

AA09 - Improved Flow for Y-Flume Launderers on Alumina Precipitation Tanks

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Abstract

Queensland Alumina Limited (QAL) uses several Y-shaped launders (Y-flumes) at the discharge of the last precipitation tanks to direct flow into classifiers. Scale builds up in these launders causing flow restrictions and difficulty in opening the valves at the discharge end of the Y-flume. A laboratory experimental study was undertaken using a purpose made model Y-flume at CSIRO. It was found that stagnant flow zones developed at the launder inlet section, corresponding to where scale/sedimentation are found at full-scale at QAL. A baffle installed in the inlet area of the Y-Flume was conceived and tested. The stagnant zones were found to be eliminated by this design modification in the tests. This was found to result an improved flow and suspension of the solids. A full-scale trial with the proposed modification installed at QAL, demonstrated significant reduction in scale growth.

Keywords: Scale, sedimentation, launder, alumina precipitation, laboratory flow modelling.

1. Introduction

Queensland Alumina (QAL) uses several Y-shaped launders (Y-flumes) to direct flow from the outlet of two precipitation tanks into a classifier. An example of a Y-flume is shown in Figure 1 (a) and (b). Flow is only down one side of the Y-flume, depending on which tank is the last online tank in the row. Flow out of the bottom of the “Y” is via two outlet pipes equipped with bayonet valves, located on opposite sides of the launder. Of these, one pipe is in operation and the other standby. The slurry then flows by gravity to the downstream classifier units.

With the flow path aligned in one direction for prolonged periods (approximately 90 days), it becomes difficult to swap flow directions, as the alternate flow path is heavily scaled and difficult to use as seen in Figure 1(c). Although some sections of the flume can be chemically cleaned with a caustic solution, this approach is ineffective on hard scale which can only be removed by mechanical methods (jack-hammering and/or hydro-blasting) which are time consuming and expensive with additional safety hazards.

Slurry flow through open channels, with constant cross section is well understood in the literature [1]. However, the flow in an apparently simple Y-Flume geometry as used at QAL can be complex, having poor flow distribution with stagnant zones that may lead to sedimentation and scale formation.

