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Title:	Velocity Measurements in IABR Inoculation Ponds		
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SIGNATURES

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EXECUTIVE SUMMARY

Flow velocity in two IABR inoculation ponds was measured using a Vectrino-II which is a submersible probe. Vectrino-II can measure velocity time-series in three different directions. These time-series can then be used to extract the mean flow velocity components as well as the turbulence characteristics in all directions. In these experiments, the submersible probe was remotely traversed inside the pond using a cart and a telescopic pole, which was built at IABR by the maintenance group.

For an average pond depth of 11’’, the paddlewheel power consumption was measured to be 3 kW (4 horse power). The pond flow velocity average over entire pond is 38 cm/s. Based on these data, the paddlewheel efficiency is estimated to be 8%, which is at the upper range of the designed efficiency for 2.2 acre IABR ponds (the design for IABR was 6%-8%). As a result, if the 2.2-acre ponds’ paddlewheels can generate the same performance, the flow velocity in those ponds would become about 20 cm/s. The maximum local velocity, which was measured at the U-turn upstream of the paddlewheel (Promxial end) is 74 cm/s. On the other hand, the minimum velocity, which was measured along the inner wall at the return channel, was -15 cm/s. Turbulence data were also extracted from the velocity time series, which showed that at the region downstream of the paddlewheel the flow is highly turbulent whereas at the other regions is weekly turbulent.

PURPOSE

The purpose of this study is to document the flow quality (such velocity less than 10 cm/s and large deadzone area) in inoculation ponds and determine the uniformity conditions across the channels. In addition, we measure the paddlewheel efficiency in order to use it as a benchmark for determining whether the paddlewheel in 1.1 and 2.2 acre ponds can generate the designed flow rate.

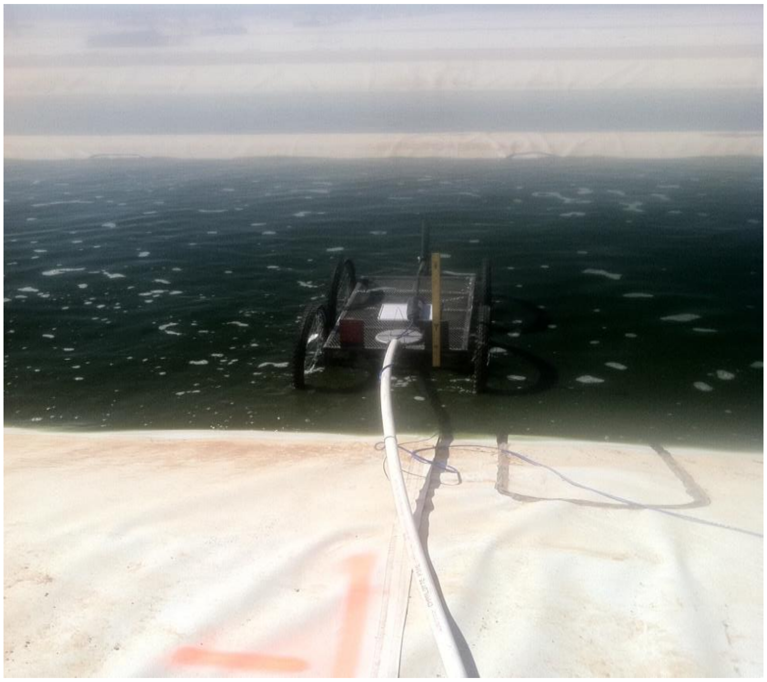

Figure 1. Measurement Cart which carries the VectrinoII and the probe.

BACKGROUND

Flow velocity in Inoculation ponds II and IV was measured using a Vectrino-II. The submersible probe of Vectrino-II can sample velocity signals in three different directions along a 1.4'' vertical line with a frequency up to 100 Hz. In other words, the probe measures time-series of instantaneous velocity components in x-y-z directions. These time-series can then be used to extract mean flow velocity components as well as the turbulence characteristics for three different directions.

