FINAL REPORT

LARGE SCALE AND LIVE BED LOCAL PIER SCOUR EXPERIMENTS

PHASE 1

LARGE SCALE, CLEARWATER SCOUR EXPERIMENTS

SUBMITTED TO:

FLORIDA DEPARTMENT OF TRANSPORTATION
605 Suwannee Street
Tallahassee, Florida 32399-0450

FDOT Contract Number
BB-473

University of Florida Contract Number
4910 45-11-344

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September 2003

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D	=	circular cylinder diameter;
D_{16}	=	sediment size for which 16 percent of bed material is finer
D_{50}	=	median sediment grain diameter;
D_{84}	=	sediment size for which 84 percent of bed material is finer
d_{se}	=	equilibrium scour depth;
d_s	=	scour depth at the end of the experiment, or
	=	Time dependent scour hole depth.
K_{cp}	=	peak value of normalized clearwater scour depth
K_s	=	shape factor
σ	=	standard deviation of sediment particle size distribution, $\sqrt{\frac{D_{84}}{D_{16}}}$;
V	=	depth averaged velocity;
V_c	=	depth averaged velocity at threshold condition for sediment motion (sediment critical velocity);
y_0	=	approach water depth;
μ	=	dynamic viscosity of water
ρ_s	=	mass density of sediment
ρ_w	=	mass density of water
τ	=	bed shear stress
τ_c	=	critical bed shear stress

CLEARWATER LOCAL SEDIMENT SCOUR EXPERIMENTS

Introduction

The accurate prediction of sediment scour depths near bridge piers under design storm conditions is very important in bridge design. Under-prediction can result in costly bridge failure and possibly the loss of lives, while over-prediction can result in millions of dollars wasted on the construction of a single bridge. The physical processes involved are very complex and difficult to analyze, and thus most design scour depth predictive equations are based on laboratory scale experimental results. An ongoing bridge scour research program at the University of Florida is directed at increasing the understanding of scour processes and improving the accuracy of design scour depth predictions.

In spite of a significant research effort over the last four decades, at a number of institutions around the world, there is still disagreement among researchers regarding such fundamental aspects of the problem as the most appropriate way to normalize the parameters required to characterize the scour processes. Even the variable used to normalize the equilibrium scour depth differs among researchers. Some use the local (unscoured) water depth while others use the diameter/width of the structure.

The research described in this report was a joint effort by the University of Florida and the USGS Conte BRD Laboratory to extend the knowledge of local sediment scour processes through large-scale experiments. All of the experiments were conducted in a large, flow-through type flume in the USGS Laboratory in Turners Falls, Massachusetts. Three different circular cylinder diameters [0.915 m (3 ft), 0.305 m (1 ft), and 0.114 m (4.5 in)], three different sediment grain sizes (D_{50} = 0.22 mm, 0.80 mm and

2.9 mm) and a range of water depths were investigated. All experiments were conducted in the clearwater scour range of velocities.

A brief description of the facilities, instrumentation and procedures is presented in the body of the report along with a summary of the results. Detailed information regarding the experiments and the results is presented in the appendices.

Research Objectives

Research by the lead author and his students has shown that normalized, equilibrium local scour depths can be adequately described in terms of three dimensionless parameters, y_0/D, V/V_c, and D/D_{50}, where y_0 is the water depth, D the structure diameter/width, V the depth averaged velocity, V_c the depth averaged critical velocity, and D_{50} the median sediment grain diameter. Laboratory data obtained by the lead author and other researchers prior to this work correlated well with these parameters for the range of values for which data was available. The range of available data was limited due to the sizes of flumes available for this type of research. In particular, the range of values for D/D_{50} was very limited and far from the values for prototype structures. Experiments at the University of Florida indicated a trend in the data with increasing values of D/D_{50} that had not been observed before. If correct, this trend could have a significant impact on equilibrium scour depth predictions for large prototype structures. Thus, one of the objectives of this research was to obtain local scour data for larger values of D/D_{50}.

The rate at which local scour occurs and the dependence of this rate on the sediment, flow and structure parameters is another problem that has plagued researchers in this field. A second objective of this study was to provide accurate scour depth versus time data for a range of sediment, flow and structure parameters.

Phase I of this study covers the clearwater scour range of velocities $\left(\text{i.e.,} 0.45 \le V/V_c \le 1\right)$. Phase II will address the live bed scour range of velocities $\left(V/V_c > 1\right)$. The live bed experiments will be conducted by the lead author in a flume at the University of Auckland in Auckland, New Zealand during the first half of 2002. This is the final report for Phase I of this investigation.

Facilities and Instrumentation

<u>Facilities</u>

All of the tests were conducted in a large 6.1 m (20 ft) wide, 6.4 m (21 ft) deep, 38.4 m (126 ft) long, flow-through type flume, located at the USGS Conte Laboratory. An aerial photograph of the USGS Laboratory is shown in Figure 1. Schematic drawings

Figure 1. The USGS-BRD Conte Anadromous Fish Research Center in Turners Falls, Massachusetts.

of the flume used for this research are shown in Figures 2 and 3. The test section was the width of the flume, 9.8 m (32 ft) long and started 24.4 m (80 ft) downstream of the entrance. The sediment in the test area was 1.83 m (6 ft) deep as shown in Figure 2. Water for the flume was supplied from a hydroelectric power plant reservoir adjacent to the building housing the flume. Water flowed from the reservoir, through the flume, and discharged into the Connecticut River downstream of control structures in the river. The drop in water elevation from the reservoir to the bottom of the flume is approximately 6.5 m (21 ft). The main advantage of a gravity driven flume, such as this, is that large flow discharges can be obtained without pumps. There are, however, disadvantages to flow-through systems. Other than water depth and flow velocity there is little control on the water used in the experiments. For example, the water temperature will be that of the

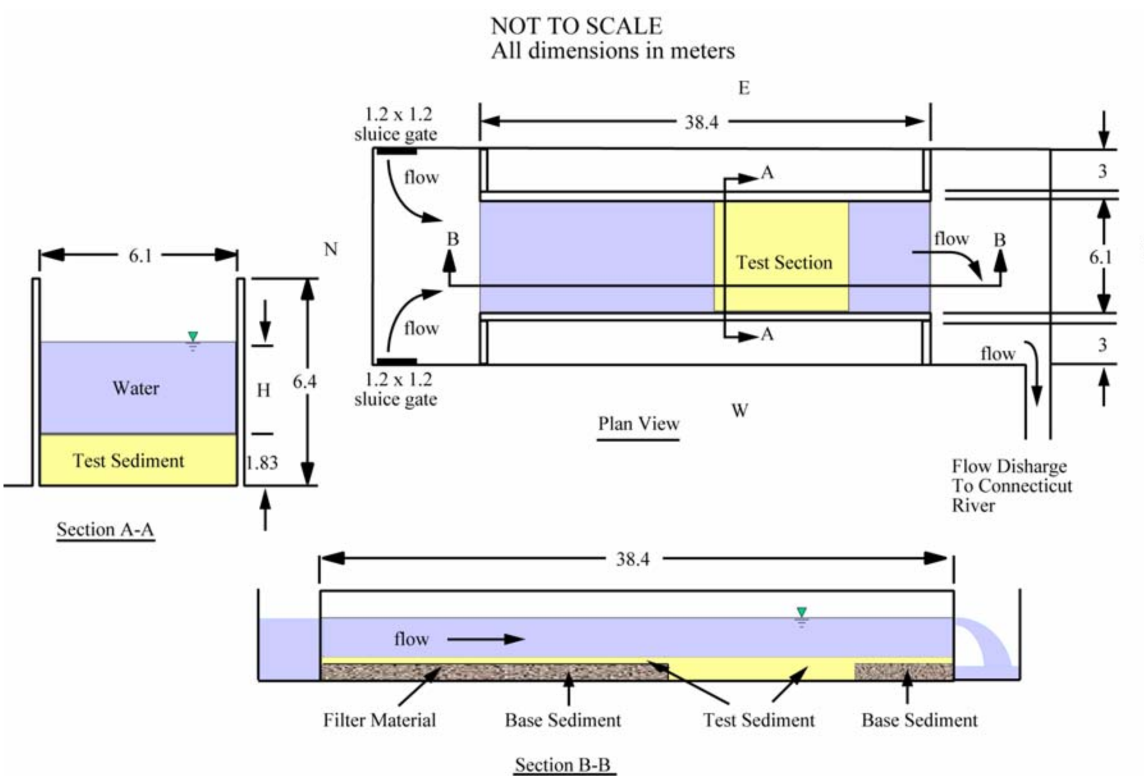

Figure 2. Schematic drawing of the flume used for this research.

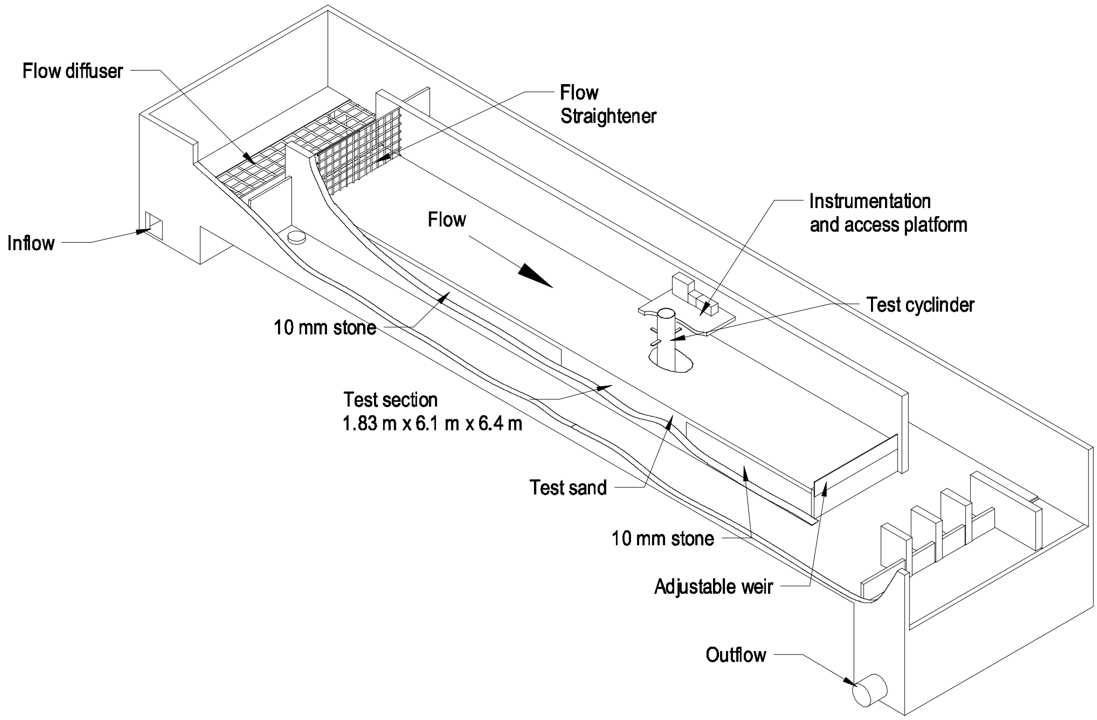

Figure 3. Isometric drawing of the flume illustrated in Figure 2.

reservoir and at this location the range in temperatures was from slightly above freezing during the winter months to around 26° C during the summer. In addition, constituents in the water, such as suspended sediment, could not be controlled. The presence of suspended sediment in the water during times of heavy runoff from the Connecticut River drainage basin presented problems for some of the experiments as is discussed later in this report. The flow discharge and depth-averaged velocity were controlled with a weir located at the downstream end of the flume (see Figure 3). A bridge across the flume provided horizontal support for the tops of the test structures and a platform for the computers and data acquisition systems (see Figure 4).

Figure 4. Experimental setup showing the instrumentation bridge/platform.

Instrumentation

The instrumentation used in this research can be divided into two categories: 1) that which measures the flow parameters, and 2) that which measures scour depth. The flow parameters monitored were flow discharge (indirectly), velocity at specific locations, water depth, and temperature. The scour hole depth was monitored with internal (and on some occasions) external video cameras and with arrays of acoustic transponders. A more complete description of the instrumentation used in this research is presented in Appendix B.

The height of the weir at the downstream end of the flume was set for the desired water depth and flow discharge for each experiment. Flow velocities were measured at two locations, 2 m (6.6 ft) upstream and 1.0 m (3.3 ft) to the side of the center of the test structure with electromagnetic flow meters. The vertical position of the meters was set at

40% of the water depth from the bed. The velocity at this location is approximately equal to the depth-averaged velocity for a fully developed logarithmic velocity profile. A commercial water level instrument, which used a near bottom mounted pressure transducer measured water depth at a location between the test structure and the weir. The water temperature was measured just downstream of the structure.

Two miniature video cameras were mounted on a platform that traversed vertically as shown in the sketch in Figure 5. The speed of the traverse mechanism was set manually and had a speed range from 1 mm/hr (0.04 in/hr) to 90 m/hr (295 in/hr). Length scales were attached to the inside of the cylinders in view of the cameras so that quantitative scour depth measurements could be obtained from the video images. Miniature video cameras were also mounted in streamline waterproof housings for viewing the scour hole from outside the structure. The 0.114 m (4.5 in), and 0.305 m (1 ft) diameter cylinders were constructed to be watertight while the 0.915 m (3 ft) diameter

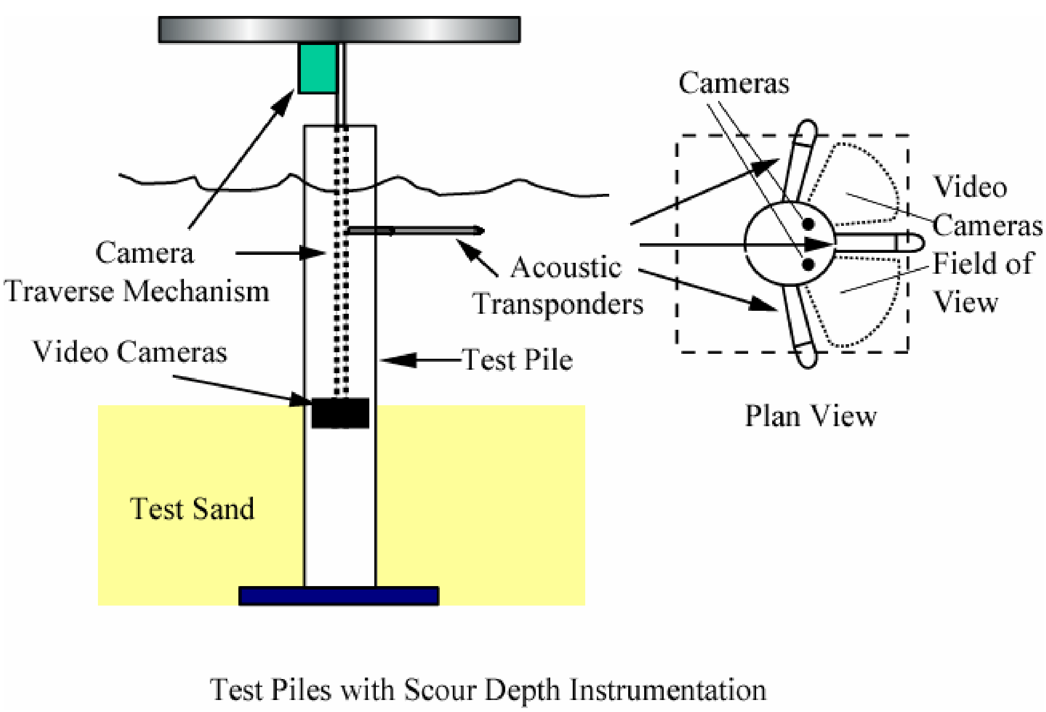

Figure 5. Schematic drawing of the local scour depth measuring instruments.

cylinder was allowed to flood during the experiment. The internal cameras for the large 0.915 m diameter cylinder were mounted in a waterproof housing. Photographs of the three internal camera arrangements are shown in Figures 6, 7, and 8.

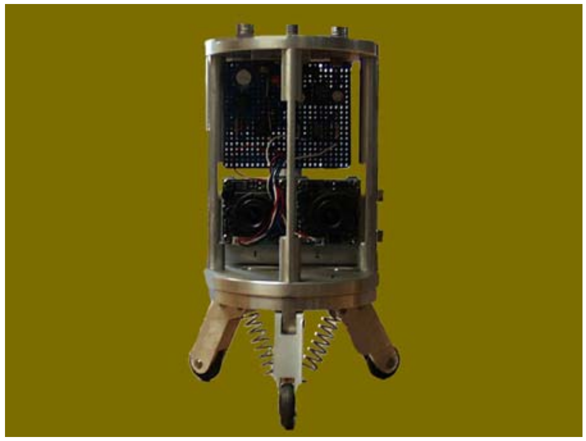

Figure 6. Internal video cameras and housing for the 0.114 m (4.5 in) diameter cylinder.

Figure 7. Internal video cameras and housing for the 0.305 m (1 ft) diameter cylinder.

Three arrays of acoustic transponders were attached to the cylinder just below the water surface. Each array contained four crystals, which produced a 2.5 cm (1 in) in diameter acoustic beam at the transducer. The spread angle of the beam was approximately 1.5 degrees. The footprint of the beam (area of the acoustic beam at the bed) varied with the water and scour hole depths. The time required for the acoustic pulse to

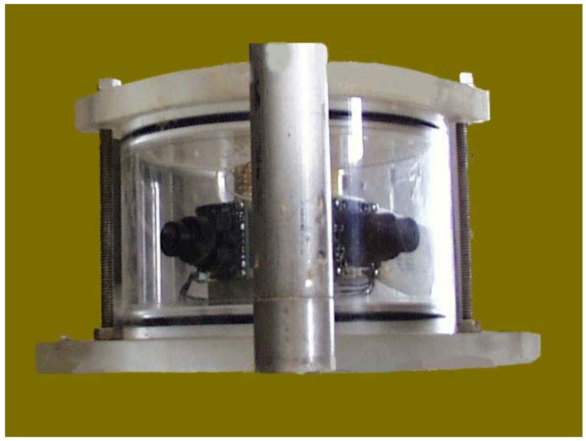

Figure 8. Watertight video camera housing for the 0.915 m (3 ft) diameter cylinder.

travel to the bed and return to the transponder was measured and the distance from the transponder to the bed computed based on the speed of sound in water at that temperature. This system provided scour hole depth measurements at the 12 locations along three radial lines throughout the experiments. A diagram of one of the transponder arrays is given in Figure 9. Photographs of the transponders are shown in Figures 10 and 11.

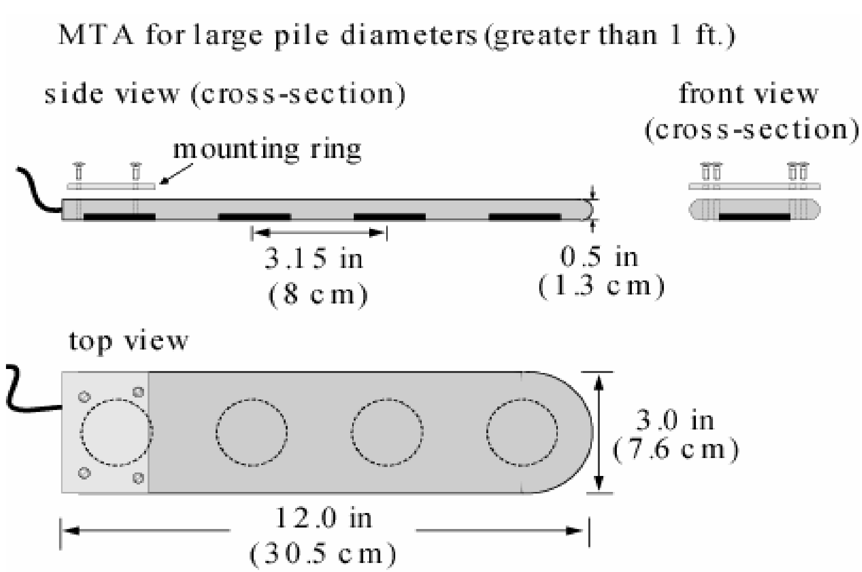

Figure 9. Diagram of the acoustic transponder array used for the 0.915 m (3 ft) diameter cylinder.

Figure 10. Acoustic transponder arrays on the 0.915 m (3 ft) diameter cylinder viewed from upstream.

Figure 11. Acoustic transponder arrays on the 0.114 m (4.5 in) diameter cylinder viewed from above.

Personal Computers were used to both control the instrumentation and to record the data. A flow chart of the instrumentation/data acquisition system is shown in Figure 12.

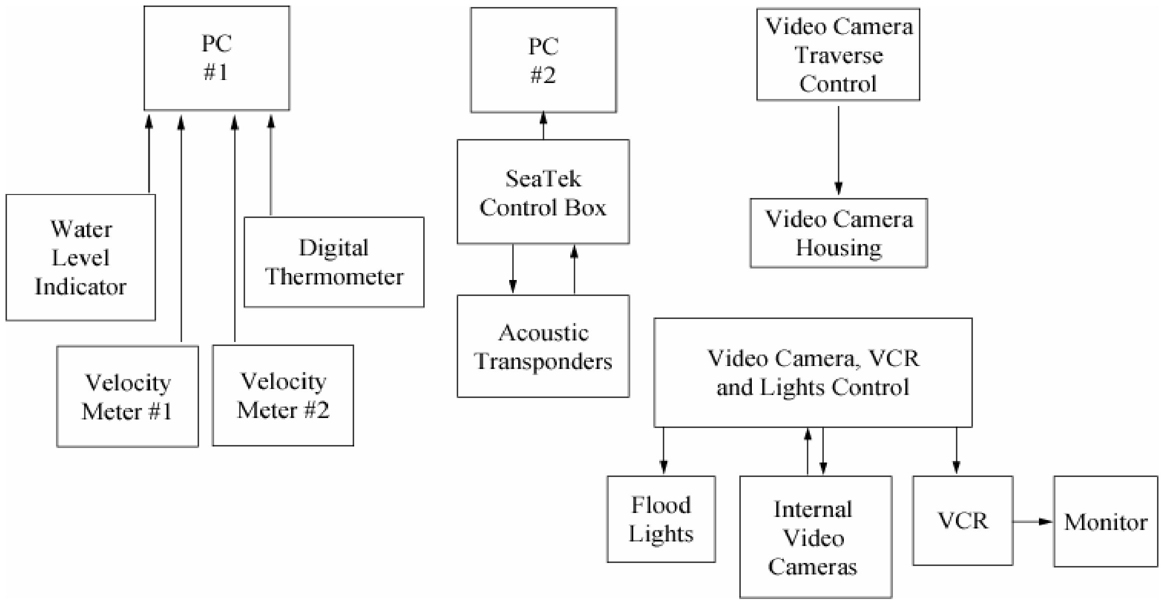

Figure 12. Diagram of the measuring system used during the experiments.

Experimental Procedure

A brief summary of the experimental procedure used in performing the local sediment scour experiments is outlined below. A more complete procedure is given in Appendix D. The procedure is divided into the tasks performed before, during and after the experimental run.

Pre-experiment

1. Compact and level the bed in the flume.
2. Fill the flume slowly and allow to stand for approximately 12 hours or until all the air trapped in the sediment has escaped. Drain the flume and re-compact the bed.
3. Take pre-experiment photographs.
4. Fill the flume slowly and allow trapped air to escape (approximately six hours).
5. Start and check all instrumentation.

During experiment

1. Measure the scour depth as a function of time with acoustic transponders and video cameras.
2. Measure the velocity, water depth, and temperature. Observe water clarity as an indicator of suspended sediment.

Post-experiment

1. Take post-experiment photographs.
2. Observe and note bed condition throughout the flume (presence of bed forms, etc.)
3. Survey the scour hole with a point gauge.
4. Reduce and analyze the data.

Results

A significant amount of local sediment scour data and information were gathered during this research program. A brief summary of the results is given in Tables 1 and 2. Two different scour depths are given in the table, the measured value at the end of the experiment and the estimated equilibrium depth. Most of the experiments conducted as part of this work were long in duration and thus the scour depths were near equilibrium at the end of the test. During some of the tests there was an increase in suspended sediment in the water from the reservoir and this proved to impact the equilibrium scour depth. This is illustrated in Figure 13 which shows three time history plots. In Experiment A ($D = 0.915$ m, $D_{50} = 0.22$ mm, $y_0 = 1.2$ m, $V = 0.30$ m/s, $V_c = 0.32$ m/s), there was a sudden increase in suspended fine sediment approximately 10 hours into the test. Experiment B was with the same structure and sediment but with a slightly higher velocity and deeper

Table 1. Flow, sediment and structure parameters summary.

Test	Flow		Sediment		Structure
	Depth (m)	Velocity (m/s)	D_{50} (mm)	σ	Diameter (m)
1	1.19	0.29	0.22	1.51	0.114
2	1.19	0.31	0.22	1.51	0.305
3	1.27	0.40	0.80	1.29	0.915
4	0.87	0.39	0.80	1.29	0.915
5	1.27	0.39	0.80	1.29	0.305
6	1.27	0.41	0.80	1.29	0.114
7	1.22	0.76	2.90	1.21	0.915
8	0.56	0.65	2.90	1.21	0.915
9	0.29	0.57	2.90	1.21	0.915
10	0.17	0.50	2.90	1.21	0.915
11	1.90	0.70	2.90	1.21	0.915
12	1.22	0.40	0.22	1.51	0.305
13	0.18	0.30	0.22	1.51	0.305
14	1.81	0.30	0.22	1.51	0.915

Table 2. The local scour results summary.

Test	Test Duration (hr)	Time to 90% d_{se} (equil.) (hr)	Max. Measured Scour Depth (m)	Estimated Equilibrium Scour Depth (m)
1	89	111	0.133	0.17
2	163	408	0.257	0.41
3	360	322	1.112	1.10
4	143	905	0.638	0.99
5	88	128	0.416	0.51
6	41	29	0.185	0.23
7	188	151	1.270	1.41
8	330	186	1.058	1.14
9	448	347	0.896	0.96
10	616	831	0.659	0.72
11	350	720	1.004	1.24
12	256	71	0.377	0.39
13	216	66	0.296	0.31
14	580	913	0.787	0.97

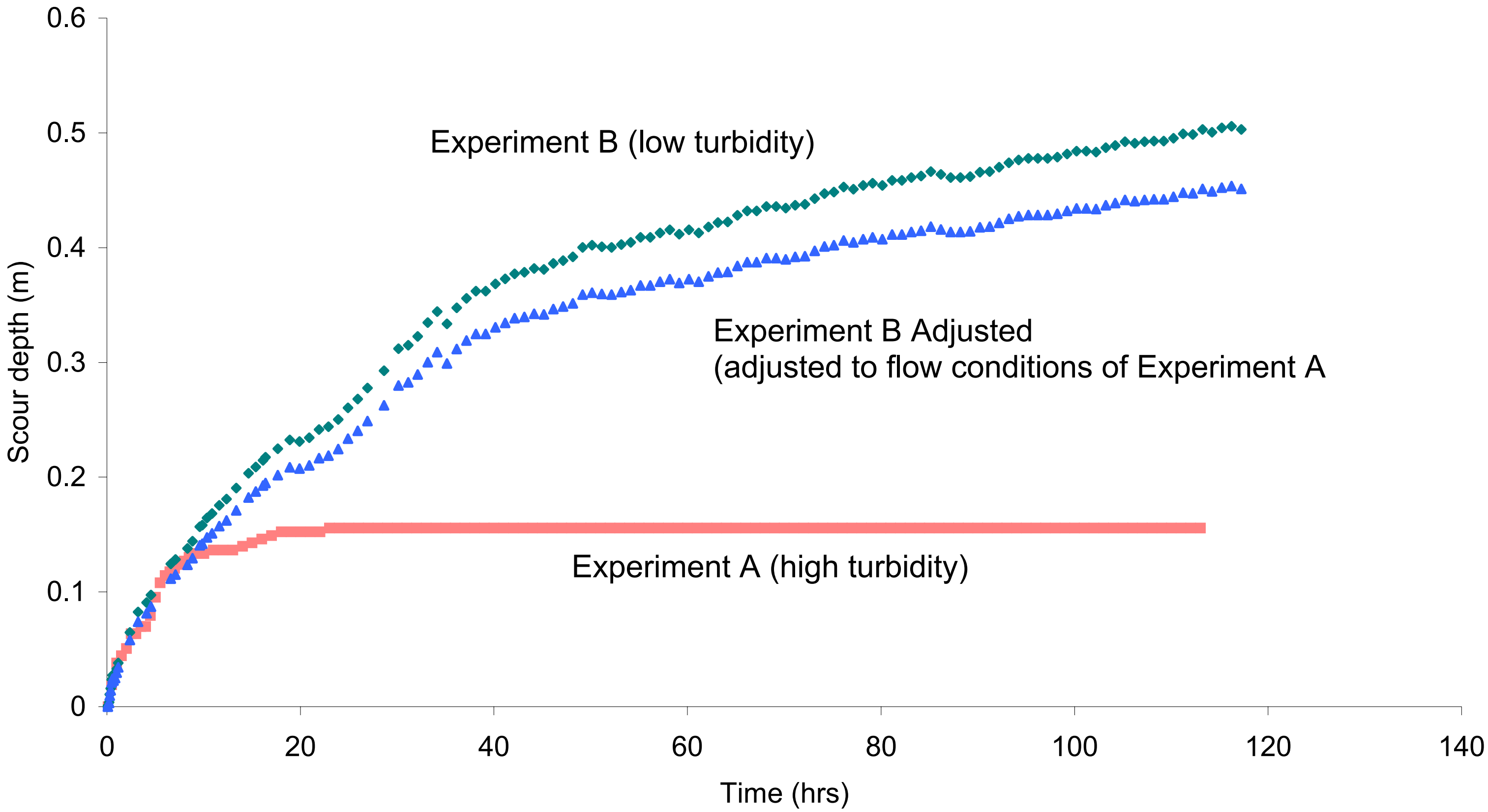

Figure 13. Graph illustrating the impact of suspended fine sediment on equilibrium local scour depths under clearwater scour conditions. Experiment A experienced a sudden increase in suspended fine sediment about 10 hours into the test. Experiment B was with the same sediment and structure but with a slightly higher velocity and a deeper water depth. In the Experiment B Adjusted plot the data for Experiment B has been analytically adjusted to the flow conditions of Experiment A (with the exception of the suspended fine sediment).

water depth (y_0 = 1.8 m, V = 0.30 m/s, V_c = 0.32 m/s). In the Experiment B Adjusted plot the data from Experiment B has been adjusted (using Equation 6) to the water depth and flow velocity conditions of Experiment A. By comparing the results from Experiment A with those from Experiment B Adjusted the impact of fine sediment can be seen. The reasons behind this affect are currently being investigated by the lead author but it is suspected that it is due to the suspended fine sediment induced reduction in bed shear stress reported by researchers working in the field of drag reduction (see e.g., Gust 1976). Additional discussion on this topic is presented in Appendix E.