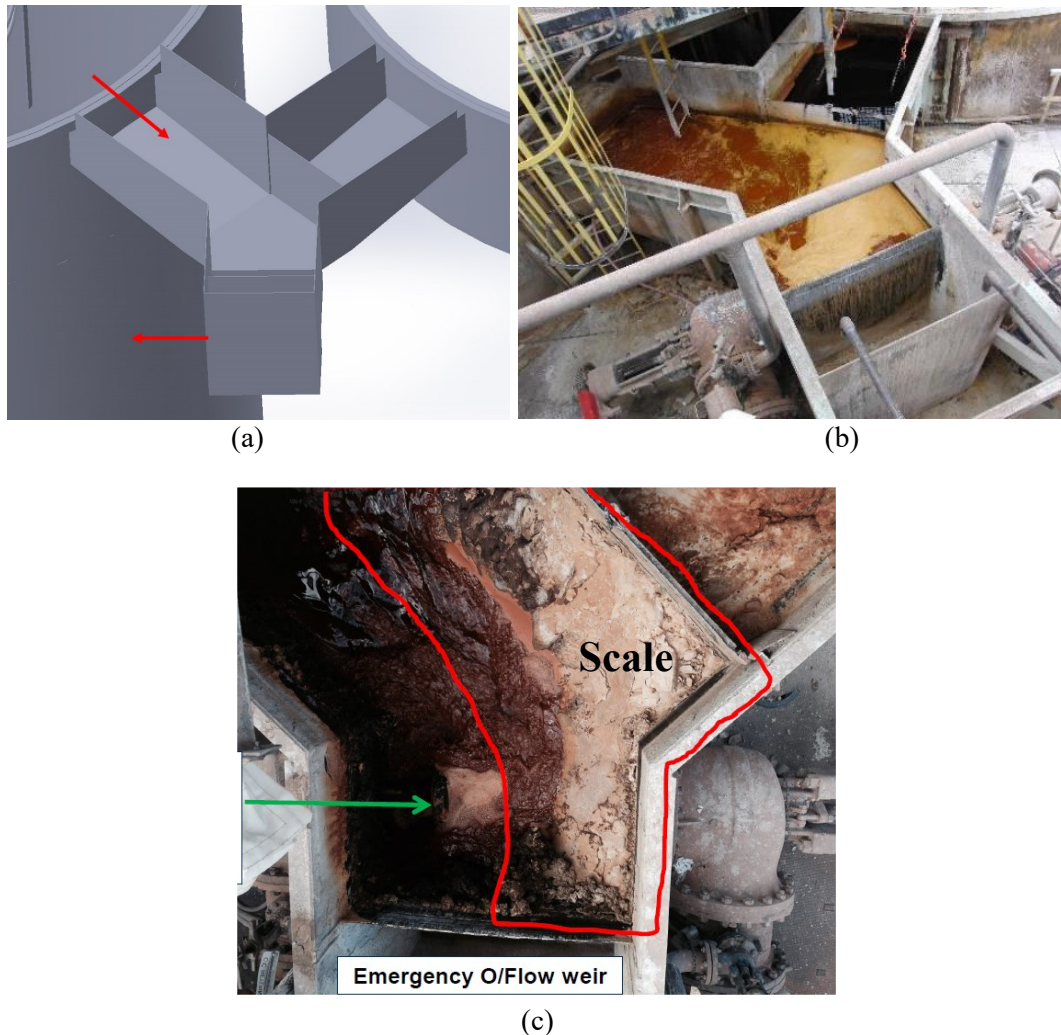


Figure 1. Y-flume launder used at QAL. (a) CAD drawing, (b) during operation, (c) extent of scale prior to de-scaling.

CSIRO Fluids engineering laboratory is specialized in flow modelling and fluid dynamics research. After discussion between CSIRO and QAL, it was decided to conduct a laboratory flow study using a geometrically scaled-down, purpose-built model Y-Flume. This paper presents the model study results, the development of a new design and its installation and operational experience at QAL.

2. Experimental Facility

An experimental Y-Flume flow model rig was set up at CSIRO in Melbourne, Australia. The test rig consisted of an approximately 1/5 geometrically scaled model of QAL's Y-Flume. The Y-end outlet was connected by the pipe and looped back to the feed chamber via a pump with its motor controlled by a Danfoss variable frequency drive (VFD). A Rosemount electromagnetic flowmeter was installed to monitor flow rate. A photograph of the rig, a schematic and a close up of the scaled down version of Y-Flume at CSIRO's laboratory in Melbourne is shown in Figure 2 (a), (b) and (c).

