final report

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Terrestrial Based Digital Connectivity at Calliope

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Abstract

Significant advances have been made in developing big data solutions across agriculture and livestock industries. This includes major advances in IoT or "Internet of Things" devices for real time data collection and the development of a range of data transformation platforms. A key factor limiting the expanded use of such solutions is connectivity. The project was established on a Central Queensland extensive grazing property, Calliope Station. IoT sensors were deployed across the property to allow monitoring of water levels in dams, weather data and soil moisture. Connectivity across water sources was established and visualised on the Hitachi Process Intelligence Control Centre. Connectivity was developed in collaboration with Vodafone using their 3G/4G network and a LoRa long-range radio network. The overall benefit cost ratio for 10 years was 2.6:1 with an internal rate of return of 40%.

Executive summary

MLA's Digital Value Chain Strategy is focused on the delivery of new technologies that allow the seamless capture, integration and interpretation of data. This process begins with data collected at the individual property scale. This includes the ability to access "near real-time" data and automated analysis and presentation of the data. Through this digitalisation the aim is to enhance overall productivity, profitability and operational efficiency.

While this strategy targets digitalisation of the farming operation, a key and fundamental issue in delivery of this goal is connectivity. Without effective connectivity the deployment for modern IoT or "Internet of Things" sensors cannot be achieved and therefore the whole program of digitalisation is challenged or compromised.

The purpose of this project was to access the capacity for digital solutions to be deployed across remote properties. To do this MLA partnered with Hitachi Consulting to lead a project that targeted four core areas. These where to:

1. enable real time data collection via selected IoT devices
2. create effective data flow networks for the transfer of data from sensors to control centres
3. use data processing methods for data analysis
4. present the data (raw and processed) in a format that can directly assist in the management of farm operations.
5.

In the project Hitachi Consulting utilised its Process Intelligence (HPI) solution. Hitachi Process Intelligence is a solution that combines advanced process and data analytics to support business decisions and accelerate digital transformation. To assess technologies that may secure connectivity, Hitachi developed a collaboration with Vodafone Australia. This collaboration was used to secure connectivity between third party IoT devices and related LoRa (Long range, low power radio networks) gateways and HPI solutions. Figure 1 indicates the proposed connectivity platform.

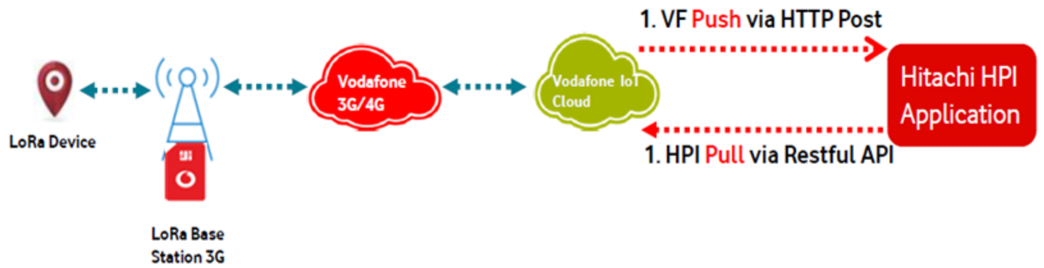

Figure 1 connectivity networks and digital integration to the Hitachi Process Intelligence Platform

Once deployed specific objectives of the project where to:

- operate a field-based data capture and management mapping exercise
- identify gaps in existing capabilities and capacities in connectivity, data capture and management
- develop a farm level data visualisation system
- demonstrate collection of data from on-farm data sensors and LoRa nodes
- establish a digital solution to supply real time business decision support
- identify gaps in connectivity and identify cost effective solutions to such issues

- quantify the farm productivity improvements associated with the implementation of a digital solution
- advise on a series of identified new data sensing devices and analytics to fill current data sensing gaps.

To test the proposed digital solution the system was deployed on the Central Queensland extensive grazing property, Calliope Station. IoT sensors where deployed across the property to allow monitoring of water levels in tanks, weather data and soil moisture in different soil depth levels. Data from ultrasonic water depth meters, water pressure sensors, weather stations and a soil moisture probe were collected.

All IoT sensors where adapted to allow appropriate access of data via the 3G/4G cellular and LoRa radio networks. Once operational, the network allowed real time data to be uploaded to the Hitachi Process Intelligence (HPI) platform. Final data transformation was completed and presented as an interactive dashboard to allow the property owners to monitor its key resources in real time and to set alarms for key resources as required.

Through a series of on farm activities the benefits of improved connectivity across the farm where assessed. Analysis demonstrated a number of management and productivity improvements resulting from improved decision making and on farm practices.

Initial upfront costs for implementing the system was $50,650. Benefits gained from improved business operations and labour cost savings exceeded $26,000 per year. The cost benefit analysis show that the system is cash flow positive within 2.5 years with a total benefit and cost saving of $54 555 after 5 years. The deployment of the IoT network and data processing intelligence was shown to provide a 57% and 151% return on investment after 5 and 10 years respectively. The overall benefit cost ratio for 10 years was 2.6:1 with an internal rate of return of 40%. This clearly shows the benefits gained from implementing the system.

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1 Background

1.1 Introduction

In partnership with the MLA Donor Company (MDC), Hitachi Consulting has been conducting a value chain pilot using Hitachi Process Intelligence (HPI) solution with other industry stakeholders. These projects are aligned to MLA's Digital Value Chain Strategy with the objective of sourcing and analysing user-friendly integrated data and trends that will enable more informed and agile decision-making across multiple value chains.

Process Intelligence is a solution that combines advanced process and data analytics to support business decisions and accelerate digital transformation. HPI can utilise data for various sources to develop predictions on resource use and allocation. HPI uses open source software and can be customised for livestock production systems. The system allows for alerts to be set for desired limits of resource use. The processing methods may also be combined with best practice management systems developed for an industry or individual property. In this way data may be analysed to allow predictions of farm operations such as ideal time to "turn off" cattle and send them to the next stage of the value chain, either feed lotting or processing and the allocation of resources.

The application of a data transformation using systems such as HPI can provided significant productivity gains to on-farm operations and overall returns to producers. Where connectivity is limiting this approach can difficult to implement and the benefits of such a system may not be realised. To overcome such issues data collected across the farm may be stored either at the location for each device or at a central location or base station via a LoRa network. The base station is positioned at a location to allow connection to local 3G/4G networks (Figure 2) where final data may be sent to HPI for processing. The HPI dashboard may be located in a central location where connectivity is assured, (e.g. farm homestead or office).

This solution will advance digital transition of data from IoT devices deployed on the property with limited cellular coverage via the Vodafone 3G network to the HPI dashboard giving the farm owner insight into data and information not previously available. This information would normally take days to accumulate manually where it is now done on an hourly basis without the farm owner having to leave the office.

1.1.1 Vodafone Enterprise Solution model

To assess remote connectivity options, Vodafone Enterprise Singapore Pte Ltd provided the technical services and equipment for connectivity on the trial station to the HPI Dashboard.

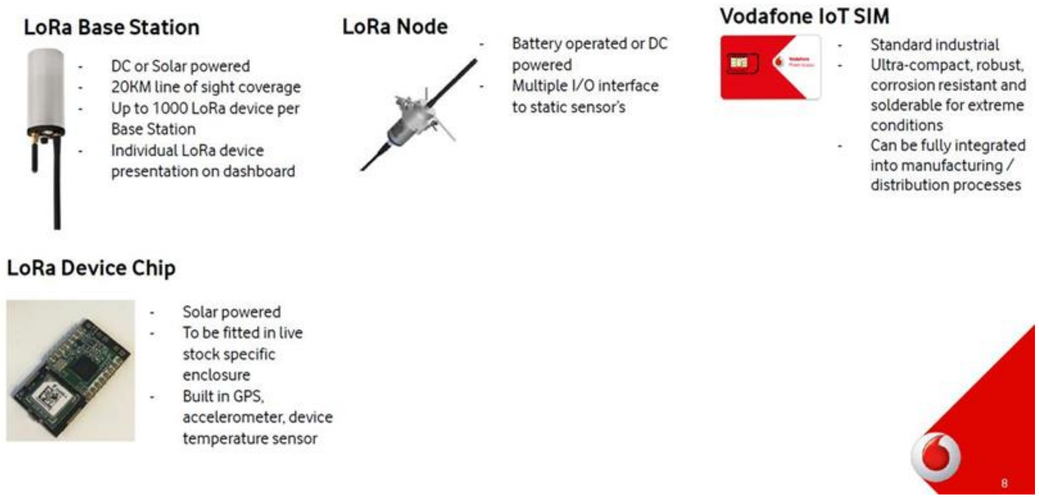

Figure 2 **Vodafone Solution model layout**

Vodafone also supplied all technical backup and support for the project. Third Party IoT equipment and devices for the project where supplied by Vodafone and installation of the equipment and devices was the responsibility of Vodafone. The project was successfully installed and IoT data from water level sensors, weather station and soil moisture probe collected and displayed on the HPI Control Centre.