The probe was inserted into the pond using a measurement cart, which was designed and built at IABR. Figure 1 shows an image of the traversing cart when it is sampling signal inside the pond. The cart was traversed across the pond remotely using a telescopic pole. The probe was used to sample velocity signals at 8 different cross-sections (measurement stations) along the pond as shown in Figure 2. At each measurement station, the flow velocity at 5 positions across the pond was measured for 40 seconds. Figure 3 shows the measurement positions across the pond cross-section. Each sampling area is a 1.4'' long line at the middle of the pond depth at each measurement position.

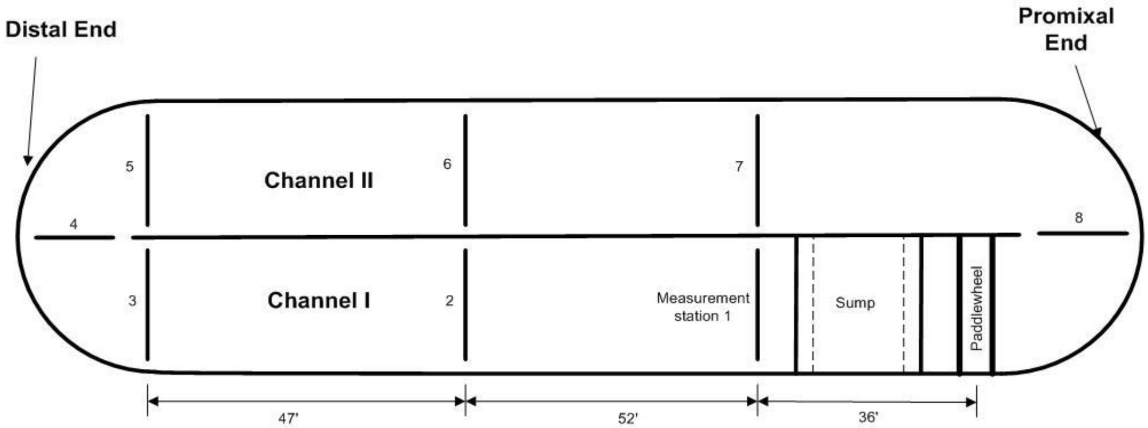

Figure 2. Pond layout and the position of the measurement stations.

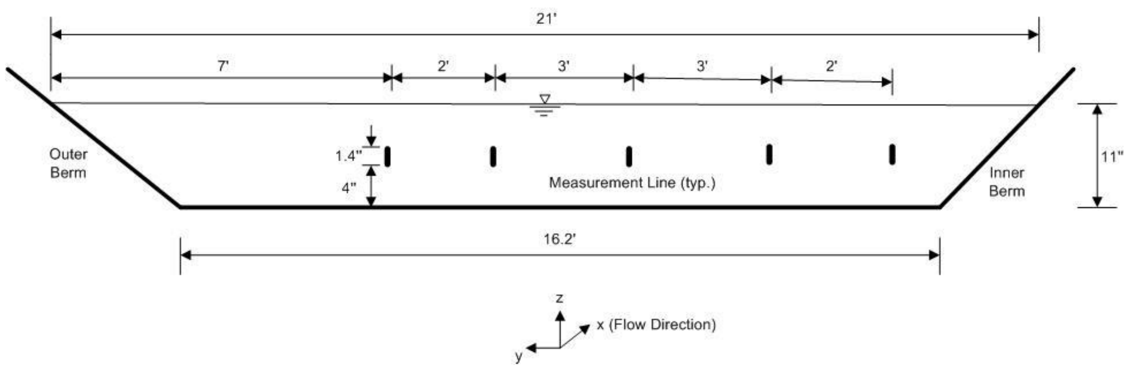

Figure 3. Layout of the pond cross-section and the position of the measurement stations.

RESULTS

Figure 4 shows the layout of the inoculation pond and the resulting velocity vectors at the measured points. At each position, Vectrino was used to measure flow velocity at 35 points along a 1.4'' long line simultaneously as the positions are highlighted in Figure 3. The velocity vectors shown in Figure 4 are the average velocity over the 35 vertical points. Taking the average for all measured data points in Figure 4, the average velocity becomes 38 cm/s. In other words the average velocity along all cross sections and different downstream positions is almost 38 cm/s. However, the local flow velocity is significantly dependent on the position relative to the paddlewheel and the position across the cross-section as well as the distance to the pond bottom. For example, the maximum velocity (74 cm/s) was measured at the Promixal end (the U-turn upstream of the paddlewheel).