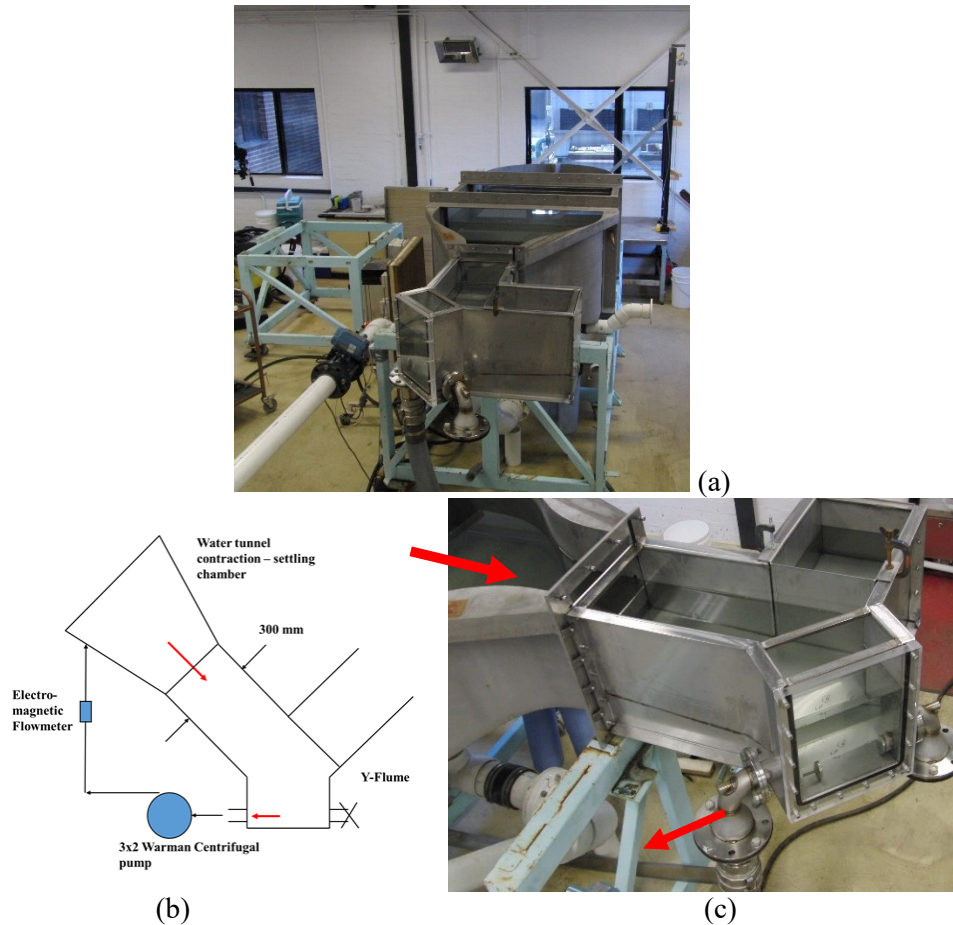


Figure 2. Y-Flume flow model test rig at CSIRO, (a) test rig overview, (b) schematic and (c) Y-flume section. Arrows indicate flow direction.

Water was used to model the slurry for the flow pattern visualization study. In some tests, a small amount of sand was introduced to validate the sedimentation behavior. The sand, which was commercially sourced (Sibelco Incast 70), had a mean size of d_{50} approximately 170 microns. The experiments were conducted at ambient conditions.

Due to the flow being driven by gravity, the Froude number parameter was kept the same as in full-scale to ensure a similar flow pattern in the model. From fluid dynamic theory, the Froude number parameter is calculated from the velocity and the channel width. The geometry and operating parameters are detailed in Table 1.

Table 1. The operating parameters and dimensions of scaled down Y-Flume.

	Scale Ratio =	0.1829
	QAL full scale	CSIRO model
Inlet launder width (mm)	1640	300
Outlet pipe diameter (mm)	300	55
Liquid depth at inlet (mm)	735	134
Flow rate (m ³ /h)	1700	58.5
Superficial velocity (m/s)	0.39	0.17
Froude number (-)	0.098	0.097

3. Test Results

3.1 Flow Visualization Study

In order to solve the issue, it was first necessary to replicate the problem phenomena observed by the plant operators at QAL. The assumption was made that a reduction in sedimentation in the flume would lead to a reduction in scaling rate due to the sedimentation reduction indicating higher velocity. The test rig was designed to model the flow behavior, rather than to replicate scale formation directly. A visualization study was conducted to confirm that the stagnant zones where solids are likely to settle out were where the scale was seen at QAL. The results of this study were recorded on video and will be presented to the audience during the coming ICSOBA 2020 conference.

From visual observations, it was found that two recirculation stagnant zones formed. One behind the weir underneath the flow stream at the inlet (elevation view), and the second, in the corner region (plan view), schematically illustrated in Figure 3. It should be noted that the stagnant zone behind the weir (elevation view) was extensive, over most of the launder inlet section. The stagnant zone in the corner (plan view) was relatively small compared to the former.

