	-	-	View Details
New	14/6/2019 2:20am	14/6/2019 6:00am	5cfd7b92788155768bb56d57	5	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 38	66-72 Rundle Mall, Adelaide	-	-	View Details
New	14/6/2019 2:10am	14/6/2019 6:00am	5cfd6c63788155768bb56d1d	5	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 259	414 Gilles Street, Adelaide	-	-	View Details
New	14/6/2019 2:05am	14/6/2019 6:00am	5cfd6c6b788155768bb56d1f	5	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 127	134 Grote Street, Adelaide	-	-	View Details
New	14/6/2019 2:05am	14/6/2019 7:05am	5d02c1a2788155768bb59552	1	Daily Min Night Noise Elevated > 5	minnightacoustic		Accelerometer 353	54 Ward Street, North Adelaide	-	-	View Details

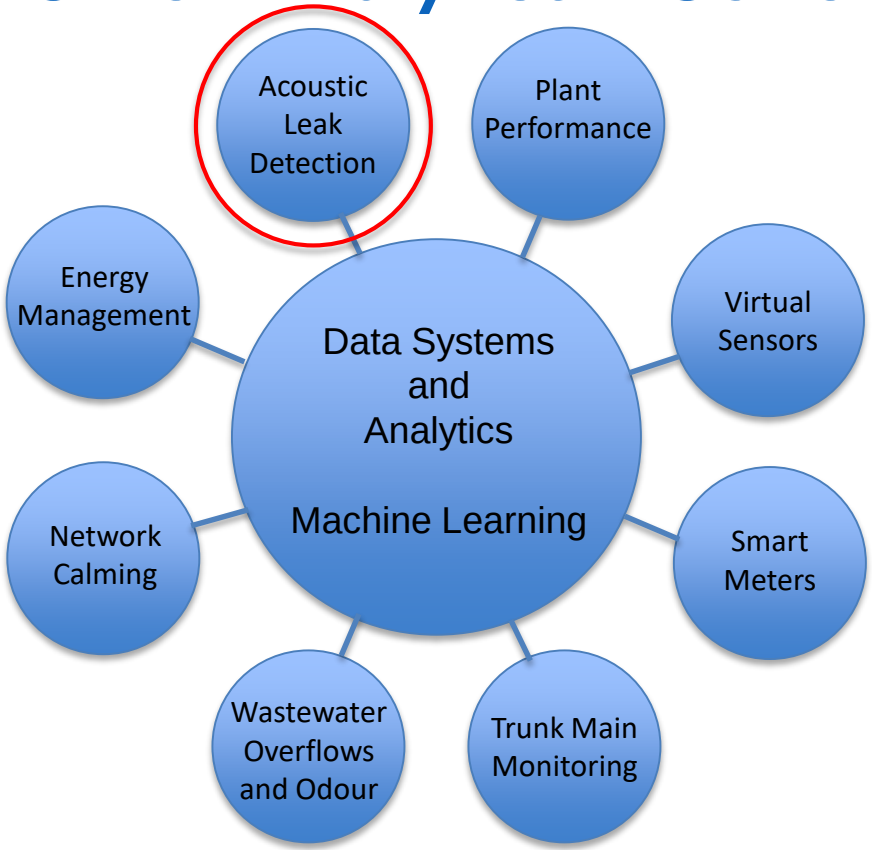
The alerts (based on changes in magnitude and frequency data) are transferred to customised dashboards for 24/7 operational monitoring.

Future Direction for SA Water

Government of South Australia

SA Water

Other Analytics – Current and Future?



SA Water are current expanding its application of data analytics and machine learning in many areas.

Stream or calculation type analytics have been/are being implemented in some areas (e.g., threshold setting, bands, basic mathematical operations, threshold setting, mean and SD, bands, limited data call back).

More complex analytics have been/are being implemented in other areas (e.g., iterations, matrix solving, statistical analysis, transforms, spectral analysis through to machine learning).

Thank you

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Government of South Australia

SA Water