Sugar Research Australia

# FINAL REPORT 2020/201

# EVALUATING THE SUITABILITY OF TWO MUD LEVEL SENSING TECHNOLOGIES FOR JUICE CLARIFIERS

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## ABSTRACT

Mud level measurement using sensors in juice clarifiers is a challenge for Australian sugar mills. Measurement of the mud/juice interface is typically by manual means and the operator must visually locate the position of the interface through sight glass windows and make adjustments to either mixed juice feed rates or mud filtration rates to keep the interface at a 'safe' operating level. High level excursions can cause carry-over of mud particles into the clarified juice (with subsequent impact on evaporation and crystallisation). If the interface is too low, then rat-holing of juice to mud can occur (impacting mud filtration and increasing filtrate recycle). Sugar mill juice clarifiers present a harsh environment for in-situ interface monitoring owing to the high temperature (100℃), varying populations of suspended floc particles, relatively fine density profiles and rotating equipment inside the vessel.

This report evaluates the performance of two different mud level measuring technologies on SRI type clarifiers: 1) an ultrasonic in-situ transducer; and 2) an externally mounted system using visual monitoring of the interface through the sight glasses. Recommendations for the viability of both these technologies and the outcomes of a cost/benefit analysis are presented.

During the 2020 crushing season both systems demonstrated their ability to identify and continuously track juice clarifier mud levels. The advantages of a visual point monitoring system (VPMS) include external installation with real-time remote visual monitoring of mud level through sight glasses, a potentially lower overall cost of installation and the ability to monitor both suspended (dispersed) solid level as well as the compacted mud level. The VPMS is also showing potential, with further software development, to provide a measure of average size of the mud flocs. The ultrasonic transducer is situated inside a clarifier vessel and offers the benefit of a simple robust installation with analogue outputs to use in a SCADA system.

## EXECUTIVE SUMMARY

Clarifier mud level measurement is a challenge to the Australian Sugar Industry. Until now there has been no reliable standard instrument-based method to measure the mud/juice interface in clarifiers. Operators have needed to visually check the level of the interface regularly through sight glass windows or external samplers and make adjustments to feed or withdrawal rates for mud filtration to keep the interface in a ‘safe’ operating position. High level excursions of the interface can lead to carry-over of mud particles into the clarified juice, adversely impacting downstream evaporation plant and crystallisation. Low level excursions of the interface may lead to “rat-holing” of juice through the mud layer, also affecting mud filtration, potentially elevating mud pols and increasing filtrate recycle. Sugar mill juice clarifiers present a harsh environment for in-situ interface monitoring due to high temperatures (>100℃) and rotating mud scraper equipment inside the vessel. Instrumentation is usually required to help minimise direct operator interaction with hazardous plant or materials and provide automation opportunities.

This project evaluated:

1) an internally mounted ultrasonic level transducer system; and

2) an externally mounted system using visual point monitoring system (VPMS) to continuously track the mud interface level through SRI clarifier sight glasses.

An Entech EchoSmart Level Transducer (BinMinder) was installed in Millaquin Mill’s SRI clarifier in the 2019 crushing season and used for the 2019 and 2020 seasons. For the 2020 crushing season, the Millaquin Mill clarification operators manually recorded mud level based on visual observation through the sight glasses several times every day during operation. These data provided a reference for comparison to the data from the ultrasonic level transducer. In the 2020 crushing season, a BinMinder similar to the one installed in Millaquin Mill, along with a VPMS were installed and tested on a SRI clarifier at Victoria Mill.

The BinMinder measurement principle is to direct an ultrasonic signal at a specific frequency of 657kHz vertically towards the mud/juice interface through the juice within the clarifier and evaluate the returning signals to calculate and record the distance to the interface from a defined point of reference (floor or top of the clarifier). The velocities of the signal through the juice are inputs to the transducer. The signal from the transducer is conditioned to ignore interference from the stirring arms and update level measurements at predefined intervals. The VPMS communicates with the cameras using QUT-developed software to capture the incoming images at 1 second intervals. Each incoming image is compared to the previous image and, using the differences between those images, recognises the locations of the maximum change.

The main conclusions from the project were:

- Both the VPMS and the BinMinder are capable of reliably measuring the mud-juice interface although slightly different locations for the interface are provided.
- The recorded interface at Victoria Mill using the VPMS was typically 0.04m above the recorded interface using BinMinder. The difference between the manually recorded mud interface level and the BinMinder readings for the Millaquin Mill was typically less than 0.1m.
- The visual camera system showed the settling of the floc particles above the mud level and it appears that the VPMS could be developed further and provide an average floc size and possibly average settling rate. This development would be of major benefit to the monitoring and control of the flocculation process.

It is proposed that the VPMS will be tested for another season at Victoria Mill and operated in conjunction with the already-installed BinMinder. The VPMS should also send real time visual data to the appropriate control room so that operators can check and validate results and conditions. There remains some work to enable continuous data flow from the VPMS to the SCADA system. After the 2021 season the VPMS should be commercially available to all Australian mills.

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# 1. BACKGROUND

## 1.1 Mud level measurement in the clarifier

Mud level measurement using sensors in juice clarifiers is a challenge for Australian sugar mills. The need for a suitable interface measuring system has been discussed at many industry forums. An internal clarifier transducer was trialled in 2007 and 2008 crushing seasons by SRI, but the unit failed due to high contact temperatures within the clarifier.

The usual system of mud level measurement and control is for the operator to visually locate the position of the mud/juice interface through sight glass windows and adjust the mud filtration rate to keep the interface at a 'safe' operating level. High level excursions can cause carry-over of mud particles into the clarified juice while, if the interface is too low, rat-holing of juice to mud can occur. To minimise the operator interaction, and increase automation, this project evaluated:

1) an ultrasonic in-situ level transducer (an Entech EchoSmart Level Transducer), known as "BinMinder"; and
2) a custom-made externally mounted system using visual monitoring of the interface through the sight glasses.

These investigations were undertaken on a SRI clarifier at Victoria Mill. Both systems have reached the stage where they can identify and continuously track juice clarifier mud levels.

The Entech EchoSmart Level Transducer was installed in Millaquin Mill's clarifier in the 2019 crushing season and used for the 2019 and 2020 seasons. For the 2020 crushing season, the Millaquin Mill's clarification operators manually recorded the mud level, based on visual observation through the sight glass, every day (at least 3-4 times a day). These data provided a reference for comparison to the data from the ultrasonic level transducer. Millaquin Mill provided these data for inclusion in the investigations.

## 1.2 Implementation of the measuring systems

### *1.2.1. Entech Design EchoSmart Level Transducer (BinMinder)*

This transducer is located within the juice above the mud interface. Figure 2 shows a schematic of the installation with recommended and actual locations of the transducer within the clarifier. The clarifier at Victoria Mill is a first-generation SRI clarifier (with no perforated plate and a single feed) allowing the transducer to be mounted in a vertical 125mm diameter, stainless steel standpipe installed through the roof of the clarifier. The transducer is supplied with an automatic hot water flushing system to help prevent the working face from becoming fouled with solids. The standpipe was designed with several 100mm perforations to prevent stagnation of juice, whilst still providing mechanical protection. This pipe also allowed an instrument technician safer access to the transducer and flushing system, minimising the hazard of high temperature vapour flowing directly from the top of the clarifier. The location of the transducer head was about 300 mm from the outer wall and 2600 mm from the bottom of the clarifier. The sensor location was nearer the wall than shown in the standard figure, and this could be acoustically managed by settings for the device. The SRI clarifier at Millaquin Mill contains a perforated plate, so the transducer was located through the side wall of the clarifier below the perforated plate. The measurement principle is to send an ultrasonic signal at 657 kHz vertically down towards the interface and then intelligently processing the returning signals to calculate the distance to the interface. The velocity of the signal through the juice is an input to the transducer. The settings allow for the dimensions of the clarifier, operating depths, position of the transducer within the clarifier, null or dead-zone, and can also allow for regular passing of the mud scraper arms.

Performance of the transducer depends on: (1) process liquid in which the ultrasonic signal is being transmitted, (2) interface material, (3) freedom from objects interrupting signal transmission, and (4) areas of excessive turbulence (EchoSmart Operation and Installation Manual, 2019).

Most relatively uniform and homogeneous liquids found in water and wastewater treatment applications and many industrial process applications are suitable for transmitting the ultrasonic pulse. Excessive amounts of suspended solids, gas or air bubbles or other concentrations of solids in the supernatant fluid may inhibit or obstruct the signal. The sensor should be positioned to avoid these conditions if possible (EchoSmart Operation and Installation Manual, 2019).

The EchoSmart Sensor relies on minimal qualifying characteristics of the material that it is measuring. Relatively dense, well-settled suspended solids form a well-defined interface and are effective in reflecting the signal to the sensor. Low density material (< 0.5% solids) that is not well-settled does not form a well-defined interface and is less effective in reflecting the signal to the sensor. Manufacturer advice is that where possible, the sensor should be located in an area that minimizes exposure to these conditions. Ideally the sensor should be in an area where the material (sludge) is relatively deep in the tank under normal process operating conditions (EchoSmart Operation and Installation Manual, 2019).