Equilibrium depths were estimated by extrapolating a curve fit to the data. The function used to fit the data was first used by J. Sterling Jones (personal communication) and is given in Equation 1.

$$d_s = a\left(1-\frac{1}{1+abt}\right)+c\left(1-\frac{1}{1+cdt}\right) \tag{1}$$

This function does a good job fitting the majority of clearwater scour time history data. Most clearwater scour time history plots display at least two distinctive rates. The divisions between rates are clearly defined in some cases while in others the change is more gradual. In order to use Equation 1 for extrapolation of data it is essential that there is sufficient data in the second (lower rate of scour) regime. Obviously, the longer the duration of the test the more accurate the extrapolation to equilibrium scour depth. Equilibrium scour depths were estimated for all tests including those affected by suspended fine sediment. The confidence level for the shorter duration tests and those with suspended sediment is, of course, lower than that for the remaining tests. It does appear from the time history plots and some analysis of the longer duration data that the equilibrium scour depths obtained by this method error on the high side (i.e., the predicted scour depths represent upper bound values for the conditions tested).

The coefficients in Sheppard's clearwater scour equations (1995) have been slightly adjusted to accommodate these conservative equilibrium scour depth values. The resulting equations are given below:

$$\frac{d_{se}}{D} = 2.5\,K_s\, f_1\left(\frac{y_0}{D}\right) f_2\left(\frac{V}{V_c}\right) f_3\left(\frac{D}{D_{50}}\right) \tag{2}$$

where

$$f_1\left(\frac{y_0}{D}\right) \equiv \mathit{tanh}\left[\left(\frac{y_0}{D}\right)^{0.4}\right], \tag{3}$$

$$f_2\left(\frac{V}{V_c}\right) = 1 - 1.75\left[\ln\left(\frac{V}{V_c}\right)\right]^2, \tag{4}$$

$$f_3\left(\frac{D}{D_{50}}\right) = \frac{D/D_{50}}{0.4\left(D/D_{50}\right)^{1.2} + 10.6\left(D/D_{50}\right)^{-0.13}}, \text{ and} \tag{5}$$

K_S = Shape factor (1 for circular piles). Substituting Equations 3-5 into Equation 2 results in:

$$\frac{d_{se}}{D} = K_s 2.5\left\{\mathit{tanh}\left[\left(\frac{y_0}{D}\right)^{0.4}\right]\right\}\left\{1 - 1.75\left[\mathit{ln}\left(\frac{V}{V_c}\right)\right]^2\right\}\left\{\frac{D/D_{50}}{0.4\left(D/D_{50}\right)^{1.2} + 10.6\left(D/D_{50}\right)^{-0.13}}\right\} \tag{6}$$

A plot of measured versus predicted (using Equation 6) equilibrium scour depths for the clearwater data obtained during this research and that of other researchers is shown in Figure 14.

Conclusions

The primary objectives of this research were to extend the existing data base for local sediment scour into areas of larger structure to sediment diameter ratios and to verify that the equilibrium scour depth dependency on this ratio, found in earlier studies at the University of Florida, held. Both objectives have been met. The coefficients in Sheppard's equations have been slightly modified to accommodate the conservative equilibrium scour depths obtained by extrapolating the measured depths to infinite flow durations. The revised equations do a good job of fitting the data in the clearwater scour range as can be seen in Figure 14.

The next phase of this work will address equilibrium scour depths under live bed scour conditions. Sheppard's equations in the live bed scour range are based on limited laboratory data and the hypothesis that a "live bed scour depth peak" occurs and that it occurs at the point when the bed "planes out" (i.e., under the conditions when the bed forms disappear and the bed away from the structure becomes planar). More laboratory data is needed in this important range of flow conditions so that these equations can be tested/verified. Live bed scour experiments will be conducted by the lead author in a flume at the University of Auckland in Auckland, New Zealand during the early part of 2002.

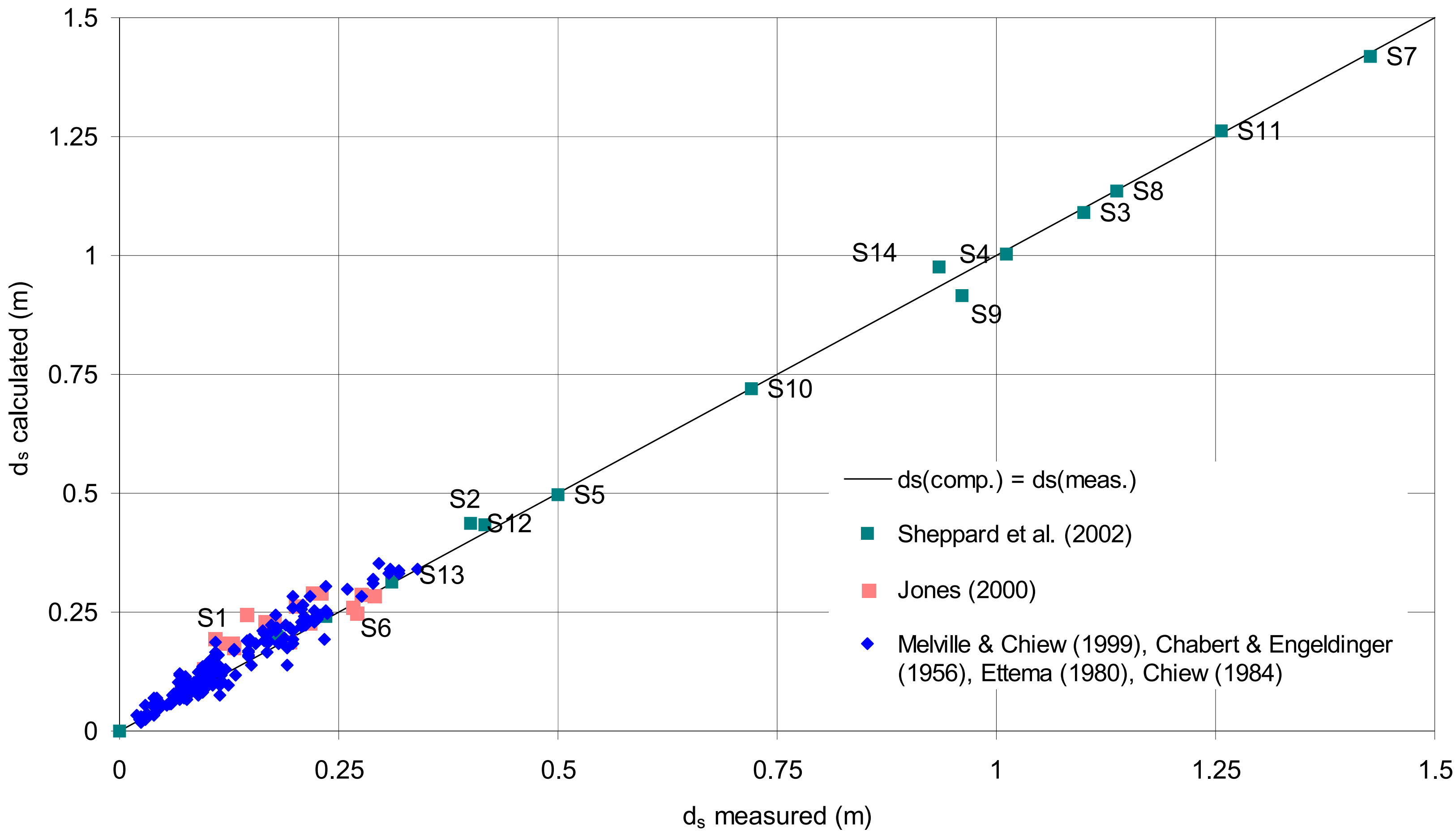

Figure 14. Measured versus predicted (using Equation 6) equilibrium scour depths for the clearwater data obtained during this research and for data from other researchers [Sheppard et al. (2002), Jones, J.S. (2000), Melville, B.W. and Chiew, Y.M. (1999), Chabert, J. & Engeldinger, P (1956), Ettema, R. (1980), Chiew, Y.M. (1984)].

BIBLIOGRAPHY

Ahmad, M. 1953. "Experiments on design and behavior of spur dikes." *Proc. of International Hydraulics Convention*, St. Anthony Falls Hydraulic Laboratory, Minneapolis, MN, 145-159.

Ahmad, M. 1962. "Discussion of 'Scour at bridge crossings' by E.M. Laursen." *Trans. of ASCE*, 127, pt. I(3294), 198-206.

Baker, R.E. 1986. "Local scour at bridge piers in non-uniform sediment." *Report No. 402*, Department of Civil Engineering, University of Auckland, Auckland, New Zealand.

Basak, V. 1975. "Scour at square piers." Devlet su isteri genel mudulugu, Report No. 583, Ankara, Turkey.

Blench, T. 1962. "Discussion of 'Scour at bridge crossings' by E.M. Laursen." *Trans. of ASCE*, 127, pt. I(3294), 180-183.

Blevins, R.D. 1984. *Applied Fluid Dynamics Handbook*. Van Nostrand Reinhold, New York.

Bonasoundas, M. 1973. "Non-stationary hydromorphological phenomena and modelling of scour process." *Proc. 16th IAHR Congress*, Vol. 2, Sao Paulo, Brazil, 9-16.

Breusers, H.N.C., Nicollet, G., and Shen, H.W. 1977. "Local scour around cylindrical piers." *Journal of Hydraulic Research*, 15(3), 211-252.

Chabert, J., and Engeldinger, P. 1956. "Etude des affouillements autour des piles des ponts." Laboratoire National d'Hydraulique, Chatou, France.

Chiew, Y.M. 1984. "Local scour at bridge piers." *Master's Thesis*, Auckland University, Auckland, New Zealand.

Chitale, S.V. 1962. "Discussion of 'Scour at bridge crossings' by E.M. Laursen." *Trans. of ASCE*, 127, pt. I(3294), 191-196.

Cunha, L.V. 1970. "Discussion of 'Local scour at bridge crossings' by Shen, H.W., Schneider, V.R. and Karaki, S.S." *Trans. of ASCE*, 96(HY8), 191-196.

Ettema, R. 1976. "Influence of material gradation on local scour." *Master's Thesis*, Auckland University, Auckland, New Zealand.

Ettema, R. 1980. "Scour at bridge piers." *PhD Thesis*, Auckland University, Auckland, New Zealand.

Froehlich, D.C. 1988. "Analysis of on-site measurements of scour at piers." *Proc. of the 1988 National Conference on Hydraulic Engineering*, ASCE, New York, 534-539.

Gao, D.G., Posada, G., and Nordin, C.F. 1992. "Pier scour equations used in the People's Republic of China." Draft, Department of Civil Engineering, Colorado State University, Fort Collins, CO.

Garde, R.J, Ranga Raju, K.G., and Kothyari, U.C. 1993. *Effect on unsteadiness and stratification on local scour*. International Science Publisher, New York.

Graf, W.H. 1995. "Local scour around piers." *Annu. Rep.*, Laboratoire de Recherches Hydrauliques, Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland.

Gust, G. 1976. "Observations on turbulent-drag reduction in a dilute suspension of clay in sea-water." Fluid Mechanics: 75 (1), 29-47.

Hancu, S. 1971. "Sur le calcul des affouillements locaux dams la zone des piles de ponts." *Proc. 14th IAHR Congress*, Vol. 3, Paris, France, 299-313.

Hanna, C.R. 1978. "Scour at pile groups." *Master of Engineering Thesis*, University of Cantebury, Christchurch, New Zealand.

Henderson, F.M. 1966. *Open Channel Flow*. Macmillan, New York.

http://vortex.spd.louisville.edu/BridgeScour/whatis.htm. 1998. Bridge scour internet site, Department of Civil Engineering at the University of Louisville.

Inglis, S.C. 1949. "The behavior and control of rivers and canals." *Central Water Power Irrigation and Navigation Report*, Publication 13, part II, Poona Research Station, Poona, India.

Jain, S.C., and Fischer, E.E. 1979. "Scour around circular bridge piers at high Froude numbers." *Rep. No. FHWA-RD-79-104*, FHWA, Washington DC.

Jette, C.D., and Hanes, D.M. 1997. "High resolution sea-bed imaging: an acoustic multiple transducer array." *Measurement Science and Technology*, 8, 787-792.

Jones, J.S. 2000. In personal communication by e-mail to D.M. Sheppard.

Jones, J.S., and Sheppard, D.M. 2000. "Scour at Wide Piers," accepted for publication in the *Proceedings* for the 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management Conference, Minneapolis, MN, July 30-August 2.

Krishnamurthy, M. 1970. "Discussion of 'Local scour at bridge crossings' by Shen H.W., Schneider, V.R. and Karaki, S.S." *Trans. of ASCE*, 96(HY7), 1637-1638.

Laursen, E.M. 1962. "Scour at bridge crossings." *Trans. of ASCE*, 84(HY1), 166-209.

Laursen, E.M., and Toch, A. 1956. "Scour around bridge piers and abutments." *Bulletin No. 4*, Iowa Highway Research Board, Ames, IA.

Melville, B.W. 1975. "Local scour at bridge sites." *Report No. 117*, University of Auckland, School of Engineering, Auckland, New Zealand.

Melville, B.W. 1985. "Live-bed scour at bridge piers." *Journal of Hydraulic Engineering*, 110(9), 1234-1247.

Melville, B.W. 1997. "Pier and abutment scour-an integrated approach." *Journal of Hydraulic Engineering*, 123(2), 125-136.

Melville, B.W., and Chiew, Y.M. 1999. "Time scale for local scour at bridge piers." *Journal of Hydraulic Engineering*, 125(1), 59-65.

Melville, B.W., and Sutherland, A.J. 1988. "Design method for local scour at bridge piers." *Journal of Hydraulic Engineering*, 114(10), 1210-1226.

Neill, C.R. 1964. "River bed scour, a review for bridge engineers." *Contract No. 281*, Res. Council of Alberta, Calgary, Alberta, Canada.

Neill, C.R. 1973. *Guide to Bridge Hydraulics*. Roads and Transportation Association of Canada, University of Toronto Press, Canada.

Nicollet, G., and Ramette, M. 1971. "Affouillement au voisinage de pont cylindriques circularies." *Proc. of the 14th IAHR Congress*, Vol. 3, Paris, France, 315-322.

Pilarczyk, K.W. 1995. "Design tools related to revetments including riprap." *River, Coastal and Shoreline Protection: Erosion Control using Riprap and Armour Stone*, John Wiley & Sons, New York, 17-38.

Raudkivi, A.J., and Ettema, R. 1977. "Effect of sediment gradation on clear water scour." *Journal of Hydraulic Engineering*, 103(10), 1209-1212.

Rouse, H. 1946. *Elementary Fluid Mechanics*. John Wiley & Sons, New York.

Shen, H.W. 1971. "Scour near piers." *River Mechanics*, Vol. II, Chapter 23, Colorado State University, Fort Collins, CO.

Shen, H.W., Schneider, V.R., and Karaki, S.S. 1967. "Mechanics of local scour." *Pub. No. CER66HWS22*, Civil Engineering Department, Colorado State University, Fort Collins, CO.

Sheppard, D.M. 1997. "Conditions of maximum local scour." *Report No. UFL/COEL-97/006*, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, FL.

Sheppard, D.M. 2000. "A Method for Scaling Local Sediment Scour Depths from Model to Prototype," accepted for publication in the *Proceedings* for the 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management Conference, Minneapolis, MN, July 30-August 2.

Sheppard, D.M. 2000. "Physical Model Local Scour Studies of the Woodrow Wilson Bridge Piers," accepted for publication in the *Proceedings* for the 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management Conference, Minneapolis, MN, July 30-August 2.

Sheppard, D.M., and Jones, J.S. 1998. "Scour at complex pier geometries." *Compendium of Scour Papers from ASCE Water Resources Conferences*, Eds. E.V. Richardson and P.F. Lagasse, ASCE, New York.

Sheppard, D.M., and Jones, S. 2000. "Local Scour at Complex Piers," accepted for publication in the *Proceedings* for the 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management Conference, Minneapolis, MN, July 30-August 2.

Sheppard, D.M., Odeh, M., Glasser, T., and Pritsivelis, A. 2000. "Clearwater Local Scour Experiments with Large Circular Piles," accepted for publication in the *Proceedings* for the 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management Conference, Minneapolis, MN, July 30-August 2.

Sheppard, D.M., and Ontowirjo, B. 1994. "A local sediment scour prediction equation for circular piles." *Report No. UFL/COEL-TR/101*, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, FL.

Sheppard, D.M., Sheldon, J., Smith, E., and Odeh, M. 2000. "Hydraulic Modeling and Scour Analysis for the San Francisco-Oakland Bay Bridge," accepted for publication in the *Proceedings* for the 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management Conference, Minneapolis, MN, July 30-August 2.

Sheppard, D.M., Zhao, G., and Ontowirjo, B. 1995. "Local scour near single piles in steady currents." *ASCE Conference Proceedings: The First International Conference on Water Resources Engineering*, San Antonio, TX.

Shields, A. 1936. "Anwendung der Aehnlichkeitsmechanik und der turbulenz forschung auf die geschiebebewegung." Mitt. Preuss. Versuchanstalt Wesserbau Schiffbau, Berlin, Germany.

Sleath, J.F. 1984. *Sea Bed Mechanics*. John Wiley & Sons, New York.

Snamenskaya, N.S. 1969. "Morphological principle of modelling of river-bed processes." *Science Council of Japan*, vol. 5-1, Tokyo, Japan.

Tison, L.J. 1940. "Erosion autour des piles de ponts en riviere." *Annales des Travaux Publics de Belgique*, 41(6), 813-817.

U.S. Department of Transportation. 1995. "Evaluating scour at bridges." *Hydraulic Engineering Circular No. 18*, Pub. No. FHWA-IP-90-017, FHWA, Washington, DC.

Venkatadri, C. 1965. "Scour around bridge piers and abutments." *Irrigation Power*, January, 35-42.

White W. R. 1973. "Scour around bridge piers in steep streams." *Proc. 16th IAHR Congress*, Vol. 2, Sao Paulo, Brazil, 279-284.

APPENDIX A
TEST FACILITIES

The USGS-BRD Conte Anadromous Fish Research Center (CAFRC) is located in Turners Falls, Massachusetts (see Figure A-1). The Engineering building houses three parallel open channels shown in the schematic drawings in Figures A-2 and A-3. Photographs of the middle 6.1 m (20 ft) wide flume at various stages of an experiment are shown in Figure A-4. This channel has a width of 6.1 m (20 ft), height of 6.4 m (21 ft) and a length of 38.6 m (126 ft). The laboratory is located between a hydroelectric power plant reservoir and the Connecticut River. The flow in the flume is generated by an approximately 6.4 m (21 ft) head difference between the reservoir and the floor of the flume. An intake pipe connects the flume to the reservoir. Grates at the entrance to the

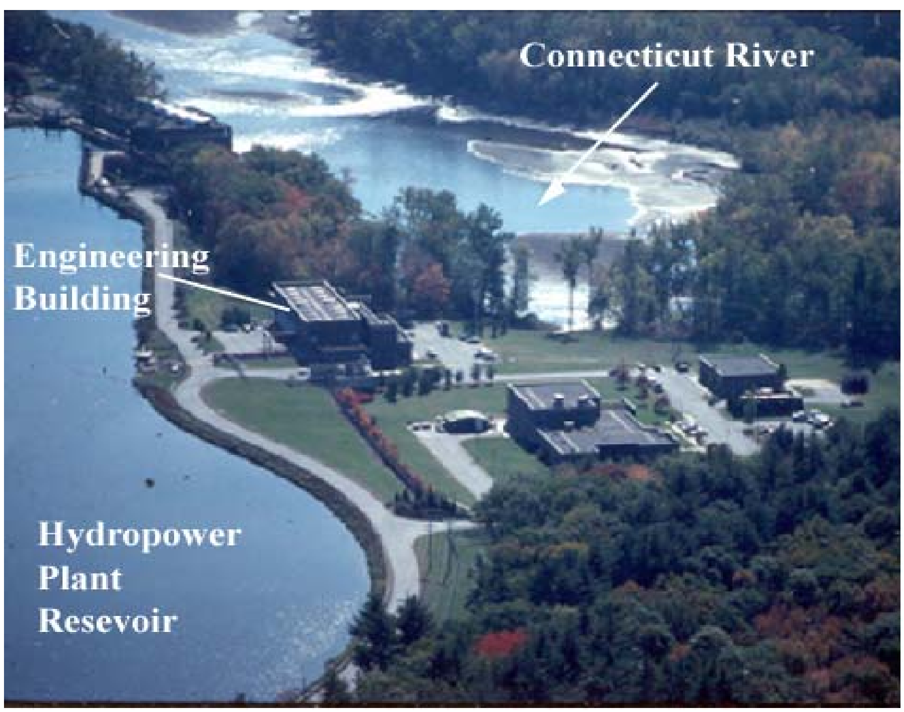

Figure A- 1. The USGS-BRD Conte Anadromous Fish Research Center located in Turners Falls, Ma.

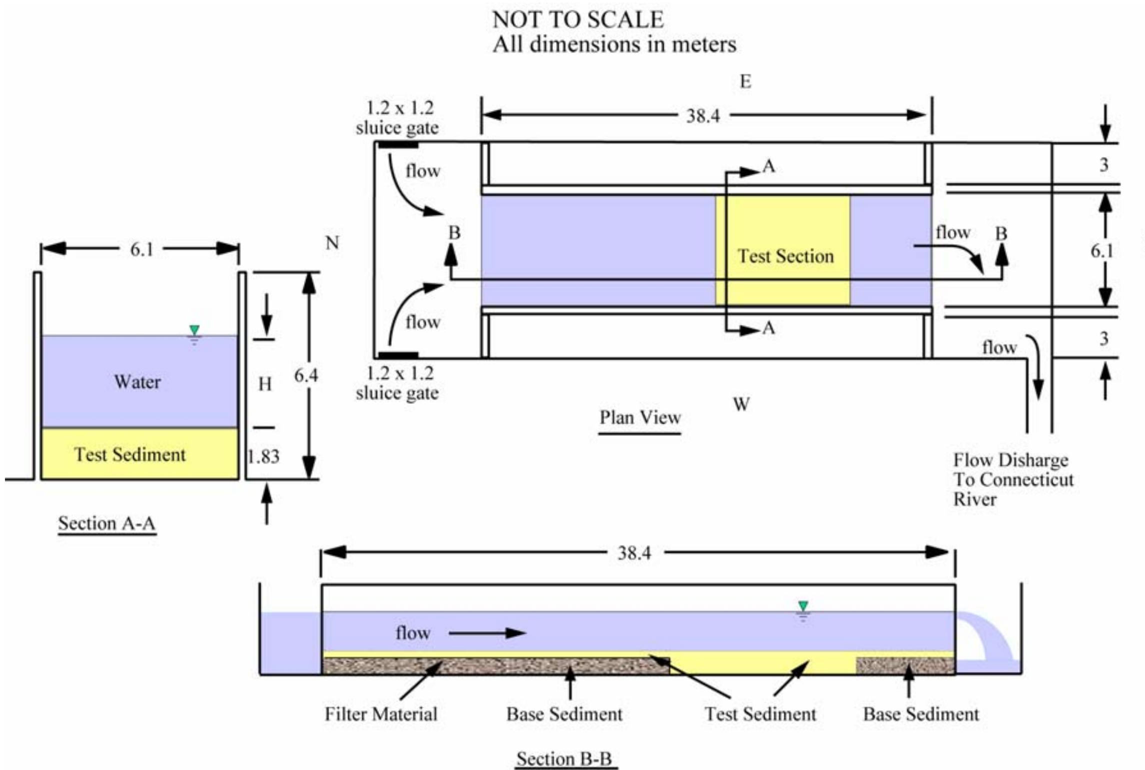

Figure A- 2. Schematic drawing of the flume in which the tests were conducted.

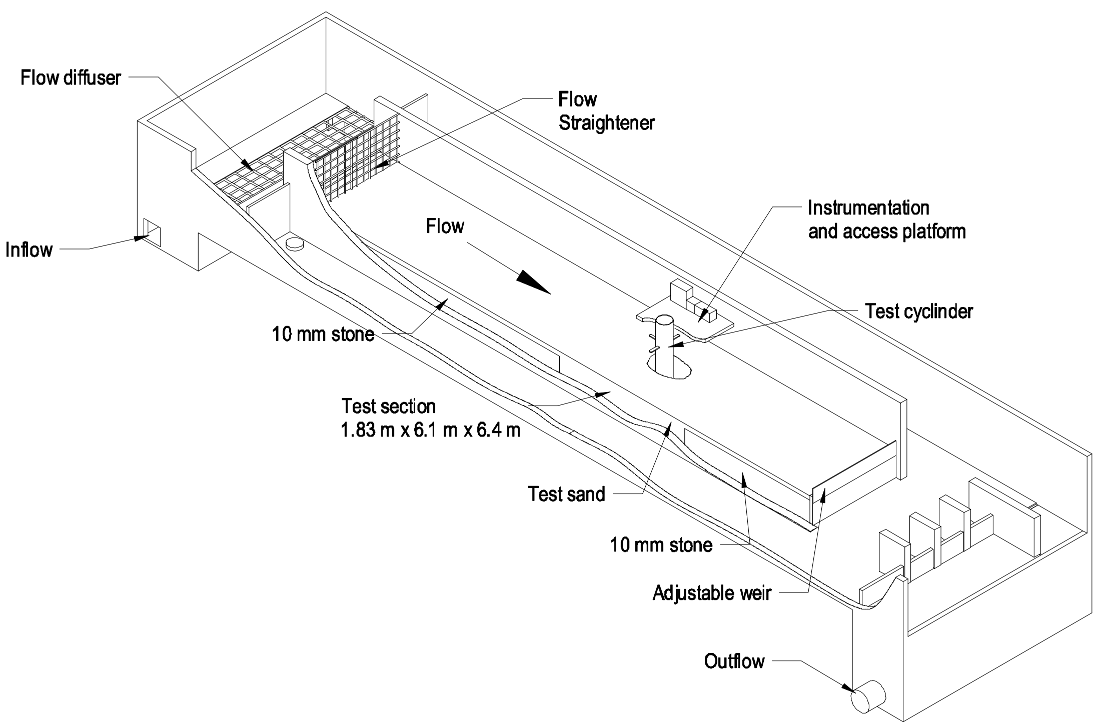

Figure A- 3. Isometric drawing of the flume illustrated in Figure A-2.

1.8 m diameter intake pipe provide a coarse filter for the incoming flow. The flow through the main intake pipe is controlled by two sluice gates. A discharge as large as 9.9 cms (350 cfs) can be achieved with the two main sluice gates. In order to reduce the amount of test sediment required, a 1.6 m (5 ft) layer of gravel was placed everywhere except the test section. Test sediment was placed to depths of 1.8 m (6 ft) in the test section and 0.328 m (1 ft) over the gravel as shown in Figures A-2 and A-3. The test section started 24 m (80 ft) downstream from the entrance and was 9.8 m (32 ft) in length and 6.1 m (20 ft) wide. The filler material (gravel) was used since it was much less expensive and allowed faster drainage. A slotted flow straightener at the flume entrance was used to create a more uniform flow across the flume. A non-erodible material was placed on the bed from the entrance to a point 6.1 m (20 ft) downstream. This material was needed to prevent sediment movement in this area of high bed shear stress.

A platform was placed across the flume for the purposes of 1) locating the instrumentation and data acquisition systems, 2) providing access to the test structures, and 3) providing additional horizontal support for the test cylinders. The vertical position of the platform could be adjusted according to the water level for the experiment. A weir was located at the downstream end of the flume for the purpose of controlling the water depths and discharge.