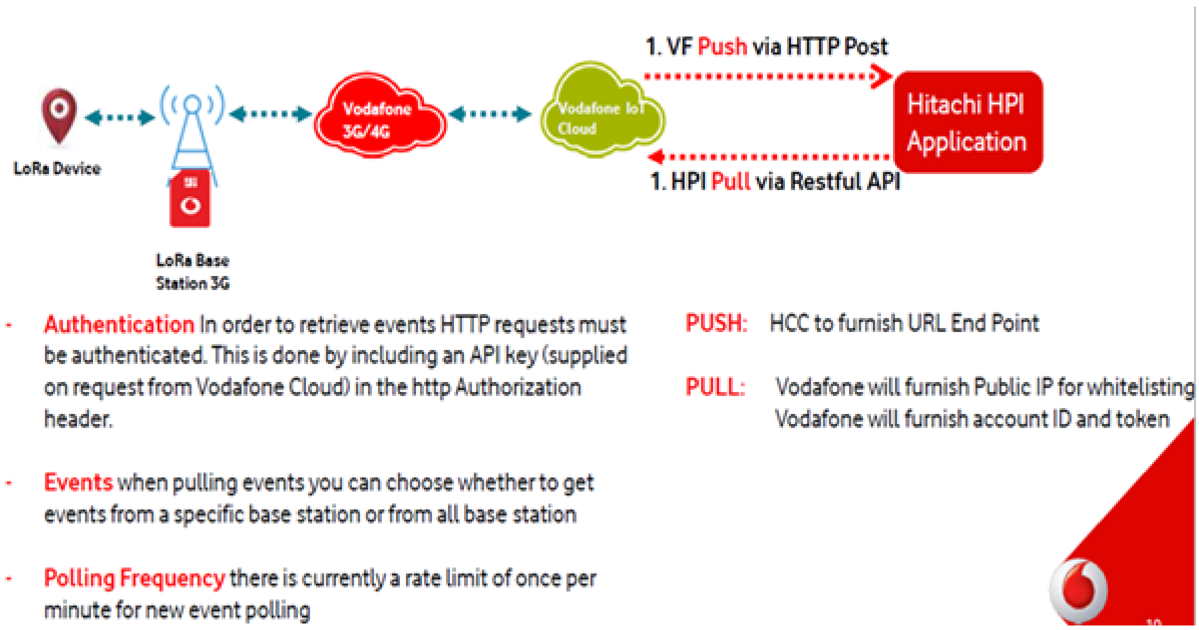

Figure 3 **Process from IoT device to through Vodafone Cloud to HPI Control Centre.**

2 Project Objectives

2.1 Digital data transformation from a mobile network to an open source process intelligence control centre

The Terrestrial Digital Connectivity Project is a proof of concept IoT networking initiative designed to work in conjunction with the Hitachi Process Intelligence (HPI) platform and its ability to process information gathered from the field. The overall objective was to provide productivity improvements through decision support and process intelligence for a small/medium cattle enterprise with currently limited connectivity.

2.1.1 Specific objectives

Objectives included:

- Detailed data capture and management mapping exercise of Calliope Station using existing evaluation tools developed by Hitachi
- Identify gaps in existing capabilities and capacities in connectivity, data capture and management
- Provide appropriate access to the on-farm sensory data (through a series of pilots with water and soil monitoring sensors) and a farm level visualisation system
- Collect data from on-farm data sensors and LoRa nodes
- Establish a digital solution via a GSM or cellular network integrated into the HPI Calliope on-farm real time business decision dashboard
- Evaluate a suite of connected Agriculture IoT devices across the entire farm connected to the homestead
- Identify gaps in connectivity and identify cost effective solutions for small/medium farming enterprises
- Quantify on farm productivity improvements associated with the implementation of a digital solution providing consistent full coverage from paddock to homestead
- Advise on a series of identified new data sensing devices and analytics to fill current data sensing gaps

3 Methodology

3.1 Staged Process Implementation

3.1.1 Stage 1 Assessment of on-farm connectivity and producer needs

The following steps were followed in assessing on farm connectivity

- Hitachi agribusiness tools and analytics where deployed for rapid assessment of Calliope Station operations. An assessment and mapping exercise was undertaken across the operations using Hitachi Process Intelligence Rapid Assessor. Data was collected, collated and gaps identified in existing capabilities and capacities in data capture and management.
- Review of the property was completed to determine the feasibility of implementing connectivity and data capture devices on farm.
- Stage 1 involved establishing current connectivity capacity and capability, determining Calliope Station connectivity needs from paddock to homestead; homestead to internet and identifying potential connections to external operations and other providers. A design-led thinking exercise was undertaken with the producer and Hitachi team to determine connectivity capacity and customer needs.
- A work schedule for installing IoT devices across paddock to homestead was scoped.

3.1.2 Stage 2 Commission trial

The following steps were followed in implementing the trial with the property owner:

- Operational monitoring requirements were identified
- Specific LoRa and on-farm sensing devices installed
- Data analysis configured within HPI
- Customised dashboard options developed in consultation with property owner
- Farm operations for data capture, analyses and management reviewed with project team and property owner

3.1.3 Stage 3 Run Trial and technical support

The following steps were followed in conducting the trial:

- Connectivity protocols established and executed
- Homestead to Paddock connectivity protocols tested and validated
- HPI data input and analysis methods validated and discussed with property owner

3.1.4 Stage 4 Financial analysis and project benefit rationale

Independent cost benefit and business case report was developed in assessing the implementation of the solution. This included review of all costs related to IoT devices, LoRa gateways, 3G/4G connectivity and operation of HPI data management systems.

Benefits were considered in consultation with property owner. This included assessing improvements in profitability, productivity and labour efficiencies.

Benefit costs analysis was completed by considering both 5- and 10-year operational costs and returns. Economic analysis involved assessment of Net Present Values based on 5% discount rates.

4 Results

4.1 Sensors and base stations

The LX Group of Sydney was Vodafone's preferred supplier of the IoT devices and LoRa system for the trial at Calliope Station. Installation was done on the identified water tanks, paddock for the soil moisture probe and weather station.

The following equipment was supplied:

SKU	Description	Qty
LX-BN3L4A	Blue Node (433 MHz, Private LoRa)	21
LX-BS3L4	Base Station (433 MHz, Private LoRa)	8
LXMB-10	Ultrasonic Sensor (10m range)	16
LXD-WS10	Davis Weather Station (Temp/Hum/Wind/Rain)	1
AQ-SS400SDI12	Soil Moisture Probe Aquacheck 400mm (4 sensor depths)	4
LX-SK25	Solar Kit for Base Station	5
LXTG-ANT433-	LoRa 433 MHz 3dBi High Gain Antenna (DigiKey OMB. 433.B03F21 + C58LL-SMAM-2438-NM)	5
LX-RT10	Range Tester	1

Table 1 Equipment list supplied to Calliope from the LX Group

The data from these IoT devices was connected through a network of gateways from the IoT devices to LoRa base stations equipped with a Vodafone sim cards to the LX cloud-based server and exported to a HPI Control Centre.

4.2 Technical Challenges and their solutions

4.2.1 3G/4G Network connection from base stations

The base stations were programmed to either connect to a 3G or 4G network. The switching between networks results caused the base station to be reset on multiple occasions. The base station was moved to shadow it from the 4G network through geographical terrain positioning, however this resulted in the loss of connectivity with some of the gateways at reservoirs.

Programming of the base station to either work on the 3G or 4G network with the 3G network (433MHz) the preferred solution resolved the base station resetting issue.