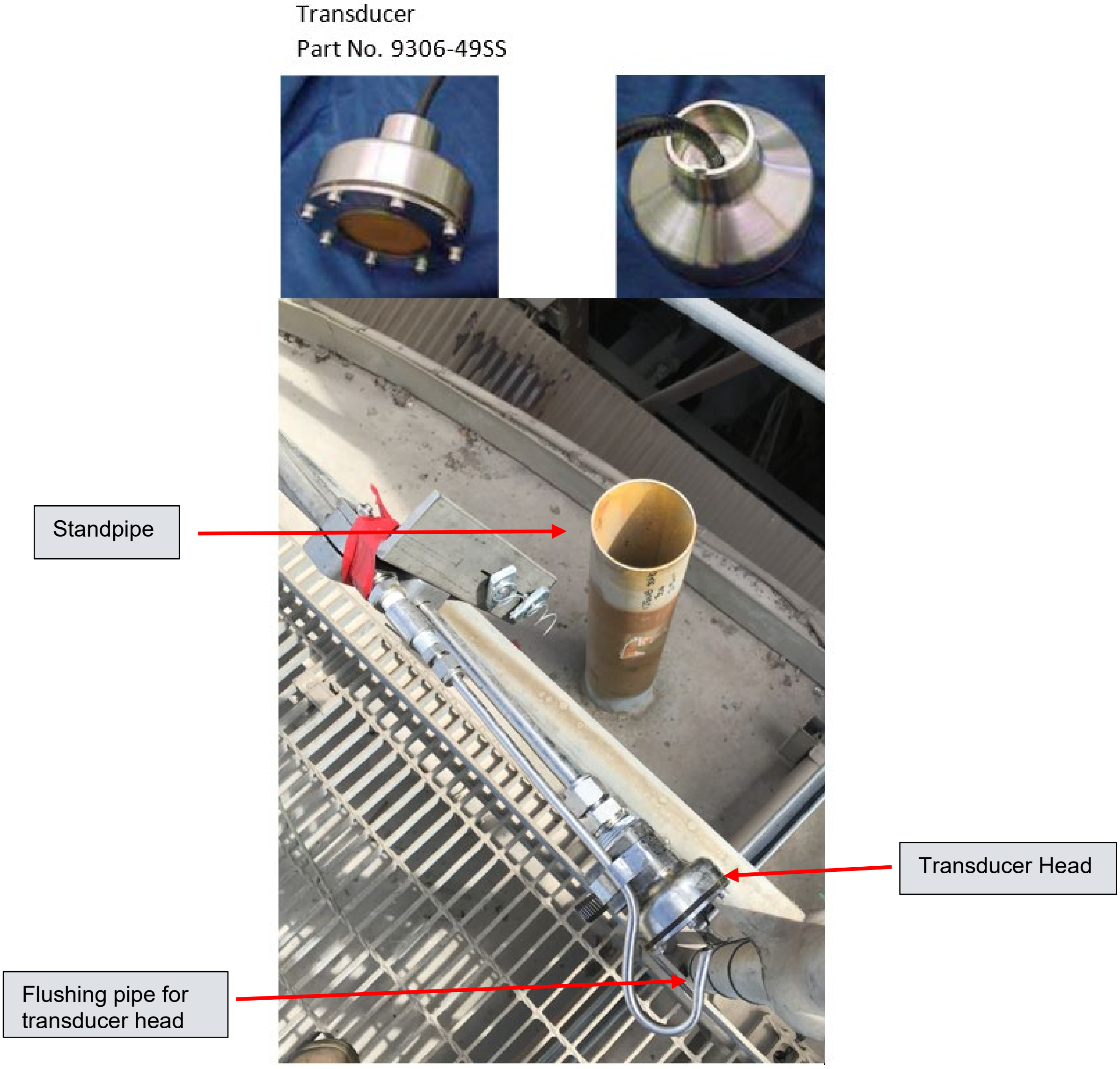


**Figure 1 - Entech Design BinMinder 9300 Transducer and Standpipe**

Based on the above descriptions for the EchoSmart transducer, the measurement of the mud interface in a sugar juice defecation clarifier should be an ideal application.

The EchoSmart HMI display presents the actively updated signal waveform generated by the sensor and used to determine the Level or Range measurement (Figure 3). The horizontal x-axis is a distance axis based on the span between the sensor (lower, left side of the screen) and the bottom of the tank (lower, right side of the screen). The vertical y-axis corresponds to the strength of signal at locations between the sensor and the bottom of the tank.

The HMI Tank View Display shows a scaled cross-sectional view of the tank (Figure 4). The arrow on the left side of the tank provides a visual indication of the primary interface. Suspended solids that may be indicated in the echo waveform are represented by pixilated gradients above the primary interface. A null zone immediately below the sensor head can also help it ignore the “turbulent” area where flocculated juice is being fed to the bulk juice in body of the clarifier.

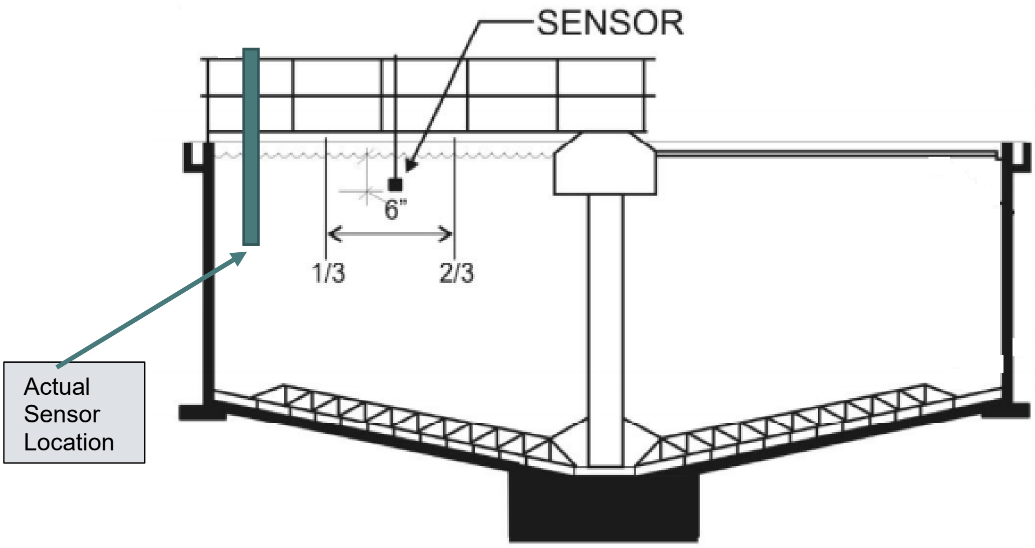


**Figure 2 Typical cross section of a clarifier and location of the BinMinder (EchoSmart Operation and Installation Manual, 2019)**

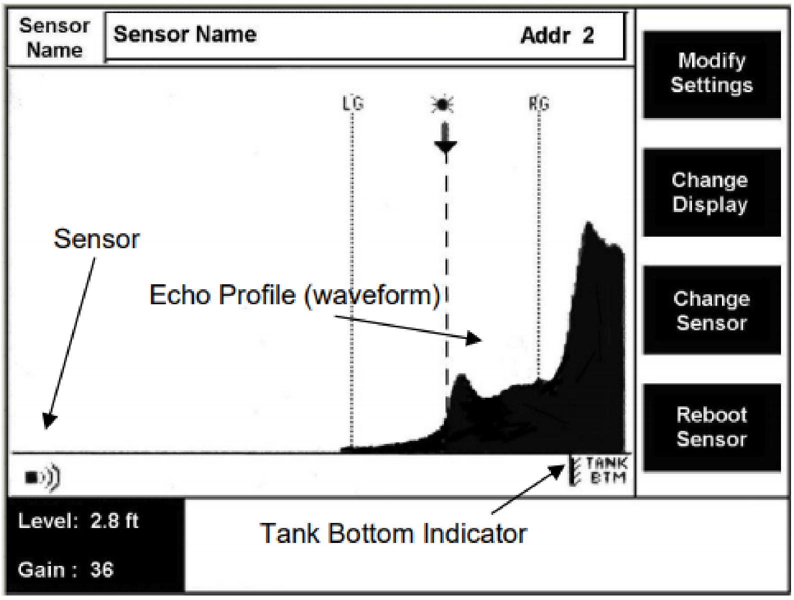


**Figure 3 Echo profile display (EchoSmart Operation and Installation Manual, 2019)**

The EchoSmart device was supplied as specified in Appendix 12.2

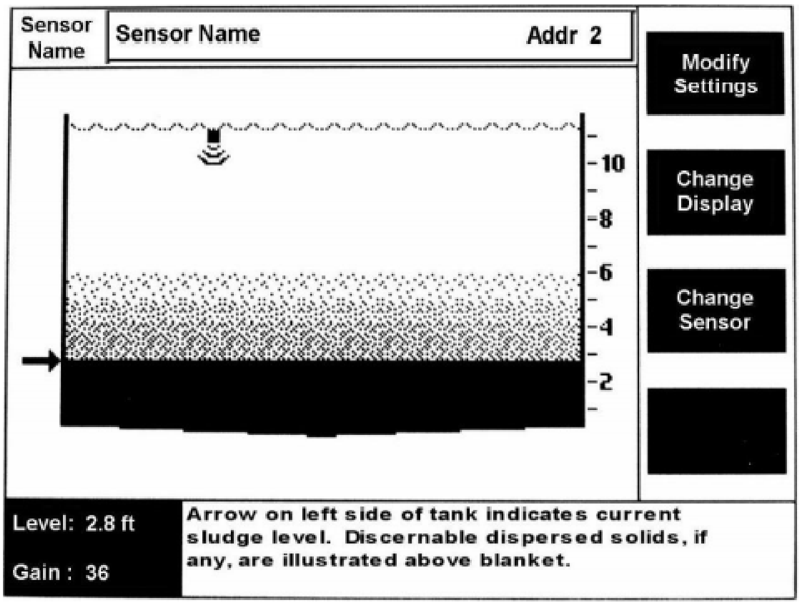


**Figure 4 Tank view display (EchoSmart Operation and Installation Manual, 2019)**

### *1.2.2. Visual point monitoring system (VPMS)*

The point monitoring system uses cameras directed onto the sight glasses to continuously track the mud interface level through the sight glasses. Figure 5 shows the sight glasses of Victoria Mill before installation of the VPMS.