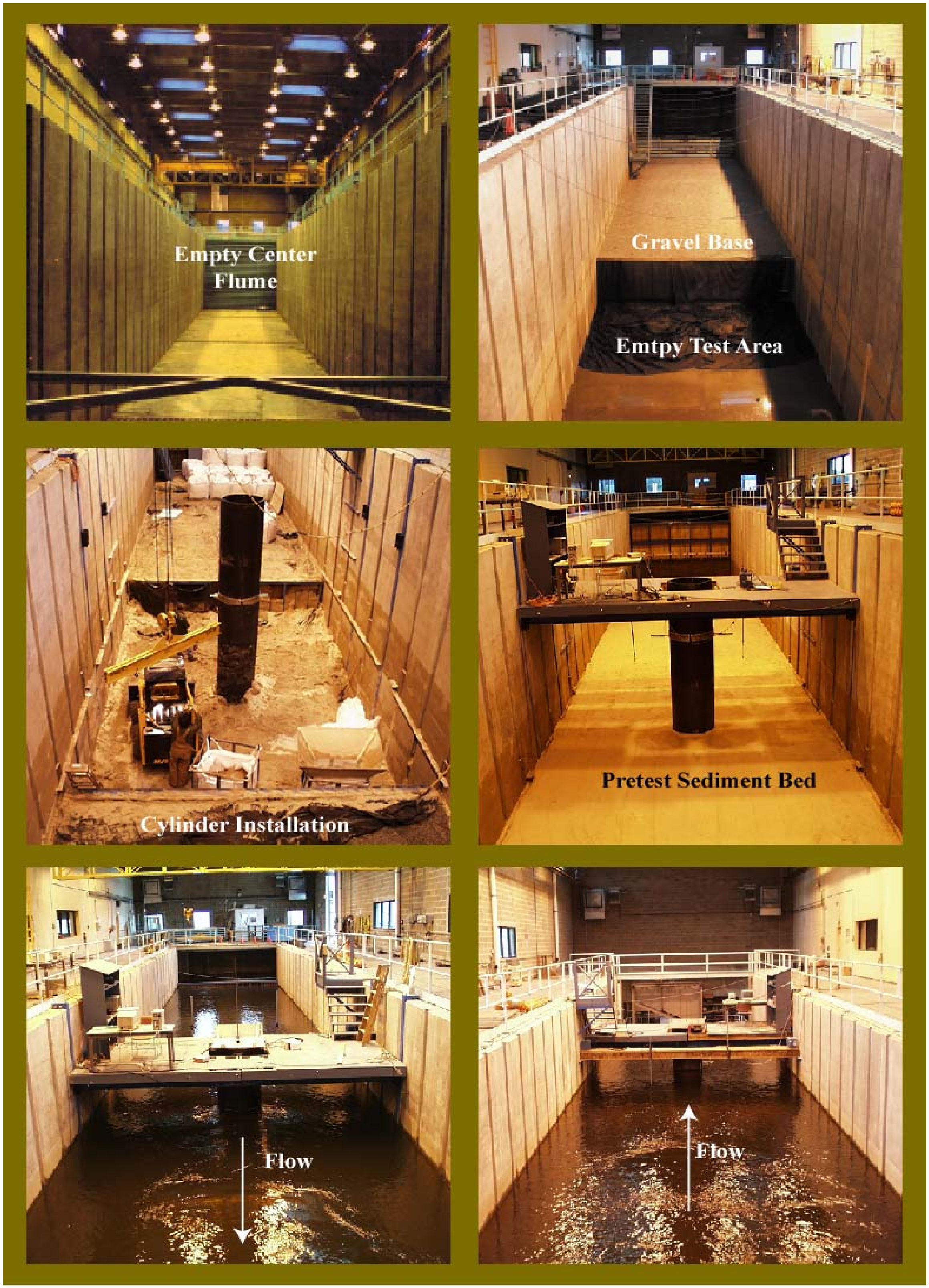

Figure A- 4. Photographs of the test flume at various stages of setup and use.

APPENDIX B
INSTRUMENTATION

The instrumentation used during the clearwater local scour experiments can be placed into two categories. The first category is that used to measure flow parameters and includes velocity meters, water level indicators and temperature probes. The second category covers that used to measure local scour depth. This includes acoustic transponders, internal and external video cameras and the associated data acquisition systems. A description of the instrumentation used is presented in this appendix.

Velocity Measurement

Two commercial electromagnetic current meters were used to measure flow velocity, [Marsh-McBirney Models 523 [13 mm (0.5 in) diameter sensor] and 511 [38 mm (1.5 in) sensor]]. The water velocity was measured at the same two horizontal locations for all of the experiments. The meters were located a distance of 2 m (6 ft) from the sides of the flume and approximately 2 m upstream from the center of the test structures. The vertical positions of the velocity sensors were four tenths of the water depth from the bed. At this location the velocity is approximately equal to the depth-averaged velocity for a fully developed logarithmic velocity profile. The time over which the velocity was averaged was increased until the measurement was steady. This value was found to be approximately one minute. Velocities at the same elevation of the sensors were also measured using an impeller type current meter (Ott-meter). The Ott meter was a C 2 Small Current Meter and the propeller was a No.1-113040 with a Z-30 quartz counter. This instrument was used periodically during the experiments to check the electromagnetic meters. The accuracy of the Marsh-McBirney meters is ±2% of the reading as reported by the manufacturer.

Water Level Measurement

A Bern-Hydrawater water level instrument was used to measure water level. This instrument uses a near bottom mounted pressure transducer. The water level was measured at the same location for all of the experiments downstream of the test structure and approximately 4 m, (13 ft) upstream of the weir. The time over which the water level was averaged was one minute. The accuracy of the water level meter was 0.01 % of the full-scale readings according to the manufacturer.

An AC2626K Temperature Measurement

An Analog Devices temperature sensor was used to measure water temperature. The temperature was measured at the same location for all experiments, approximately 3 m, (10 ft) downstream from the test structures. The time over which the temperature was averaged was one minute. The accuracy of the temperature measurement is estimated to be ± 1°C.

Acoustic Transponders

Two different acoustic transducer systems were used, one for the 0.114 m (4.5 in) and 0.305m (1 ft) cylinders and one for the 0.915 m (3 ft) cylinder (see Figures B-1 and B-2). Each system consisted of three arrays and each array contained four crystals. Each crystal produces a narrow acoustic beam [2.5 cm (1 in) in diameter at the crystal] that can be used to measure distance from the crystal to the bed. The transducers are called Multiple Transducer Arrays or simply MTAs. They were positioned at the front of the

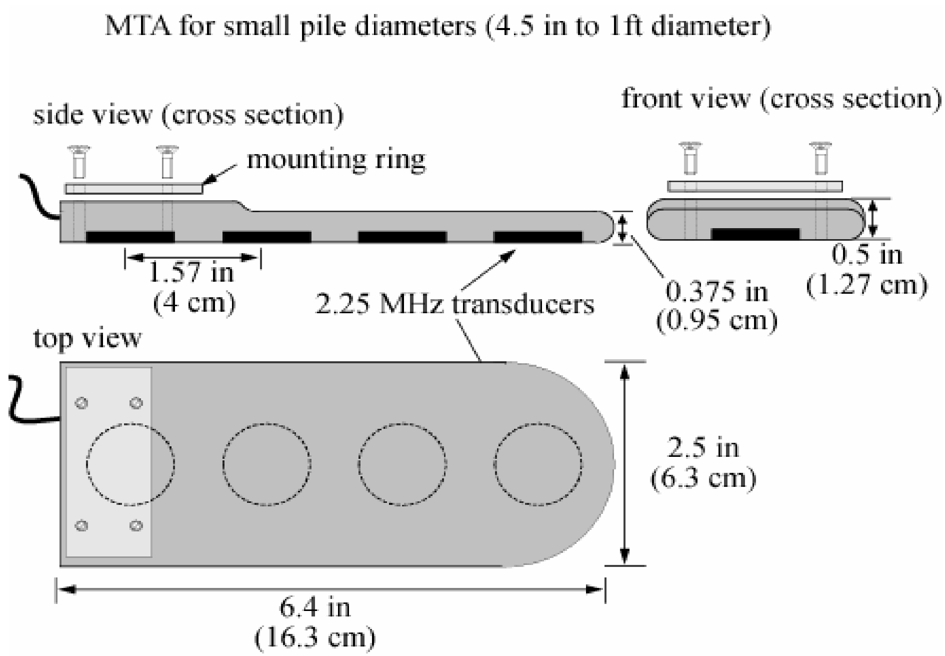

Figure B- 1. Detailed schematic of the acoustic transponder arrays used for the small structures.

structure and at angles of 83° from the front as shown in Figure B-3. Aluminum bands were used to attach the arrays to the cylinders. Their distance from the bed varied depending on the water (and scour hole) depth, but they were always located

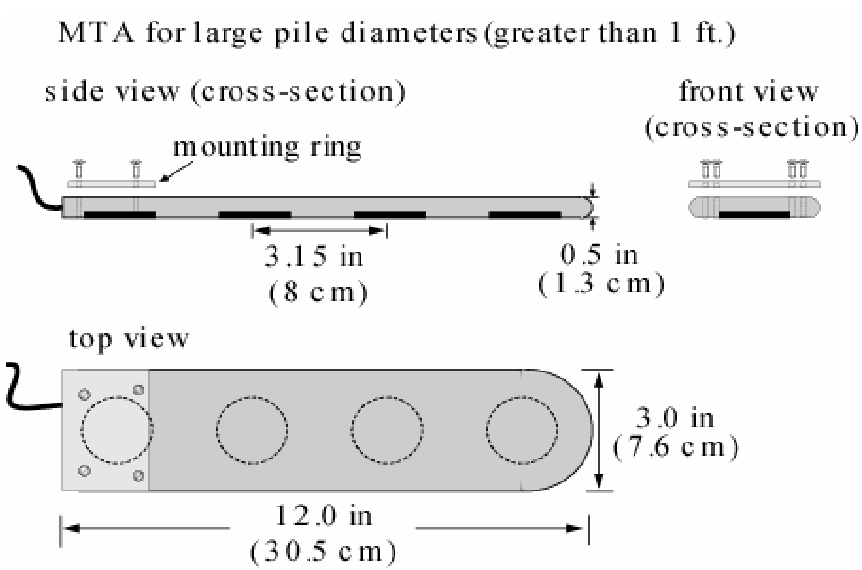

Figure B- 2. Detailed schematic of the acoustic transponder arrays used for the large structure.

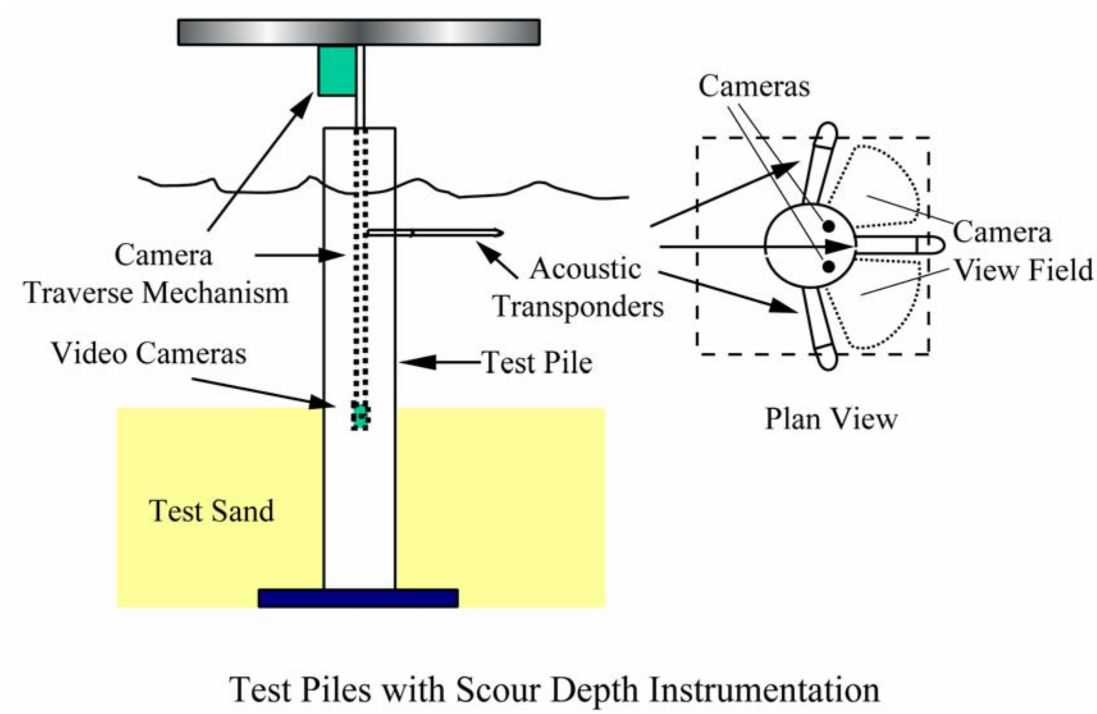

Figure B- 3. Schematic of the local scour depth measuring devices.

approximately 10 cm (4 in) below the water surface so as not to interfere with the scour processes. The MTAs were built specifically for this application by Seatek®. For a more detailed description of the system, see Jette and Hanes (1997).

The crystal spacing for the small and large cylinder arrays is 4 cm (1.6 in) and 8 cm (3.1 in), respectively. The crystals are 2.5 cm (1 in) in diameter and the acoustic beam has a spread angle of 1.5 degrees. The footprint, diameter of the beam at the bed, for a transducer located 0.915 m (3 ft) from the bed is 5 cm (2 in). The MTA's operate at a frequency of 2.25 MHz. An aluminum band was used to attach the arrays to the cylinder.

Video Measurements

Video cameras were used to monitor the location of the water-sediment interface at the cylinder. Two cameras were mounted to a transversing mechanism that was located inside the cylinders as shown in the schematic drawing in Figure B-3 and the photographs in Figures B-4 through B-6. The transverse speed, which was set manually, had a range from 1 mm/hr (0.04 in/hr) to 90 m/hr (295 in/hr). Length scales attached to the inside of the cylinders allowed accurate measurements of the bed elevation at the cylinders to be made from the video images. The video signal from the cameras was sent to a VHS VCR where it was recorded. A control system was used to set the duration of the recordings and the intervals between recordings. A switching circuit switched between the two cameras. An example recording sequence is: record from camera Number 1 for 15 seconds, switch to camera Number 2 and record for 15 seconds, shut

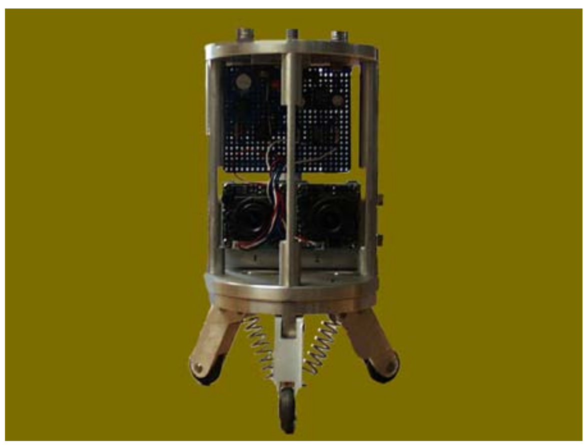

Figure B- 4. The internal cameras for the 0.114 m (4.5 in) diameter cylinder.

Figure B- 5. The internal cameras for the 0.305 m (1 ft) diameter cylinder.

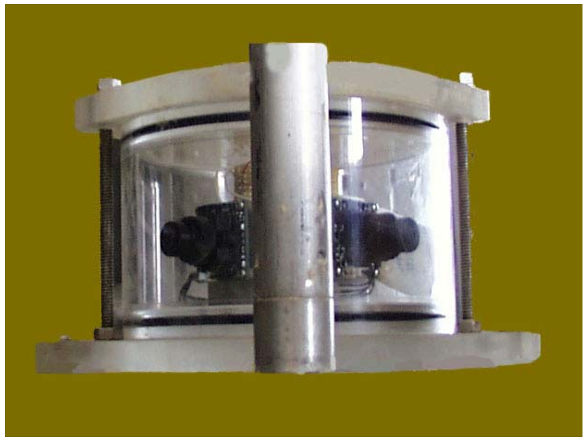

Figure B- 6. The sealed internal cameras for the 0.905 m (3 ft) diameter cylinder.

down for 10 minutes then start-up and repeat the sequence. Down facing floodlights near the cylinder were also turned on and off in phase with the recordings with the controller. The large 0.915 m (3 ft) diameter cylinder was flooded with water during the experiments. The cameras for this cylinder thus had to be mounted in a waterproof housing as shown in Figure B-6. The 0.114 m (4.5 in) and 0.305 m (1 ft) diameter cylinders were sealed and therefore water-tight. Additional video camera photographs are shown in Figure B-7.

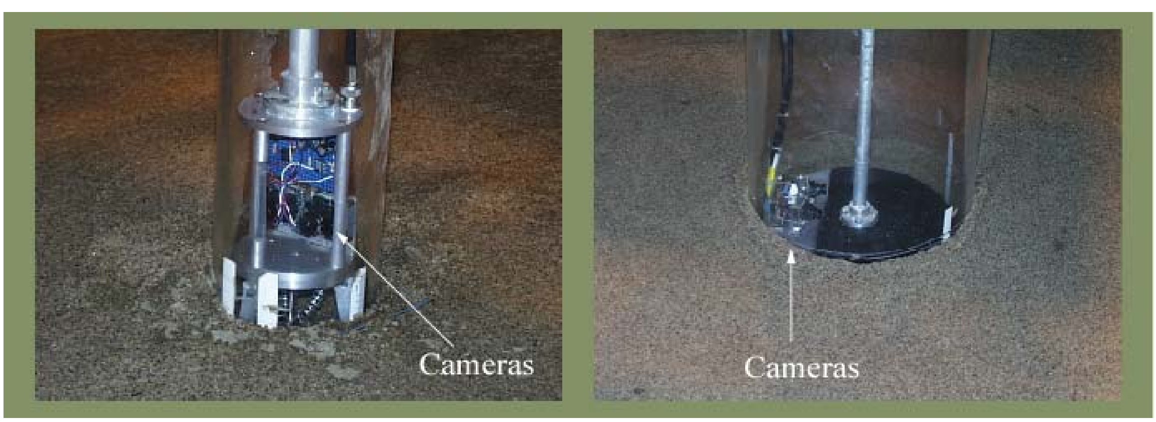

Figure B- 7. Photographs of the forward-looking internal cameras positioned inside the 0.114 m (4.5 in) and 0.305 m (1 ft) diameter watertight cylinders.

Measurement Setup

Flow charts of the measurement systems are shown in Figure B-8. Two personal computers with 486 processors were used for data acquisition. One was used for velocity, water elevation and temperature data and one for the acoustic transducer data. The first computer was programmed to take one-minute samples of velocity, water elevation and temperature every 30 minutes throughout the experiment. The data were written to a file on the hard drive. The second personal computer was connected to the acoustic transducers through a control box (SeaTek Control Box). The purpose of the control box was to convert the signals from all 12 crystals to distances from the transducers to the bed. The communication between the personal computer and the commercial acoustic control box was done with the communication software, Crosstalk®. The data was viewed on a computer screen and stored on a hard drive. Data were sampled for ten seconds every ten minutes.

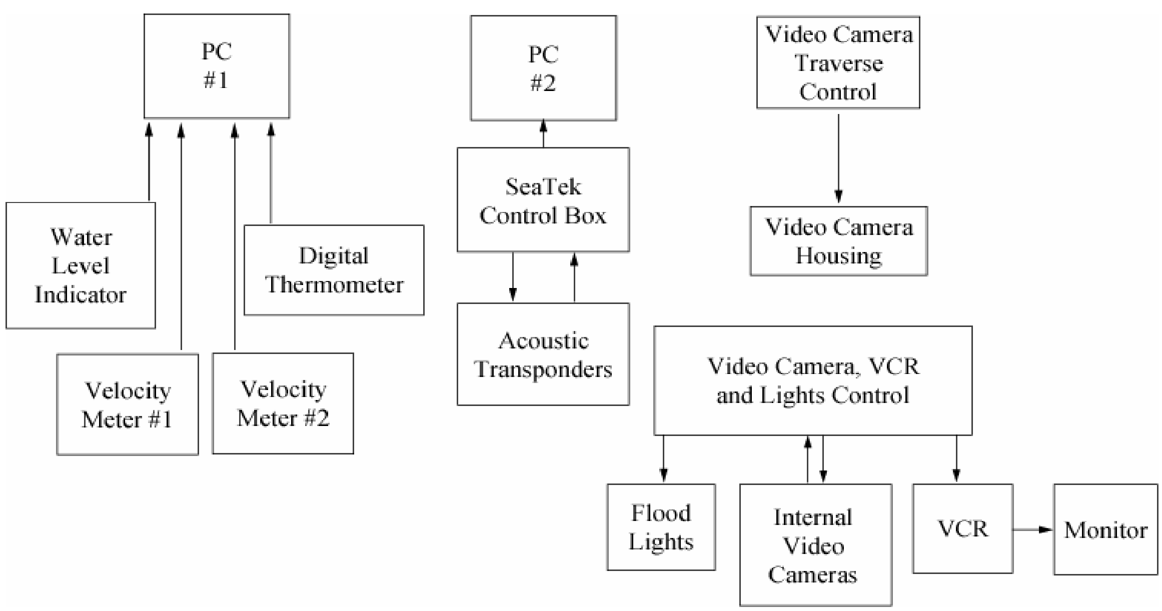

Figure B- 8. Diagram of the measuring system used during the experiments.

APPENDIX C
EXPERIMENTAL DATA

Experiment 1
Scour Summary Form

Circular Pile diameter, D: **0.114 m**

Sediment:

Type:	**Quartz**	Start Date:	**08/22/1998**	Start Time:	**5:23 PM**
D_{50}(mm):	**0.22**	Stop Date:	**08/26/1998**	Stop Time:	**7:59 PM**
σ:	1.51				
ρ_s (Kg/m^3):	**2650**	Duration:	**87 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.28**	**0.30**
Maximum(m/s):	**0.35**	**0.35**
Minimum(m/s):	**0.21**	**0.27**

Channel average velocity from weir (m/s): **0.28**

Critical (sediment) velocity, V_c (m/s): **0.32**

Bed Relative Roughness, RR: **5**

Water depth, y_0 :
- Average water depth(m): **1.19**
- Minimum(m): **1.16**
- Maximum(m): **1.20**

Water Temperature:
- Average (degrees C): **23.6**
- Maximum (degrees C): **24.1**
- Minimum (degrees C): **23.2**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.104**
- Maximum depth from internal video cameras (m): **0.115**
- Maximum depth from point gauge (m): **0.133**
- Maximum scour depth (m): **0.133**

Dimensionless Parameters:

y_0/D: **10.4** V/V_c: **0.89** D/D_{50}: **518**

d_s/D: **1.17**

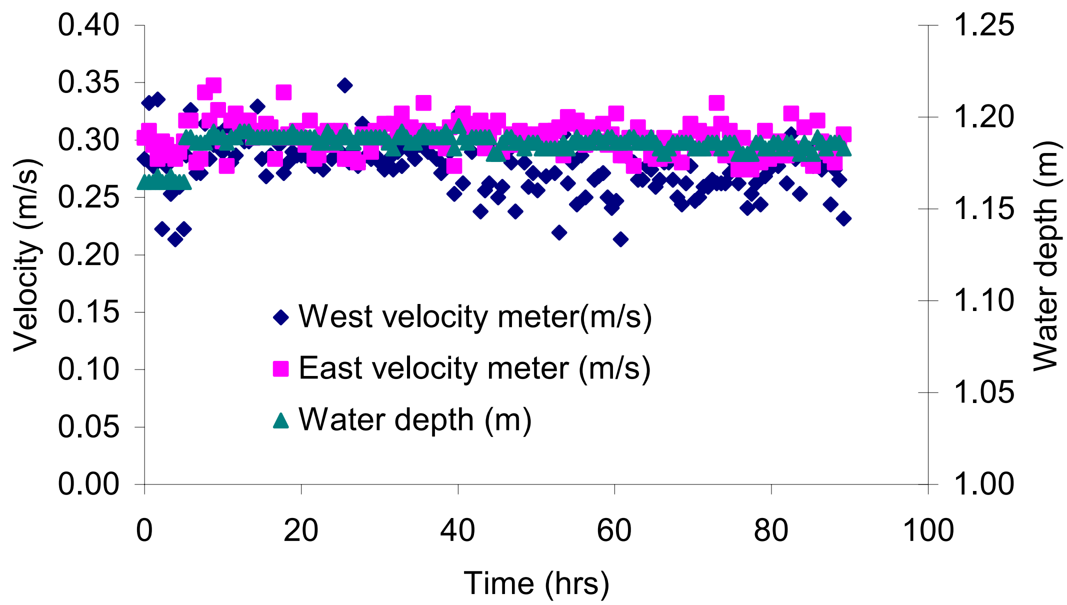

Figure C- 1. Measured velocity and water depth for experiment 1.

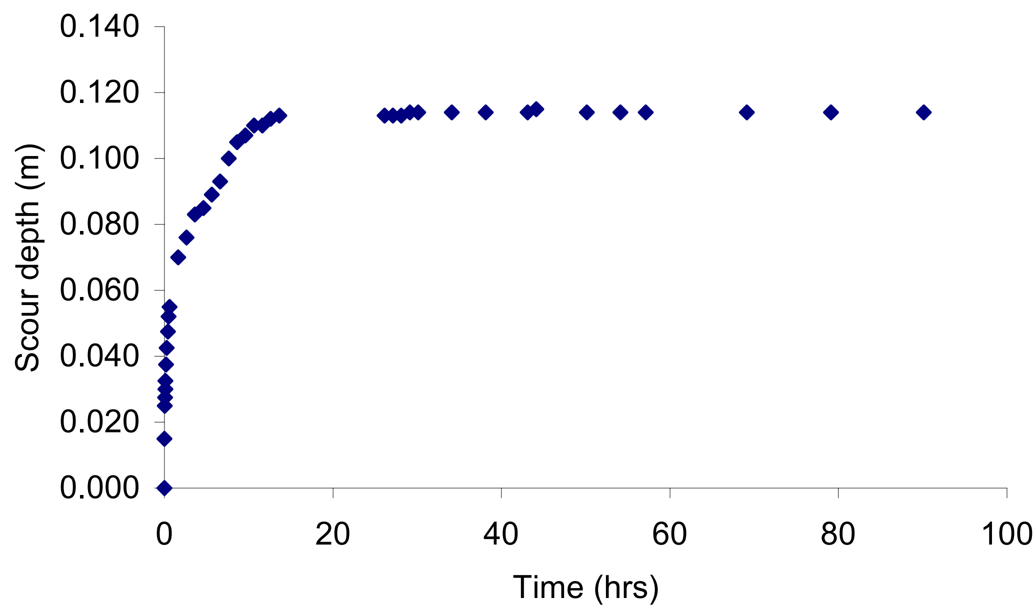

Figure C- 2. Measured local scour data from the internal video camera for experiment 1.

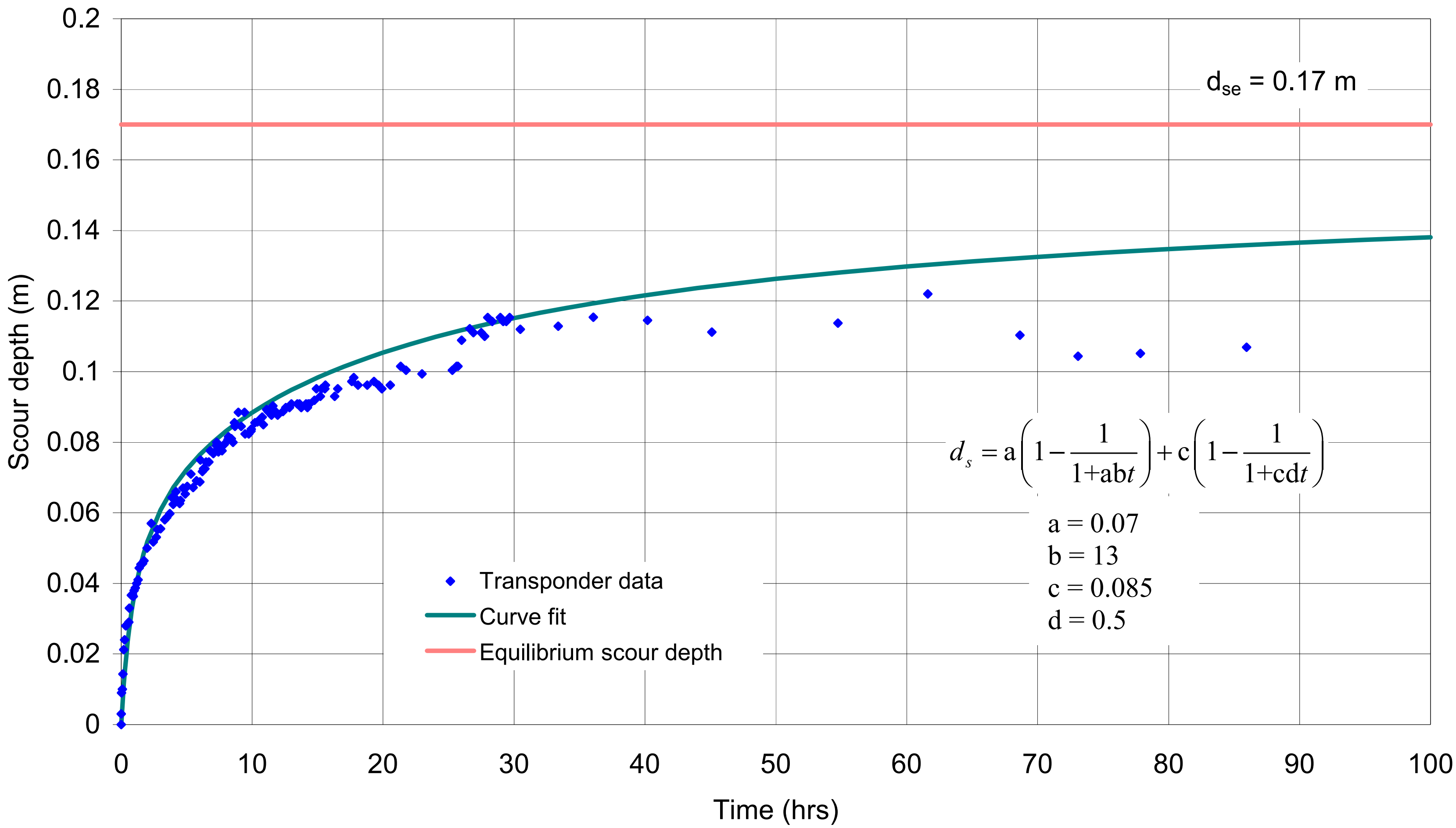

Figure C- 3. Curve fit to the local scour data measured with the acoustic transponder data for experiment 1.