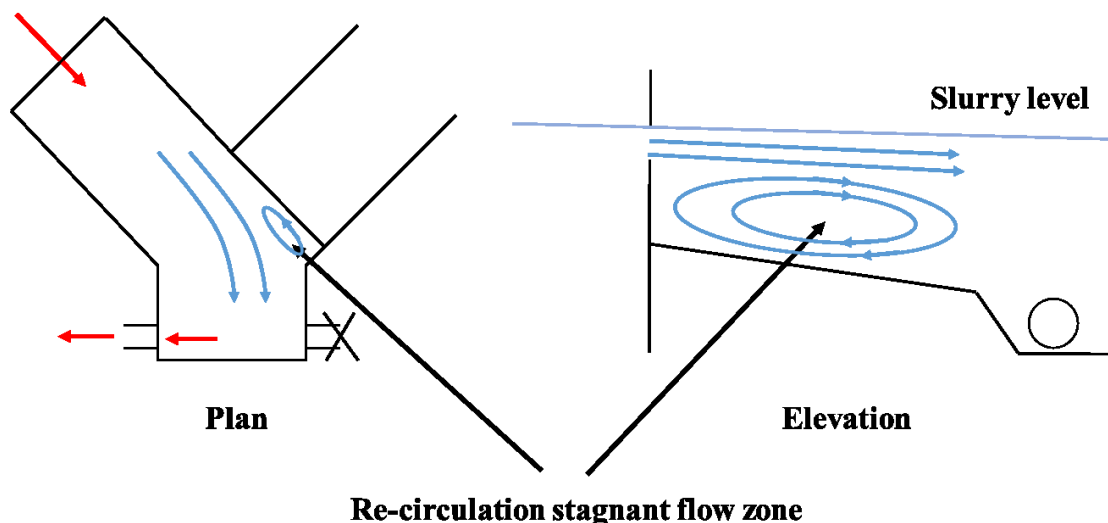


Figure 3. Stagnant zones observed during tests in CSIRO scale model.

From the visual observations, it may be reasoned that sedimentation could develop on the floor behind the weir which may cement into scale over the floor of the Y-Flume. The vicinity of the corner may also experience scaling. This was in accord with full-scale observations at QAL, refer to Figure 1 (c), where scale developed behind the weir and built up in the corner on the floor. Interestingly, the scale formed in the corner appears to be much larger than the size of the stagnant zone. It is thought that this may be caused by increased growth once the scale started in the corner.

Several design modifications were tested. These included an iterative process of installing various shaped inserts, with the goal to minimize the stagnant zones. The final design (Figure 4) consists of a baffle plate, inserted into the flow downstream of the weir with the aim of re-directing the flow downward. This meant that the recirculation zone over the floor was largely eliminated.