The system consists of four action cameras (GoPro 8), four fans to cool the cameras, two rows of LEDs for providing required light, power supply, four capture cards to transfer the real-time images from the cameras directly to a PC, the PC to run the developed software that reads the incoming images, analyses them, and interprets the mud level (Figure 6).

The cameras were directly connected to the power supply via USB C cable to avoid interruption. All four cameras were equipped with the latest firmware and GoPro Media Mod to display the footage on a screen via micro-HDMI output (Product Manuals, 2019). Figure 7 shows the side view of one of the installed cameras.

Each camera was initially installed to be cooled by a S5 80mm fan. The speed of each fan was adjustable, however on occasions the temperature at the side of the clarifier was too high to prevent the cameras overheating without supplementary cooling.

Highly efficient and lightweight DuroSite LED linear lighting was used to illuminate the sight glasses from the left side. DuroSite is highly resistant to shock and vibration. Its fully gasketed IP66 rated enclosure makes it suitable for dusty & wet locations. The light source came with a polycarbonate lens and was sufficient to illuminate the sight glasses with 3,300-7,900 lumens. Later, a LF2B-F3P-ATHWW2-1M LED was added to the right side of the sightglasses to help balance the image brightness. The new light source was only sufficient to illuminate the sight glasses to 1000 lumens. To stop reflection, a matt black paint was used to cover the edge of sight glasses, and an enclosure was formed around the sight glasses using a non-reflective blackout curtain material.

**Figure 5 Clarifier at Victoria Mill before the visual camera system installation**

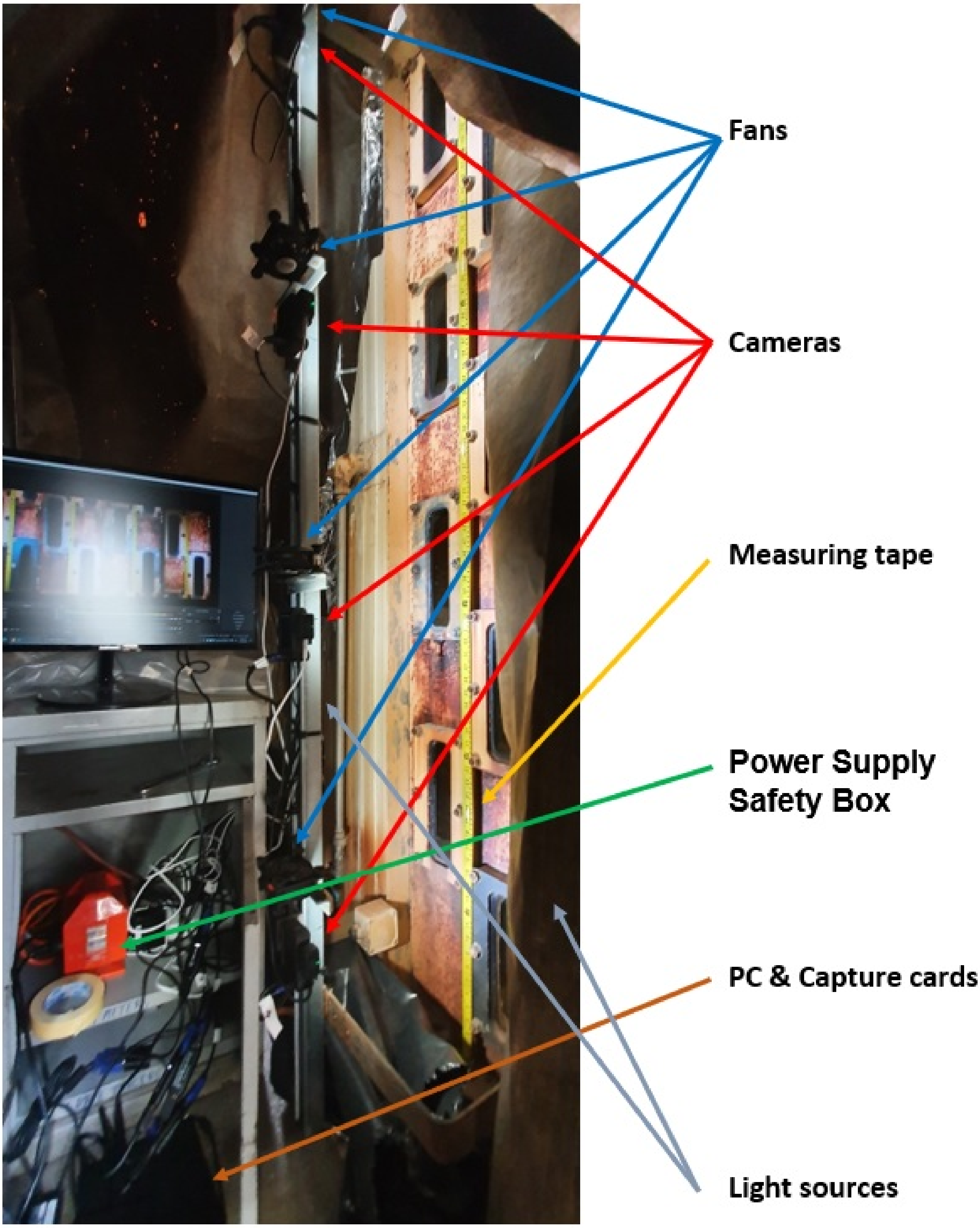


**Figure 6 Clarifier at Victoria Mill after the visual camera system installation**


**Figure 7 Camera and fan configuration (side view)**

A measuring tape was installed in the gap between the sight glasses as shown in Figure 8 to allow level measurement calibration of the images and provide a reference position.

The software to analyse the captured images was developed at QUT in Python 3.7. This software communicates with the capture cards and obtains the incoming data at one second intervals. The received images were cleaned, cropped and prepared for analysis. The prepared image was converted to a matrix based on the colour intensity of its pixels. In the next step the matrix was compared with the previous matrix produced from the former image to recognise the locations of maximum change.

**Figure 8 Measuring tape to allow calibration of the images**

Figure 9 shows a snapshot of the results from the video point measuring system taken on 16th of November at 15:18. The results contain the images from 2 to 5 sight glasses, with the level added to the left side of each image. It is clear that the mud level at this instance was 68cm.