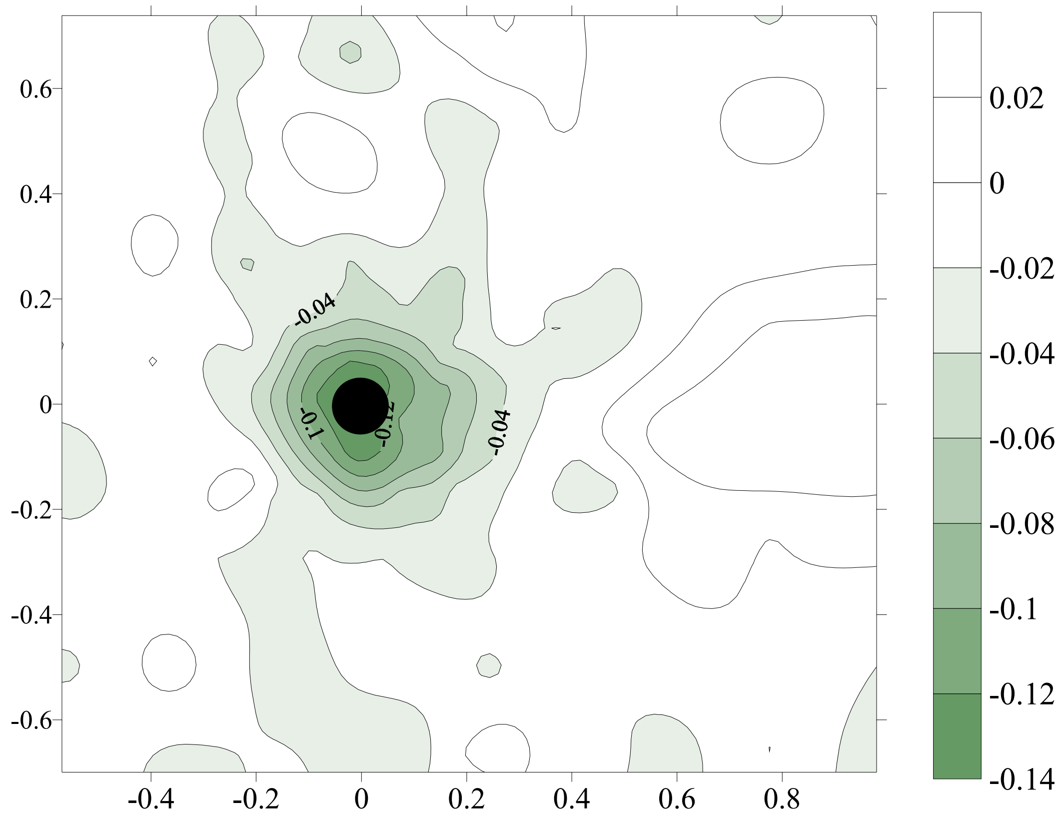

Figure C- 4. Bed elevation contours at completion of experiment 1 referenced to the original bed. All dimensions are in meters.

Table C-1. The rate of scour depth from the internal video camera for experiment 1.

Time (hrs)	Depth (m)
0.00	0.000
0.02	0.015
0.05	0.025
0.08	0.028
0.10	0.030
0.12	0.033
0.20	0.038
0.28	0.043
0.40	0.048
0.50	0.052
0.62	0.055
1.62	0.070
2.62	0.076
3.62	0.083
4.62	0.085
5.62	0.089
6.62	0.093
7.62	0.100
8.62	0.105
9.62	0.107
10.62	0.110
11.62	0.110
12.62	0.112
13.62	0.113
26.12	0.113
27.12	0.113
28.12	0.113
29.12	0.114
30.12	0.114
34.12	0.114
38.12	0.114
43.12	0.114
44.12	0.115
50.12	0.114
54.12	0.114
57.12	0.114
69.12	0.114
79.12	0.114
90.12	0.114

Figure C- 5. Experiment 1 (D = 0.114 m, D_{50} = 0.22 mm) before test.

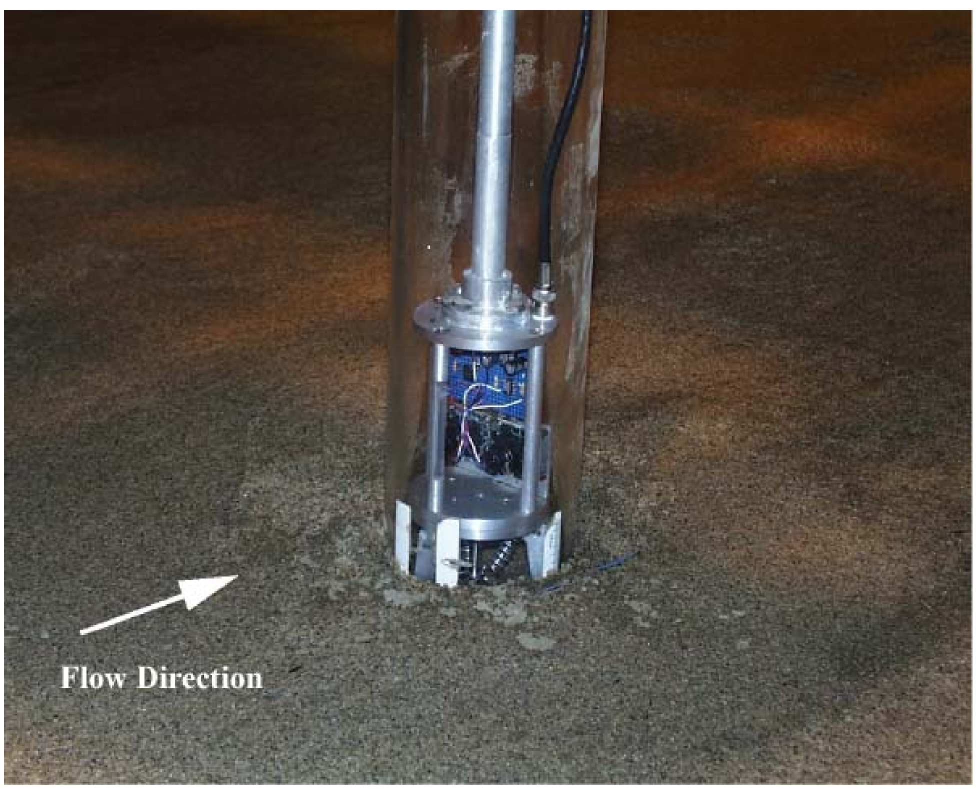

Figure C- 6. Experiment 1 (D = 0.114 m, D_{50} = 0.22 mm) before test.

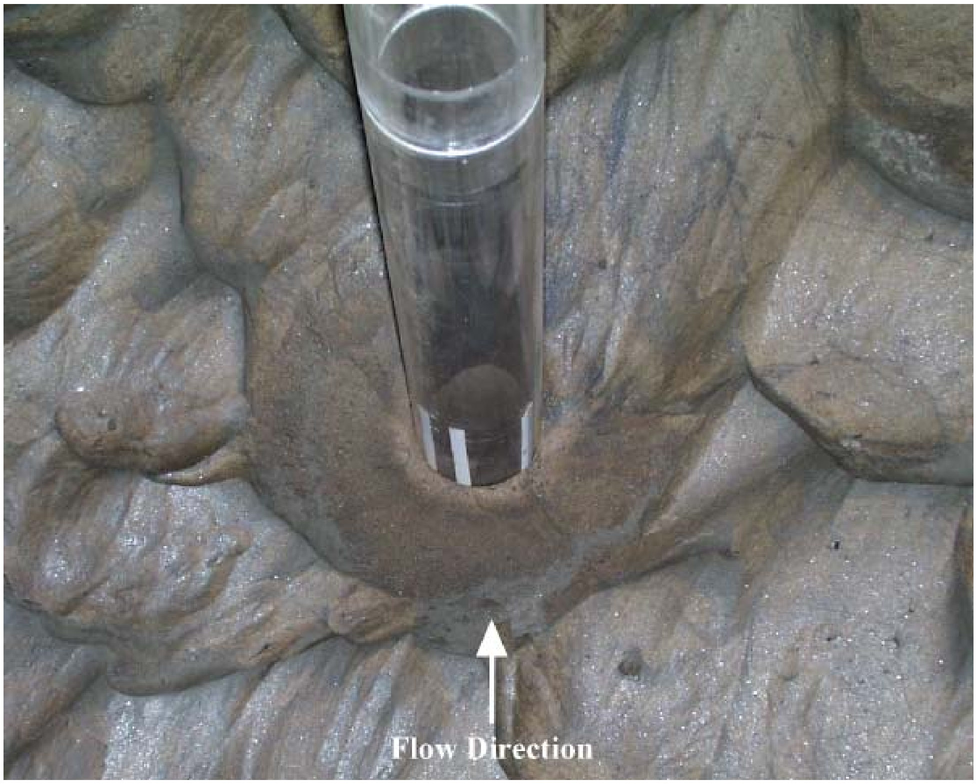

Figure C- 7. Experiment 1 (D = 0.114 m, D_{50} = 0.22 mm) after test.

Experiment 2
Scour Summary Form

Circular Pile diameter, D: **0.305 m**

Sediment:

Type:	**Quartz**	Start Date:	**08/28/1998**	Start Time:	**7:55 PM**
D_{50}(mm):	**0.22**	Stop Date:	**09/04/1998**	Stop Time:	**3:20 PM**
σ:	1.51				
ρ_s (Kg/m^3):	**2650**	Duration:	**163 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.29**	**0.32**
Maximum(m/s):	**0.34**	**0.35**
Minimum(m/s):	**0.25**	**0.25**

Channel average velocity from weir (m/s): **0.29**

Critical (sediment) velocity, V_c (m/s): **0.32**

Bed Relative Roughness, RR: **5**

Water depth, y_0 :
- Average water depth(m): **1.20**
- Minimum(m): **1.19**
- Maximum(m): **1.21**

Water Temperature:
- Average (degrees C): **23.9**
- Maximum (degrees C): **24.5**
- Minimum (degrees C): **23.0**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.213**
- Maximum depth from internal video cameras (m): **0.255**
- Maximum depth from point gauge (m): **0.257**
- Maximum scour depth (m): **0.257**

Dimensionless Parameters:

y_0/D: **3.9** V/V_c: **0.96** D/D_{50}: **1386**

d_s/D: **0.84**

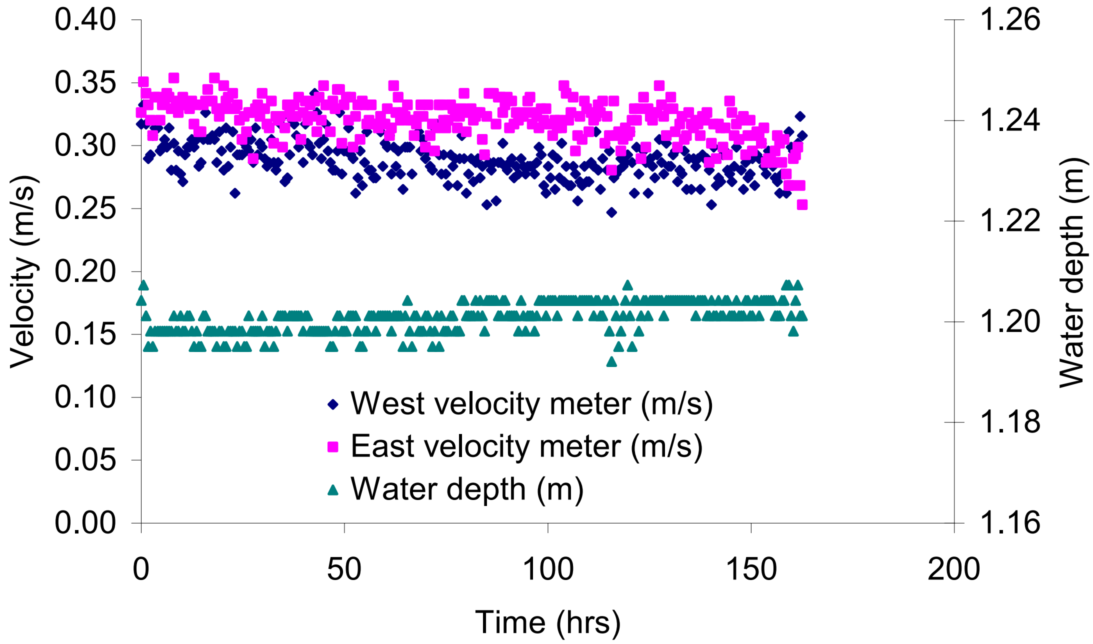

Figure C- 8. Measured velocity and water depth for experiment 2.

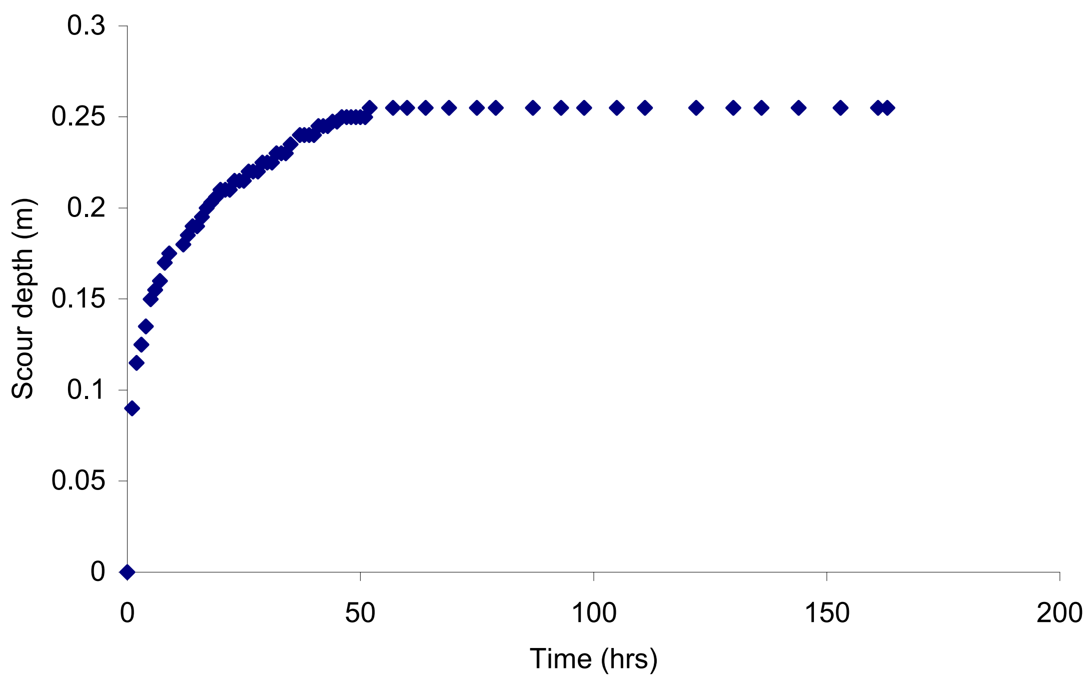

Figure C- 9. Measured local scour data from the internal video camera for experiment 2.

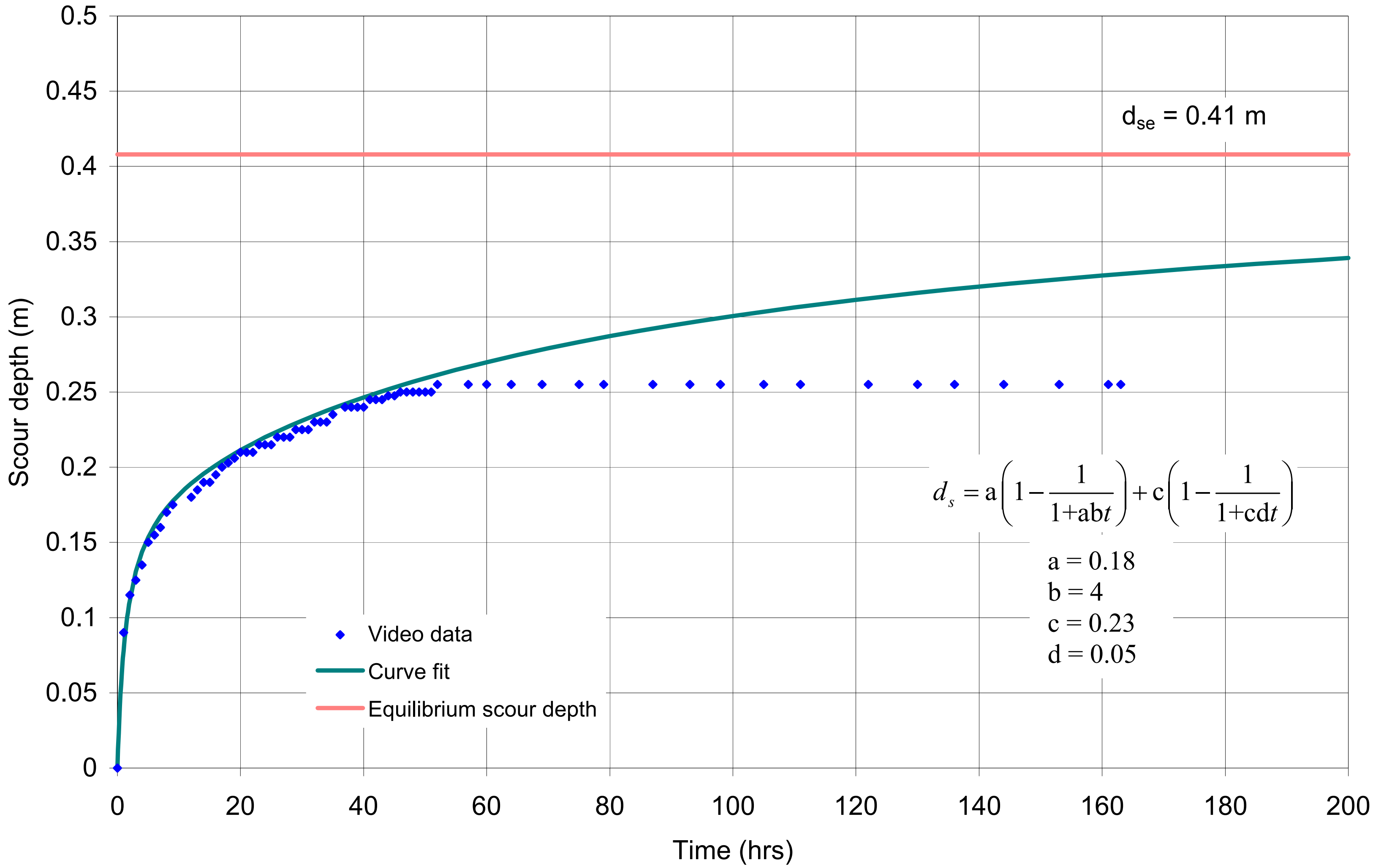

Figure C- 10. Curve fit to the local scour data measured with the internal video camera for experiment 2.

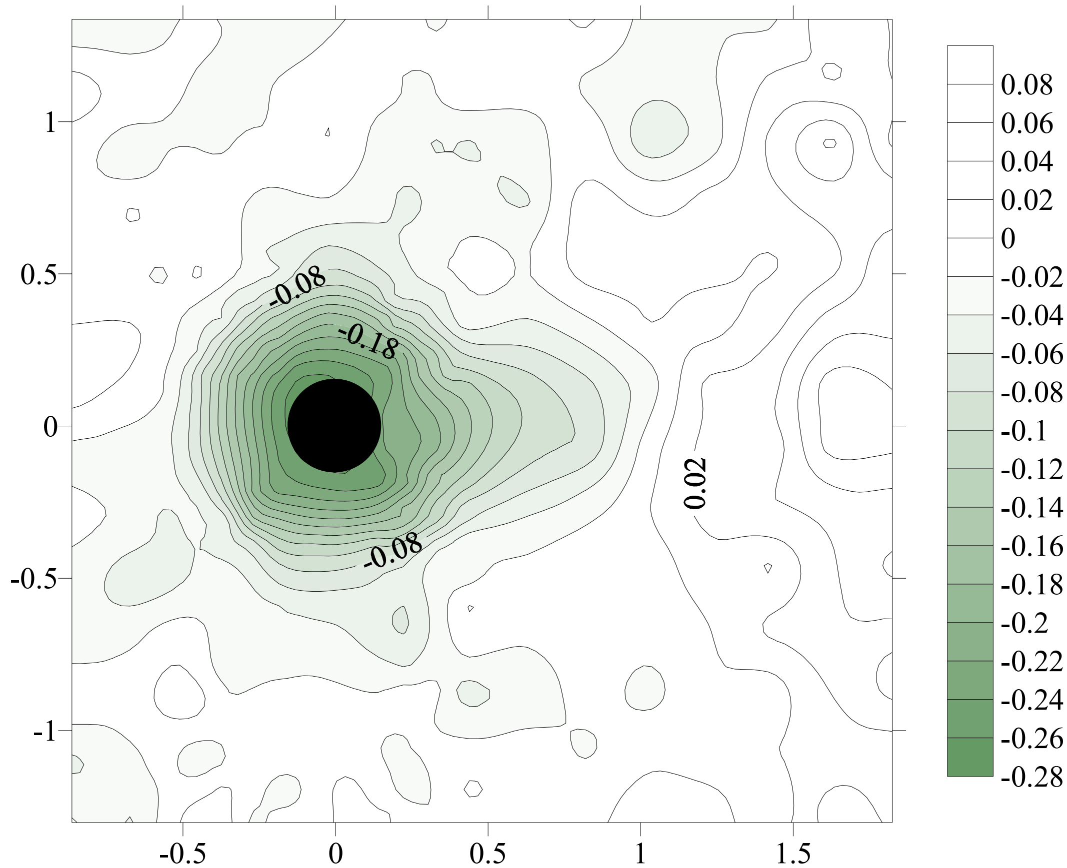

Figure C- 11. Bed elevation contours at completion of experiment 2 referenced to the original bed. All dimensions are in meters.

Table C- 2. The rate of scour depth from the internal video camera for experiment 2.

Time (hrs)	Depth (m)	Time (hrs)	Depth (m)
0	0	43	0.245
1	0.09	44	0.2475
2	0.115	45	0.2475
3	0.125	46	0.25
4	0.135	47	0.25
5	0.15	48	0.25
6	0.155	49	0.25
7	0.16	50	0.25
8	0.17	51	0.25
9	0.175	52	0.255
12	0.18	57	0.255
13	0.185	60	0.255
14	0.19	64	0.255
15	0.19	69	0.255
16	0.195	75	0.255
17	0.2	79	0.255
18	0.203	87	0.255
19	0.206	93	0.255
20	0.21	98	0.255
21	0.21	105	0.255
22	0.21	111	0.255
23	0.215	122	0.255
24	0.215	130	0.255
25	0.215	136	0.255
26	0.22	144	0.255
27	0.22	153	0.255
28	0.22	161	0.255
29	0.225	163	0.255
30	0.225		
31	0.225		
32	0.23		
33	0.23		
34	0.23		
35	0.235		
37	0.24		
38	0.24		
39	0.24		
40	0.24		
41	0.245		
42	0.245		

Figure C- 12. Experiment 2 (D = 0.305 m, D_{50} = 0.22 mm) before test.

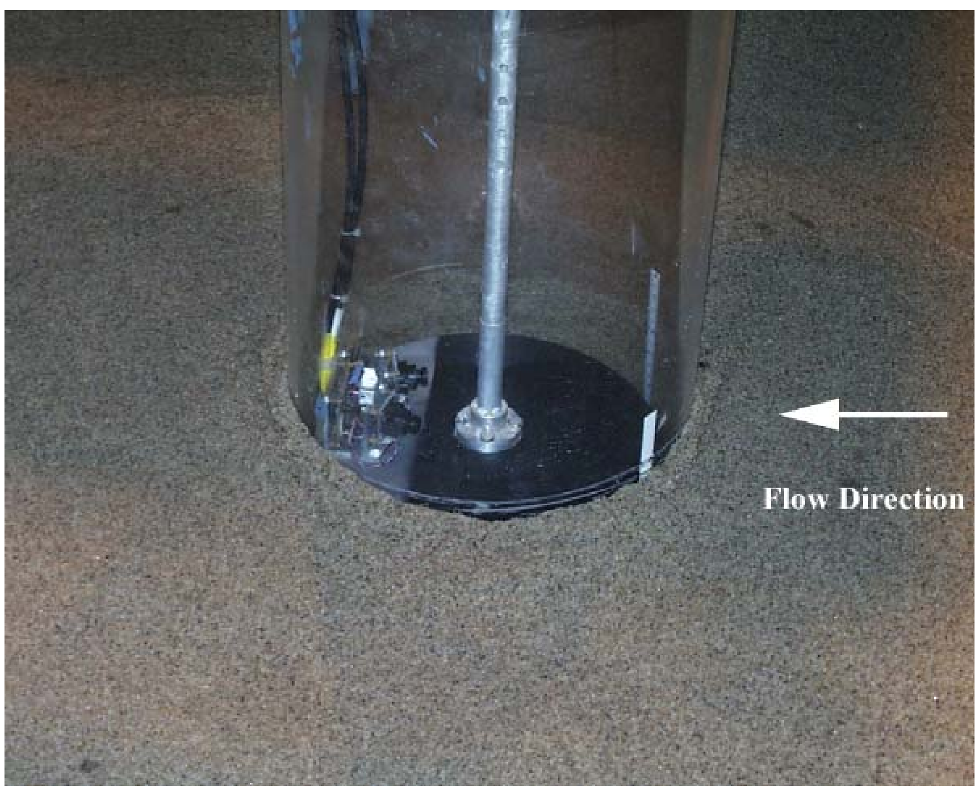

Figure C- 13. Experiment 2 (D = 0.305 m, D_{50} = 0.22 mm) before test.

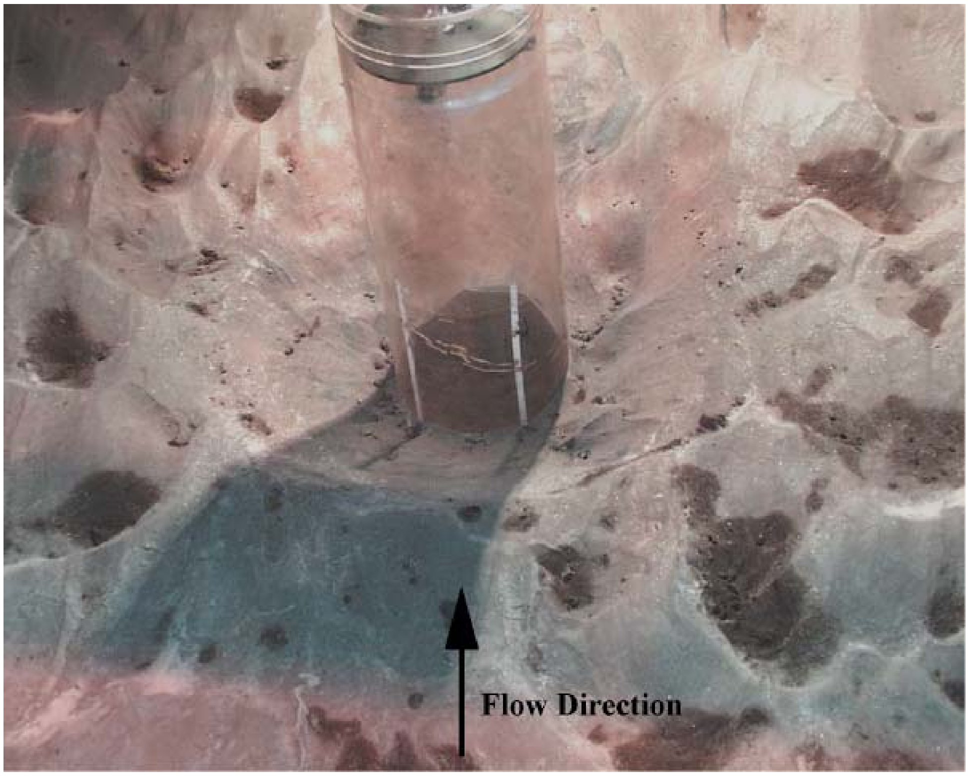

Figure C- 14. Experiment 2 (D = 0.305 m, D_{50} = 0.22 mm) after test.

Figure C- 15. Experiment 2 (D = 0.305 m, D_{50} = 0.22 mm) after test.

Figure C- 16. Experiment 2 (D = 0.305 m, D_{50} = 0.22 mm) after test.

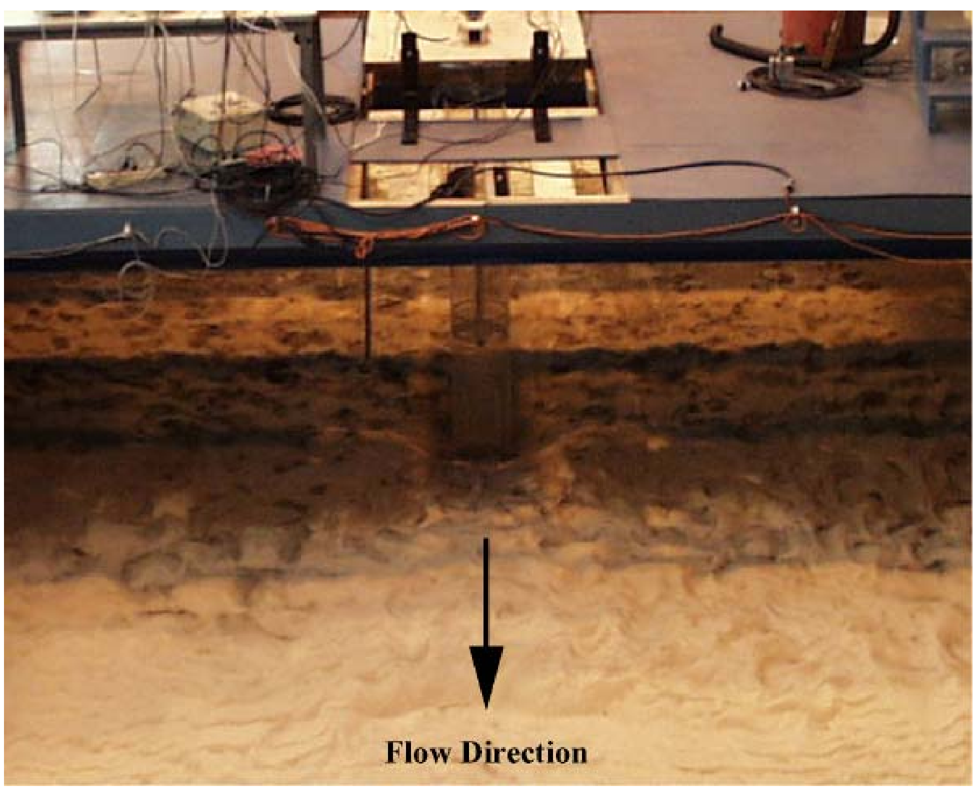

Figure C- 17. Experiment 2 (D = 0.305 m, D_{50} = 0.22 mm) after test.