4.2.2 Software upgrades of Gateways

A set of extra gateways (Bluenodes) was supplied to Calliope Station to replace faulty Bluenodes. A software upgrade v2.3 was done to them by LX, however they could not be connected to the system.

Reprogramming the new Bluenodes to the previous software version was successful and they could be utilised. This issue highlighted a quality management issue that was subsequently addressed.

4.2.3 Ultrasonic water depth sensors

The installation of these sensors in tanks resulted in various false readings of the water levels. In the black polythene tanks moisture condensates on the sensor resulting in false readings. In the brown/yellow tanks there were fewer false readings.

In open cement reservoirs, algae forms on the water surface. When a patch of these algae moves underneath the ultrasonic sensor it shows the tank to be empty which resulted in wasted time and trips to the reservoirs.

The solution to the above problem was to replace all the ultrasonic sensors with water pressure sensors which have not given one false reading since installation and are much easier to install and maintain.

4.2.4 Base station antennas

To further improve connectivity, base station was equipped with high gain multidirectional 433mHz antennas to ensure that all signals from the Bluenodes were captured and relayed.

4.3 Location of sensors and equipment

Table 2 provides a final list of Display names, Device ID, and position – (Latitude and Longitude).

Calliope 2019 May					
Display Name	Current device ID	Lat	Long	old device/details	HPI Displaying Data
Back of Oaky	A01317018B41FC41	-24.07403	150.94727		Updated
Bericks	A0131701341F9EED	-24.063333	150.996666	new site	
Black Swamp	A01317012EF1EB89	-24.061968	150.75334	1.9m full	Updated
Borrow Pit	A0131701A8104DA3	-24.082479	150.756423		Updated
Brass Yards	A01317012B863466	-24.06795	151.01083	depth sensor now 10m range, 1.8m full .1m	Updated
Bull	A0131701C6E44F9D	-24.092612	150.766162	replaced	Updated
Bull Branch Base	B0211806467FA617	BaseStation			
Colenso Base	B0211806C2AAC392	BaseStation			
Cup & Saucer	A0131701DD2E5B1B	-24.111293	150.765817		Updated
Front Lockerbie	A0131701FFA1BF8A	-24.03544	151.01462		Updated
Hillside Dundee	A0131701992C8B28	-24.013106	150.731174	replaced	Updated
Hillside Terraweena	A013170148EA9CF4	-24.02612	150.77721		Updated
House Dam	a01317017a8a7c45	-24.026885	150.972155	replaced	Updated
Kiora Yards	a0131701fe709bfb	-24.086706	150.872931	new site	
Maxwelton	A013170150F5C36E	-24.068393	150.903564		Updated
Maxwelton Base	B0211806CBBD820E	BaseStation			
Middle Brass	A01317019F181B2C	-24.09514	151.01848	depth sensor now 10m range, 1.8m full .1m	Updated
New Paddock	A0131701AA6975F5	-24.065283	150.739024	replaced	Updated
No 3	A0131701D5FBA195	-24.057385	150.773155	replaced	Updated
Oaky Ck Yards	A01317018A98622D	-24.05428	150.94325	new node was	Updated
Oaky Creek Yard	A01317012DF03FF0	-24.05425	150.9437	remove aa from name	Updated
Paradise	A0131701942F667A	-24.05292	150.78489	replaced	Updated
Railway Paddock	A0131701B01281F4	-24.0551861	150.959136		Updated
Redshirt Yard	A01317014CF121DC	-24.082014	150.771307		Updated
Road Paddock	A013170151D86B5C	-24.17727	150.69958		Updated
Roadside Dundee	a0131701ce200dd8	-24.02606	150.74837	replaced	Updated
Toms Creek	A01317016DE801EC	-24.0821638	150.9139166	new site	
Top	A0131701198888D8	-24.150667	150.726	new site	
Top Brass	A013170138E06380	-24.1043862	151.0172638		Updated
Top corner/cult	A01317017D91E24F	-24.186283	150.712813	remove (s from name	Updated
Top Fairly	A01317014A8EB912	-24.111767	150.859965		Updated
Top of Range Base	B0211806A49B4BF6	BaseStation			
Tyrone Yard	A0131701F4B75848	-24.058734	150.8626		Updated

Table 2 List of installed sensors at Calliope Station May 2019

4.4 Hitachi Process Intelligence Control Centre (HPI CC) Display

Data from the sensors deployed at Calliope Station was successfully transferred across the LoRa network to the HPI Control Centre.

The home page shows a summary of the farm main activities. The water and weather data are displayed in real time.

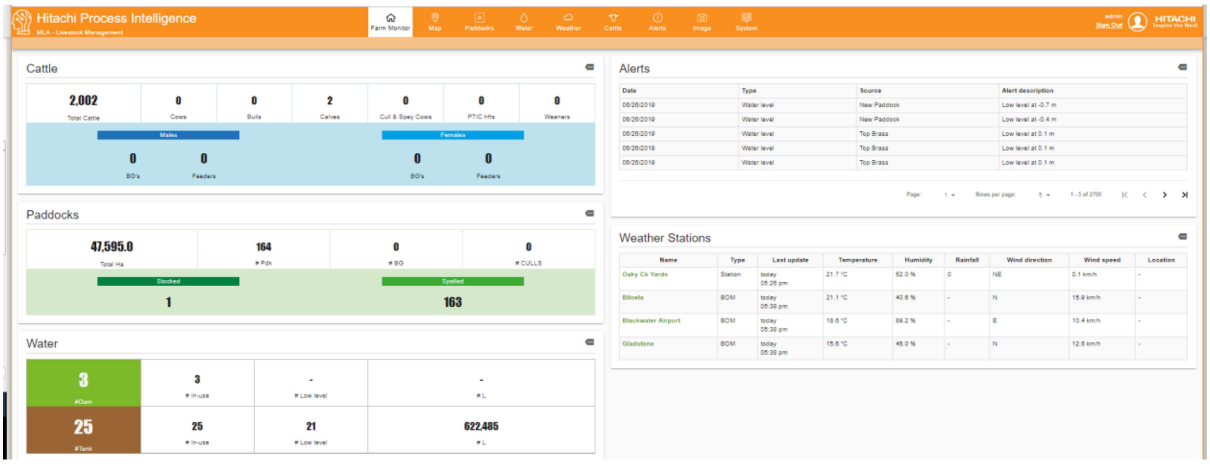

Figure 4 HPI Control Centre Calliope Station Home Page

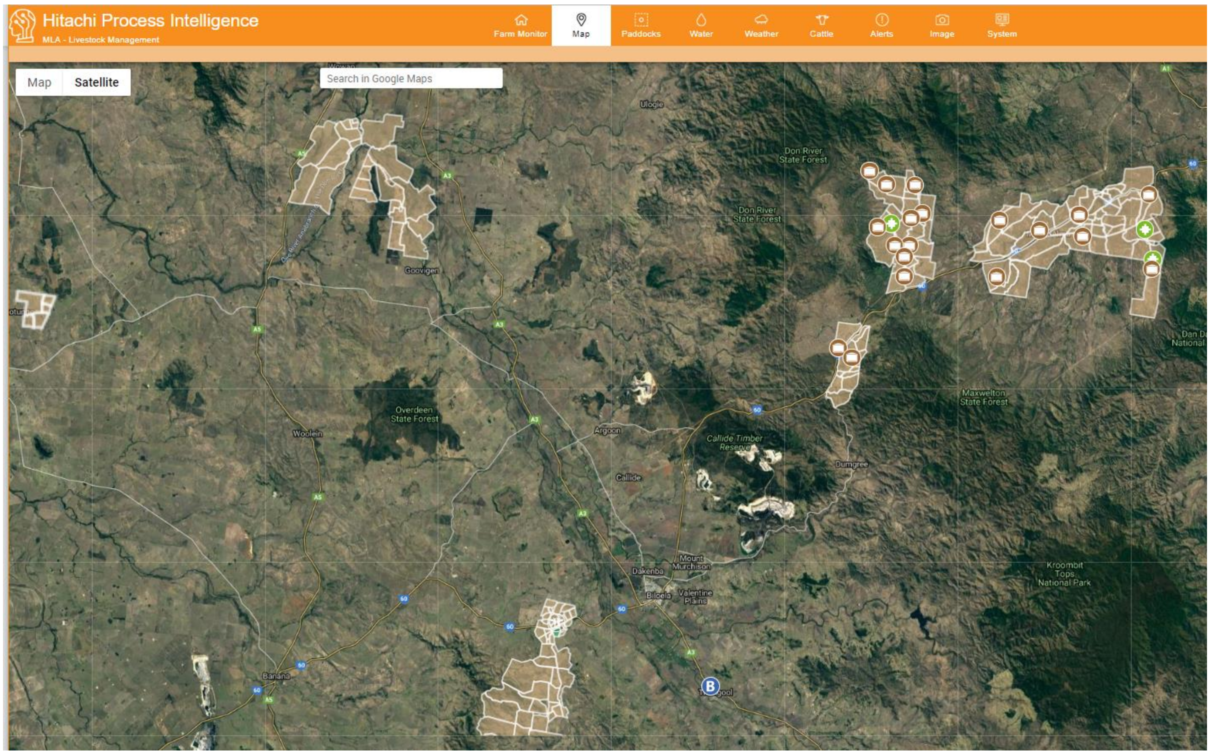

Figure 5 Map of Calliope station property locations and paddocks where sensors are installed.