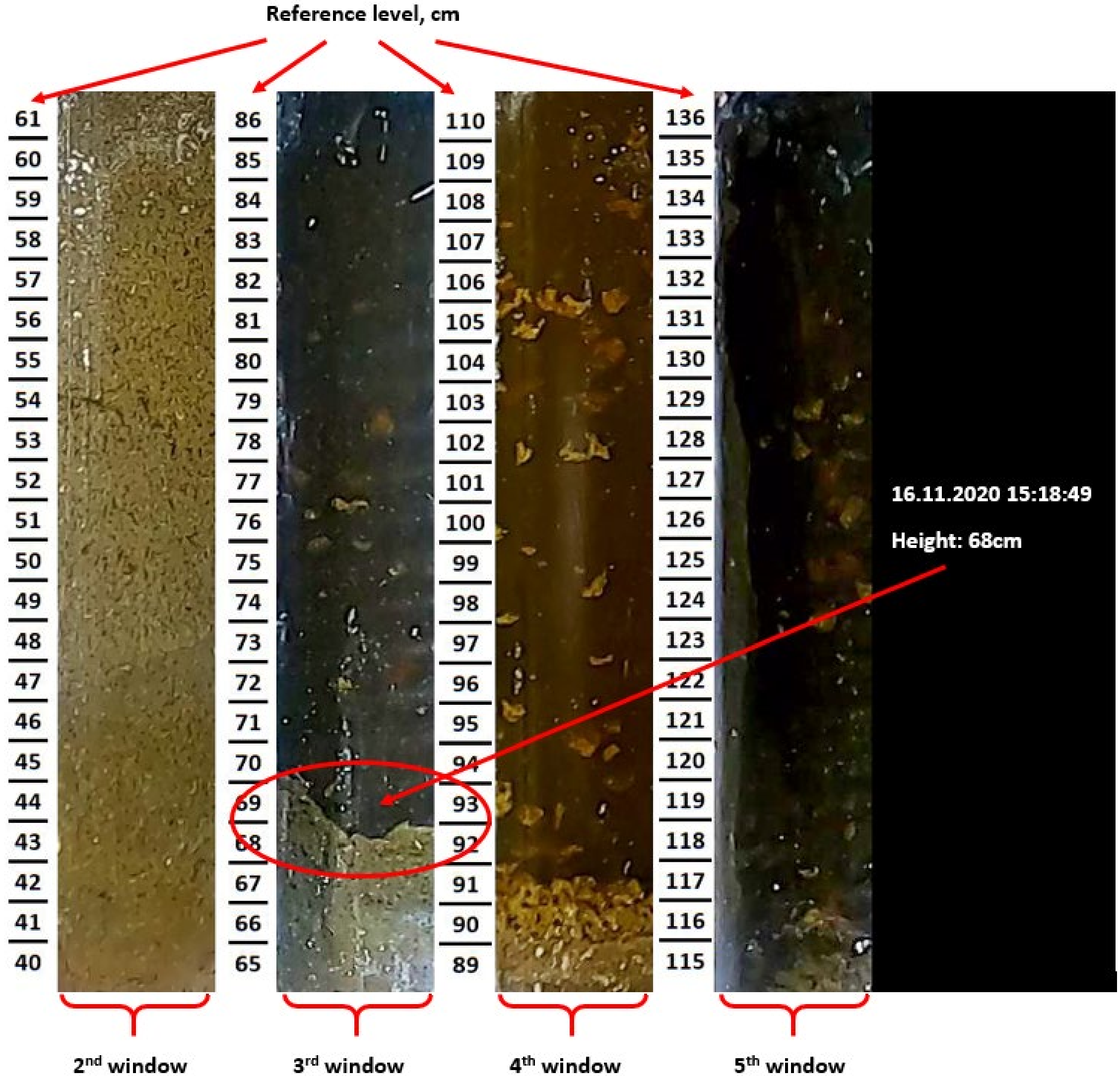


**Figure 9 Sample of images and results from the visual camera system**

## 2. PROJECT OBJECTIVES

The objectives of the project were to:

- Determine the suitability of the Entech EchoSmart Level Transducer in a dynamic high temperature juice environment to continuously track clarifier mud level.
- Determine the suitability of a visual camera system and point monitoring platform to continuously track mud interface level through the sight glasses of the clarifier.
- Correlate the interface measurements from the two technologies with levels recorded by the operators.
- Evaluate the benefits to the factory and conduct a cost/benefit analysis for the two technologies.
- Report the application of both systems to Australian mills and provide recommendations on the preferred system and its implementation.

## 3. OUTPUTS, OUTCOMES AND IMPLICATIONS

### 3.1 Outputs

The outputs from the project are:

- Knowledge of the suitability of each technology to provide a reliable measurement of the position of the mud/juice interface.

- Suggestions for modifications to minimise the effects of any shortcomings in each of the technologies.
- A platform for implementing the monitoring system using real-time streaming.
- Recommendations for the preferred technology and the outcomes of a cost/benefit analysis.

QUT would supply the developed platform to interested mills at no charge.

The information from the project is available to assist mills to implement either measurement system.

### 3.2 Outcomes and Implications

The main outcome provides the production managers and instrument engineers with the information to assess the suitability of the two measuring systems for their factories and defines the procedures they need to install the appropriate system on their factory's clarifier(s). This abovementioned information includes but is not limited to knowledge of the performance of the two measuring techniques and comparison between the data obtained from the two methods in 2019 and 2020 crushing seasons at Millaquin and Victoria Mills. The benefits to a mill to install a VPMS include the remote real-time monitoring of the sight glasses, nominally a less expensive installation, and the option to monitor the suspended solid level as well as the compacted mud-juice interface. The benefits of the ultrasonic transducer include compact installation, thermally robust device, responsive real-time interface tracking and indication of the floc settling layer.

Experiences and troubleshooting exercises during the commissioning of the two systems are also relevant outcomes:

- The readings of ultrasonic transducer did not match with the mud level, and after extensively investigating the problem, it was determined that the firmware for the transducer junction box was incorrectly configured. After the manufacturer replaced the firmware, the results from the transducer were consistent and reliable.
- Due to the heavy rains and interruptions to crushing mid-season and issues with automating water supply application, the bottom sight glasses of the clarifier backfilled with mud and became blocked. The flushing system was not able to remove mud from the bottom glass, so it was decided to only track glasses 2 to 5 (measured from the bottom). These glasses were in the main range of interest for changes in mud level.
- Due to the high temperature inside the curtained enclosure, the cameras experienced overheating several times during the test period. The cameras' internal protection automatically caused them to shut down when their operating temperatures exceeded 50° C, requiring the system to be rebooted each time.
- The difference between the LED light sources intensities on either side of the sight glasses produced brighter images for sight glasses 2 and 4 compared to sight glasses 3 and 5. The DuroSite light source illuminated sight glasses 2 and 4 with an intensity of 3,300-7,900 lumens.

## 4. INDUSTRY COMMUNICATION AND ENGAGEMENT

### 4.1 Industry engagement during course of project

As stated in section 3 the main outcome is to provide the mill production managers and instrument engineers with the information to assess the suitability of the two technologies and implement the preferred measurement system.

Engagement to date has been with test sites, the manufacturer and supplier of the BinMinder to optimise settings. Operators also made observations and developed confidence in using the systems for level measurement. There has been no communication with any of the SRA Adoption Officers.

The information available for adoption by the Australian sugar industry is listed in the Outputs.

A paper is being prepared for presentation at the 2022 ASSCT Conference. Results and application into the industry were presented to mill staff in key cane growing regions through the Regional Research Seminar series conducted in March 2021.

### 4.2 Industry communication messages

BinMinder offers straightforward installation for clarifier mud level measurement. The VPMS provided useful mud interface level measurement and an opportunity to provide enhancements including floc particle size, settling velocity and dispersion layer information.

# 5. METHODOLOGY

The methodology for the project was to evaluate the in-situ transducer and evaluate the external monitoring system using point monitoring of the interface through the sight glasses.

The majority of the evaluation work was undertaken on an SRI clarifier at Victoria Mill.

The work program involved the following phases:

- Install the Entech EchoSmart Level transducer on the SRI clarifier at Victoria Mill and make any modifications to the installed transducer at Millaquin Mill.
- Purchase and install the required video cameras, cables, mounting brackets, light sources, and light shielding enclosure on the sight glass windows of the SRI clarifier at Victoria Mill.
- Develop the software platform for interface tracking. The platform that was developed for the purpose of "point tracking" included the following steps:
    1. Capture images and store them in the local drive.
    2. Analyse the images to identify the sight glasses in each image.
    3. Detect objects within each image and assign pixels to those objects.
    4. Undertake frame to frame object tracking. This step tracks the motion and position of the recognised objects within the region of interest from each image and so determine the mud interface through the movement of its position.
- Record data from the measurement systems and the interface level information observed by the operators on the Victoria Mill and Millaquin Mill clarifiers. Prepare correlations of level for the two systems.

# 6. RESULTS AND DISCUSSION

## 6.1 Assessment of the BinMinder results

At Victoria Mill the BinMinder recorded the interface of the compacted mud where at Millaquin Mill measurements were recorded for the interface of both the compacted mud and the top of the suspended solid layer. It should be noted that Victoria and Millaquin Mills did not use the same range and tank bottom reference settings. The supplier was queried and at this stage has not provided information to explain the differences. The range for the sensor at Millaquin Mill was set at 4000 mm while at Victoria Mill it was 2000 mm. At Victoria Mill the zero-reference point was the bottom of the lower sight glass and at Millaquin Mill this point was approximately 200mm above the floor of the clarifier. During commissioning, the initial setting for the speed of sound was found to be different from previous research conducted at Victoria Mill, and as a result further adjustment was required.

Figure 10 and Figure 11 show the compacted interface level of more than 150,000 measurements using the BinMinder from the 2019 and 2020 crushing seasons at Millaquin Mill. The results indicate that in 2019 crushing season, 47% of the time the mud level was between 0.7 to 1.4m, this number reduced to 40% in the 2020 crushing season. It is also evident that in 2020, about 3% of the time the level of the mud was in the range of 3.3 to 4.0 m which would have increased the chance of mud carry-over to the juice stream. In 2019, the maximum logged mud level is 3.5m, and only 3.4% of the data lay between 2.8 to 3.5m.