Experiment 3
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**12/02/1998**	Start Time:	**1:47 PM**
D_{50}(mm):	**0.80**	Stop Date:	**12/17/1998**	Stop Time:	**3:37 PM**
σ:	1.29				
ρ_s (Kg/m^3):	**2650**	Duration:	**362 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.39**	**0.41**
Maximum(m/s):	**0.43**	**0.46**
Minimum(m/s):	**0.27**	**0.25**

Channel average velocity from weir (m/s): **0.43**

Critical (sediment) velocity, V_c (m/s): **0.47**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **1.27**
- Minimum(m): **1.23**
- Maximum(m): **1.28**

Water Temperature:
- Average (degrees C): **8.5**
- Maximum (degrees C): **9.6**
- Minimum (degrees C): **7.1**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **1.063**
- Maximum depth from internal video cameras (m): **1.016**
- Maximum depth from point gauge (m): **1.112**
- Maximum scour depth (m): **1.112**

Dimensionless Parameters:

y_0/D: **1.4** V/V_c: **0.85** D/D_{50}: **1144**

d_s/D: **1.22**

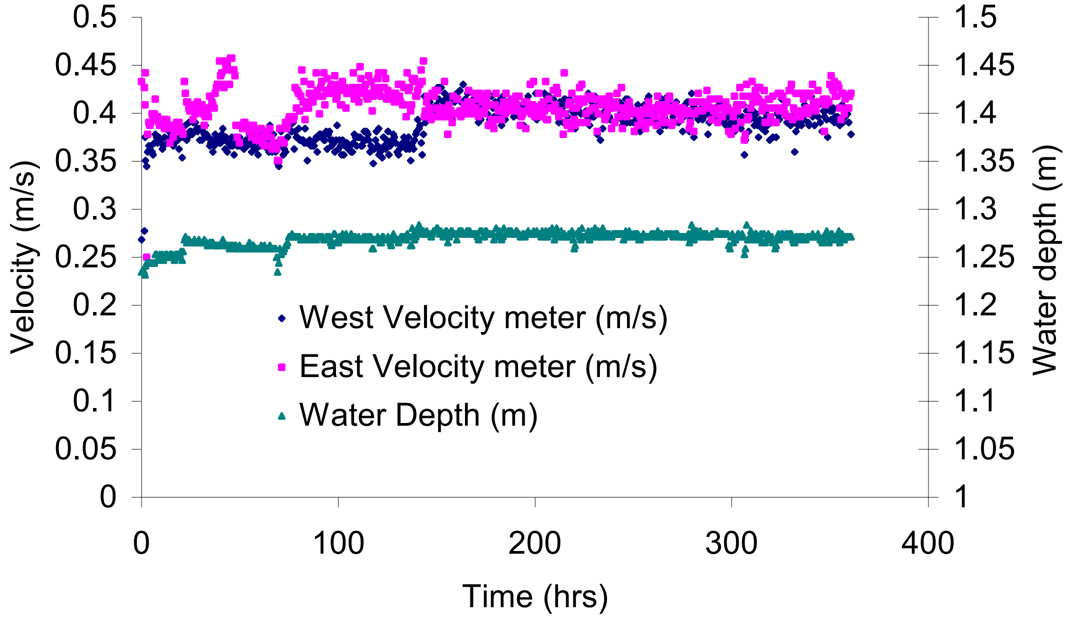

Figure C- 18. Measured velocity and water depth for experiment 3.

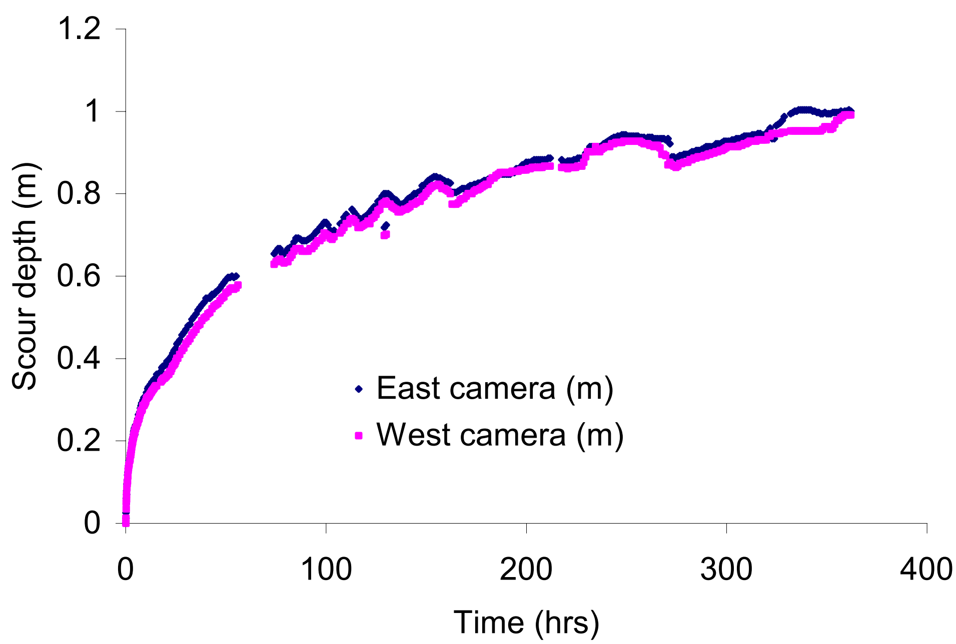

Figure C- 19. Measured local scour data from the internal video camera for experiment 3.

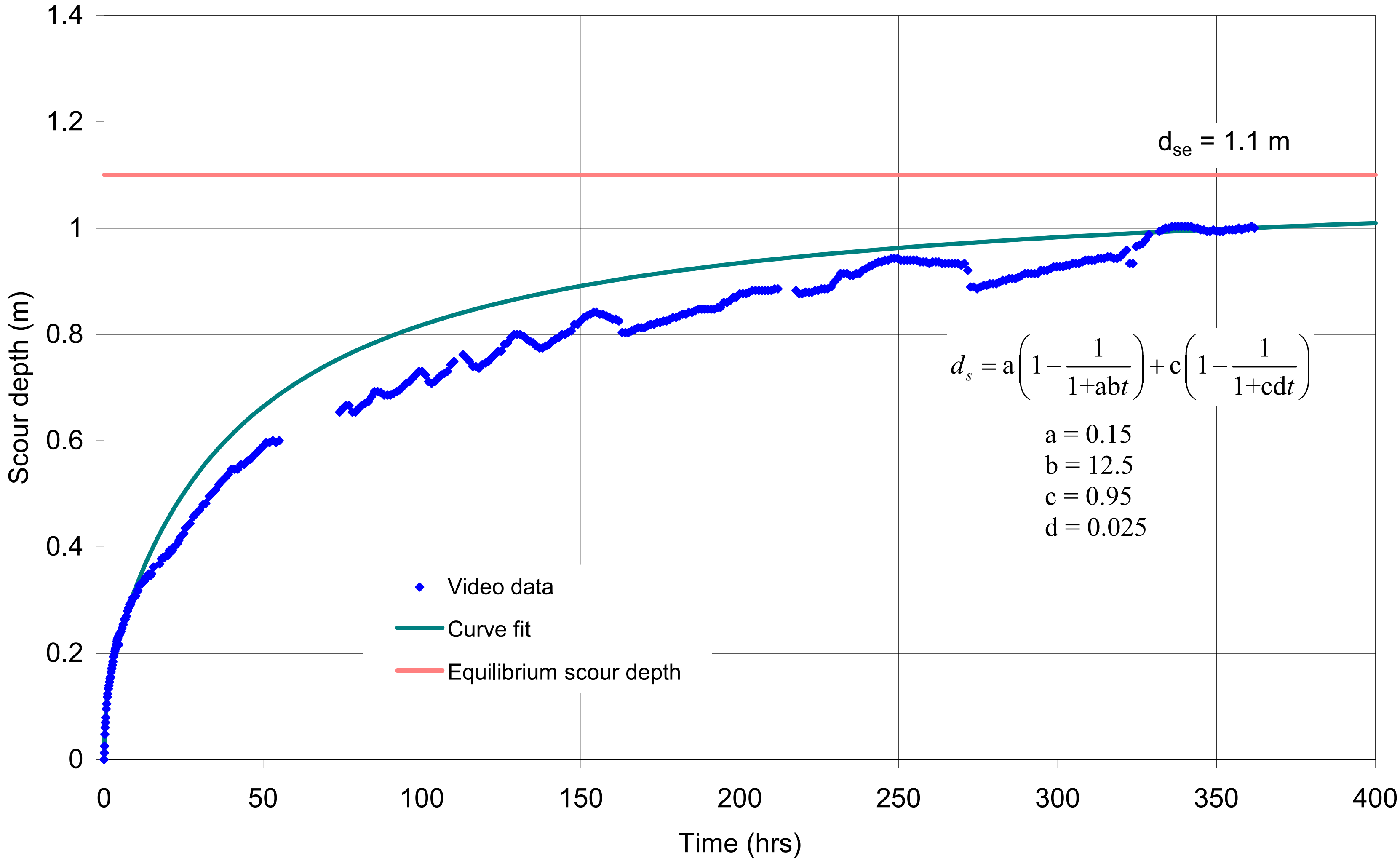

Figure C- 20. Curve fit to the local scour data measured with the acoustic transponder data for experiment 3.

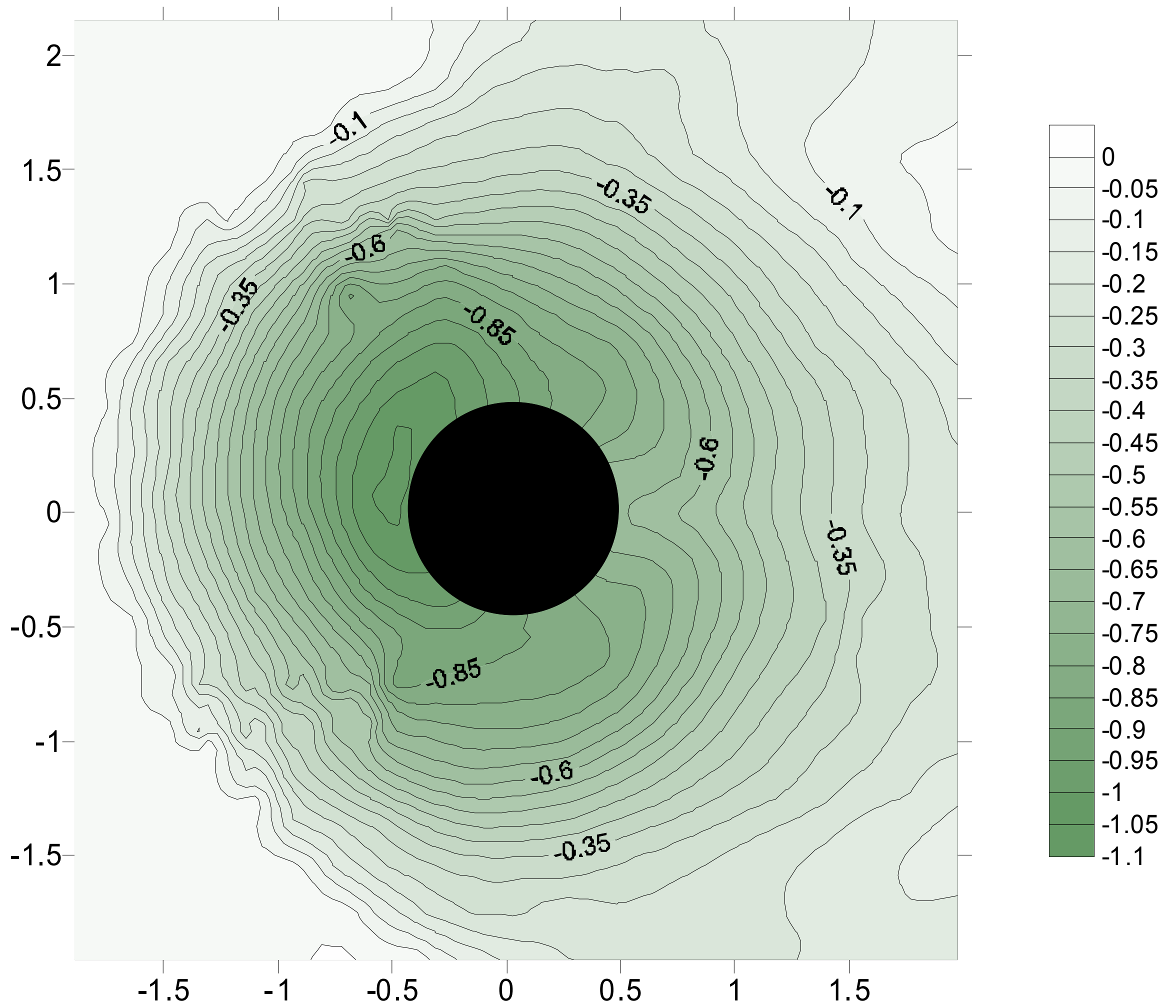

Figure C- 21. Bed elevation contours at completion of experiment 3 referenced to the original bed. All dimensions are in meters.

Table C-3. The rate of scour depth from the internal video cameras for experiment 3.

Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)
0.00	-0.010	0.000	7.03	0.260	0.270	25.07	0.394	0.426
0.08	0.000	0.013	7.37	0.267	0.279	25.57	0.400	0.435
0.17	0.013	0.025	7.70	0.273	0.286	26.08	0.400	0.438
0.25	0.035	0.048	8.03	0.273	0.292	27.08	0.410	0.445
0.33	0.051	0.060	8.37	0.276	0.292	28.08	0.419	0.457
0.40	0.057	0.070	8.70	0.286	0.299	29.08	0.426	0.464
0.50	0.070	0.079	9.03	0.286	0.305	30.08	0.435	0.470
0.67	0.086	0.095	9.37	0.289	0.305	31.08	0.441	0.480
0.83	0.095	0.105	9.70	0.292	0.308	32.08	0.448	0.483
1.00	0.102	0.118	10.03	0.295	0.308	33.08	0.457	0.495
1.17	0.114	0.124	10.38	0.302	0.318	34.08	0.464	0.502
1.33	0.127	0.133	10.72	0.305	0.318	35.08	0.470	0.508
1.50	0.133	0.140	11.05	0.305	0.327	36.08	0.480	0.518
1.67	0.140	0.146	11.38	0.308	0.330	37.08	0.483	0.524
1.83	0.143	0.152	11.72	0.308	0.330	38.08	0.492	0.530
2.00	0.152	0.156	12.05	0.311	0.333	39.08	0.499	0.537
2.17	0.156	0.165	12.38	0.314	0.337	40.08	0.502	0.546
2.33	0.165	0.171	12.72	0.318	0.337	41.08	0.508	0.546
2.50	0.165	0.171	13.05	0.321	0.343	42.08	0.511	0.546
2.67	0.171	0.178	13.55	0.324	0.343	43.08	0.521	0.556
2.83	0.178	0.184	14.05	0.327	0.349	44.08	0.527	0.556
3.00	0.184	0.194	14.55	0.330	0.346	45.08	0.530	0.562
3.17	0.191	0.197	15.05	0.333	0.349	46.08	0.534	0.565
3.35	0.194	0.203	15.55	0.333	0.362	47.08	0.540	0.572
3.52	0.197	0.206	17.55	0.343	0.368	48.08	0.546	0.578
3.68	0.203	0.210	18.05	0.346	0.378	49.08	0.549	0.584
3.85	0.206	0.216	18.57	0.349	0.381	50.08	0.559	0.591
4.02	0.210	0.222	19.07	0.353	0.381	51.08	0.562	0.597
4.18	0.216	0.225	19.57	0.353	0.384	52.08	0.568	0.597
4.35	0.216	0.229	20.07	0.356	0.384	53.08	0.572	0.600
4.52	0.222	0.232	20.57	0.359	0.394	54.08	0.568	0.597
4.68	0.222	0.216	21.07	0.362	0.394	55.08	0.572	0.600
4.85	0.229	0.235	21.57	0.362	0.394	56.08	0.578	
5.02	0.229	0.238	22.07	0.368	0.400	74.08	0.629	0.654
5.37	0.235	0.241	22.57	0.368	0.403	75.08	0.635	0.661
5.70	0.241	0.248	23.07	0.375	0.407	76.08	0.638	0.667
6.03	0.245	0.254	23.57	0.381	0.413	77.08	0.642	0.667
6.37	0.251	0.264	24.07	0.384	0.419	78.08	0.635	0.654
6.70	0.254	0.264	24.57	0.387	0.422	79.08	0.632	0.654

Table C-3 (continued)

Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)
80.08	0.635	0.661	118.97	0.724	0.743	157.97	0.813	0.835
81.08	0.635	0.667	119.97	0.727	0.746	158.97	0.813	0.832
82.08	0.645	0.670	120.97	0.734	0.749	159.97	0.810	0.829
83.08	0.651	0.673	121.97	0.727	0.756	160.97	0.807	0.829
84.08	0.661	0.683	122.97	0.740	0.762	161.97	0.800	0.826
85.08	0.667	0.692	123.97	0.743	0.769	162.97	0.775	0.803
86.08	0.667	0.692	124.97	0.749	0.769	163.97	0.775	0.803
87.08	0.667	0.690	125.97	0.759	0.781	164.97	0.775	0.803
88.08	0.661	0.686	126.97	0.762	0.784	165.97	0.778	0.807
89.08	0.661	0.686	127.97	0.775	0.794	166.97	0.784	0.810
90.08	0.661	0.686	128.97	0.778	0.800	167.97	0.788	0.813
91.08	0.661	0.689	129.97	0.781	0.800	168.97	0.788	0.813
92.07	0.667	0.692	130.97	0.775	0.800	169.97	0.794	0.813
93.07	0.667	0.696	131.97	0.775	0.797	170.97	0.800	0.816
94.07	0.673	0.702	132.97	0.769	0.791	171.97	0.800	0.819
95.07	0.680	0.708	133.97	0.765	0.788	172.97	0.800	0.819
96.07	0.686	0.711	134.97	0.762	0.784	173.97	0.807	0.823
97.07	0.686	0.718	135.97	0.756	0.778	174.97	0.810	0.823
98.07	0.692	0.724	136.97	0.756	0.775	175.97	0.810	0.826
99.07	0.705	0.730	137.97	0.759	0.775	176.97	0.813	0.826
100.07	0.702	0.730	138.97	0.762	0.778	177.97	0.816	0.829
101.07	0.699	0.724	139.97	0.762	0.781	178.97	0.819	0.832
102.07	0.692	0.711	140.97	0.765	0.788	179.97	0.823	0.832
103.07	0.689	0.708	141.97	0.769	0.791	180.97	0.823	0.835
104.07	0.696	0.711	142.97	0.775	0.794	181.97	0.832	0.838
129.07	0.699	0.718	143.97	0.775	0.800	182.97	0.838	0.838
130.07	0.702	0.724	144.97	0.778	0.800	183.97	0.838	0.842
107.07	0.705	0.727	145.97	0.781	0.803	184.97	0.845	0.842
108.07	0.711	0.730	146.97	0.781	0.807	185.97	0.848	0.845
109.07	0.718	0.743	147.97	0.791	0.819	186.97	0.851	0.848
110.07	0.727	0.749	148.97	0.794	0.819	187.97	0.851	0.848
111.07	0.727		149.97	0.800	0.826	188.97	0.851	0.848
112.07	0.737		150.97	0.807	0.832	189.97	0.851	0.848
112.97	0.740	0.762	151.97	0.813	0.835	190.97	0.851	0.848
113.97	0.737	0.756	152.97	0.816	0.838	191.97	0.851	0.848
114.97	0.730	0.749	153.97	0.819	0.842	192.97	0.854	0.851
115.97	0.718	0.740	154.97	0.819	0.842	193.97	0.854	0.851
116.97	0.718	0.740	155.97	0.823	0.838	194.97	0.854	0.861
117.97	0.721	0.737	156.97	0.819	0.838	195.97	0.854	0.861

Table C-3 (continued)

Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)
196.97	0.857	0.864	240.67	0.915	0.927	279.67	0.877	0.896
197.97	0.857	0.870	241.67	0.915	0.931	280.70	0.877	0.896
198.97	0.857	0.870	242.67	0.921	0.934	281.70	0.883	0.899
199.97	0.857	0.877	243.67	0.921	0.937	282.70	0.883	0.902
200.97	0.861	0.877	244.67	0.924	0.937	283.70	0.886	0.902
201.97	0.861	0.877	245.67	0.924	0.940	284.70	0.886	0.905
202.97	0.864	0.880	246.67	0.924	0.940	285.70	0.889	0.905
203.97	0.864	0.883	247.67	0.924	0.943	286.70	0.889	0.905
204.97	0.864	0.883	248.67	0.927	0.943	287.70	0.889	0.908
205.97	0.864	0.883	249.67	0.927	0.943	288.70	0.892	0.911
206.97	0.864	0.883	250.67	0.927	0.940	289.70	0.892	0.915
207.97	0.864	0.883	251.67	0.927	0.940	290.70	0.896	0.915
208.97	0.867	0.883	252.67	0.927	0.940	291.70	0.896	0.915
209.97	0.867	0.883	253.67	0.927	0.940	292.70	0.899	0.915
210.97	0.867	0.886	254.67	0.927	0.940	293.72	0.899	0.915
211.97	0.867	0.886	255.67	0.927	0.940	294.70	0.902	0.921
217.67	0.864	0.883	256.67	0.927	0.937	295.70	0.902	0.921
218.67	0.864	0.877	257.67	0.924	0.937	296.70	0.905	0.921
219.67	0.864	0.877	258.67	0.921	0.937	297.70	0.905	0.924
220.67	0.861	0.880	259.67	0.921	0.934	298.70	0.908	0.927
221.72	0.864	0.880	260.67	0.921	0.937	299.70	0.911	0.927
222.67	0.864	0.880	261.67	0.918	0.937	300.70	0.915	0.927
223.67	0.864	0.883	262.67	0.918	0.937	301.70	0.915	0.927
224.67	0.864	0.883	263.67	0.915	0.934	302.70	0.915	0.931
225.67	0.867	0.886	264.67	0.918	0.934	303.70	0.915	0.931
226.67	0.867	0.886	265.67	0.918	0.934	304.70	0.915	0.934
227.67	0.867	0.886	266.67	0.911	0.934	305.70	0.915	0.934
228.67	0.877	0.889	267.67	0.896	0.934	306.70	0.918	0.934
229.67	0.889	0.899	268.67	0.896	0.934	307.70	0.918	0.937
230.67	0.902	0.905	269.67	0.892	0.931	308.70	0.921	0.940
231.67	0.902	0.915	270.67	0.870	0.934	309.70	0.921	0.940
232.67	0.902	0.915	271.67	0.877	0.921	310.70	0.924	0.940
233.67	0.902	0.915	272.67	0.870	0.889	311.70	0.927	0.940
234.67	0.915	0.911	273.67	0.867	0.889	312.70	0.927	0.943
235.67	0.908	0.911	274.67	0.864	0.886	313.70	0.927	0.943
236.67	0.902	0.915	275.67	0.867	0.889	314.70	0.927	0.943
237.67	0.908	0.915	276.67	0.873	0.892	315.70	0.931	0.946
238.67	0.911	0.921	277.67	0.873	0.892	316.70	0.931	0.946
239.67	0.915	0.924	278.67	0.877	0.896	317.70	0.931	0.943

Table C-3 (continued)

Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)
318.70	0.931	0.943	359.97	0.991	1.000
319.70	0.931	0.946	360.97	0.991	1.004
320.70	0.940	0.953	361.97	0.991	1.000
321.70	0.940	0.959			
322.70	0.946	0.934			
323.70	0.946	0.934			
324.70	0.946	0.965			
325.70	0.946	0.969			
326.70	0.946	0.972			
327.70	0.950	0.978			
328.70	0.950	0.988			
331.97	0.953	0.994			
332.97	0.953	0.997			
333.97	0.953	1.000			
334.97	0.953	1.000			
335.97	0.953	1.004			
336.97	0.953	1.004			
337.97	0.953	1.004			
338.97	0.953	1.004			
339.97	0.953	1.004			
340.97	0.953	1.004			
341.97	0.953	1.004			
342.97	0.953	1.000			
343.97	0.953	1.000			
344.97	0.953	0.997			
345.97	0.953	0.997			
346.97	0.953	0.994			
347.97	0.956	0.994			
348.97	0.962	0.997			
349.97	0.962	0.994			
350.97	0.962	0.994			
351.97	0.956	0.994			
352.97	0.959	0.997			
353.97	0.969	0.997			
354.97	0.978	0.997			
355.97	0.978	0.997			
356.97	0.985	1.000			
357.97	0.988	0.997			
358.97	0.991	1.000			

Figure C- 22. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) before test.

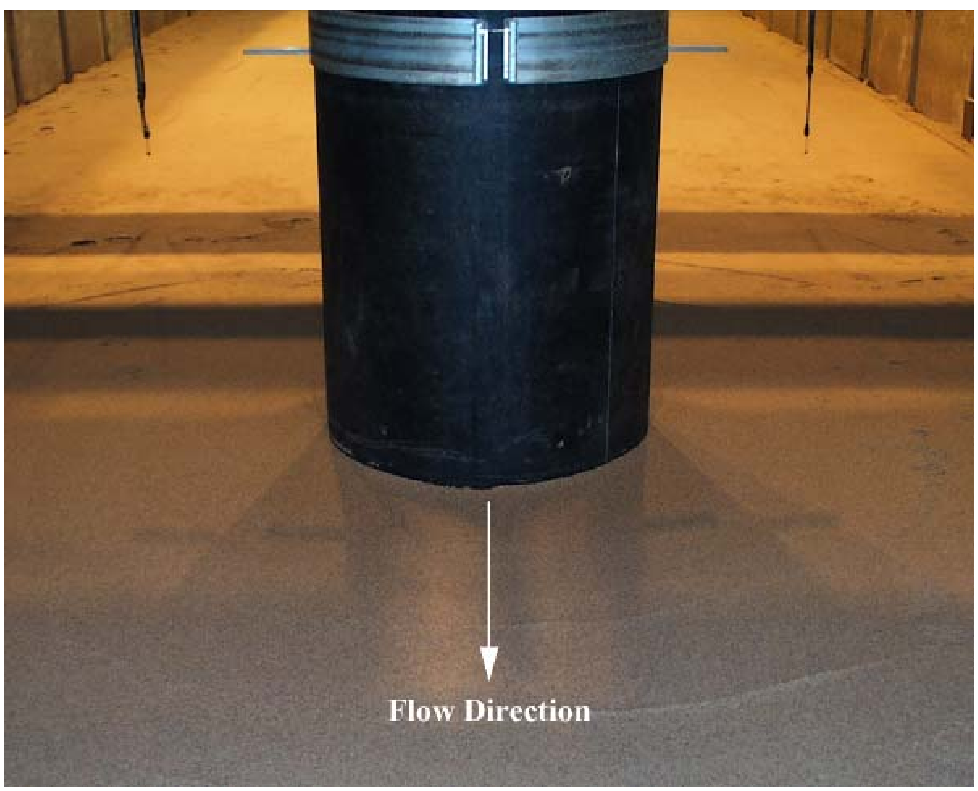

Figure C- 23. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) before test.

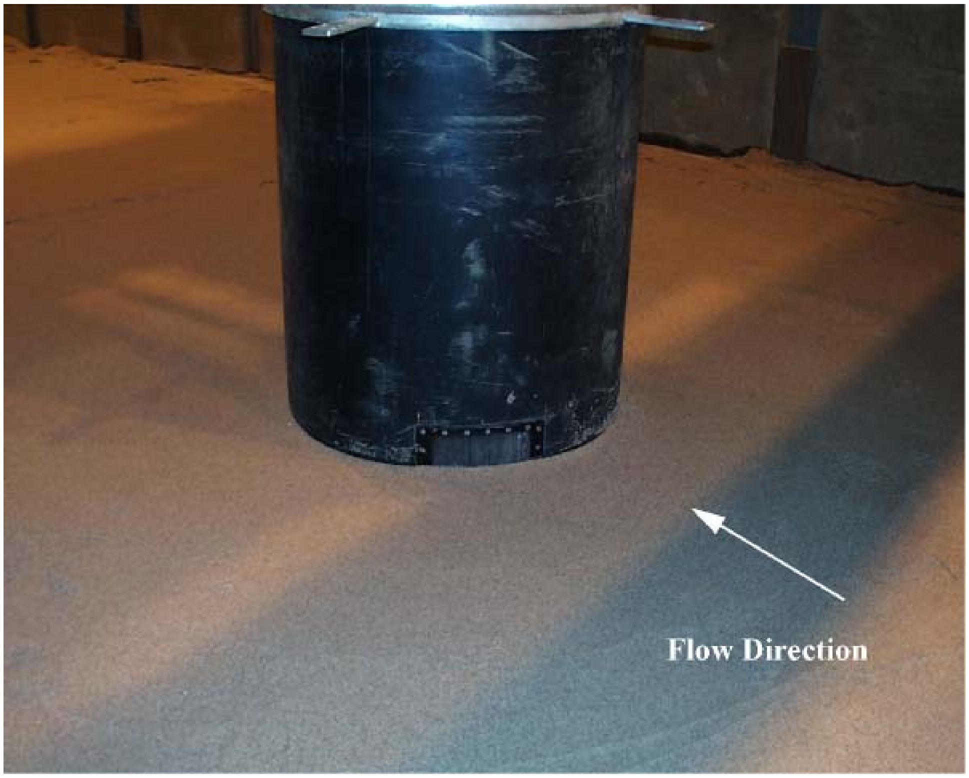

Figure C- 24. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) before test.

Figure C- 25. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) after test.

Figure C- 26. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) after test.