The maps show the paddocks on the properties and with the sensors installed at its exact location.

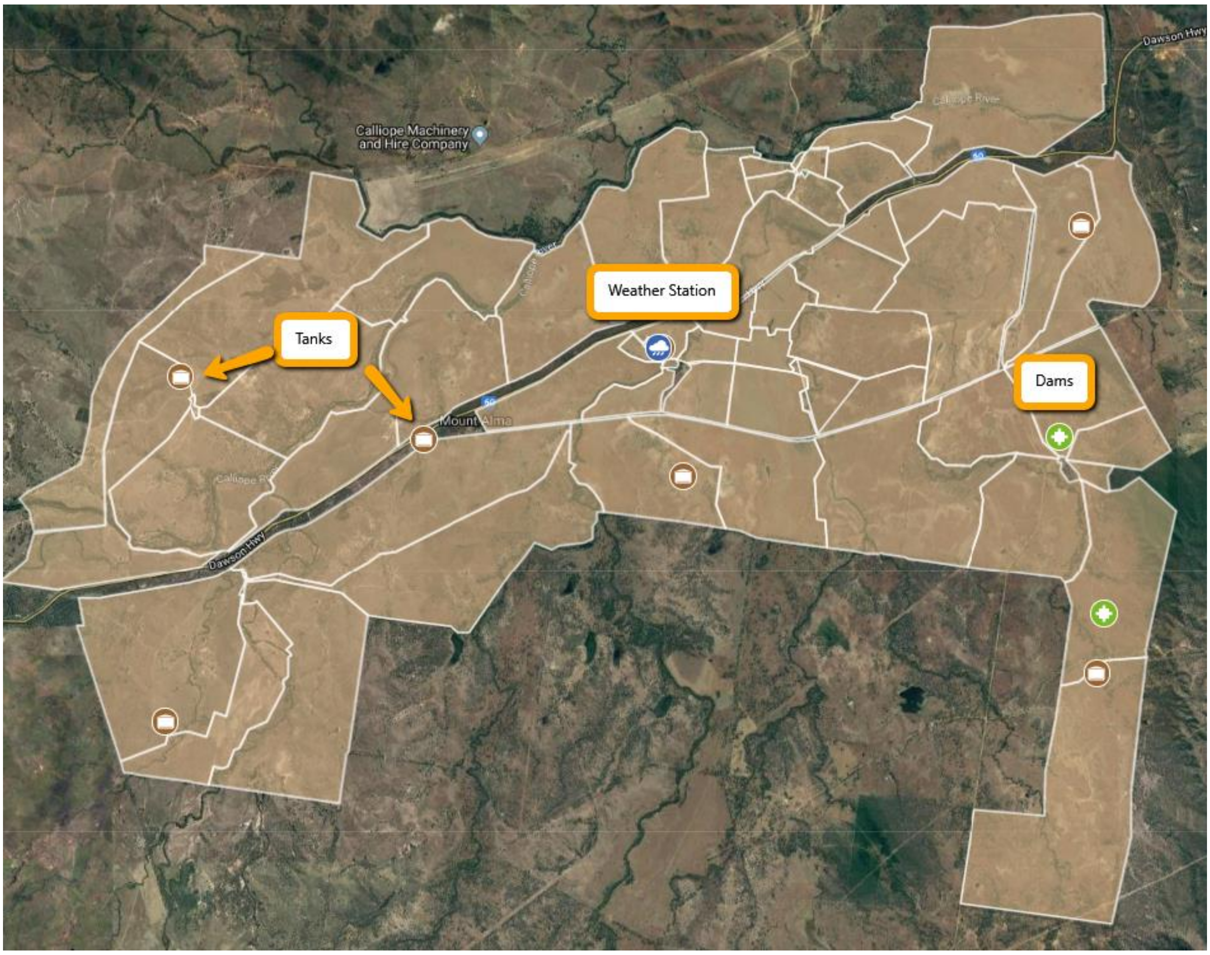

Figure 6 Icons illustrating the location tanks, weather station and dams

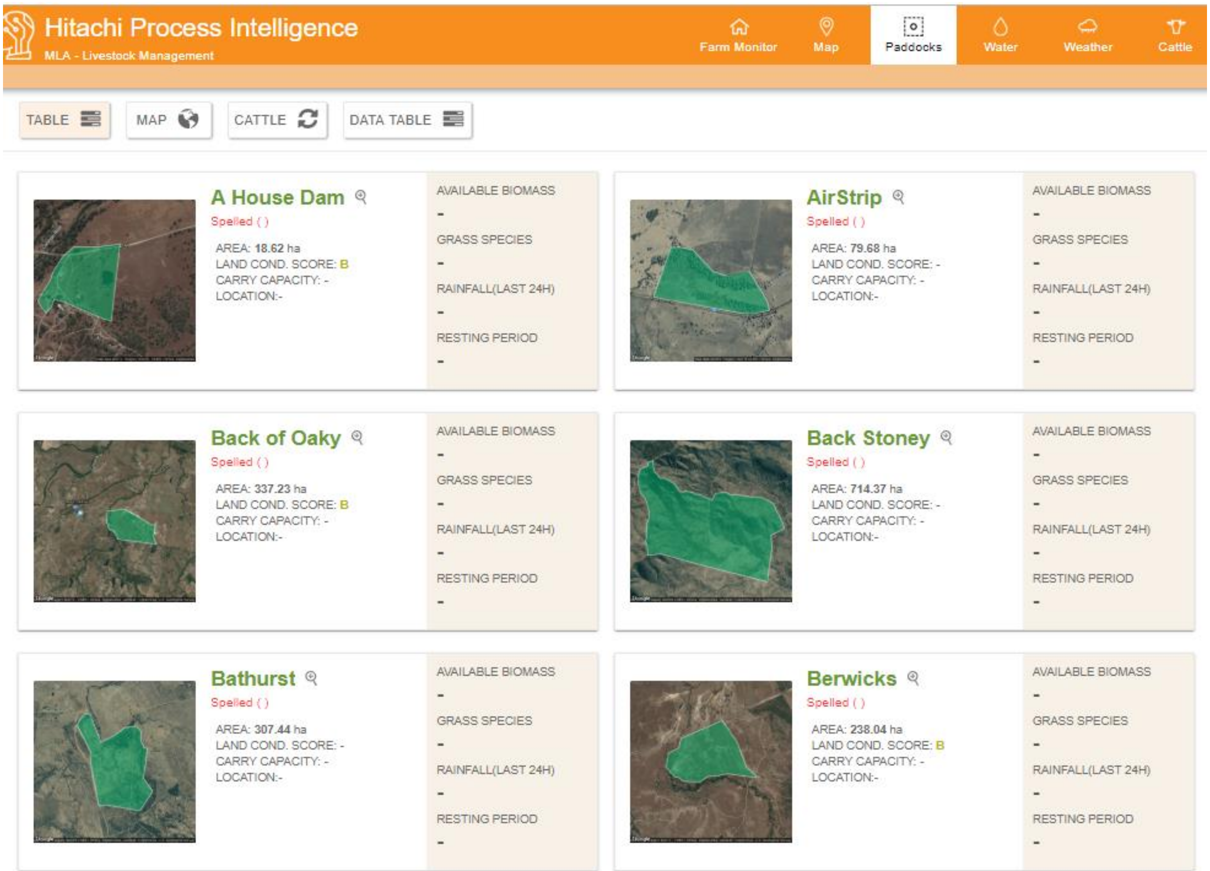

Figure 7 Map showing the different paddocks with size of each.