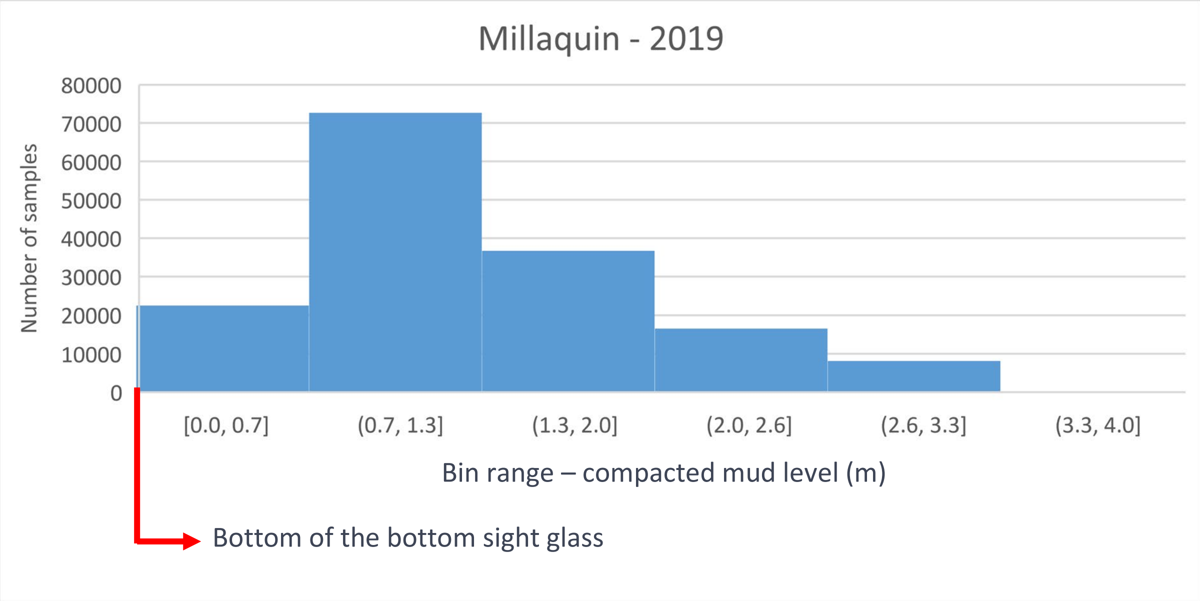


**Figure 10 Mud level distribution obtained from BinMinder at Millaquin Mill in 2019**

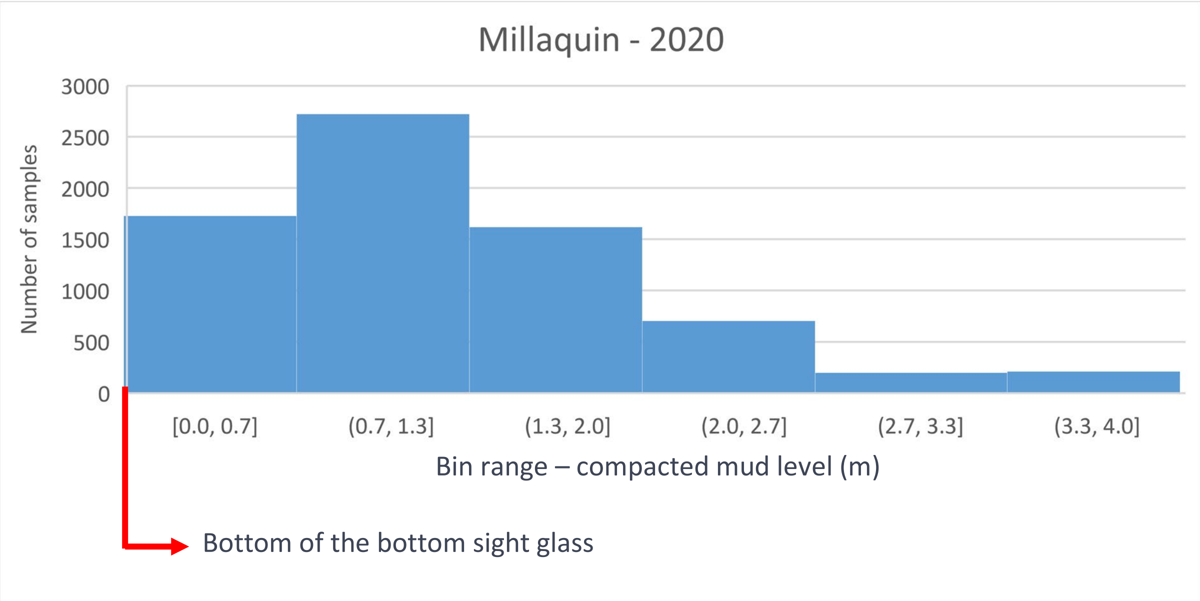


**Figure 11 Mud level distribution obtained from BinMinder at Millaquin Mill in 2020**

Analysing the total recorded data obtained from the BinMinder at Victoria Mill in the 2020 crushing season (Figure 12) illustrates a similar pattern to that observed at Millaquin Mill. For 57% of the time the logged data was in the range of 0.2 to 0.4m, and only 0.7% of the time the mud level was above 0.70m. It is important to mention that the BinMinder at Victoria Mill was principally measuring and recording the compacted (high density) mud level.


**Figure 12 Mud level distribution obtained from BinMinder at Millaquin Mill in 2020**

As previously mentioned, the BinMinder is able to be configured to also measure the interface of the low-density material suspended on top of the compacted layer. The instrument team at Millaquin Mill adjusted the BinMinder to measure both the compacted mud level and the level at the top of the suspended solids above the compacted mud. Figure 13 summarises the differences between the signals for the levels of the compacted mud and suspended solids layers for each single data point in the 2020 crushing season at Millaquin Mill.

This comparison shows that, in the majority of samples (61%), the layer of suspended solids was only 0.05 – 0.1 m thick, and only in 4.5% of the cases is the thickness more than 0.5m. The median of the suspended solids layer thickness at Millaquin Mill in 2020 crushing season was 0.08m. Unfortunately, no visual data were recorded to validate this thickness at Millaquin Mill. This layer is slightly thicker than observed in the Victoria Mill clarifier (usually 0.04m). Possible reasons for having a thin layer of suspended flocs over the compacted mud layer could be differences in mud flocculation quality, mud loading and higher mud settling or withdrawal rates, plus the action of the scrapers in compacting the mud.

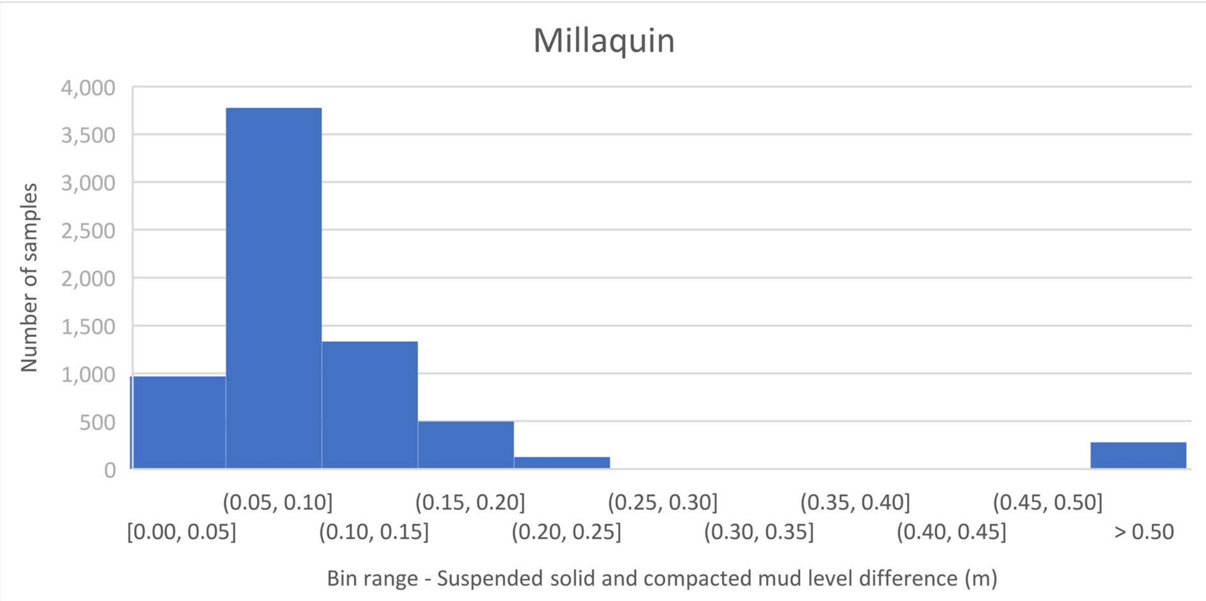


**Figure 13 Distribution of the difference in level of the suspended solids and compacted mud level at Millaquin Mill in 2020**

In the 2020 crushing season at Millaquin Mill, the operators were asked to log the mud level (by visual inspection) a few times every day. There were 503 visual readings. Figure 14 shows the difference between the BinMinder readings (high density mud level) and the level logged by the operator (calculated as BinMinder reading – operator reading). It is notable that in more than 54% of the cases, the BinMinder readings were larger than the visual reading by up to 0.3m, and 40% of the samples were smaller by up to 0.3m. The median of this difference is +0.1m i.e. the BinMinder provided a slightly higher reading than the operator. A possible reason for the differences observed in the data comes from the BinMinder configuration including signal gain, reference velocity, location of the sensor (distance from the wall affecting the perception of the mud surface profile across the clarifier) and changes in the juice media above the interface.