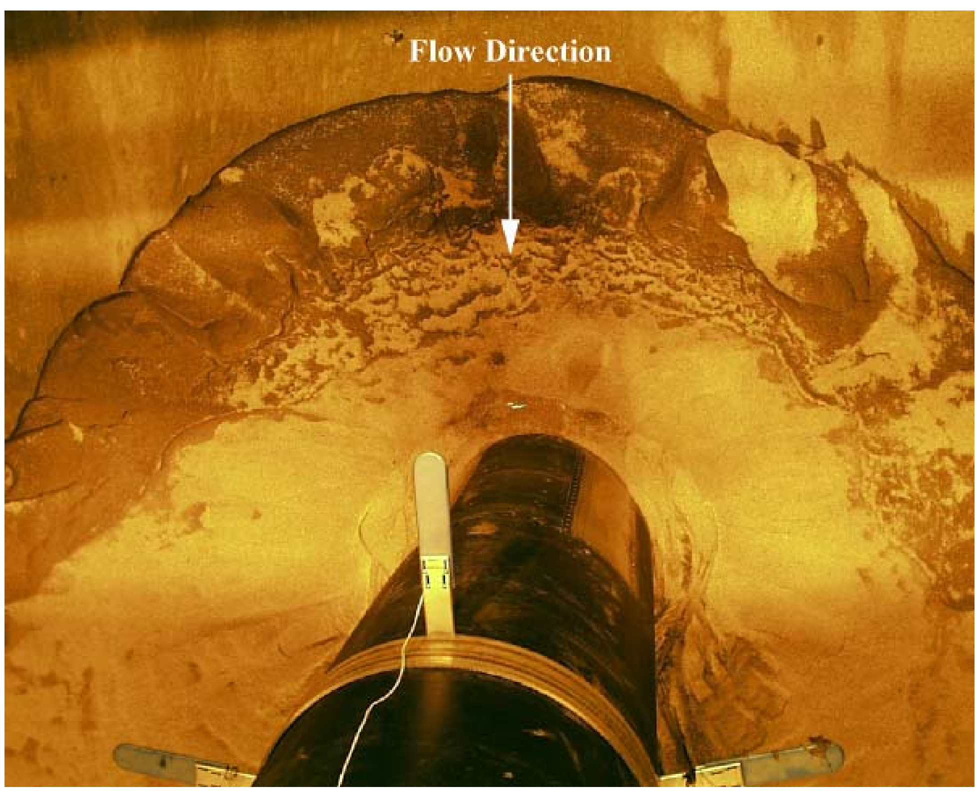

Figure C- 27. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) after test.

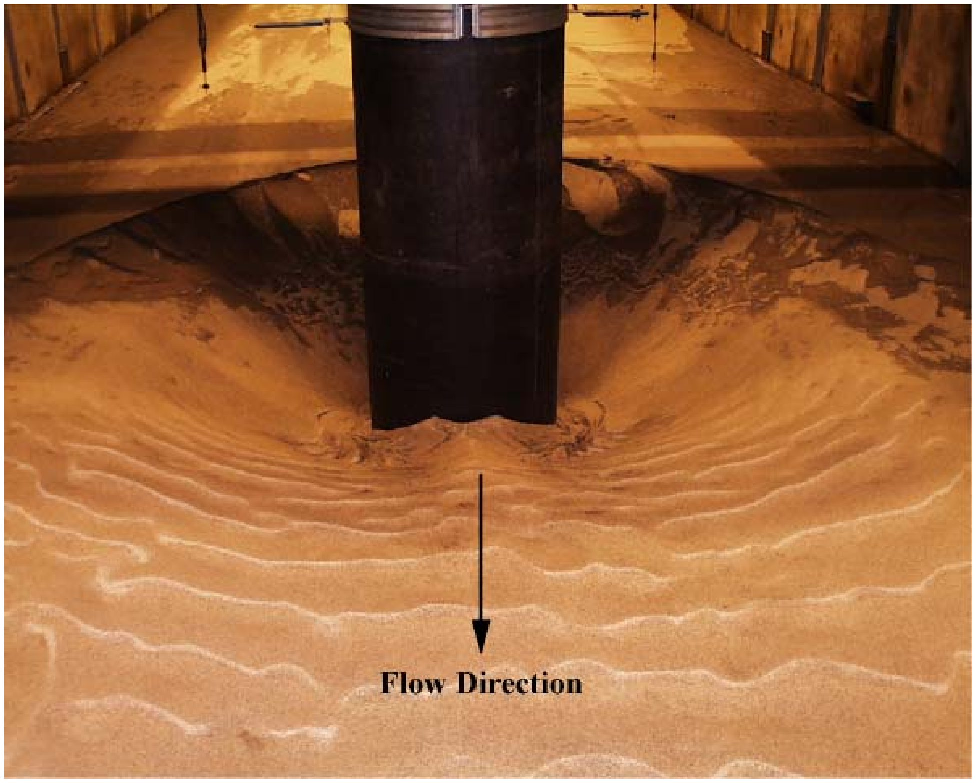

Figure C- 28. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) after test.

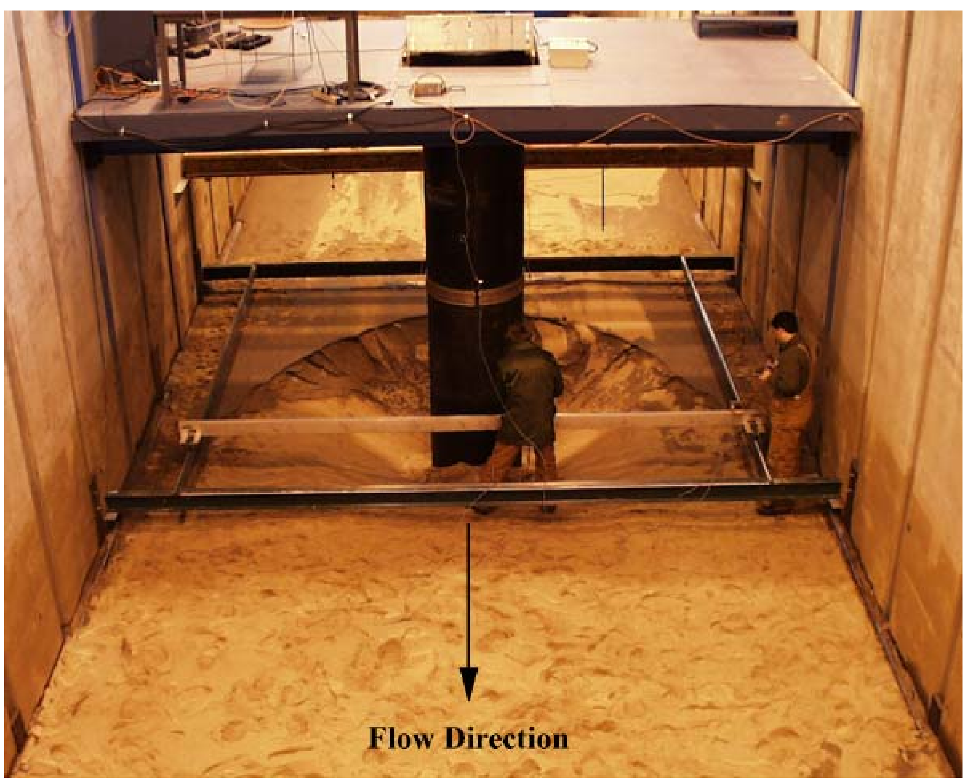

Figure C- 29. Experiment 3 (D = 0.915 m, D_{50} = 0.80 mm) during point gauging.

Experiment 4
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**01/29/1999**	Start Time:	**1:30 PM**
D_{50}(mm):	**0.80**	Stop Date:	**02/04/1999**	Stop Time:	**1:15 PM**
σ:	1.29				
ρ_s (Kg/m^3):	**2650**	Duration:	**143 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.40**	**0.33**
Maximum(m/s):	**0.44**	**0.38**
Minimum(m/s):	**0.36**	**0.21**

Channel average velocity from weir (m/s): **0.38**

Critical (sediment) velocity, V_c (m/s): **0.46**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **0.87**
- Minimum(m): **0.87**
- Maximum(m): **0.85**

Water Temperature:
- Average (degrees C): **0.5**
- Maximum (degrees C): **0.9**
- Minimum (degrees C): **0.2**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.465**
- Maximum depth from internal video cameras (m): **0.622**
- Maximum depth from point gauge (m): **0.638**
- Maximum scour depth (m): **0.638**

Dimensionless Parameters:

y_0/D: **1.0** V/V_c: **0.85** D/D_{50}: **1144**

d_s/D: **0.70**

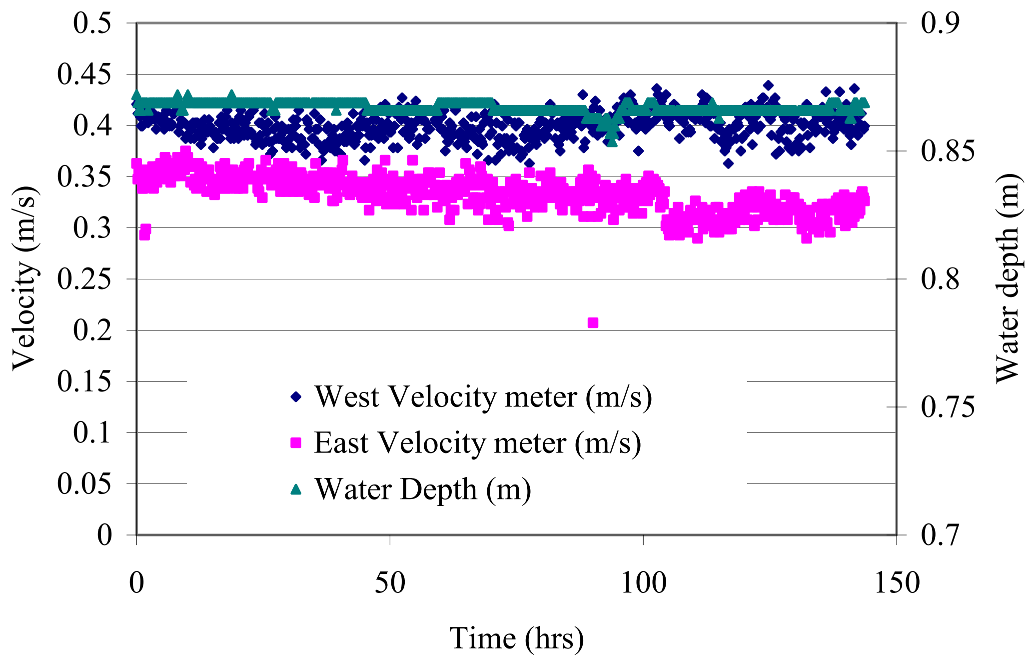

Figure C- 30. Measured velocity and water depth for experiment 4.

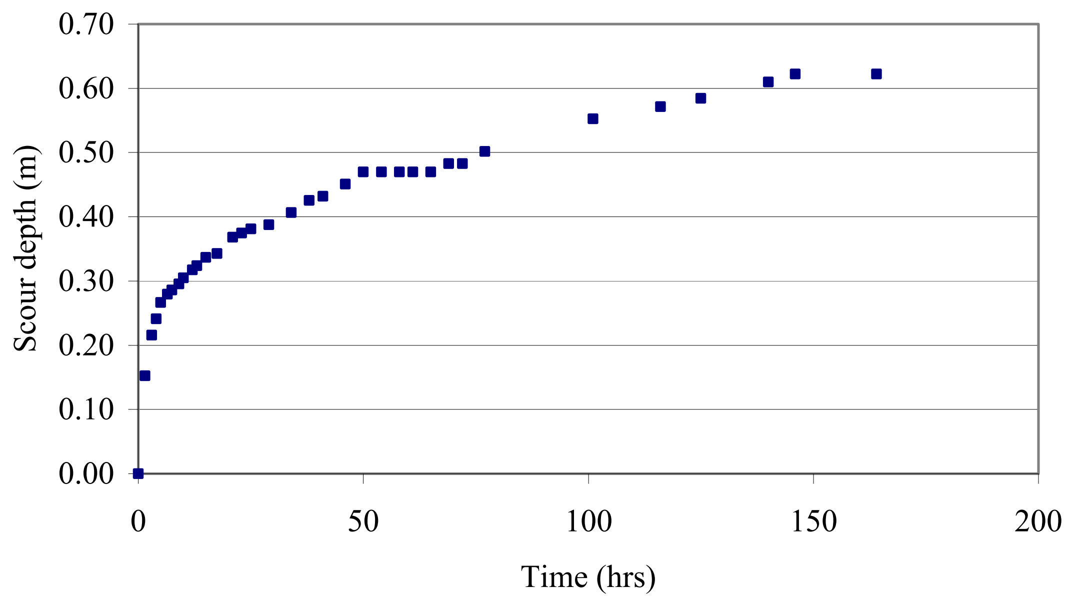

Figure C- 31. Measured local scour data from the internal video camera for experiment 4.

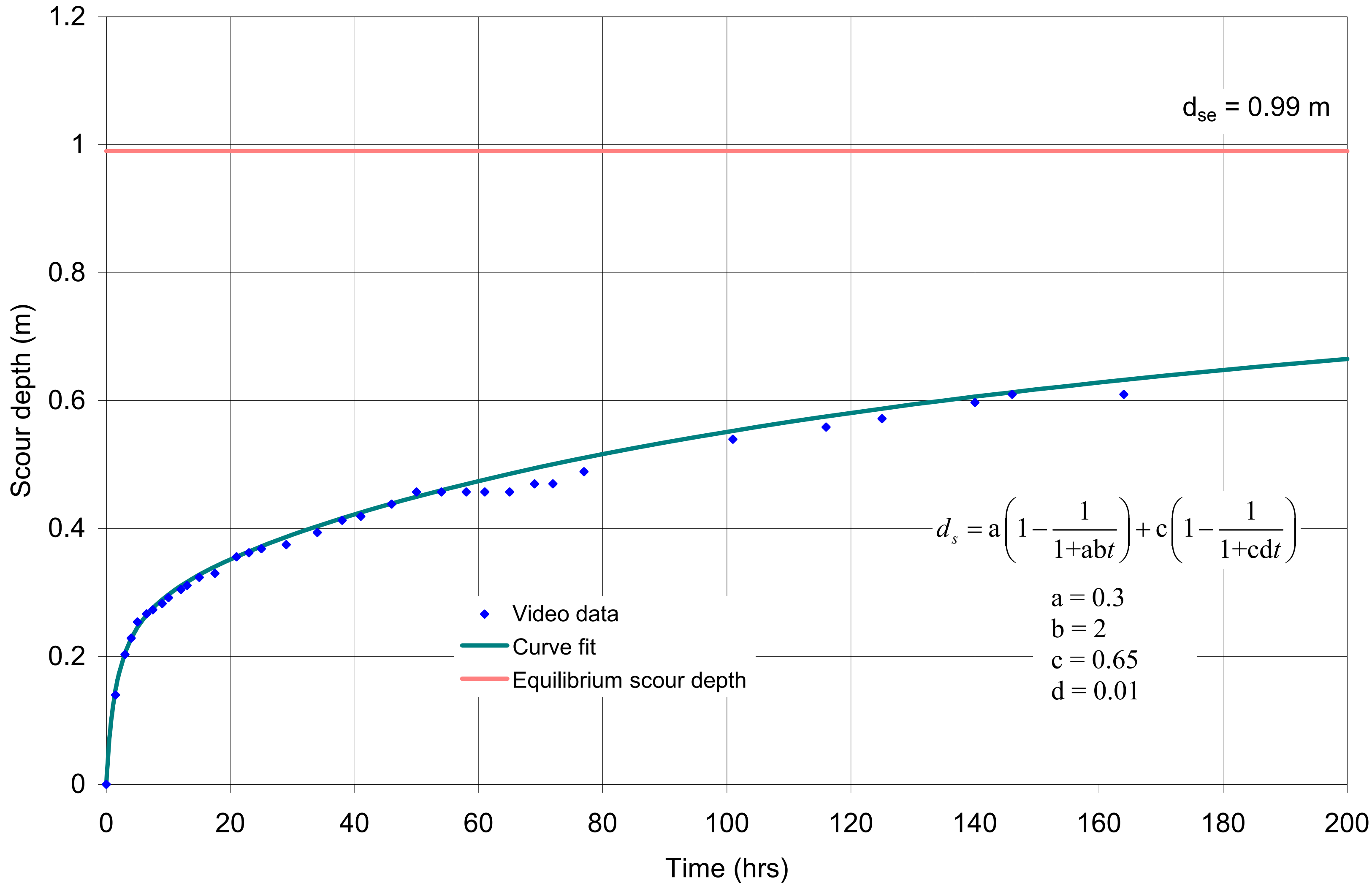

Figure C- 32. Curve fit to the local scour data measured with the internal video cameras for experiment 4.

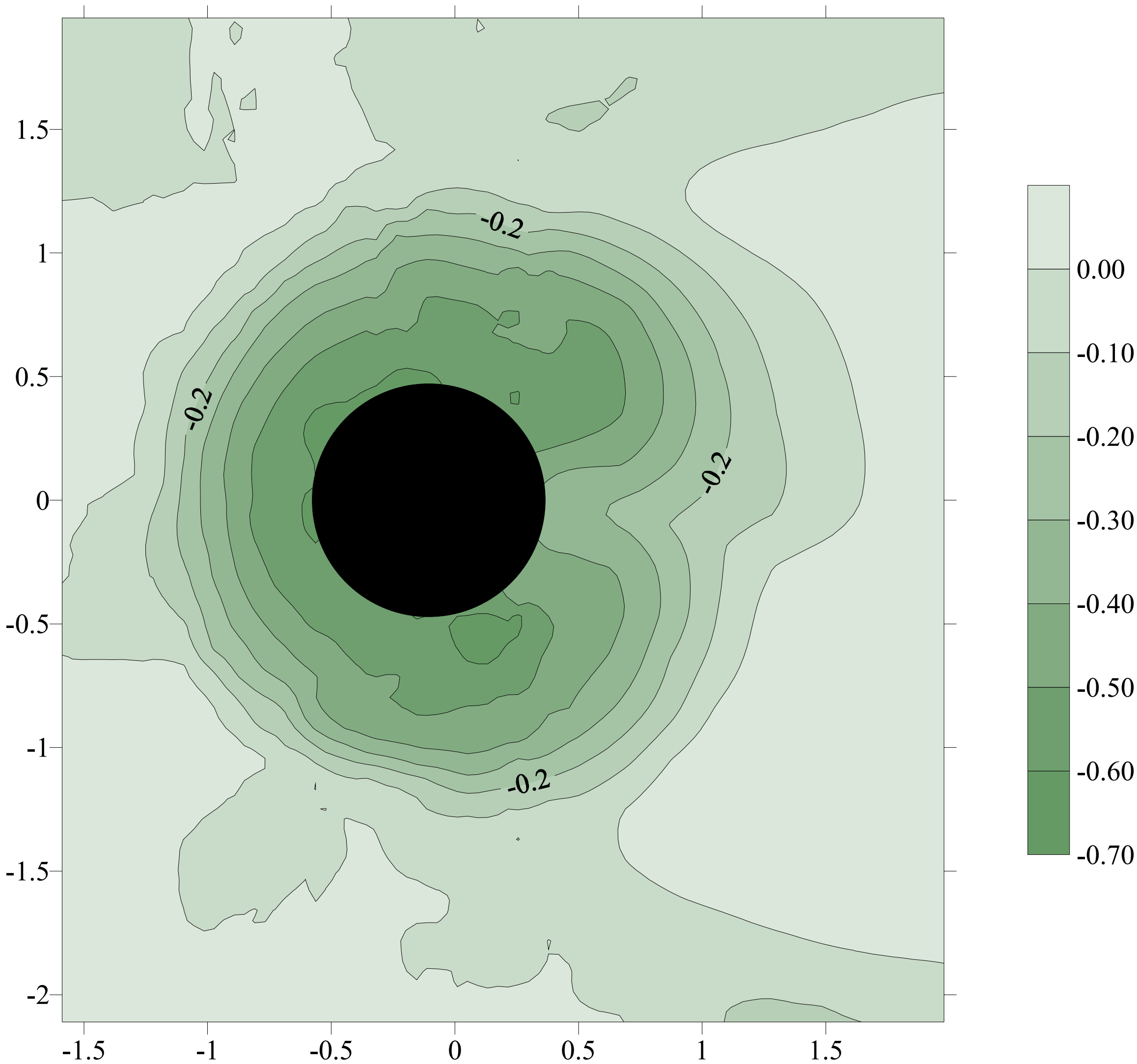

Figure C- 33. Bed elevation contours at completion of experiment 4 referenced to the original bed. All dimensions are in meters.

Table C- 4. The rate of scour depth from the internal video camera for experiment 4.

Time (hrs)	Depth (m)
0	0
1.5	0.152
3	0.216
4	0.241
5	0.267
6.5	0.279
7.5	0.286
9	0.295
10	0.305
12	0.318
13	0.324
15	0.337
17.5	0.343
21	0.368
23	0.375
25	0.381
29	0.387
34	0.407
38	0.426
41	0.432
46	0.451
50	0.470
54	0.470
58	0.470
61	0.470
65	0.470
69	0.483
72	0.483
77	0.502
101	0.553
116	0.572
125	0.584
140	0.610
146	0.622
164	0.622

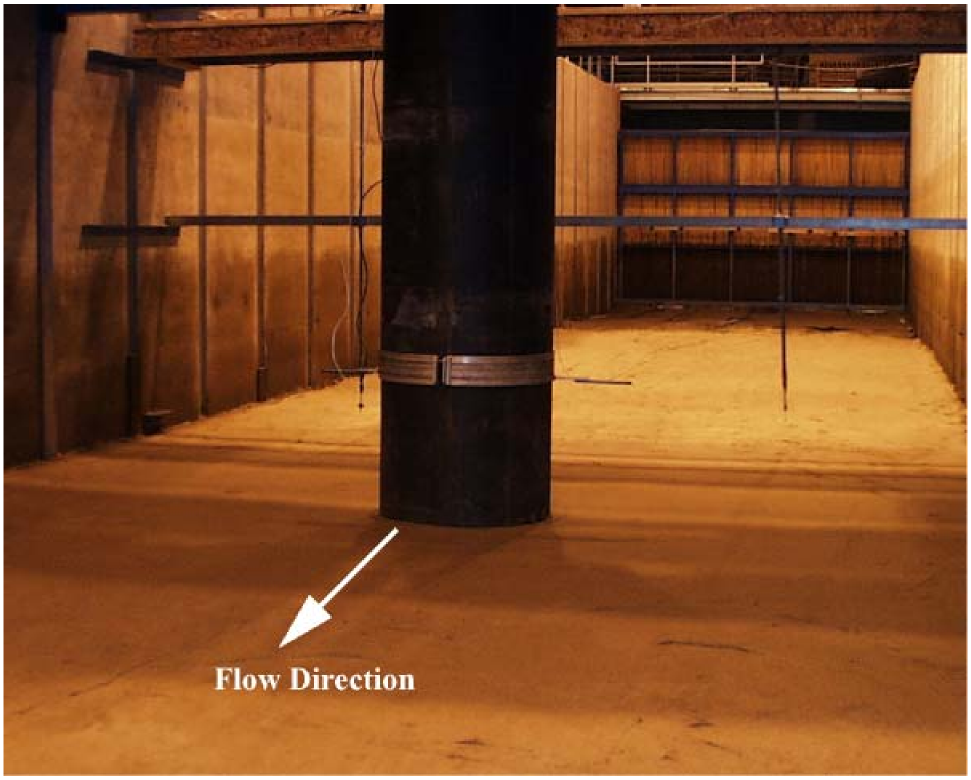

Figure C- 34. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) before test.

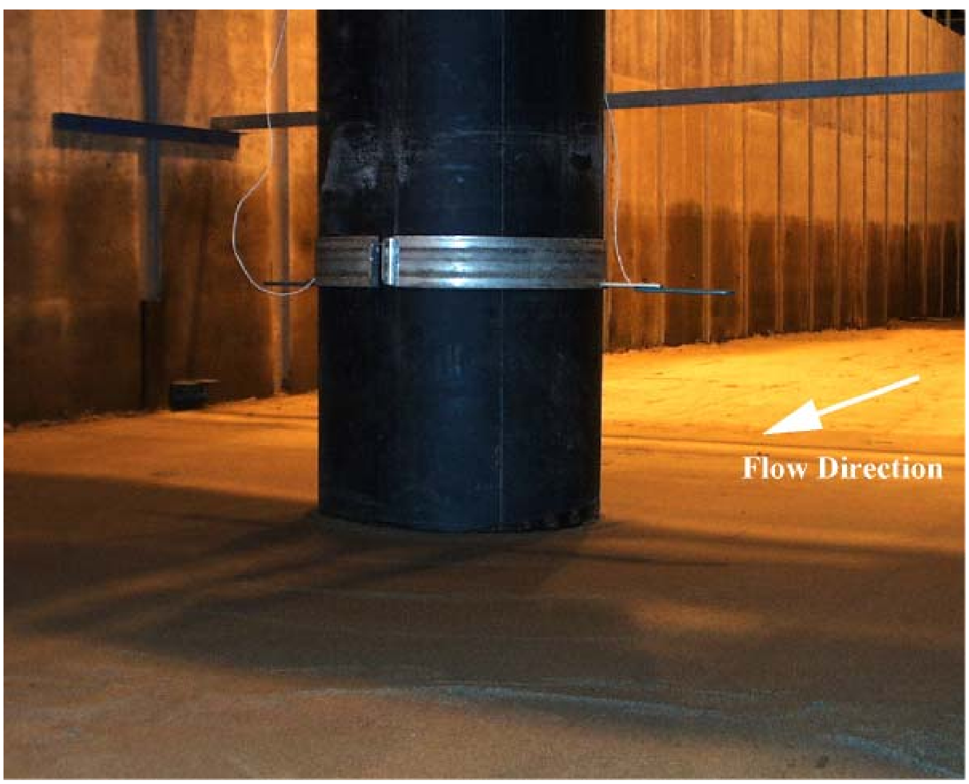

Figure C- 35. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) before test.

Figure C- 36. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) after test.

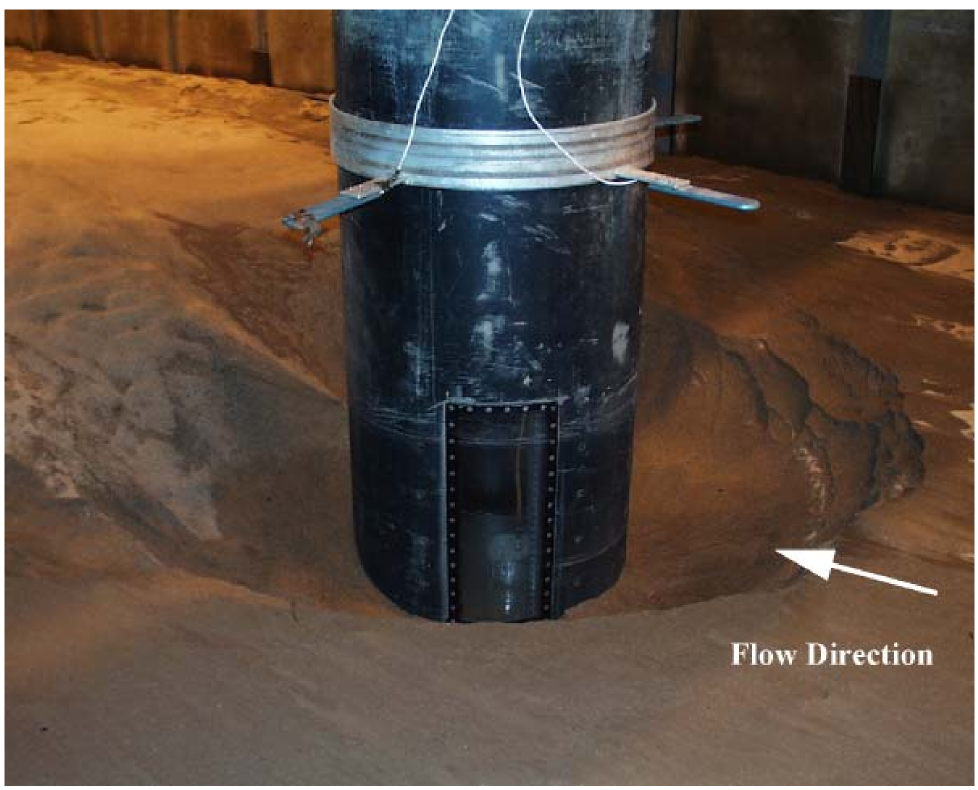

Figure C- 37. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) after test.

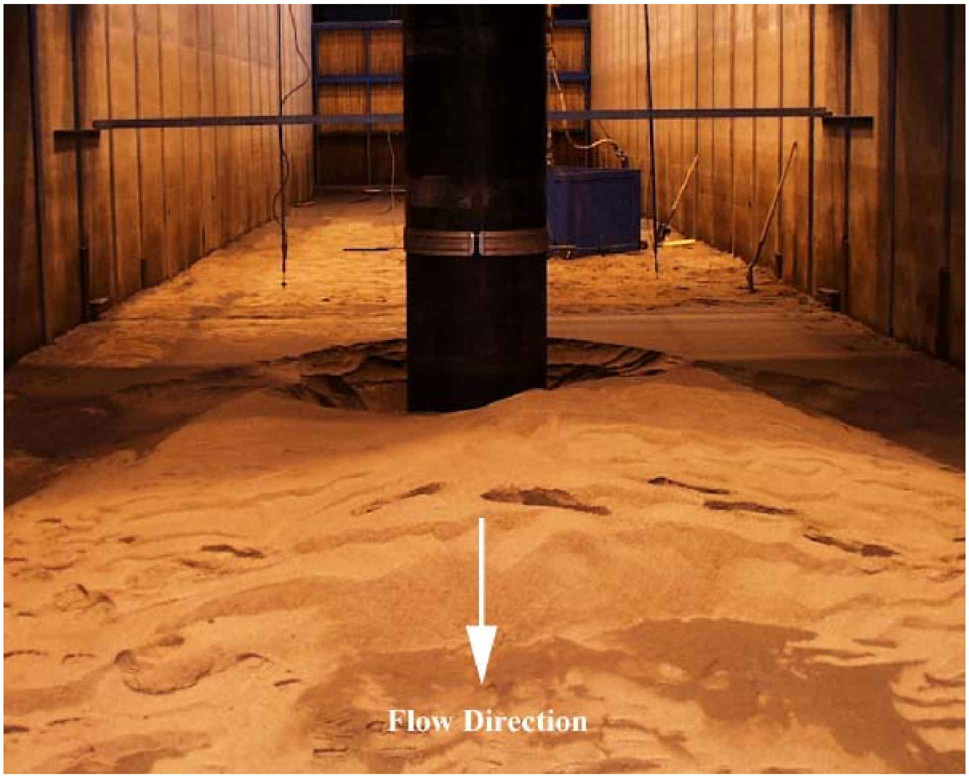

Figure C- 38. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) after test.

Figure C- 39. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) after test.