Calliope Station has 75 paddocks on their properties. Every paddock is mapped on the HPI CC, showing the name, shape and size. Further functionality of the HPI CC was not activated as it was not a requirement of the project.

Figure 8 The complete list of water levels of all the tanks and dams on Calliope Station properties.

At Calliope it is important to know that a water source can keep up with the water demand from a mob of cattle. Using a quick rotation grazing pattern mobs are traditionally larger and therefore the demand for water is higher. The graphs in figure 10 show a full view of the demand on a water source when a mob of cattle was moved into Back of Oaky paddock.

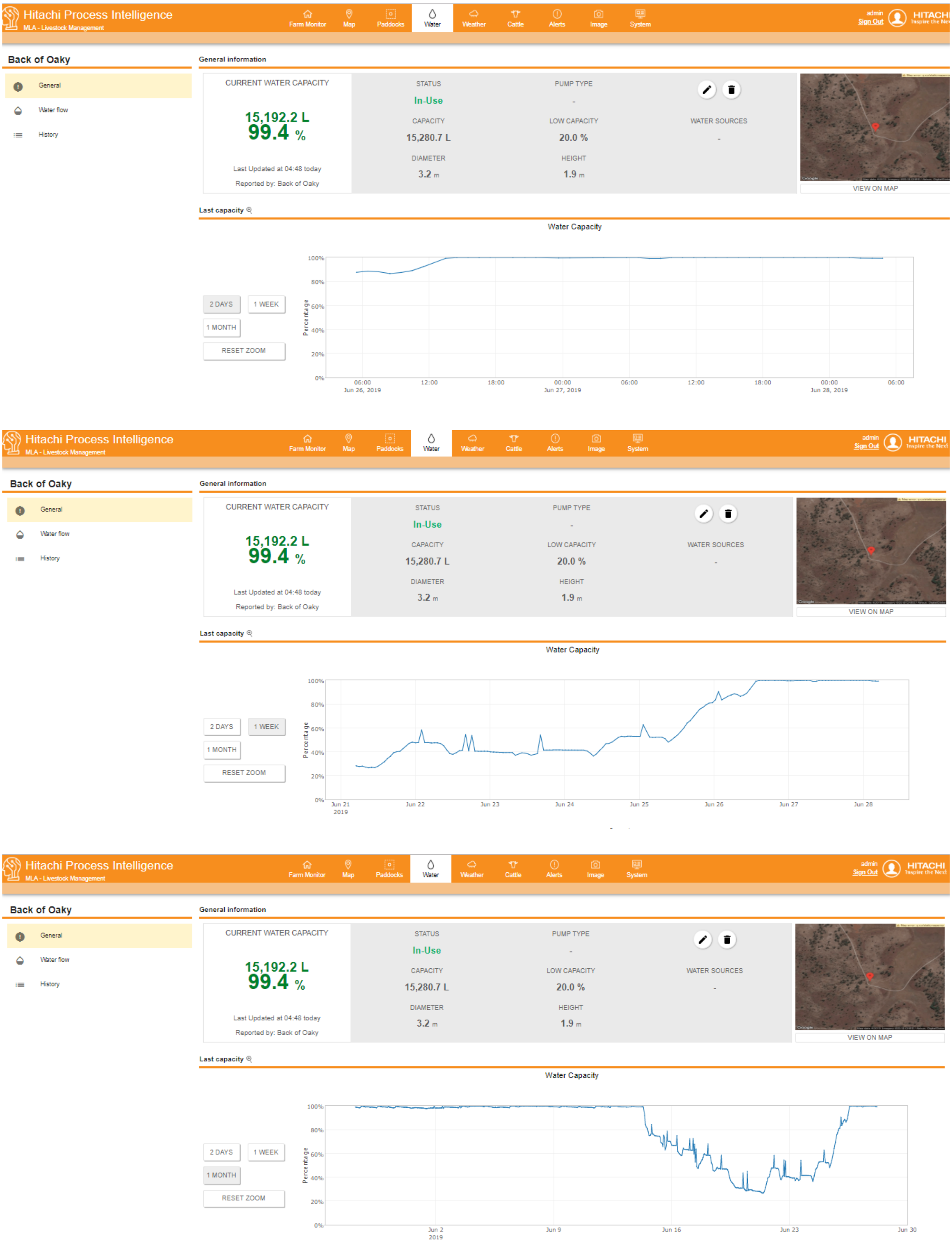

Figure 9 Actual graph of water level at "Back of Oaky" tank 2-day, 1-week, and 1-month reading graphs

As a producer the water level graph is important as it shows the ability of a water source to provide adequate water for a specific mob size from June 14 to June 26, 2019 – a period of 12 days.

A Davis weather station has been erected at Oaky Creek yards. Temperature, humidity, rainfall and windspeed data are collected and every hour updated. The following graphs show 1 week's data.

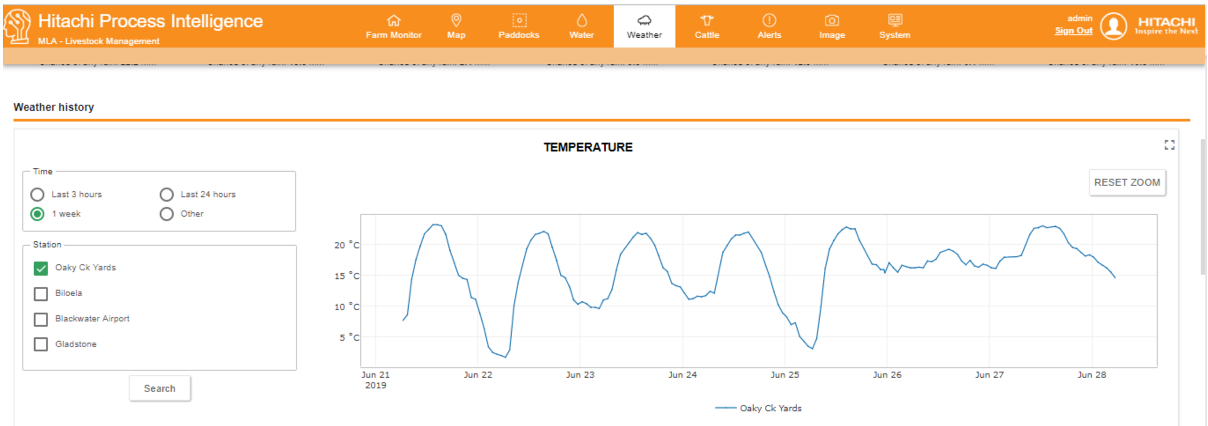

Figure 10. Temperature data showing a maximum of 23.2°C on the 21st of June and a low of 2.0 °C on the 22nd of June 2019. Noting a rain event between 26 and 27 June kept the temperature stable around 18 - 19°C.

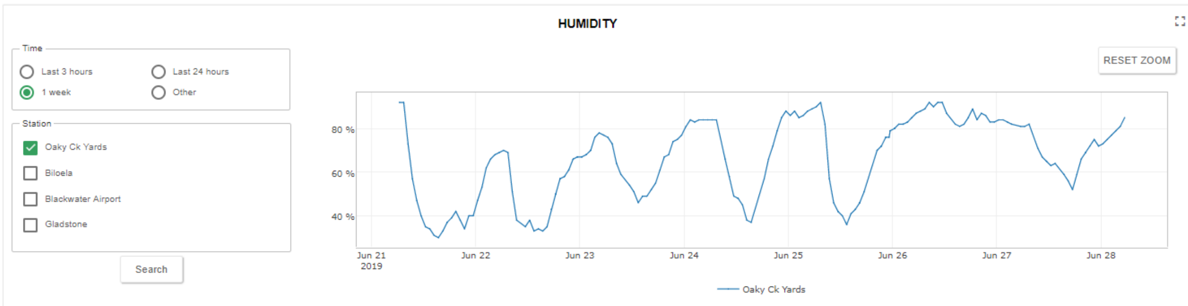

Figure 11. Humidity. Again, levels remained high between 26 – 27 June 2019.