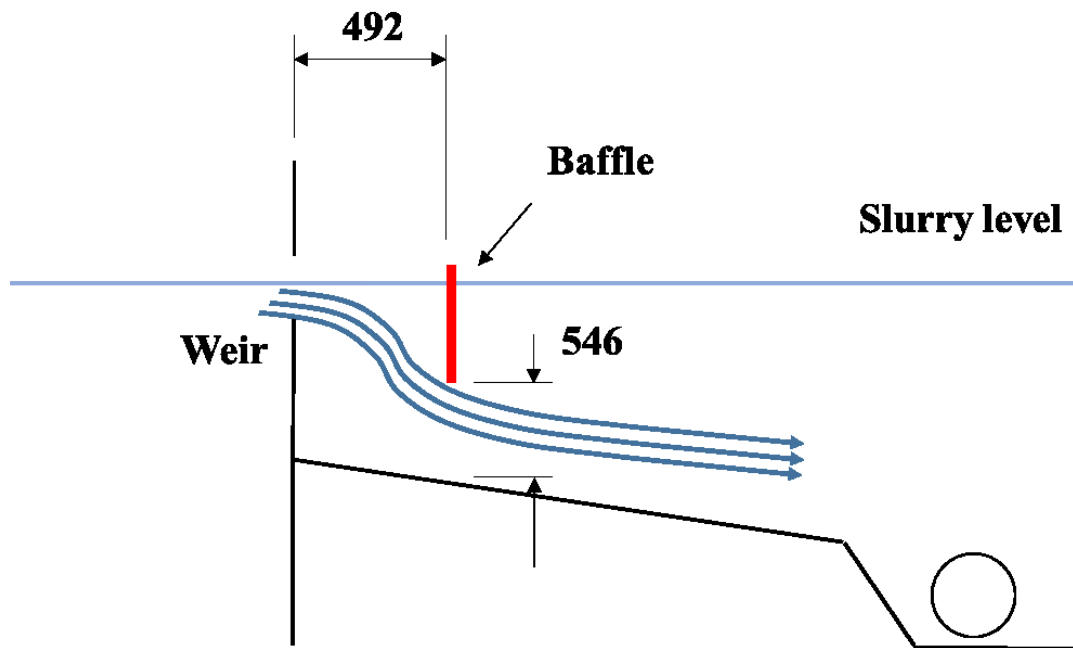


Figure 4. A design modification with an inserted baffle, dimensions in mm.

3.2 Sand Settling Study

Additional tests involving resuspending sand were conducted to confirm that the design modification was robust for a range of operating conditions. A small amount of sand (in the order approximately 200 mL) was introduced into the flow at the weir of the Y-flume and allowed to distribute throughout the flume and settle to the flume floor at a low flow condition (<150 L/min). The pump was then restarted to test the resuspension behavior under specified flow rate conditions for the various design options.

For the existing design, it was found that there was a substantial amount of sand accumulated at the bottom of the launder downstream of the inlet weir, after the test. A photo was taken after the flow (400 L/min) was turned on for a fixed period of time (7.5 minutes) as shown in Figure 5 for the existing design.