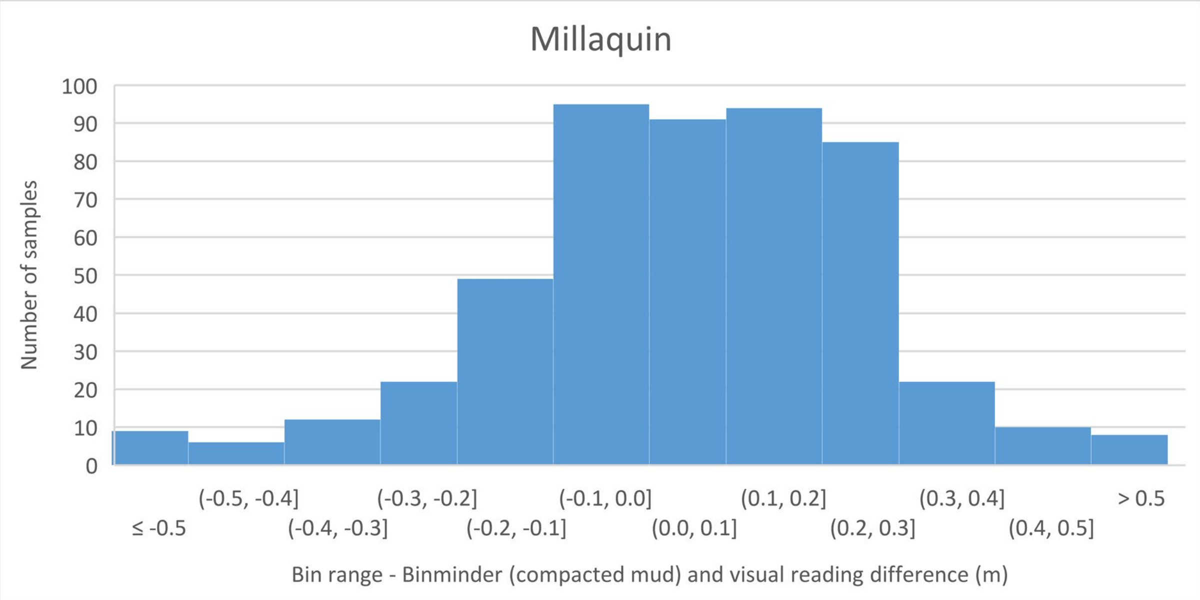


**Figure 14 Distribution of the difference in compacted mud level from BinMinder and visual reading at Millaquin Mill in 2020**

Figure 15 shows an image from the VPMS system that demonstrates the circumstances that may affect selection of the interface position. Three regions can be recognised. The upper region is the “clear juice” with detached solid particles in it. This region is recognised as liquid by the BinMinder. The bottom region is the “compacted mud”. The BinMinder can be configured to recognise the solid phase in this region. The intermediate region which is located between the two red lines is where the mud is settled but not fully compacted. Depending on the clarity of the region, the BinMinder may recognise this region as solid thus producing some variability in the selected interface position, however the surface of partially compacted mud is still of interest to an operator.

As shown by the data for both Millaquin and Victoria Mills the potential variation in the measured interface is relatively small (~0.1m) and, in terms of usage by operators for control of the station, is largely inconsequential.

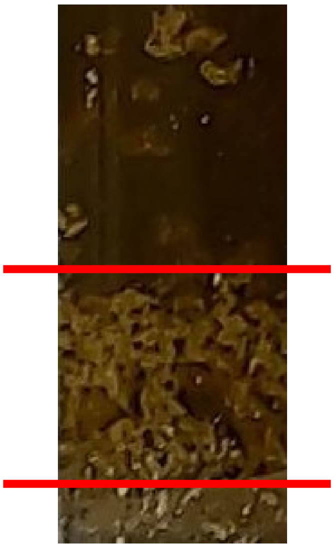

**Figure 15 Mud settlement in a clarifier showing three distinct regions**

Another consideration in measuring an interface position for use by the operators is that the surface of the mud interface is generally considered to be slightly curved with the lowest point being at the centre of the clarifier owing to the action of the scrapers in moving mud towards the central outflow and discharge from the bottom on the centreline. It would be expected that the operators would observe a slightly higher level for the interface at the sight glass windows. The expected shape of the mud interface was expected to more commonly result in the operator level being slightly higher than the BinMinder measured value.

Figure 16 shows difference between the compacted mud level and suspended solid level readings for a 24hour period at Millaquin Mill (7th of September 2020). Except for a few short periods of time, the two readings are close to each other with a consistent difference. On average the BinMinder readings for the suspended solids are ~0.06m higher than the BinMinder readings for the compacted mud level.

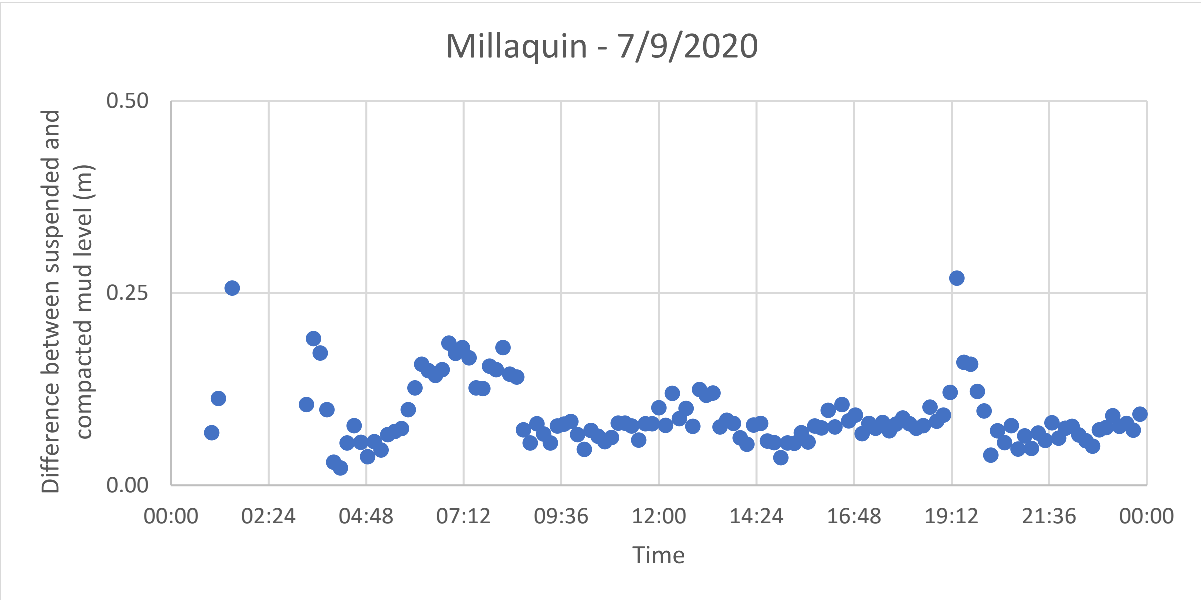


**Figure 16 Difference between the compacted mud level and suspended solid level readings**

6.2 Assessment of the VPMS results

***6.2.1 Comparison of the VPMS with the BinMinder results***

Commissioning of the VPMS was delayed to mid-November owing to the time needed to finalise contractual agreements, purchase the hardware and develop the point monitoring software.

Figure 17 shows an example of the results of the BinMinder and the VPMS installed at Victoria Mill (22nd of November 2020). The level measurement from VPMS was generally slightly higher than for the BinMinder. It is shown in Figure 18 that this difference is in order of 0.04m which is also in a good agreement with the Millaquin data. Peak values are observed in Figure 17 and Figure 18 at about every 7minutes. These peaks are associated with the rotation of the stirring arms. The effect of the rotating stirring arms was not observed in the Millaquin data.