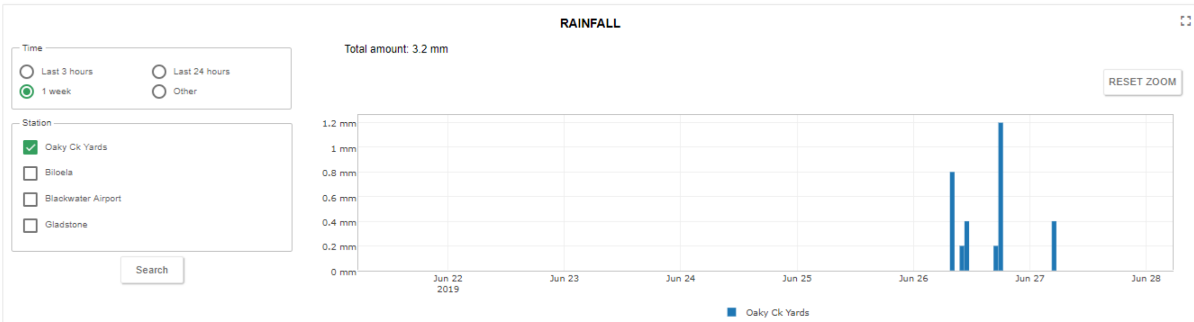

Figure 12. Rainfall data show the rainfall event on 26 – 27 June delivering only 3.2mm over this period, but a substantial influence on the temperature range due to the cloud cover and the humidity levels throughout the day and night.

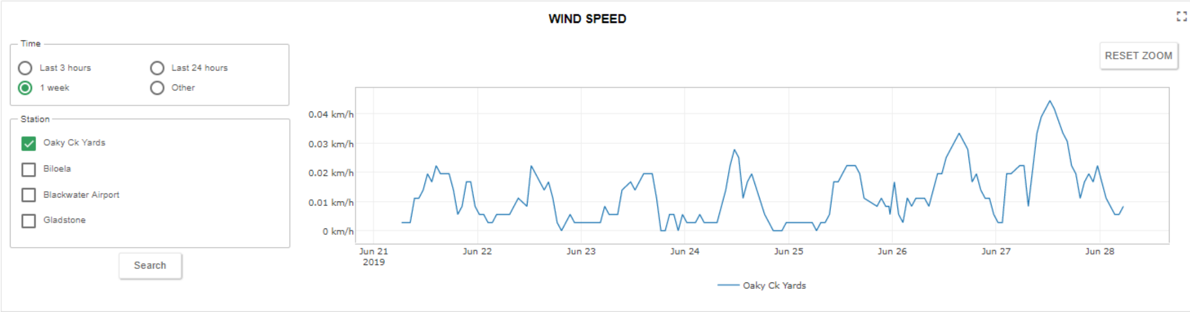

Figure 13. Windspeed data showing a slight increase in windspeed during the rain event of 26 – 27 June 2019.

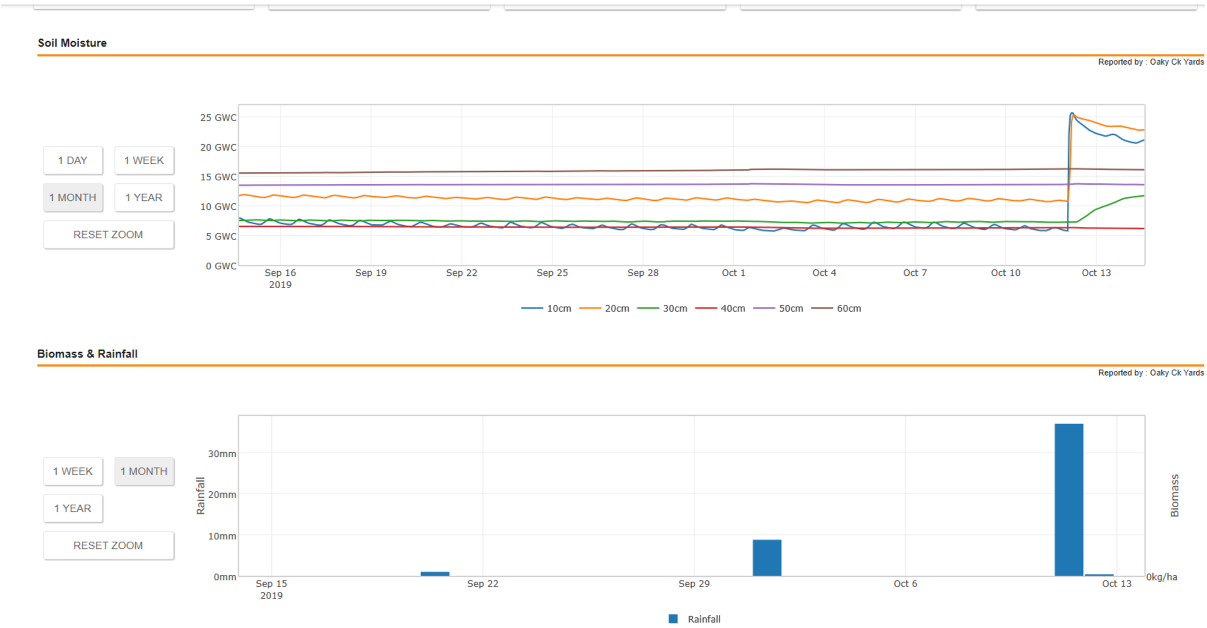

Figure 14 The effect of 37mm rainfall as it occurred on 12 October 2019 on soil moisture levels on 10cm (blue line), 20cm (orange line) and 30cm (green line)

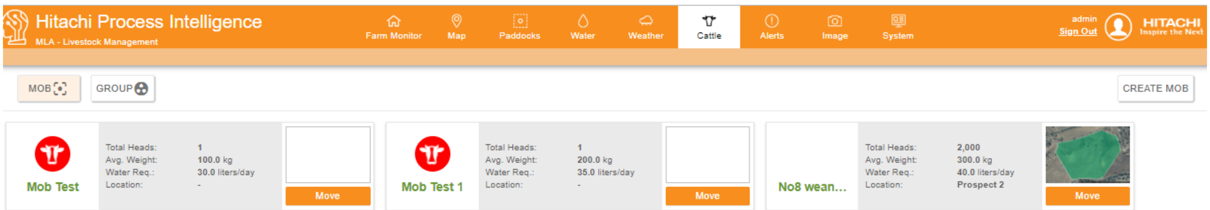

Figure 15 Cattle functionality dashboard

Cattle data is not recorded as it was not a requirement of the project.

An alert system was created to warn Calliope station management should a critical level is reached. The alerts can be set up as a trigger to notify the person assigned by email or text message or can be escalated to a second or third tier should the alert not be acknowledged.

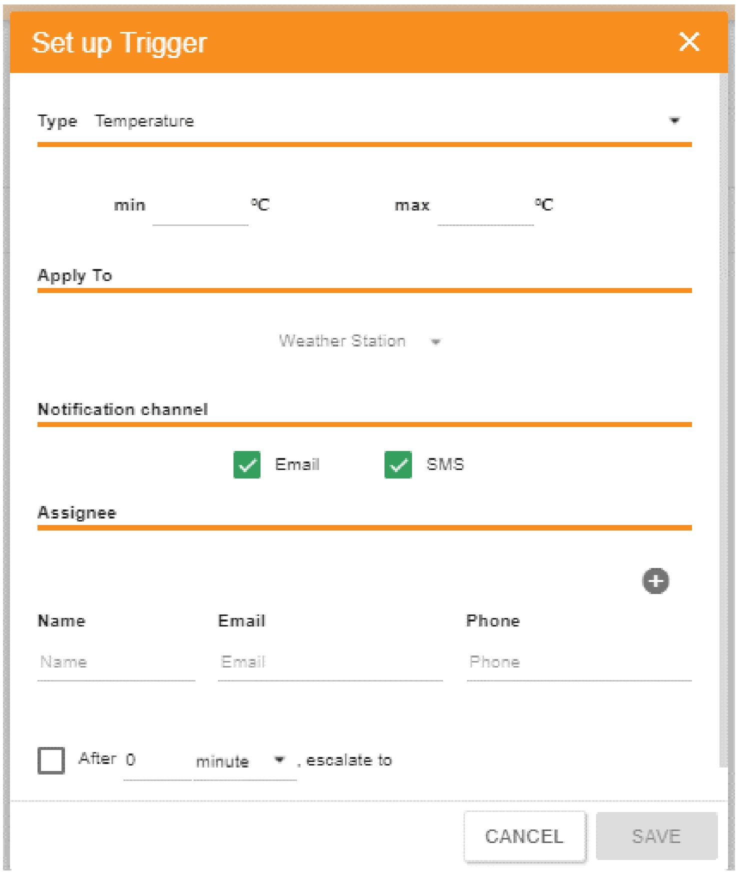

Figure 16 Setting up a trigger for an alert.