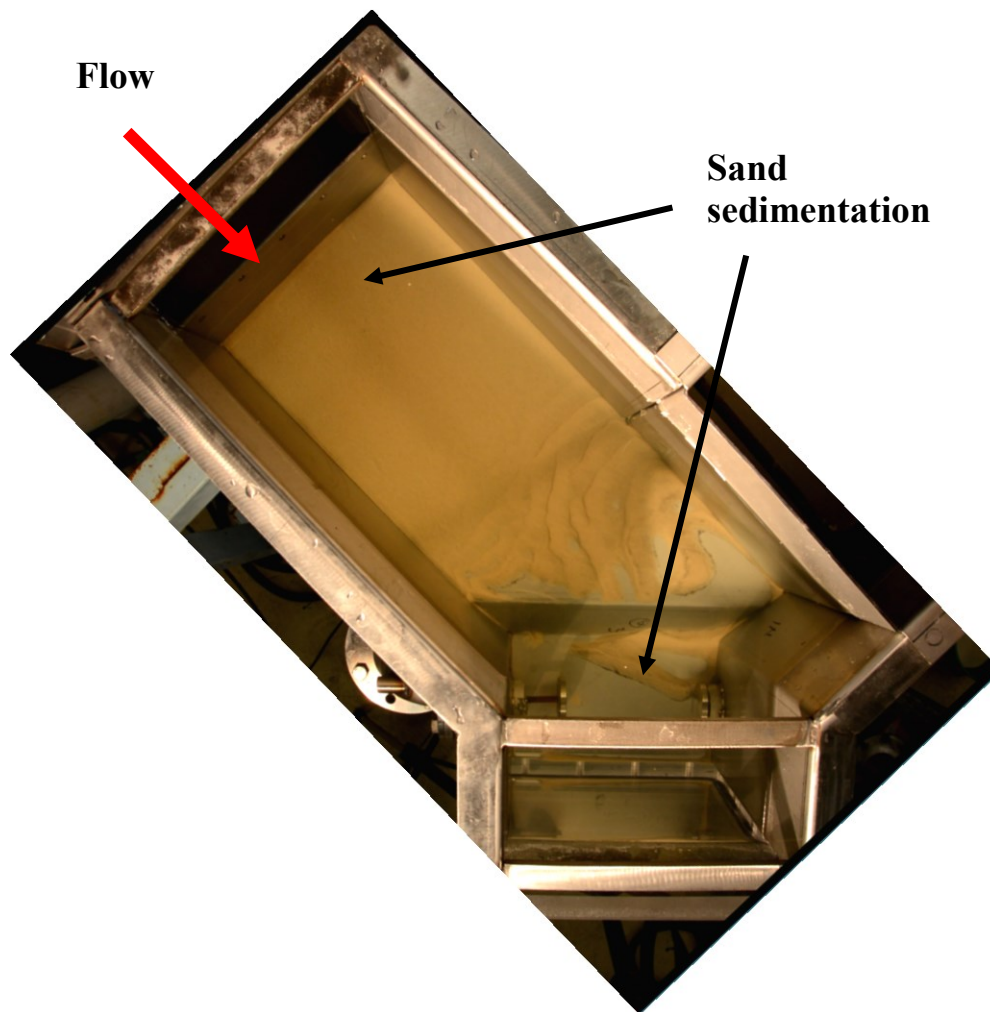


Figure 5. Base case after 7.5 of flow. This case shows sand accumulated over a significant part of the floor of the Y-Flume.

Figure 6 shows the result for the modified design which had the baffle inserted as described earlier. The floor of the flume was essentially free of sedimentation. To evaluate the sensitivity of this result to the flow rate, tests were repeated at reduced flow rates to 300 L/min and down to 150 L/min. The same result without sedimentation were observed at reduced flow rates.