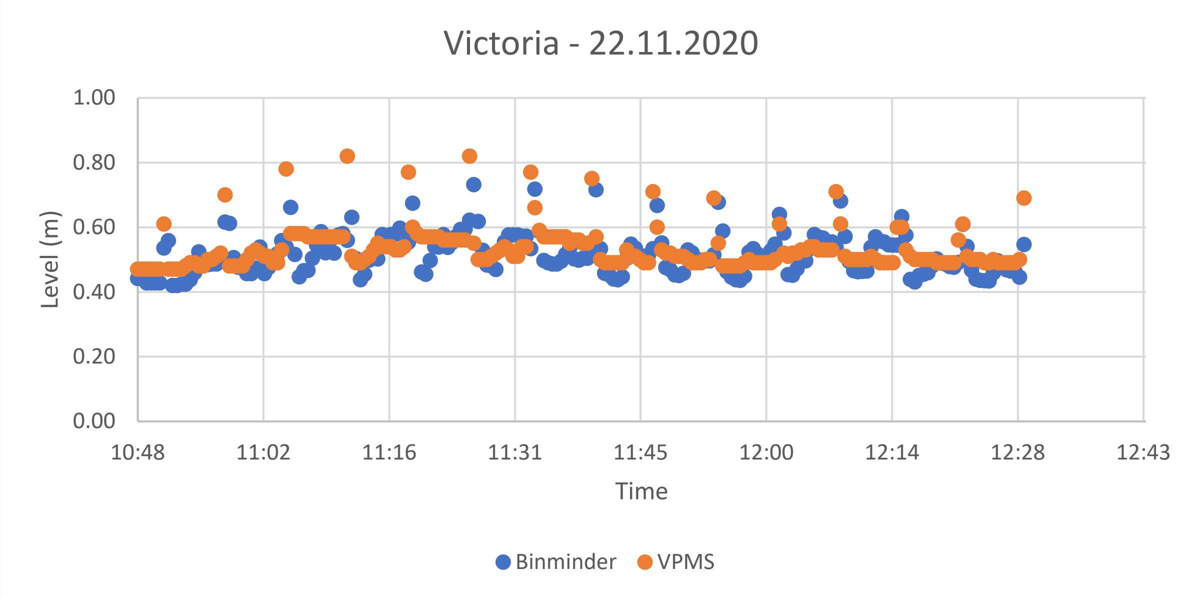


**Figure 17 Comparison between the BinMinder and VPMS data at Victoria Mill**

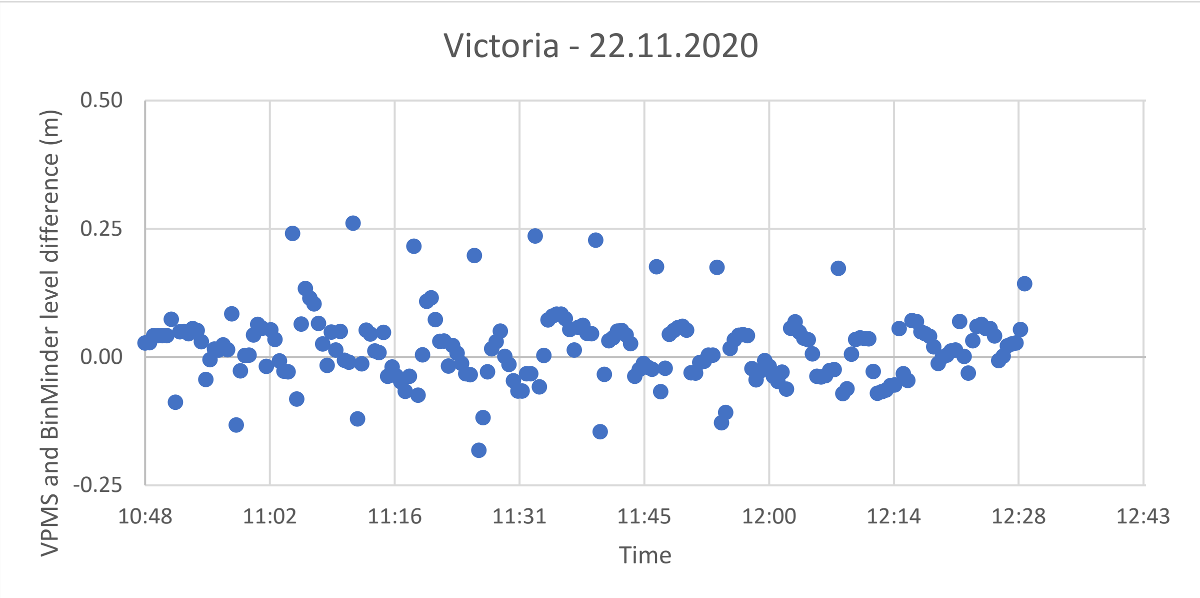


**Figure 18 Difference between the BinMinder and VPMS level readings at Victoria Mill**

Figure 19 shows an instance where the BinMinder indicates the mud level to be 0.68m, and VPMS reading is 0.55m. By closely looking into the results, one can identify that the actual mud level close to the sight glass is 0.55m. However, in this instance the BinMinder selected the level to be the top of the suspended coagulated solids.

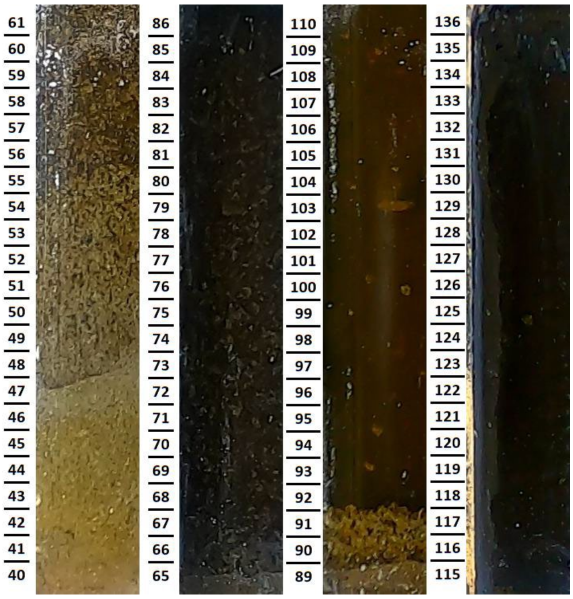

**Figure 19 Images from VPMS on 22.11.2020 at 11:54:30 am**

### *6.2.2 Operational issues using VPMS*

The VPMS was used by Victoria Mill staff from commissioning in early November to the end of the season. During commissioning and the operating period a few issues were identified to be addressed.

1. *Ineffective washing of the inside of the sight glasses.* Unfortunately, due to delays in setting up automation, the window wash system on the Victoria clarifier was not effective in removing settled solids in the window cavity later in the season when required. In Figure 20 the actual level of the mud is 0.65m, but accumulation of the suspended solids on windows 4 and 5 is also noticeable. It is relatively easy for the operator to distinguish between the actual mud level and accumulation of the solids on the sight glasses edge. However, it is a challenge for the software to differentiate between actual mud level and accumulated solids under circumstances when the level of actual mud drops, and the last observed mud level by VPMS was close to the top of the suspended solids in the window cavity.

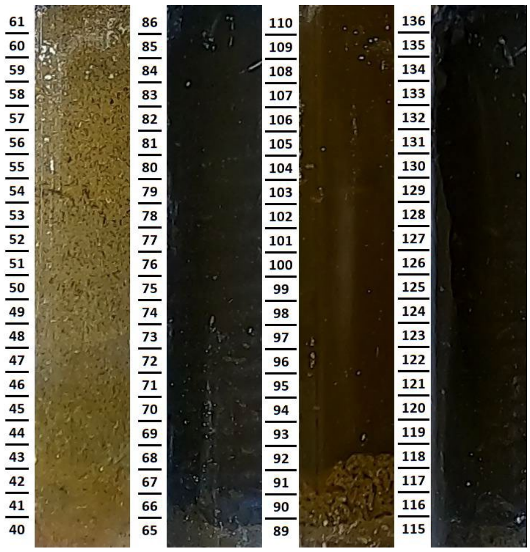

**Figure 20 Images from VPMS on 22.11.2020 at 17:56**

2. *Detection of detached mud clumps.* The VPMS images show that, on some occasions, a large clumps of coagulated solids is suspended in the juice above the mud interface. Operationally these would be isolated

to the sightglass or wall of the clarifier and may not collapse until scraper blades have passed by their position, several times, however it is informative to detect and recognise these as they form. Figure 21 shows an example of a clump of mud that is detached from the main compacted mud. VPMS detects these clumps as soon as they appear in the sight glass and, as soon as they have drifted away from the sight glass, the VPMS picks up the compacted mud level. It is important to note that both the BinMinder and VPMS provide measurements at localised positions in the clarifier, so they are not able to provide data for the full cross section of the clarifier.  Operators viewing through sight glasses are similarly providing a localised assessment.

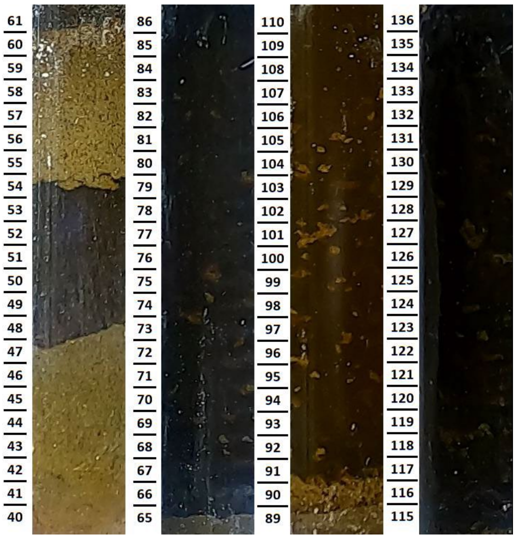


**Figure 21 Images from VPMS showing detached block of mud solids on 18.11.2020 at 00:00**

3. *Large juice pockets within the compacted mud.* During the mud compaction process, pockets of juice may occasionally form and persist. In Figure 22, it can be observed that in #2 sight glass, between 0.53m to 0.58m a pocket of juice is formed. BinMinder can identify multiple interfaces and, if defined in the settings, identifies “the last interface” as the mud level. It does not necessarily detect pockets of juice although the signal profile does provide information to suggest anomalies in mud settling profiles. For the VPMS, the existence of such pockets within the compacted mud does not affect the VPMS readings, as VPMS tracks the last mud and juice interface level which may or may not be representative of the full profile across the bottom of the clarifier.

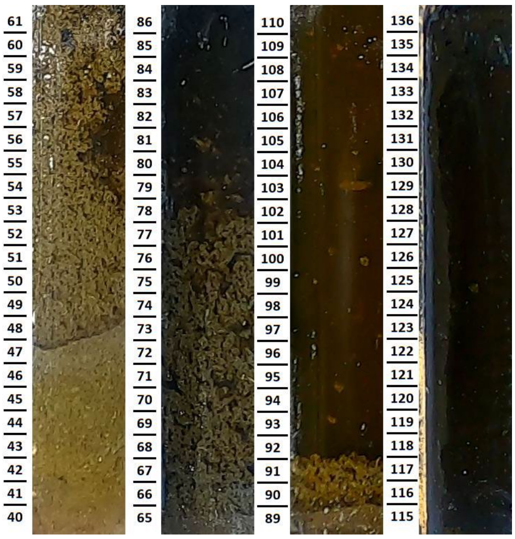


**Figure 22 Images from VPMS showing pocket of juice on 22.11.2020 at 00:19**

### *6.2.3 Additional capabilities of the VPMS*

Figure 23 identifies a potentially beneficial additional application for the VPMS viz., ability to provide an estimate of the size of the mud flocs. After discussion of this aspect with a few of the operators; in addition to monitoring the mud level they could focus on monitoring the settling of the mud flocs above the interface and observing their size and settling rate. Figure 23 shows two images (through #4 sight glass) which clearly detect suspended solids at two different times. Further development of the software would be required (outside the scope of this project) to detect and track mud flocs to provide an estimate of settling rate and average floc size. In order to obtain high quality images for evaluation of floc properties, it would be important to provide a powerful and uniform light source and also make sure that both the inner and outer surfaces of the sight glass are clean. Non reflective glass would also be useful.