Alerts can be set up for a range of events that will have an influence on management decisions. The range shown below also include gates (last on the drop-down menu), where the position of a gate can be monitored and if opened during a period where it should be closed, can trigger an alarm which may be a livestock theft.

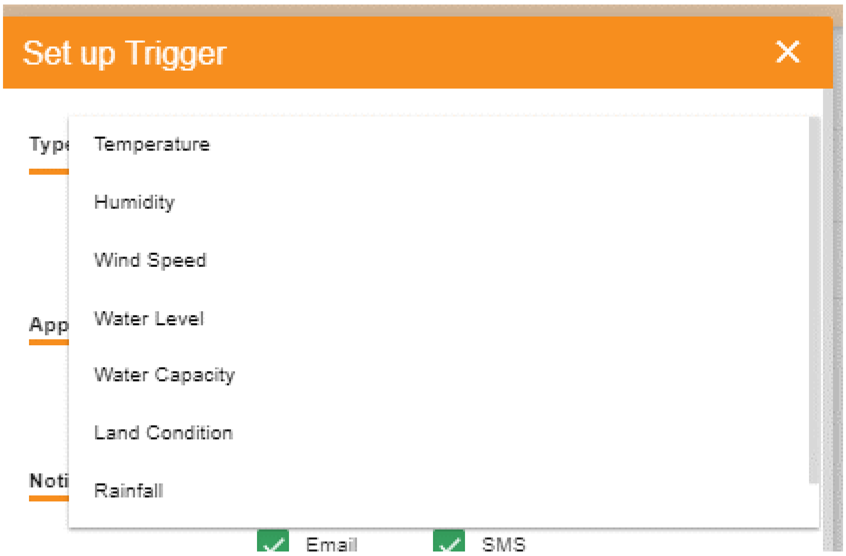

Figure 17 Setting up the trigger type. The last type is “Gate” at the bottom of the dropdown list – not shown in the image.

The Calliope Station management can also view their choice of a date range alerts that has been triggered for a certain type of event.

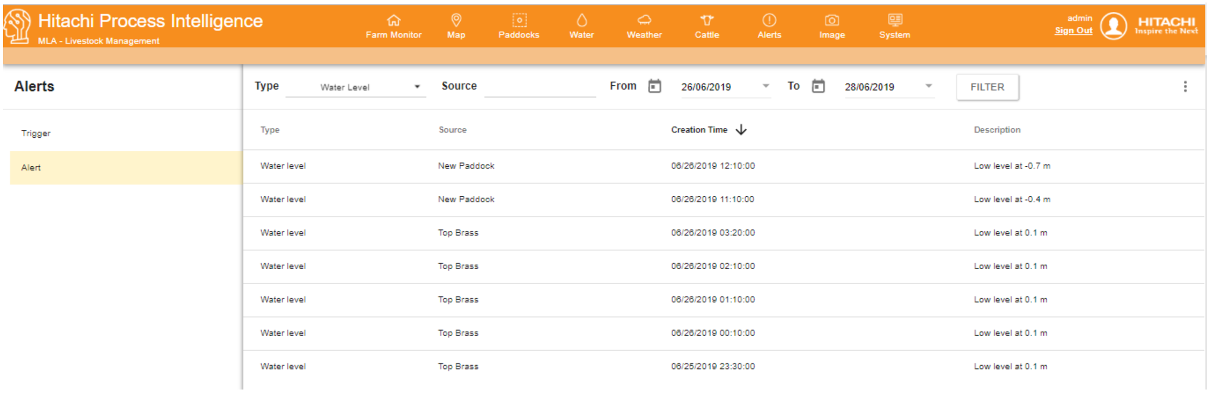

Figure 18 Tab showing alerts that have been activated over the last 2 days.

5 Discussion

The need to capture water levels on all tanks and dams at Calliope Station was identified as the most significant requirement that will have an impact on the productivity of Calliope Station. Location of each of the sites was identified on Google Maps, which was then followed by a visit to several sites to review the following type of reservoirs: polyethylene tanks, concrete dams and concrete reservoirs. The undulating terrain and location of the different water sources was identified as a potential challenge because of the LoRa network line of sight requirement for a good connection to transfer data.

No data about water levels has been traditionally captured at Calliope Station. Water levels were inspected during weekly water runs with long distances travelled to check water points. Vodafone 3G and 4G network was not available throughout the properties and locations of base stations had to be carefully selected to ensure connectivity to the Vodafone network. Rainfall was the only weather data captured and records date back to early 1900's which was meticulously kept by 3 generations of the Wilson family.

Installation of the LX equipment was done with technicians from the LX Group and Hitachi Consulting. Bluenodes connected at the water, soil and weather stations sensors connect to the base stations through the LoRa system. Base stations fitted with the Vodafone Global Sim provided connectivity to the Vodafone Mobile network and via the Vodafone Cloud with push notifications to the HPI CC. Data from the Bluenodes was successfully collected and through the Vodafone network displayed on the HPI CC.

This project delivered valuable insights into connectivity especially in the undulating terrain at Calliope. In certain instances, data from a Bluenode could be captured over 30kms on a base station whilst in other instances range was limited to 3 km because of terrain limitations. Satellite connectivity will be an alternate back-up solution where all other connectivity measures fail. Data can be sent directly from a sensor via satellite to the HPI CC as demonstrated in Project P.PSH. 0815 Assessing value chain improvements in processes, practices and technologies using optimised data capture and analytics.

5.1 Challenges connecting Gateways to Base stations

5.1.1 Elevation profile

In an undulating terrain it is difficult to establish line of sight between 2 points. Vision can be blocked by trees or not even seeing the next point as one can be unsure of the exact direction. Google Earth has a functionality "Elevation Pathway" which is a great tool to use in establishing the ideal location of a base station to connect to as many Bluenodes as possible. The figure below shows the elevation pathway as an example between 2 points on the Google Earth map.

The total distance between the 2 points is only 6.35km with the elevation starting at a height of 124m above sea level to 114 m at the end however there is a rise of 135m just before the second point which makes line of sight impossible.

This feature on Google Earth will assist the planning process tremendously in an undulating terrain such as was found at Calliope Station.