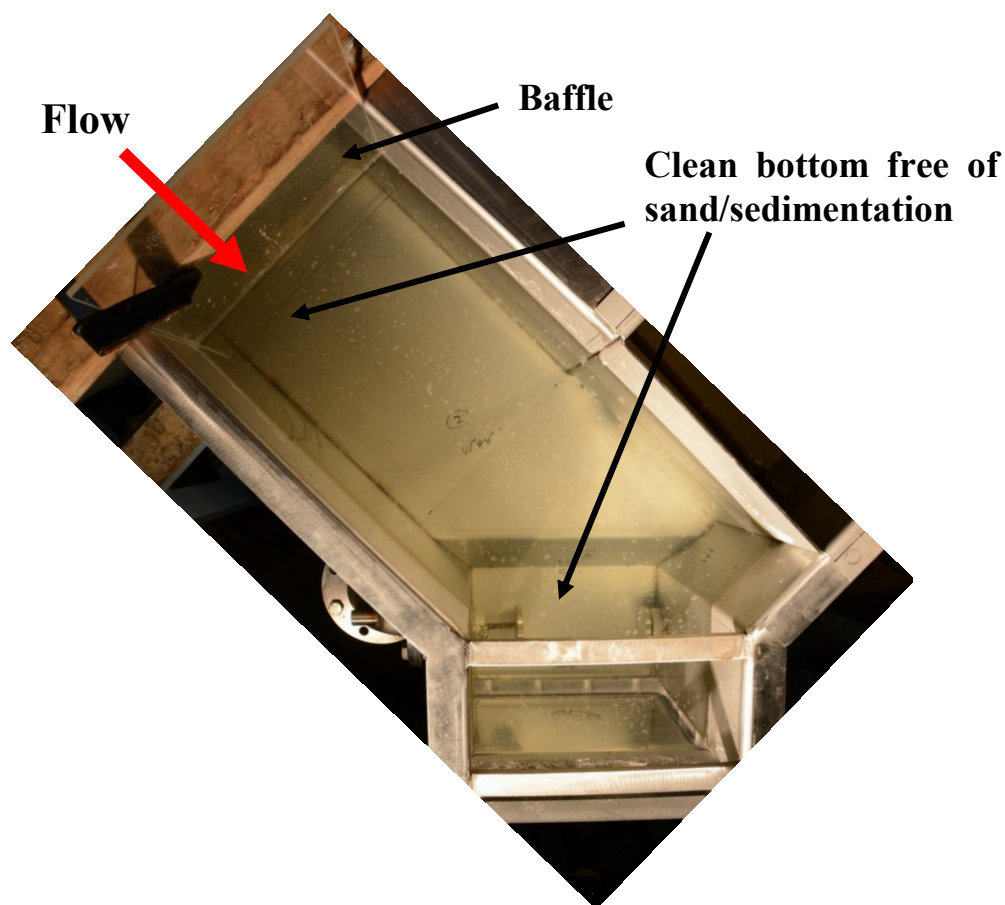


Figure 6. Modified case after 7.5 min of flow identical to that used in Figure 5. Note minimal accumulation of sand.

4. Implementation at QAL

Based on the test results, CSIRO recommended the baffle insert concept as described in Figure 4 to QAL in late 2018.

QAL implemented a full-scale version of the baffle in the H-row Y-flume in July 2019. A photograph of the flume with installed baffle is shown in Figure 7. The baffle is positioned such that full production flow is directed under the baffle, with the upper edge of the baffle set to prevent tank over-topping in emergency flow situations. The baffle completed its first full 360-day cycle of operation in June 2020.

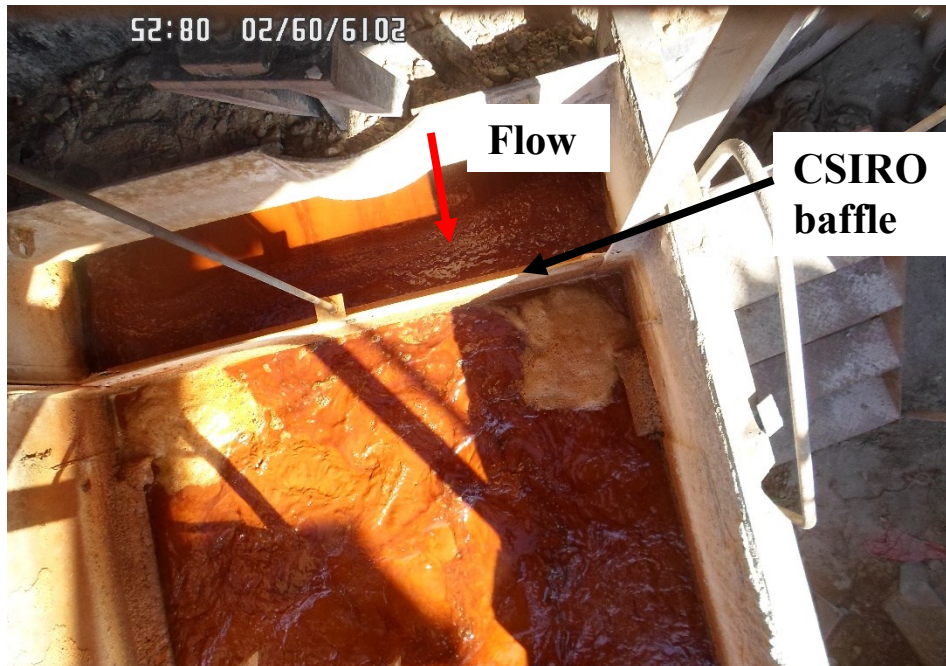


Figure 7. CSIRO baffle concept implemented at QAL, at H12. Photograph inverted to show flow in the same direction as test models.

During the full-scale trial, it was found that the outlet for the modified Y-Flume could be swapped between the two outlet valves every 90 days and the sediment cleared satisfactorily. This was not possible prior to the modification. The baffle operated over a full range of production flow rates (50-10 %), with no adjustments or modifications made to the baffle by QAL personnel.