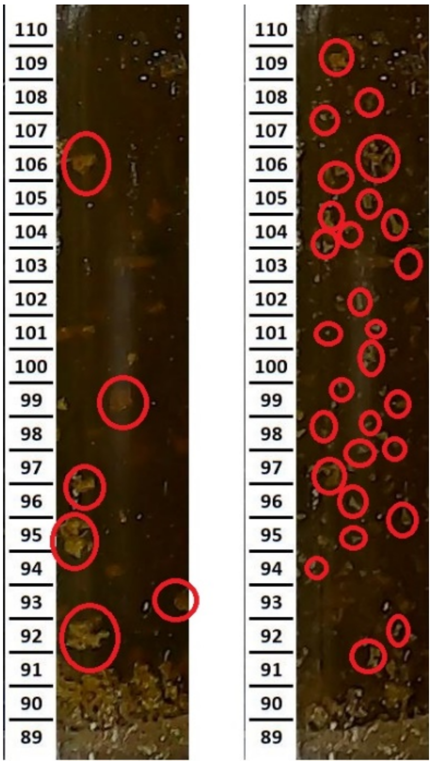


**Figure 23 Two images of #4 sight glass on 23.11.2020 at 09:58 & 10:23**

6.3 Discussion on the BinMinder and VPMS systems

The assessments of the two measurement systems have shown that:

- Both the VPMS and the BinMinder are capable of reliably measuring the mud-juice interface, and reasonably close agreement (usually to within 0.05m) in the determined mud interface is achieved even though each system is measuring the interface at different locations.
- The recorded interface at Victoria Mill using the VPMS was typically 0.04m above the recorded interface using BinMinder. The difference between the manually recorded mud interface level and the BinMinder readings for the Millaquin mill was less than 0.1m. Biases in both systems can be easily adjusted to account for clarifier dimensions and geometry.
- BinMinder installed at Millaquin Mill was configured to measure both the top of the suspended mud interface, and the compacted mud interface level. While, at Victoria Mill, the BinMinder was configured to measure the compacted mud interface level.
- Although the VPMS is capable of monitoring both the compacted mud level and the top of the suspended solids layer above the compacted mud level, it was configured to only measure the top of the suspended solids layer above the compacted mud level. Operationally the top of the suspended solids layer is more important in terms of avoiding mud carry over and determining the balance of mud withdrawal rates to filters. Also, BinMinder is not capable of detecting detached block of mud or measuring the actual mud level where juice pockets form within the compacted mud. However, VPMS is superior to BinMinder in identifying such events.
- The VPMS has the potential capability to measure the size of flocs above the suspended mud layer. Additional software would need to be developed to provide this. Measurement of the settling rates of the flocs may also be possible. This additional feature of the VPMS would assist operators in monitoring

relative settling velocity and allow them to regulate flocculant dosing rates, and other feed settings to help improve flocculation and clarifier operation.
- Both the BinMinder and VPMS provide measurements at localised positions in the clarifier and are not able to provide data relevant to the full cross section of the clarifier. Operators viewing through sight glasses are similarly providing a localised assessment to infer mud level conditions within the clarifier.

## 6.4 Benefit and cost analysis

Having a reliable real time measurement of the mud/juice interface available to the operators which is displayed and alarmed in the factory's DCS will provide several benefits in factory operations. Avoidance in mud carry over and rat-holing when the mud level is too high or too low will help provide tighter control. The benefits are estimated for a factory crushing 1.5 m tonnes cane per season as:

- Improved sugar quality quantified as the equivalent of one sugar premium ($14,000 p.a.)
- Avoidance of mill stops when severe mud carry-over occurs (up to $30,000; based on avoiding two stops of 3 h each)
- Supply of more consistent mud density to the filter station and more effective utilization of the operator's time to achieve improved filter station performance ($80,000; based on pol loss in mud cake reduced by 0.1% pol in cane)

The technology is available to all the Australian mills. Mills would need to install either the VPMS or ultrasonic transducer system and interface with their control systems for continuous monitoring. Installed cost would be approximately $11,500 for VPMS and $15,000 for the ultrasonic level transducer.

## 6.5 Recommendations for installing the VPMS and BinMinder systems

Based on the experiences during commissioning and operation of the two systems, the following recommendations are made for future installations.

BinMinder

- Details of the proposed installation of the BinMinder, including internal dimensions of the clarifier, rotation speed of mud scrapers passing under the transducer, proposed location and method of installation of the transducer, and properties of the juice medium above the compacted surface should be provided to the supplier prior to purchase to enable the unit to be supplied with preliminary configuration settings.
- Commissioning of the device requires fine tuning through advanced parameter settings for elements including the speed of sound and signal gain through the medium and other acoustic and geometric characteristics which experience has shown may differ for different clarifier installations, but are easily configurable prior to delivery and installation.

VPMS

- An enclosure with painted matte black internal surfaces should be installed to surround the sight glasses of interest for level measurement in order to eliminate stray light and minimise reflections. The cameras and lights are installed within the enclosure. A fan should be mounted on top of the enclosure to help reduce camera temperatures.
- Whilst GoPro cameras were used for the initial investigation it is recommended that two cameras with higher temperature ratings should be installed to provide sight glass images (refer to Table 1 for suggested camera specifications).
- Two LED lighting strips of identical light intensity (each >5000 lumens) should be installed on each side of the sight glasses to provide uniform lighting without reflection or shadows (see Table 1 for the specification of the lighting strips).
- The window washing system needs to be configured and automated to provide short regular washes to the inside of the clarifier sight glasses at approximately 30 minutes intervals. The window washing system needs to be robust to provide sufficient water pressure to each wash nozzle to allow effective evacuation of mud solids. If a large cavity or ledge exists at the bottom of the inside of the sight glasses, then a suitable sloped section may be provided with filler at the bottom of each of the viewing windows.

It is anticipated that the VPMS will be tested for another season at Victoria Mill where the BinMinder has been already installed. Ideally, the VPMS would also send real time visual data to the control room so that operators can validate results and monitor settling rates. After the 2021 season the VPMS should be commercially available to all mills.

**Table 1 Recommended VPMS parts**

| Equipment | Model / Description | Quantity | Estimated Price (AUD) |
|---|---|---|---|
| Camera | Allied Vision Prosilica GT 2000 C | 2 | $3,000 per unit |
| Light source | Vigilant LED Linear (with 3,300-7,900 lumens) | 2 | $1,000 per unit |
| Network cable | Cat 6 / shielded | 2 x 50m | $150 per 100m |
| Custom-made enclosure | | | $1,500 |
| Laptop / PC / Monitor | Windows 10 | 1 | $2,000 |

## 7. CONCLUSIONS

Both the point monitoring system and the ultrasonic transducer have shown to be capable of measuring the mud-juice interface with sufficient accuracy to be useful for remote monitoring, thus relieving the operator of one of the regular duties.

## 8. RECOMMENDATIONS FOR FURTHER RD&A

An interesting observation with the VPMS is that mud flocs can be detected in the juice phase above the interface. There may be scope to develop a system to monitor the flocculation properties. Hence, it is recommended to further develop the software to allow measurement of the average floc size and mud settling rate, and to evaluate the additional features of the VPMS in factory trials.

## 9. PUBLICATIONS

A paper titled “Evaluating the suitability of two mud level sensing technologies for juice clarifiers” is being prepared for presentation at the 2022 ASSCT Conference.

Results and application into the industry have been presented to mill staff in all the cane growing regions in the Research Seminar series conducted in March 2021.

## 10. ACKNOWLEDGEMENTS

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# 12. APPENDIX

## 12.1 Appendix 1 Metadata Disclosure

**TABLE 2 METADATA DISCLOSURE 1**

| | |
|---|---|
| Data | All files located in single folder 4416 |
| Stored Location | QUT server for CAB (Centre for Agriculture and the Bioeconomy). Project 4416 |
| Access | Access restricted to SRI staff in CAB |
| Contact | Ross Broadfoot/Iman Ashtiani Abdi |

## 12.2 Appendix 2 EchoSmart Clarifier Level Measurement device details

**Table 3 EchoSmart Interface Level Measurement Device Details**

| | |
|---|---|
| Transducer | Model: ETQ3-ESCHT024-100<br>Supply: 24 Vdc,<br>Outputs: 2x 4-20mA + Modbus/RS485 |
| Sensor type and connections | 657kHz, High Temperature Acoustic sensor in SS316<br>With ¾" NPT-F connection<br>20ft High Temperature Cable,<br>100 ft Standard temperature cable<br>Field mount, IP65 interface electronics to connect sensor to display electronic module |
| Sensor Flushing | SS Nozzle and mounting assembly,<br>SS Solenoid Valve, ½", 24 Vdc<br>SS Manual isolation Ball Valve, ½" |