As Figure 4 clearly shows, the flow in the channel downstream of the paddlewheel (channel I) is very uniform whereas in the opposite channel (channel II) the flow is very non-uniform as it is characterized by a substantial deadzone immediately downstream of the distal end (the U-turn opposite of the paddlewheel). It appears that by inserting guiding vanes at the distal end we might be able to eliminate this flow non-uniformity to some extent.

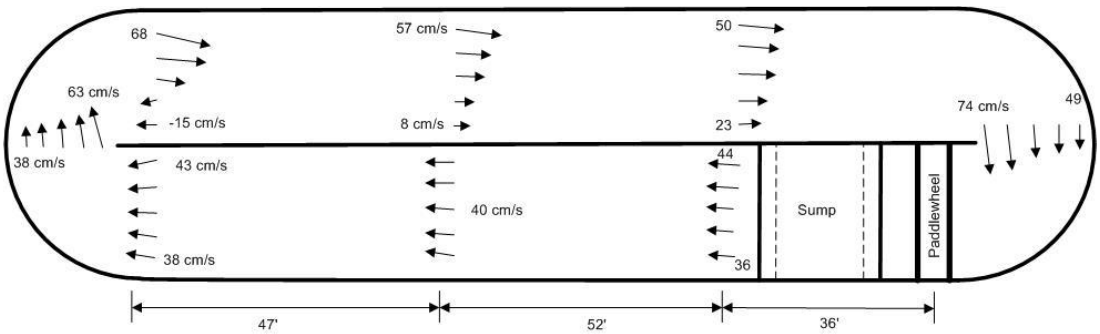

Figure 4. Inoculation pond with velocity vectors at the measured stations.

Comparing the velocity contours at cross-sections 1, 2 and 5 (see Figure 2 for their locations in the pond) we can better show the evolution of the flow uniformity across the pond cross-section. These velocity contours for these cross-sections are shown in Figures 5, 6 and 7, respectively. As one can notice the flow is significantly non-uniform at station 5 as there is a substantial flow reversal in this station, see Figure 7. However, the flow immediately downstream of the carbonation sump, (Figure 5) is less uniform than in measurement station 2, Figure 6. The flow in the measurement station 2 is very uniform and we expect it remains uniform up to the distal end (the U-turn opposite to the paddlewheel position). The measured paddlewheel power is 3 kW. Based on the measured data upstream and downstream of the paddlewheel, the induced head by the paddlewheel was estimated to be 45 mm. The calculated paddlewheel efficiency is 8%. This is consistent with our earlier paddlewheel measurements conducted at the Lac Cruces site, pond 9. If the paddlewheels in 1.1 and 2.2 acre ponds can perform similar efficiency, the induced flow velocity in those ponds can be as large as 20 cm/s.

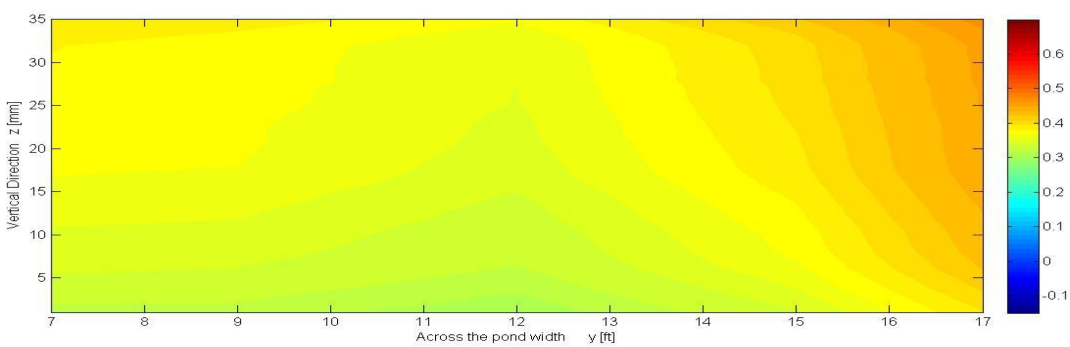

Figure 5. Velocity contour across the pond width at measurement station 1 (immediately downstream of the sump). The color bar shows the velocity in m/s.