Figure 8 shows the accumulated scale for an original Y-flume design after 360 days of service. By way of comparison, but for a different tank row (H row), Figure 9 shows the enhanced performance of the modified flume after 360 days.

The modified design shows less scale than the original. QAL has confirmed that the remaining sedimentation was cleaned by simply hosing and only took a small amount of time to clean compared with the clean-up time required for the standard arrangement. QAL also confirmed, for such a simple modification, the benefit was definitive and has plans to install this baffle arrangement on the other two Y-flumes during 2021.

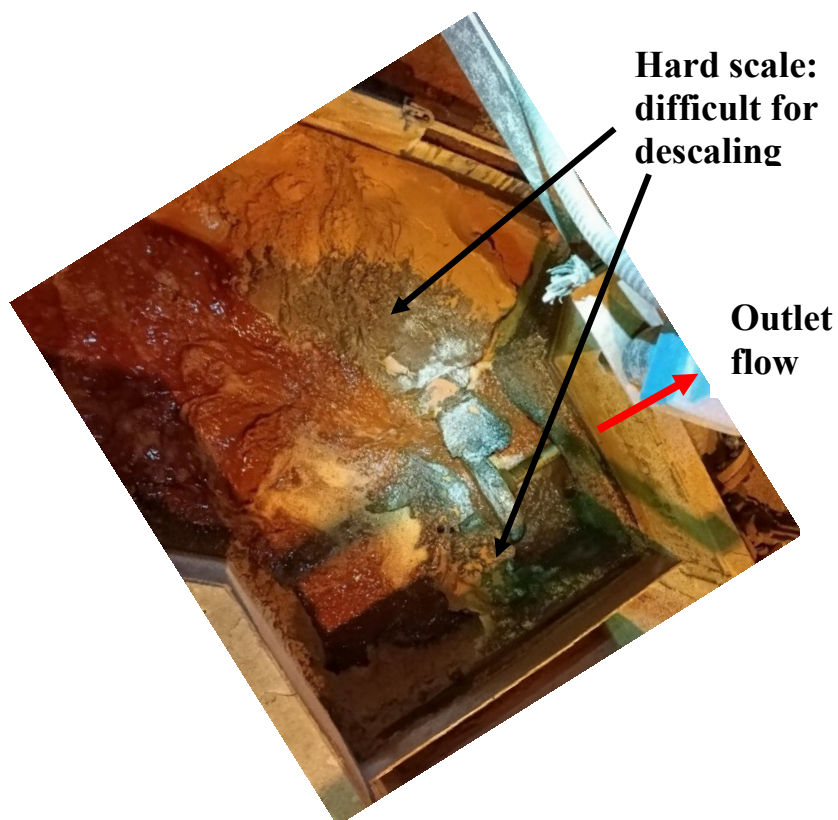


Figure 8. Photograph of scale and sediment in Y-Flume from G row, original flume design.



Figure 9. Photograph of scale and sediment in Y-Flume from H row, modified design.

5. Conclusions

A purpose-built scale model laboratory water flow test rig was built at CSIRO to study the problem of scale/sedimentation in the Y-Flume launder at the last precipitation tanks at Queensland Alumina Gladstone (QAL) Refinery in Australia.

It was found that stagnant flow zones develop behind the weir at the launder inlet section which correspond with observed scale/sedimentation in the Y-Flume at QAL.

Modifying the design by way of an installed baffle weir, the investigation found that the flow could be redirected to increase the velocity/energy over the floor of the flume, promoting minimal sedimentation and improved transport of slurry.

QAL implemented the design modification and after 12 months of operation, QAL concluded that the modified design achieved a substantial reduction in scale formation, and downtime required for descaling.

6. Acknowledgements

The authors acknowledge the support of QAL for this work and the CSIRO workshop for manufacturing the test rig.

7. References

1. Kenneth C. Wilson, Flume design for homogenous slurry flow, *Particulate Science and Technology*, Vol. 9 (1991), 149-159.