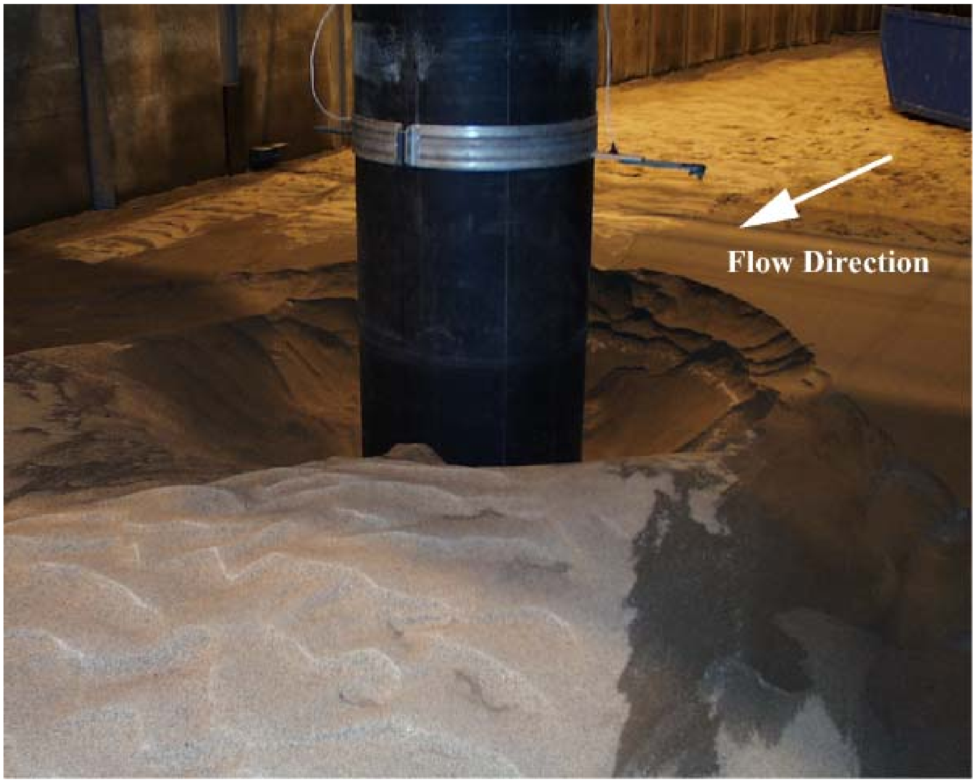

Figure C- 40. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) after test.

Figure C- 41. Experiment 4 (D = 0.915 m, D_{50} = 0.80 mm) after test.

Experiment 5
Scour Summary Form

Circular Pile diameter, D: **0.305 m**

Sediment:

Type:	**Quartz**	Start Date:	**03/11/1999**	Start Time:	**3:18 PM**
D_{50}(mm):	**0.80**	Stop Date:	**03/15/1999**	Stop Time:	**7:03 AM**
σ:	1.29				
ρ_s (Kg/m^3):	**2650**	Duration:	**87 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.41**	**0.33**
Maximum(m/s):	**0.43**	**0.41**
Minimum(m/s):	**0.38**	**0.30**

Channel average velocity from weir (m/s): **0.37**

Critical (sediment) velocity, V_c (m/s): **0.47**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **1.27**
- Minimum(m): **1.27**
- Maximum(m): **1.27**

Water Temperature:
- Average (degrees C): **1.2**
- Maximum (degrees C): **2.2**
- Minimum (degrees C): **0.8**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.384**
- Maximum depth from internal video cameras (m): **0.400**
- Maximum depth from point gauge (m): **0.416**
- Maximum scour depth (m): **0.416**

Dimensionless Parameters:

y_0/D: **4.2** V/V_c: **0.83** D/D_{50}: **381**

d_s/D: **1.36**

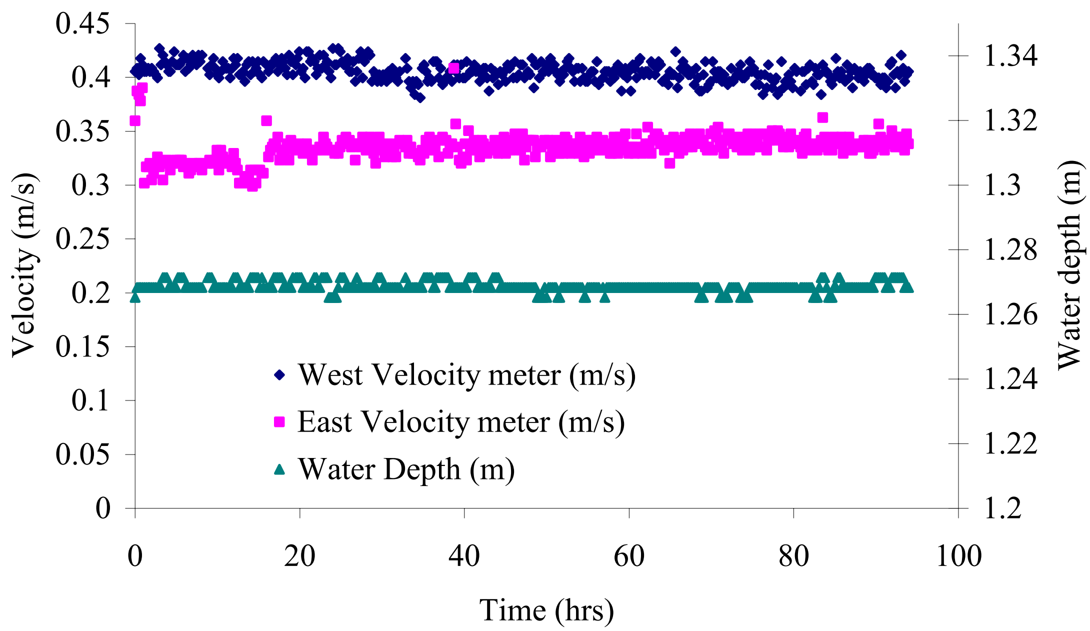

Figure C- 42. Measured velocity and water depth for experiment 5.

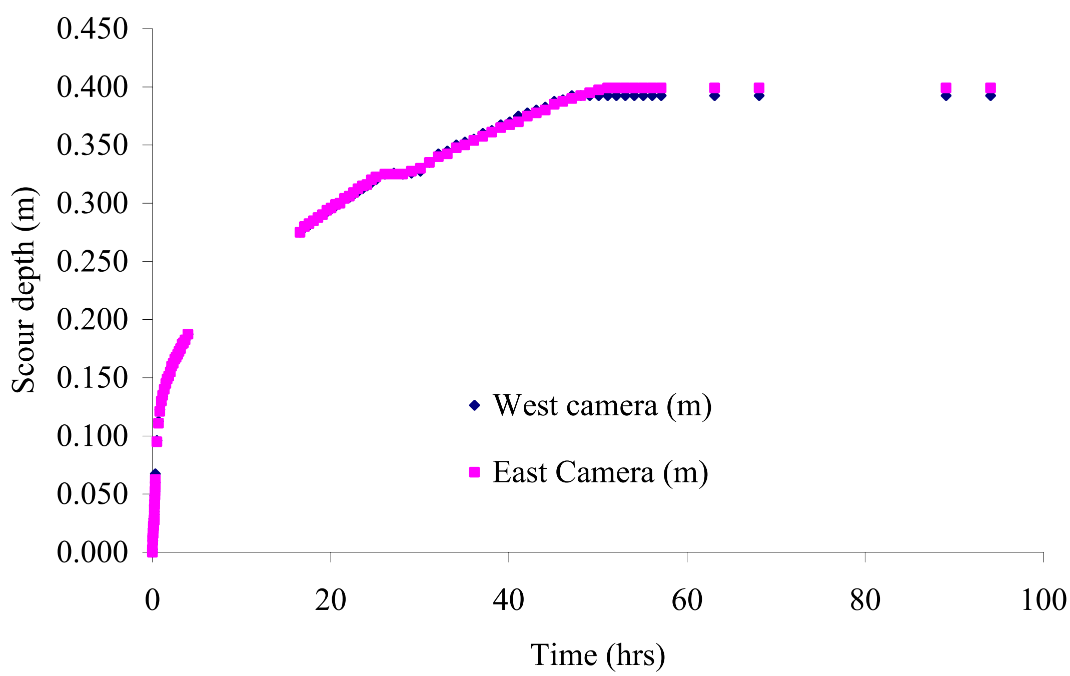

Figure C- 43. Measured local scour data from the internal video camera for experiment 5.

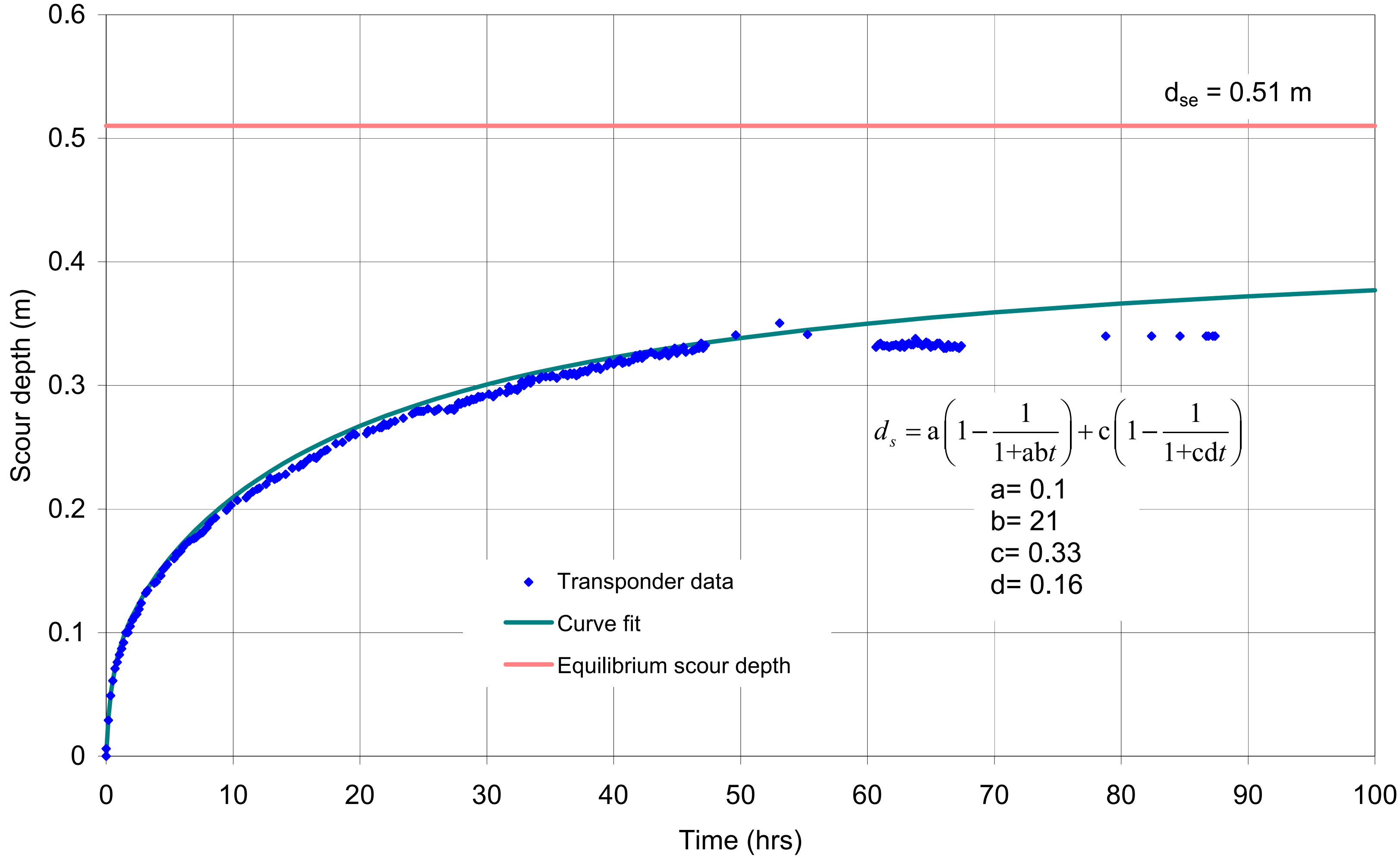

Figure C- 44. Curve fit to the local scour data measured with the acoustic transponder data for experiment 5.

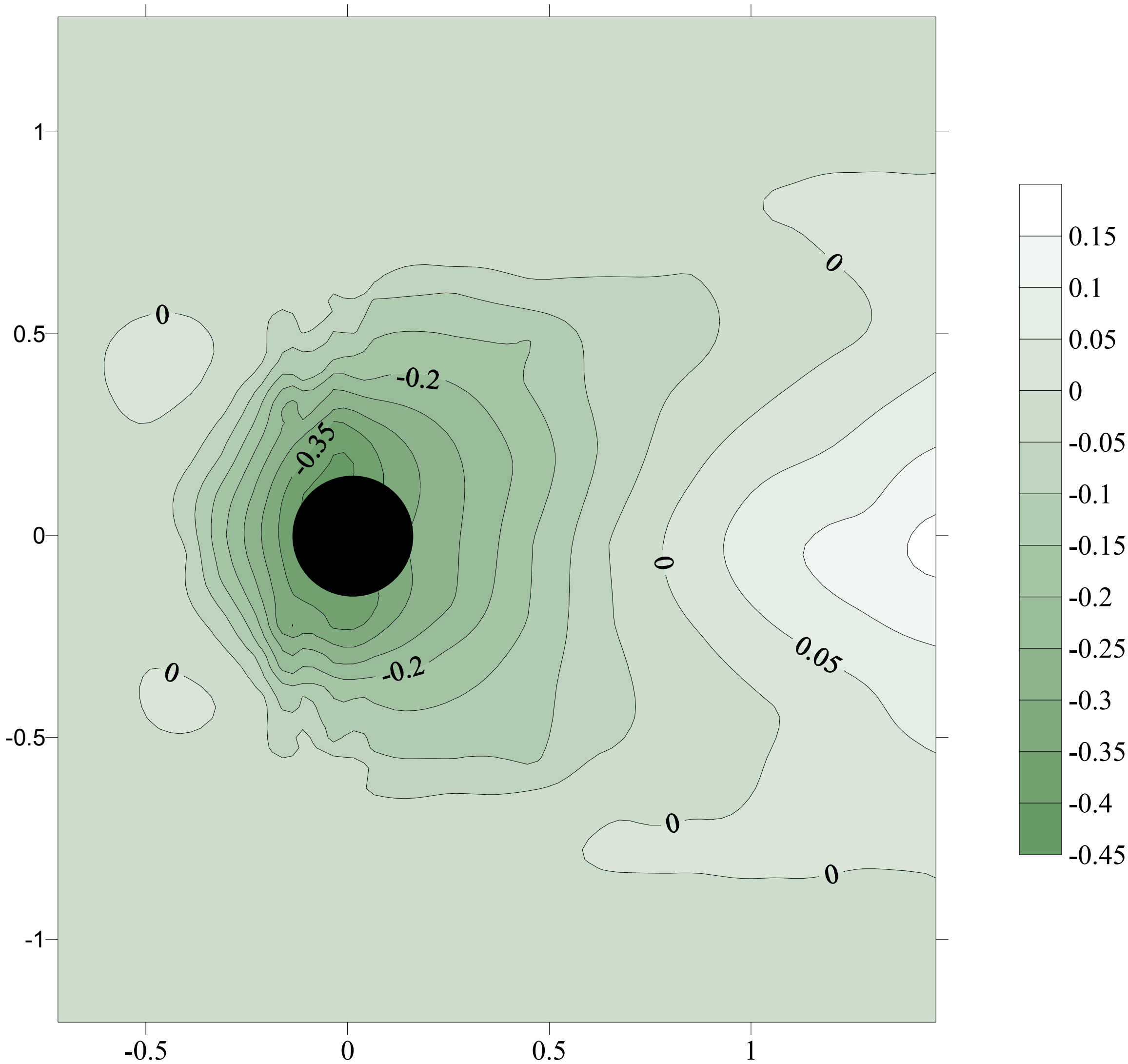

Figure C- 45. Bed elevation contours at completion of experiment 5 referenced to the original bed. All dimensions are in meters.

Table C- 5. The rate of scour depth from the internal video camera for experiment 5.

Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)
0.00	0.000	0.000	3.33	0.178	0.179	42.08	0.378	0.375
0.02	0.003	0.003	3.50	0.180	0.180	43.08	0.380	0.378
0.03	0.010	0.010	3.67	0.183	0.183	44.08	0.383	0.380
0.05	0.014	0.013	4.00	0.188	0.188	45.08	0.388	0.385
0.07	0.018	0.016	16.57	0.275	0.275	46.08	0.389	0.388
0.08	0.020	0.016	17.07	0.279	0.280	47.08	0.393	0.390
0.10	0.023	0.020	17.57	0.281	0.283	48.08	0.393	0.393
0.12	0.024	0.023	18.07	0.285	0.285	49.08	0.393	0.395
0.13	0.025	0.023	18.57	0.288	0.288	50.08	0.393	0.398
0.15	0.029	0.025	19.07	0.290	0.290	51.08	0.393	0.399
0.17	0.030	0.028	19.57	0.293	0.294	52.08	0.393	0.399
0.18	0.031	0.028	20.07	0.295	0.296	53.08	0.393	0.399
0.20	0.033	0.028	20.57	0.298	0.299	54.08	0.393	0.399
0.22	0.035	0.030	21.07	0.300	0.300			
0.23	0.040	0.038	21.57	0.304	0.304			
0.25	0.045	0.041	22.08	0.305	0.306			
0.27	0.049	0.045	22.58	0.308	0.309			
0.28	0.053	0.049	23.08	0.310	0.313			
0.30	0.055	0.053	23.58	0.313	0.315			
0.32	0.060	0.058	24.08	0.315	0.316			
0.33	0.068	0.063	24.58	0.318	0.320			
0.50	0.096	0.095	25.08	0.320	0.323			
0.67	0.113	0.111	26.08	0.325	0.325			
0.83	0.123	0.121	27.08	0.326	0.325			
1.00	0.128	0.130	28.08	0.325	0.325			
1.17	0.134	0.135	29.08	0.326	0.328			
1.33	0.140	0.140	30.08	0.328	0.330			
1.50	0.146	0.145	31.08	0.335	0.335			
1.67	0.150	0.149	32.08	0.343	0.340			
1.83	0.153	0.152	33.08	0.345	0.343			
2.00	0.158	0.155	34.08	0.350	0.348			
2.17	0.160	0.160	35.08	0.353	0.350			
2.33	0.163	0.163	36.08	0.355	0.354			
2.50	0.165	0.166	37.08	0.360	0.358			
2.67	0.169	0.168	38.08	0.363	0.361			
2.83	0.170	0.170	39.08	0.368	0.365			
3.00	0.173	0.173	40.08	0.370	0.368			
3.17	0.175	0.175	41.08	0.375	0.370			

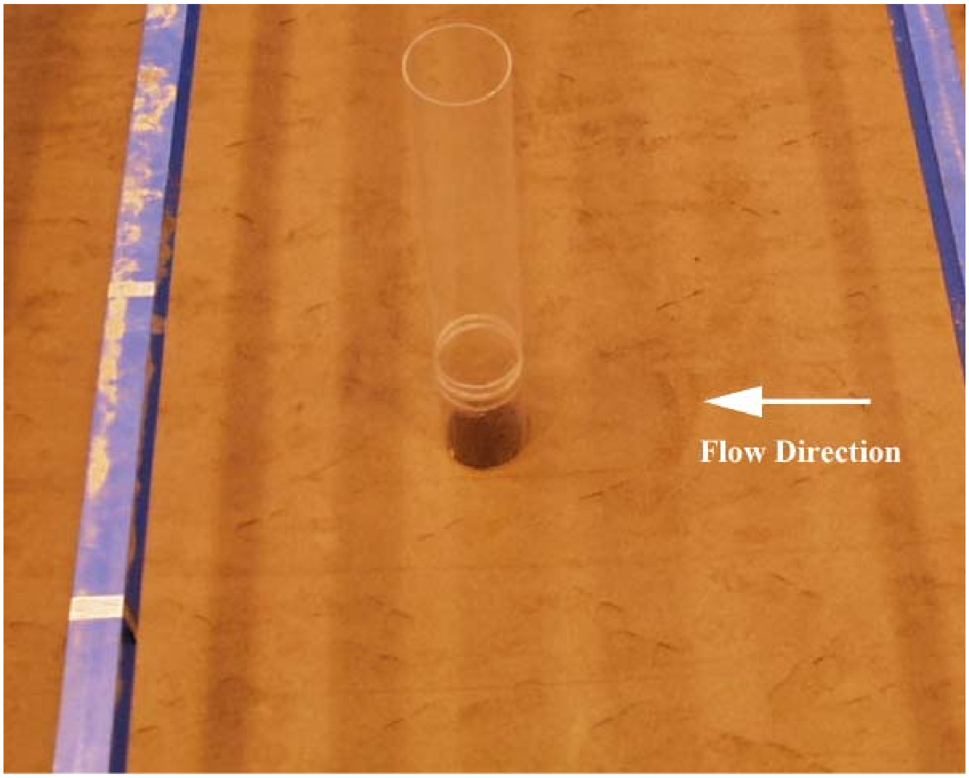

Figure C- 46. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) before test.

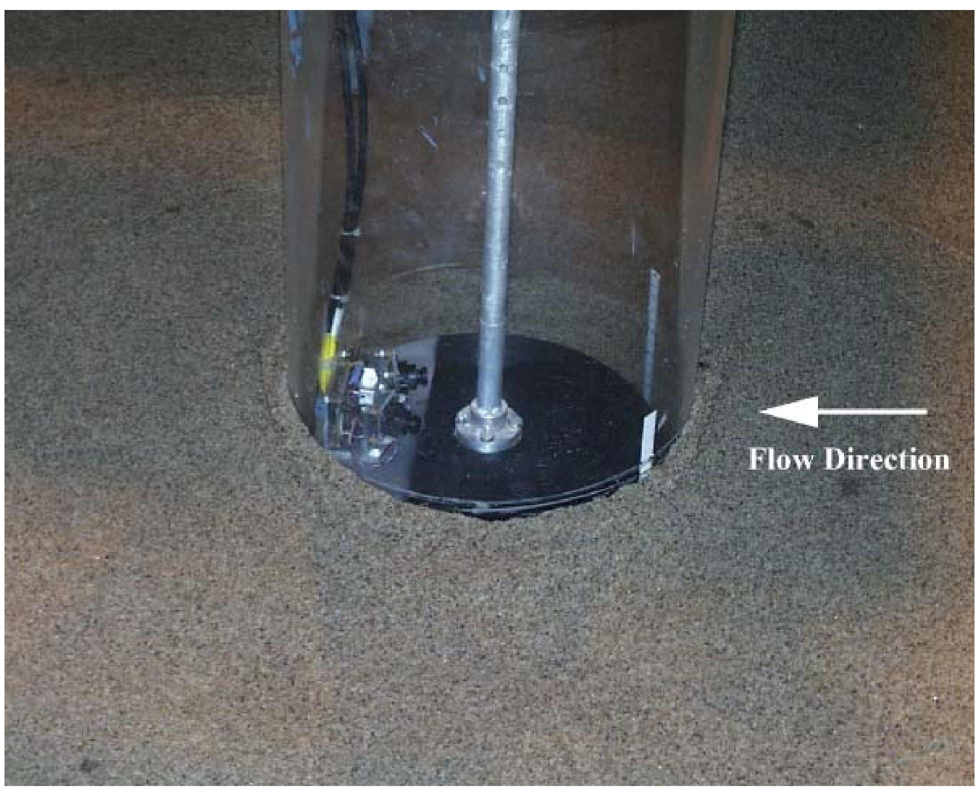

Figure C- 47. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) before test.

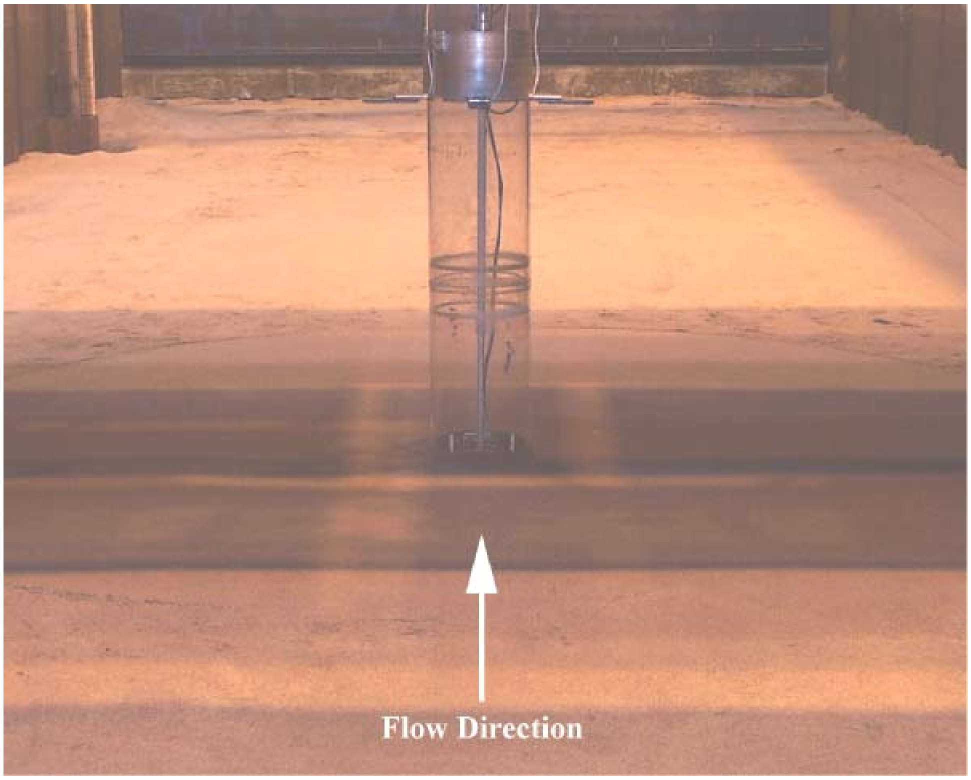

Figure C- 48. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) before test.

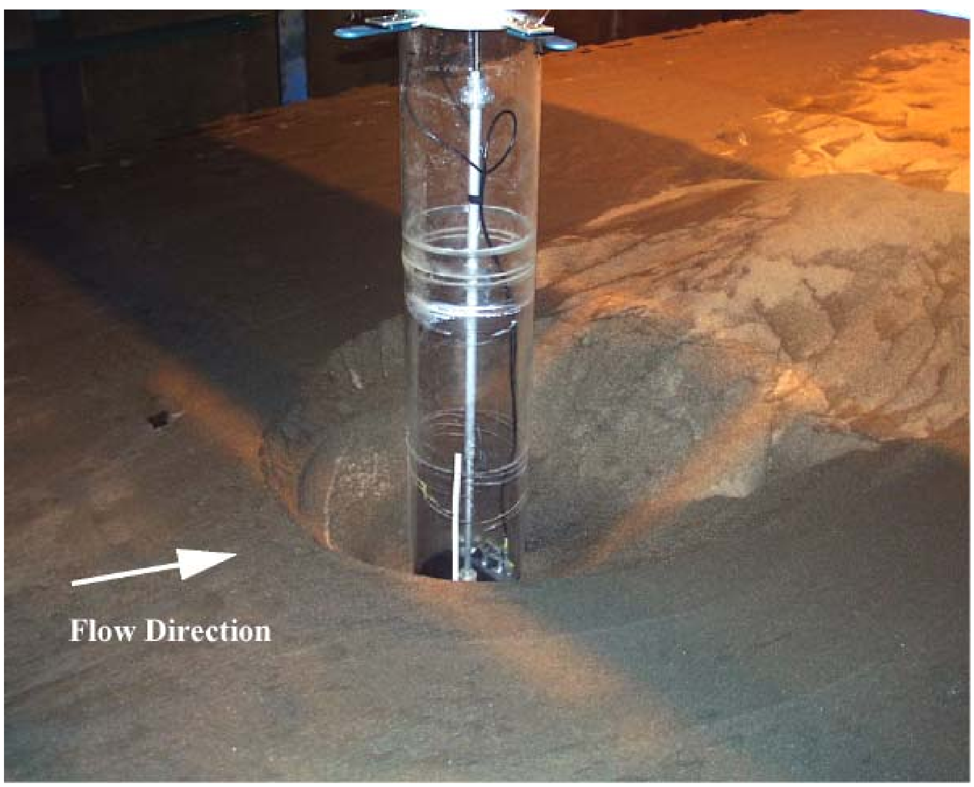

Figure C- 49. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) after test.

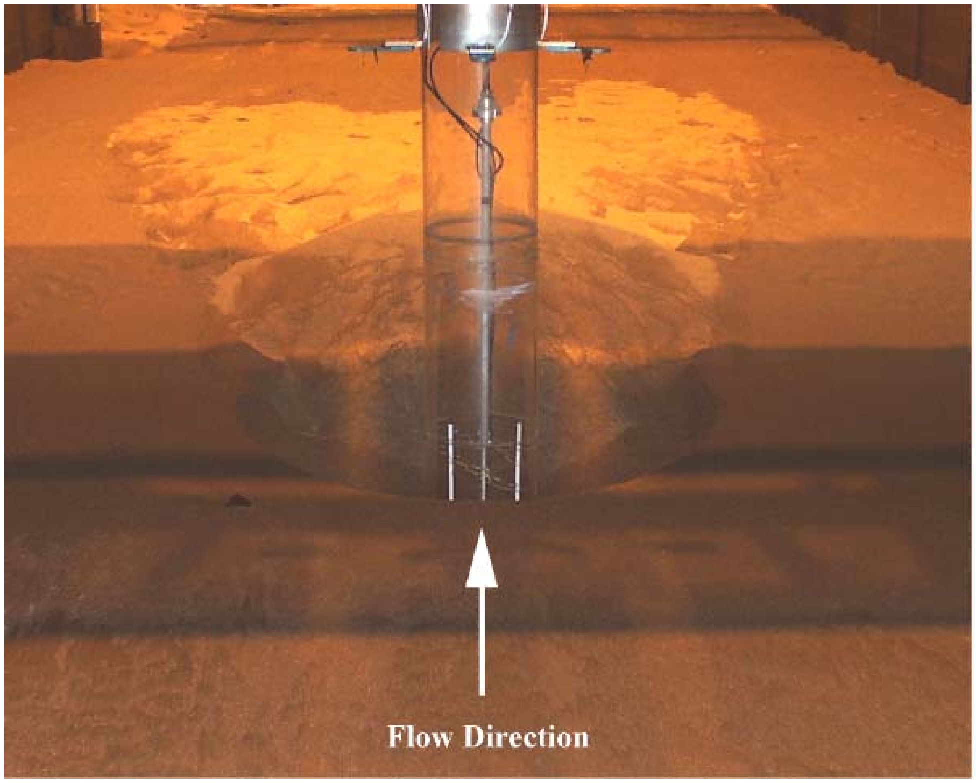

Figure C- 50. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) after test.