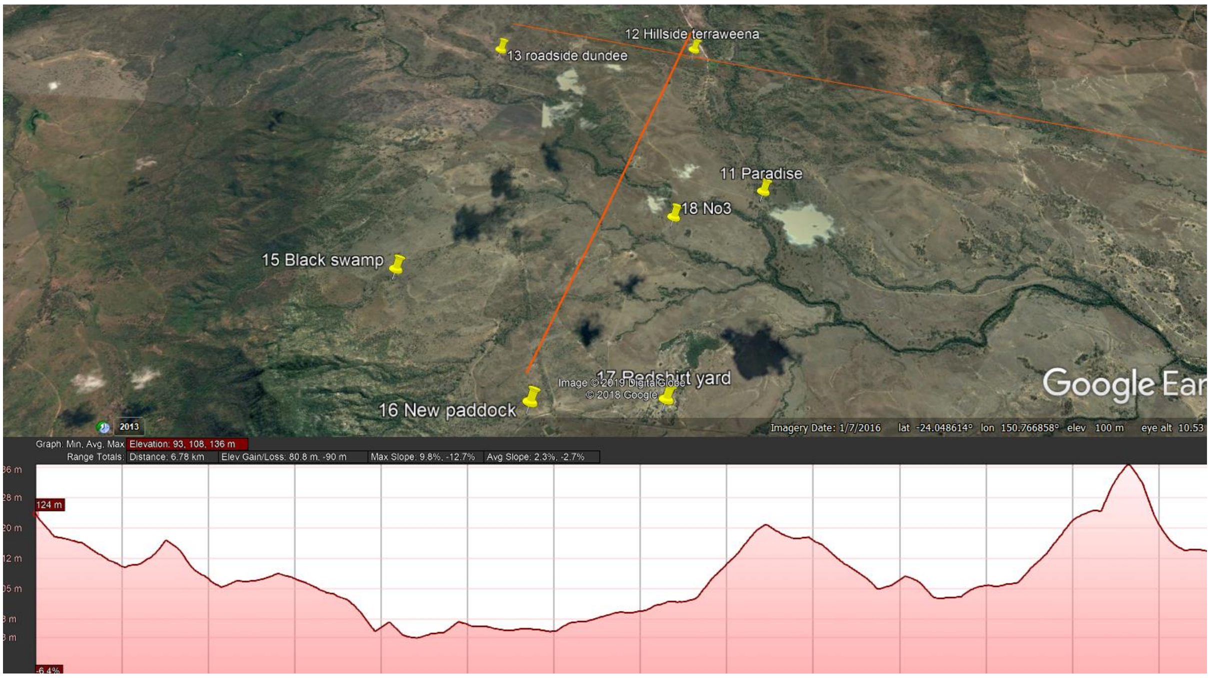

Figure 20. Elevation profile between New paddock at a height of 124 m above sea level and Hillside Terraweena 6.35 km away at 114m above sea level. A rise of 135 obscures direct line of sight to the second point.

5.1.2 Antenna choice

In certain locations it was found that the standard antenna had to be replaced with either a directional antenna or a high gain antenna to get efficient data transformation between a Bluenode and a Base Station. Obstructions such as tree density or height has in most cases played a major role in connectivity between the 2 devices.

5.2 Water level sensors to suit reservoir type

In open concrete reservoirs is was found that debris or algae drifting on the water surface absorbed the ultrasonic sensor pulses indicating an empty reservoir when it was actually full. The ultrasonic sensors were replaced by water pressure sensors which eliminated the problem.

Ultrasonic sensors placed on the inside of black plastic tanks had small evaporation droplets accumulating on surface of the sensor which indicated a full tank whilst the tank was near empty. By placing the ultrasonic sensor outside the tank and drilling a large hole through which the sensor could function eliminated the problem.

5.3 Recommendations for additional sensors

The following IoT sensors would create additional value at Calliope Cattle Station:

- Biomass calculation using a suite of technologies available i.e. multispectral imaging by a remotely piloted air systems (RPAS)
- Identification of pasture species by using digital botanal imaging with a small RPAS with artificial intelligence (AI) and Machine Learning (ML) and using it in conjunction with the multispectral imaging to calculate biomass as well as palatable and unpalatable grass species

- Tracking of cattle with GPS monitored ear tags. Developing heat maps identifying the favourite grazing zones in a paddock and focussing biomass calculations in these areas
- Incorporating walk over weighing data to provide decision support as to when to move animals to feedlots or processing
- Incorporate body condition score data with remote cameras at walk over weighing stations and water points to provide additional decision support such as when to move animals to feedlots or to processing
- Incorporating HPI best practice management to increase productivity and profitability

5.4 Cost Benefit Analysis

A Cost benefit analysis (CBA) on the improved profitability of Calliope Station was done. The CBA show a marked improvement in profit after year 2 which included the capital cost for all equipment and the installation thereof.

Factors that are not included in the CBA is stock loss which can occur when water tanks run dry.

COST BENEFIT ANALYSIS SUMMARY CALLIOPE smartsheet

QUANTITATIVE ANALYSIS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
BENEFITS						
COST SAVINGS	$ 15,500.00	$ 15,500.00	$ 15,500.00	$ 15,500.00	$ 15,500.00	$ 77,500.00
COST AVOIDANCE	$ 1,222.00	$ 1,222.00	$ 1,222.00	$ 1,222.00	$ 1,222.00	$ 6,110.00
REVENUE	$ -	$ -	$ -	$ -	$ -	$ -
OTHER	$ 9,600.00	$ 9,600.00	$ 9,600.00	$ 9,600.00	$ 9,600.00	$ 48,000.00
TOTAL BENEFITS	**$ 26,322.00**	**$ 26,322.00**	**$ 26,322.00**	**$ 26,322.00**	**$ 26,322.00**	**$ 131,610.00**
COSTS						
NON-RECURRING	$ 50,655.00	$ -	$ -	$ -	$ -	$ 50,655.00
RECURRING	$ 5,280.00	$ 5,280.00	$ 5,280.00	$ 5,280.00	$ 5,280.00	$ 26,400.00
TOTAL COSTS	**$ 55,935.00**	**$ 5,280.00**	**$ 5,280.00**	**$ 5,280.00**	**$ 5,280.00**	**$ 77,055.00**
NET BENEFIT OR COST	**$ (29,613.00)**	**$ 21,042.00**	**$ 21,042.00**	**$ 21,042.00**	**$ 21,042.00**	**$ 54,555.00**

Table 3. Cost Benefit Analysis summary for a period of 5 years.

Key areas where cost savings were made included, general business process improvement, productivity gains in animals (estimated) and reduced staffing costs. The deployment of IoT sensors and related data analysis reduced the need to manually check watering points. This allows saving in labour and vehicle running costs.

The cost and benefits were future analysed over both 5 and 10 year periods. Based on initial upfront costs for implementing the system was $50,650 and the benefits gained business operations and labour cost savings exceeded $26,000 per year, the cost benefit analysis shows that the system is cash flow positive within 2.5 years with a total benefit and cost saving of $54 555 after 5 years. The deployment of the IoT network and data processing intelligence was shown to provide a 57% and 151% return on investment after 5 and 10 years respectively. Overall benefit cost ratio for 10 years was 2.6:1 with an internal rate of return of 40%. This clearly shows the benefits gained from implementing the system.

5.5 Industry adoption

After initial teething problems, the solution is proving to be worthwhile as a major productivity solution. Time can now be spent on more urgent tasks and there are savings in labour and vehicle expenditure. The solution can be extended to monitor bores water depth, water pressure in pipelines, gate positions, flood warnings and a multitude of other applications since the LoRa system is installed.

People and vehicle movement can also be tracked which will play a major role in occupational health and safety. Knowing where every vehicle and person is on a property could make significant differences when emergencies arise.

6 Conclusions/Recommendations

6.1 Visualisation of farm data

6.1.1 Dams and tanks

One of the challenges extensive livestock operations has is monitoring of water levels in dams and tanks. This is done by traveling long distances by vehicle to inspect water sources.

Having water source levels reported on the HPI Control Centre in the comfort of your office or mobile device makes a significant difference to productivity and profitability of farming operations. Advanced warning through the alert system ensures that appropriate action is taken to rectify the problems, it also gives comfort knowing that a water source is monitored 24 hours a day.

Advanced warning of inclement weather events about to take place can also result in reducing stock losses that otherwise could have occurred.

Stress levels for both the owner and animals is reduced knowing stock water is always available and monitored. Fatalities of livestock due to water shortages can be significantly reduced.

The HPI Control Centre has several functionalities not required for this project. Capturing data of livestock through the value chain will make a huge impact on the management principles with data showing the best options to manage livestock for optimal results. This can be achieved through:

- Genetics tracking to select the best genetic traits for a breeding program
- Biomass calculation with RPAS equipped with multispectral and RGB cameras to select the best paddocks giving the highest yield on weight gains
- Pasture species identification and determining of percentage palatable species available in pastures
- Individual RFID tracking of livestock through the value chain and selecting best options to increase profitability
- Livestock tracking with GPS equipped ear tags that will show location of mobs in a paddock and current grazing patterns improving paddock management while also been able to identify sick animals that have not moved for a set period

- Decision support through algorithm development to determine mob exit dates from a paddock, decisions to buy, sell or keep livestock, best paddock selection to move a mob

7 Key Messages

7.1 IoT and connectivity

The project demonstrated that a range of sensors connected via LoRa and a mobile network can provide adequate connectivity to allow real time data collection and monitoring across remote properties.

Planning of the location of base stations is essential in setting up a LoRa network to ensure line of sight between the gateways and base stations.

7.2 Data transformation

Data analysis and prediction through HPI was able to provide real time information of water levels, weather data and soil moisture levels. Presentation of this data enabled efficient management of resources by property managers. Through improved data management productivity gains were achieved by reducing labour costs and resource management.

The project demonstrated that for effective data transformation and more particularly data presentation a co-creation model should be used with stakeholders.