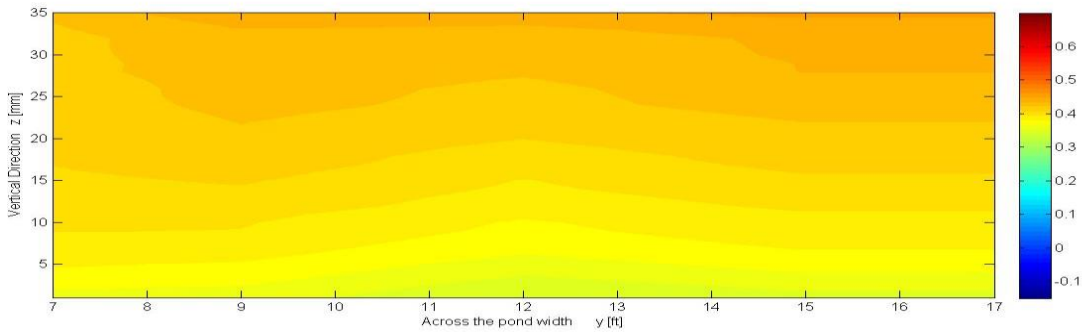

Figure 6. Velocity contour across the pond width at measurement station 2. The color bar shows the velocity in m/s.

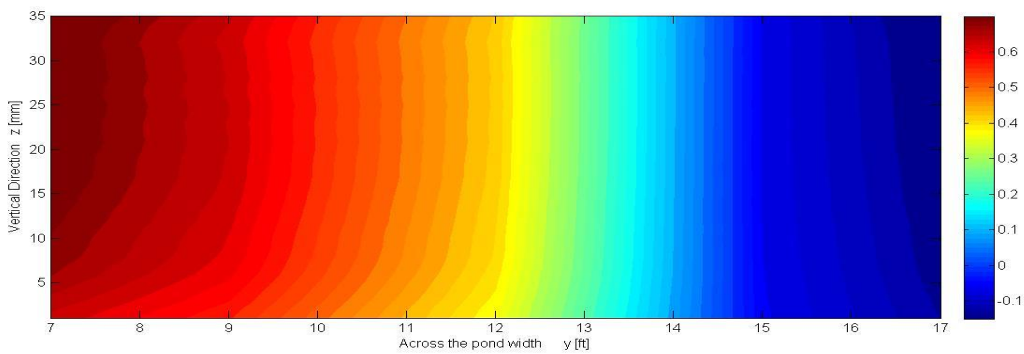

Figure 7. Velocity contour across the pond width at position 5 (downstream of the distal end).

CONCLUSIONS

Measurements of flow in two IABR Inoculation ponds showed that the velocity is almost uniform downstream of the Carbonation sump. When the flow moves downstream it becomes fully uniform. In the channel downstream of the distal end the flow is very non-uniform with a substantial deadzone area along the inner Berm. It takes almost 50 ft downstream before the deadzone is fully eliminated and the negative flow along the inner Berm disappears. In general, we can summarize the results of these experiments as:

- Paddlewheel efficiency was measured to be 8%. If the paddlewheels in 2.2 acres ponds perform the same efficiency, we would have 20 cm/s in those ponds
- The average pond velocity was measured to be 38 cm/s
- The paddlewheel power consumption was measured to be 3 kW (4 horse power)
- The maximum local velocity, which was measured at the promixal end, was 74 cm/s and the minimum velocity, which was measured along the inner wall at channel II, was -15 cm/s

- Turbulence data were extracted from the velocity time series which showed that at the region downstream of the paddlewheel the flow is turbulent while at the other regions is weekly turbulent