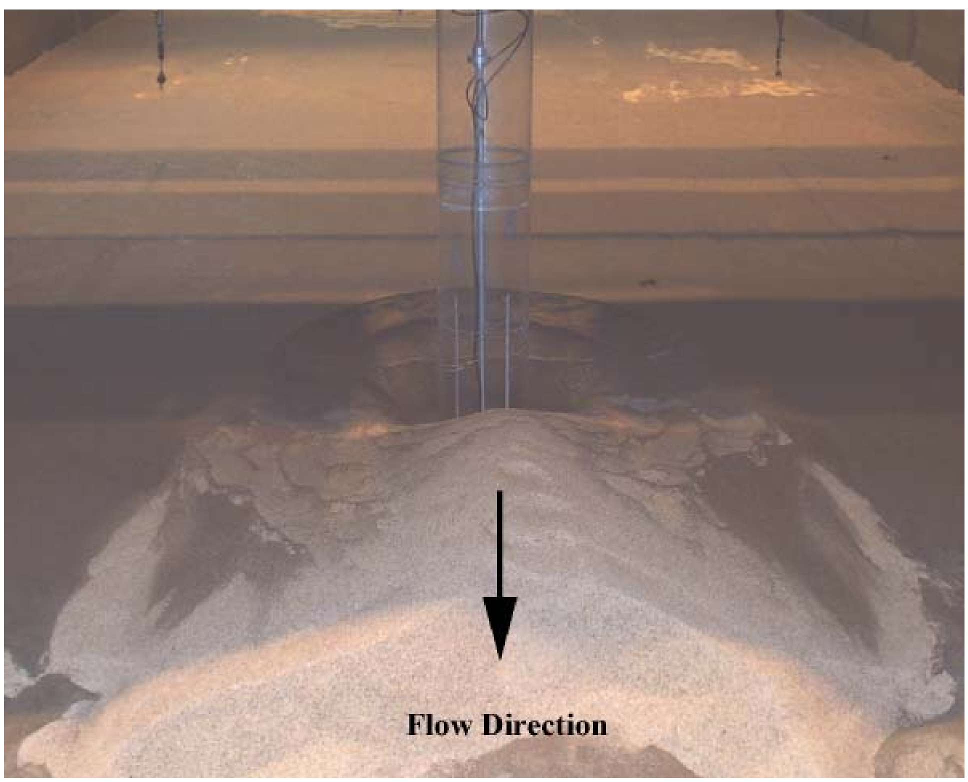

Figure C- 51. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) after test.

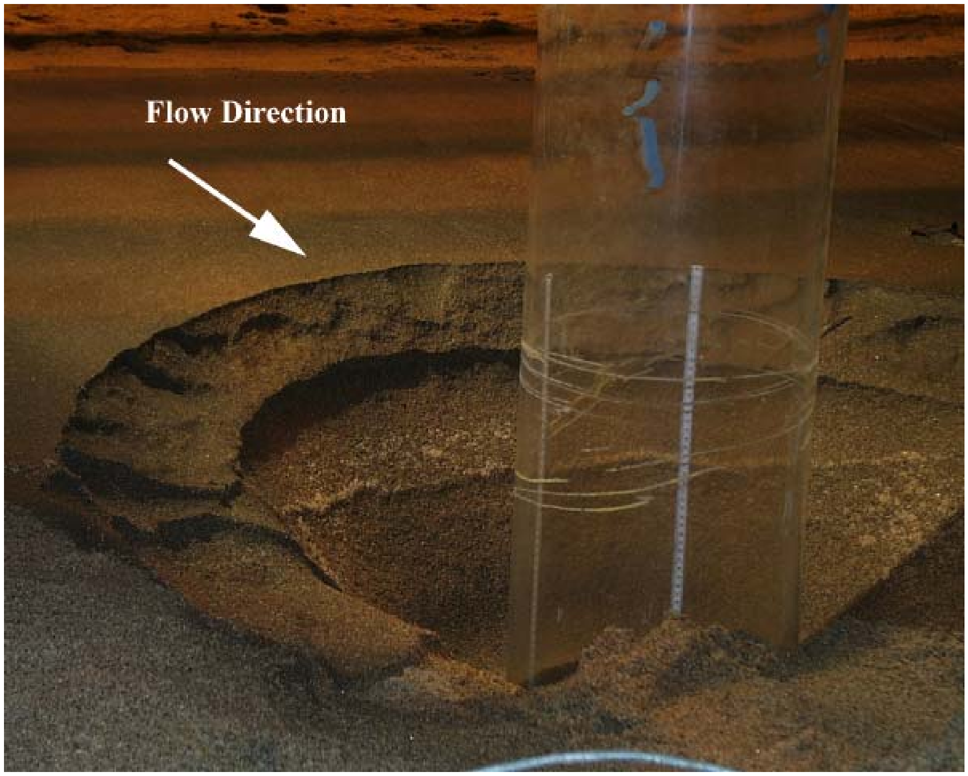

Figure C- 52. Experiment 5 (D = 0.305 m, D_{50} = 0.80 mm) after test.

Experiment 6
Scour Summary Form

Circular Pile diameter, D: **0.114 m**

Sediment:

Type:	**Quartz**	Start Date:	**03/29/1999**	Start Time:	**2:43 PM**
D_{50}(mm):	**0.80**	Stop Date:	**03/31/1999**	Stop Time:	**8:14 AM**
σ:	1.29				
ρ_s (Kg/m^3):	**2650**	Duration:	**42 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.34**	**0.43**
Maximum(m/s):	**0.36**	**0.46**
Minimum(m/s):	**0.31**	**0.39**

Channel average velocity from weir (m/s): **0.38**

Critical (sediment) velocity, V_c (m/s): **0.47**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :

Average water depth(m):	**1.27**
Minimum(m):	**1.21**
Maximum(m):	**1.28**

Water Temperature:

Average (degrees C):	**3.7**
Maximum (degrees C):	**3.5**
Minimum (degrees C):	**3.5**

Local Equilibrium Scour Depth, d_s:

Maximum depth from acoustic transponders (m):	**0.130**
Maximum depth from internal video cameras (m):	**0.171**
Maximum depth from point gauge (m):	**0.185**
Maximum scour depth (m):	**0.185**

Dimensionless Parameters:

y_0/D: **11.1** V/V_c: **0.87** D/D_{50}: **143**

d_s/D: **1.62**

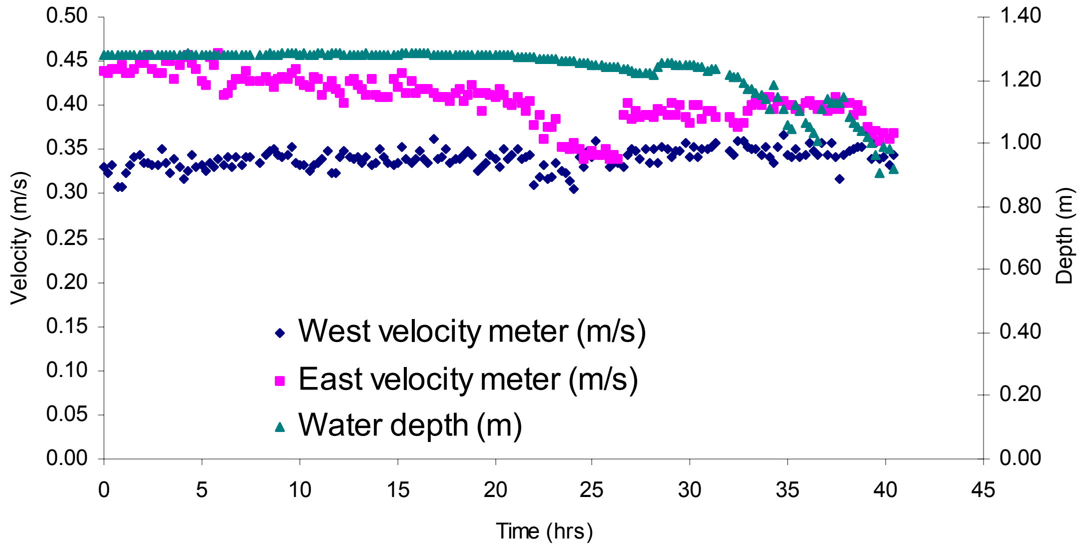

Figure C- 53. Measured velocity and water depth for experiment 6.

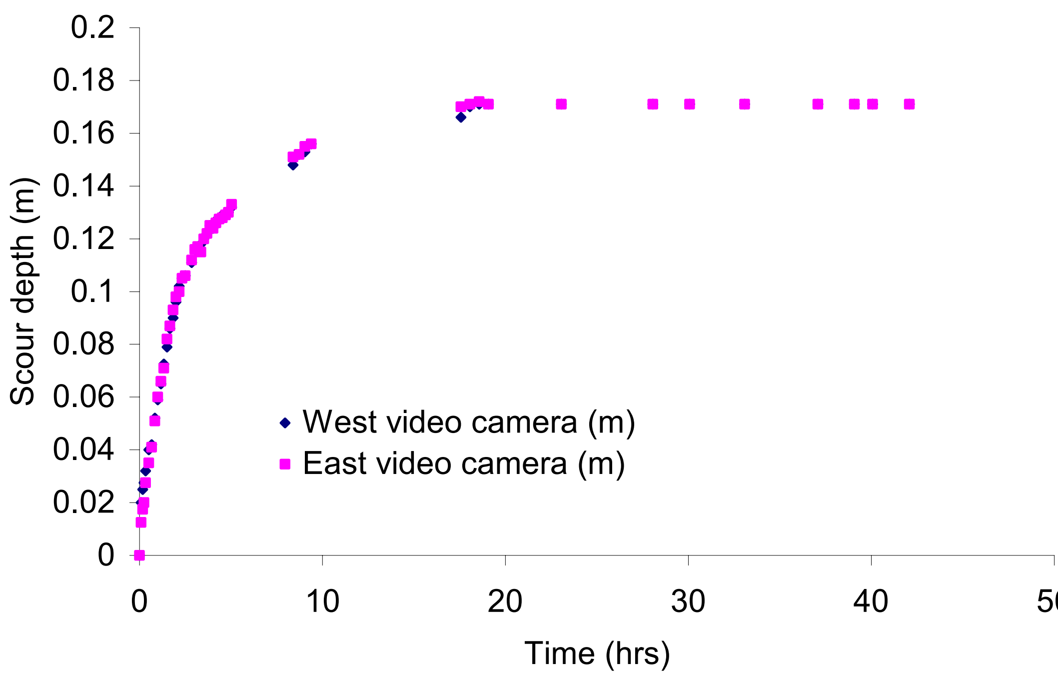

Figure C- 54. Measured local scour data from the internal video camera for experiment 6.

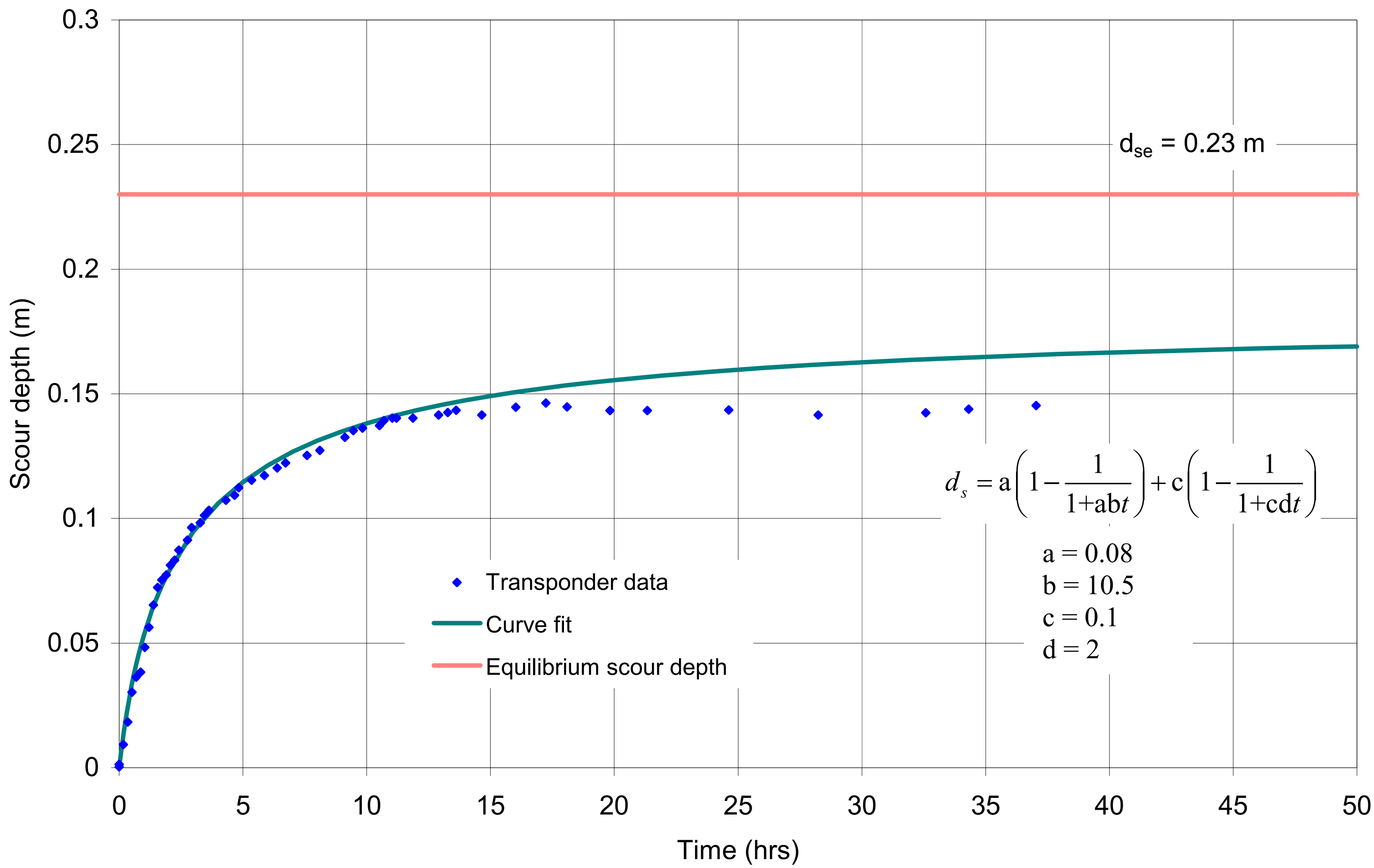

Figure C- 55. Curve fit to the local scour data measured with the acoustic transponder data for experiment 6.

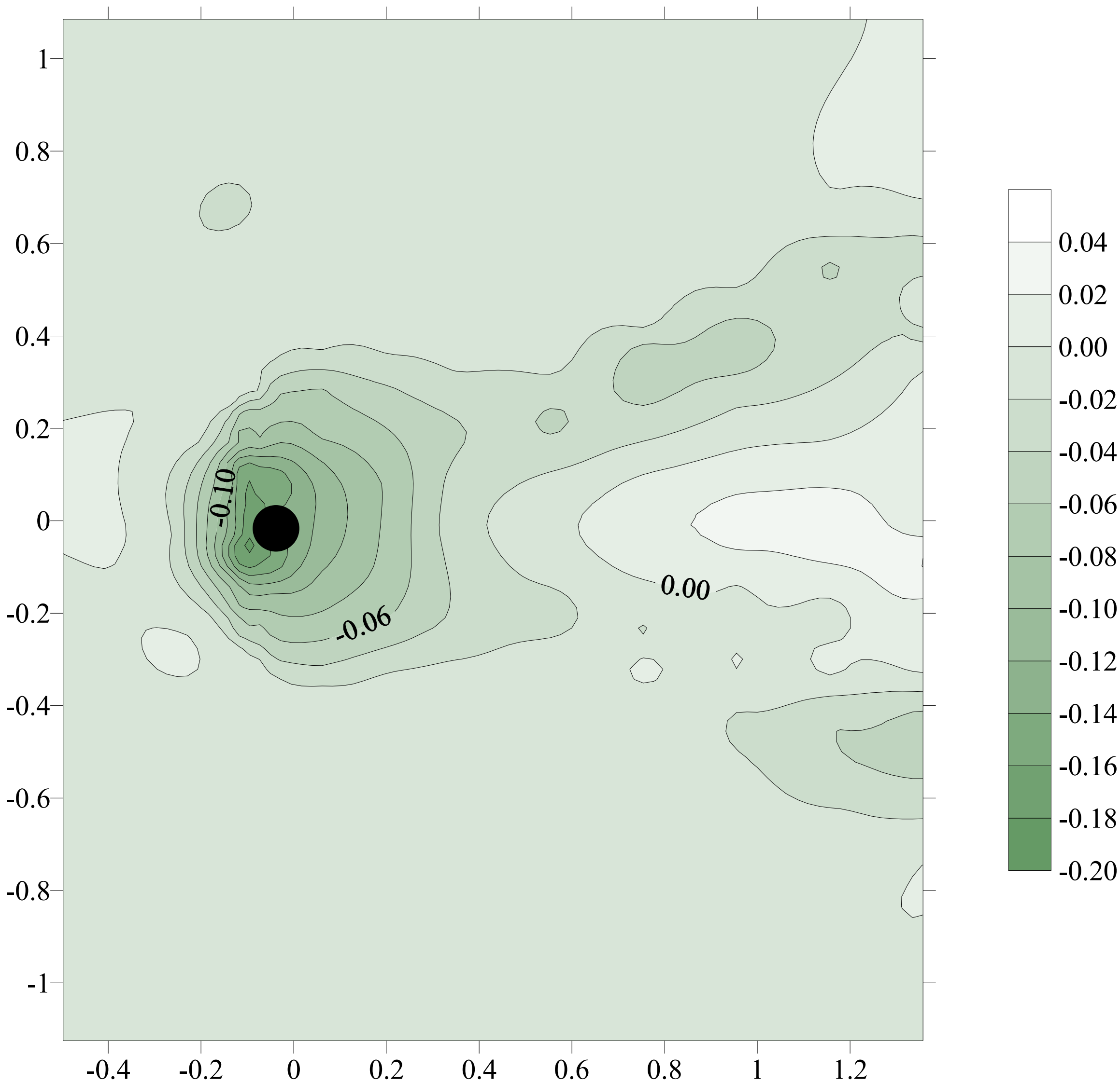

Figure C- 56 Bed elevation contours at completion of experiment 6 referenced to the original bed. All dimensions are in meters.

Table C- 6. The rate of scour depth from the internal video camera for experiment 6.

Time (hrs)	West camera (m)	East camera (m)	Time (hrs)	West camera (m)	East camera (m)
0.00	0	0	37.08	0.171	0.171
0.08	0.02	0.0125	39.07	0.171	0.171
0.17	0.025	0.0175	40.07	0.171	0.171
0.25	0.0275	0.02	42.08	0.171	0.171
0.33	0.032	0.0275			
0.50	0.04	0.035			
0.67	0.042	0.041			
0.83	0.052	0.051			
1.00	0.059	0.06			
1.17	0.065	0.066			
1.33	0.0725	0.071			
1.50	0.079	0.082			
1.67	0.086	0.087			
1.83	0.09	0.093			
2.00	0.096	0.098			
2.17	0.102	0.1			
2.33	0.105	0.105			
2.50	0.106	0.106			
2.85	0.111	0.112			
3.02	0.116	0.116			
3.18	0.116	0.117			
3.35	0.118	0.115			
3.52	0.12	0.12			
3.68	0.122	0.122			
3.85	0.125	0.125			
4.02	0.124	0.124			
4.18	0.127	0.126			
4.35	0.127	0.1275			
4.53	0.129	0.128			
4.70	0.129	0.129			
4.87	0.13	0.13			
5.03	0.132	0.133			
8.38	0.148	0.151			
8.72	0.152	0.152			
9.03	0.153	0.155			
9.38	0.156	0.156			
17.57	0.166	0.17			
18.07	0.17	0.171			
18.57	0.171	0.172			

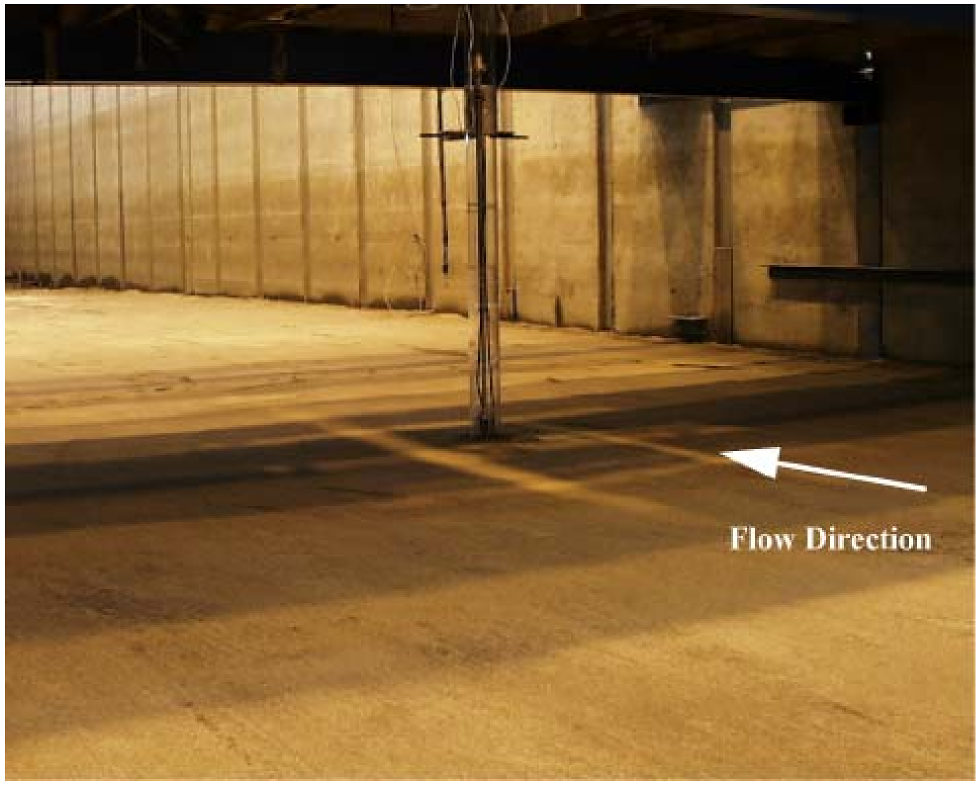

Figure C- 57. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) before test.

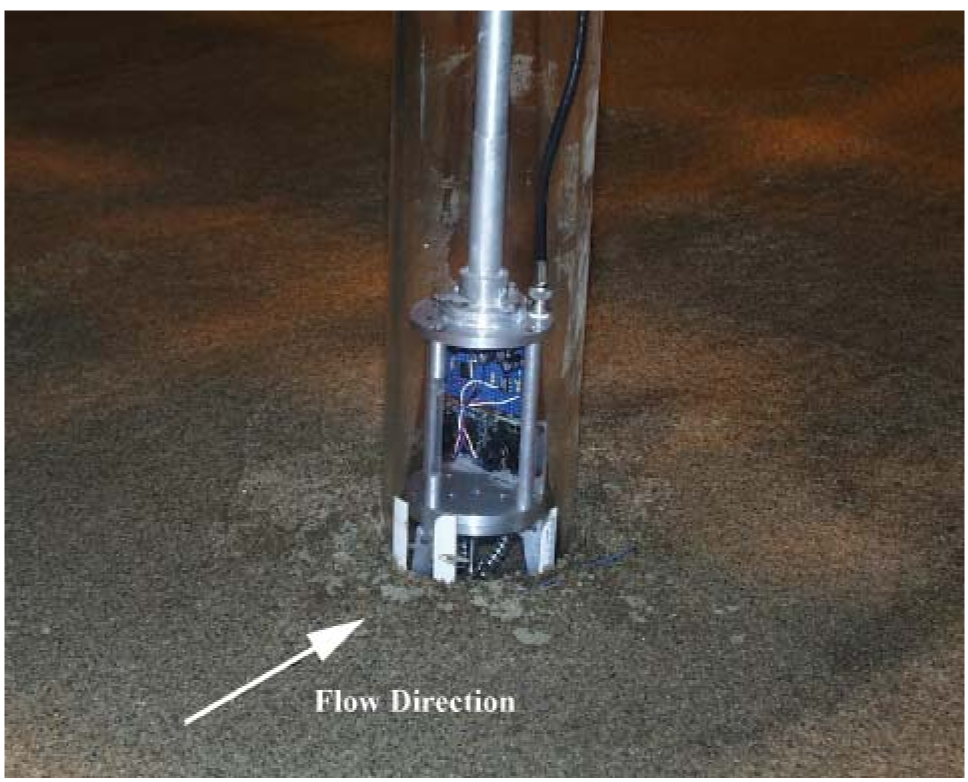

Figure C- 58. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) before test.

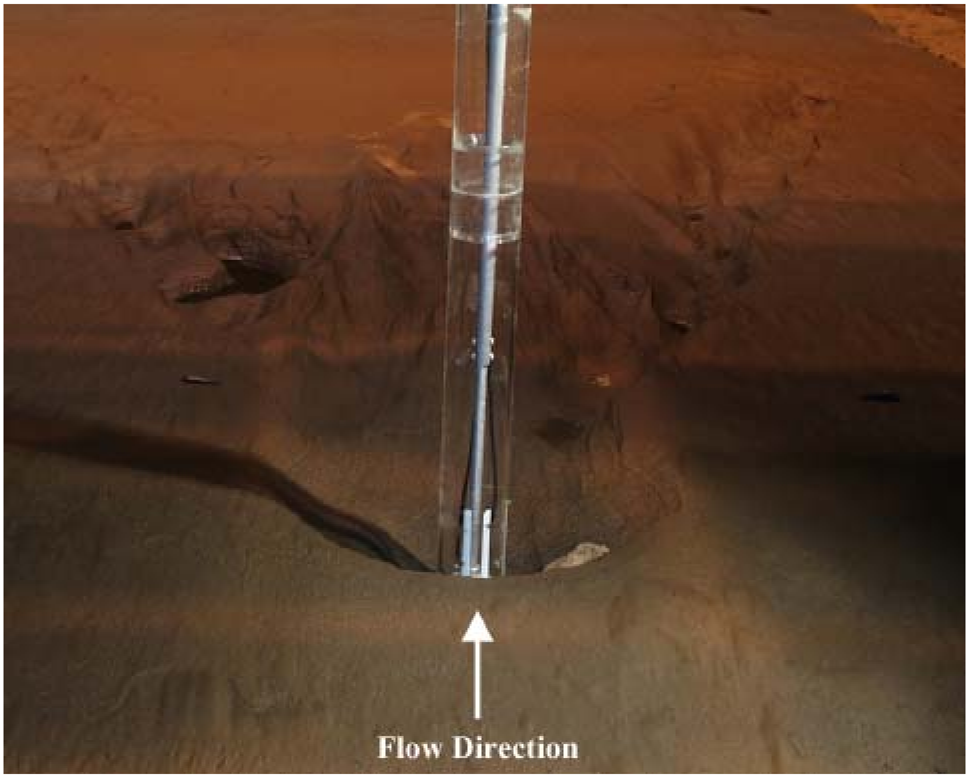

Figure C- 59. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) after test.

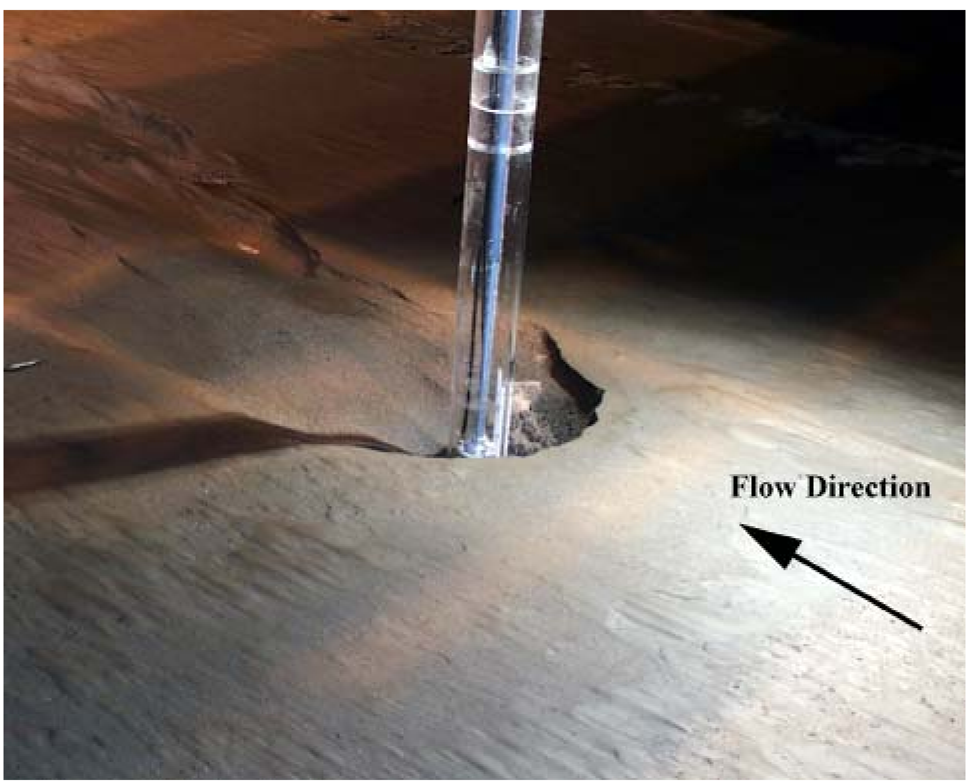

Figure C- 60. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) after test.

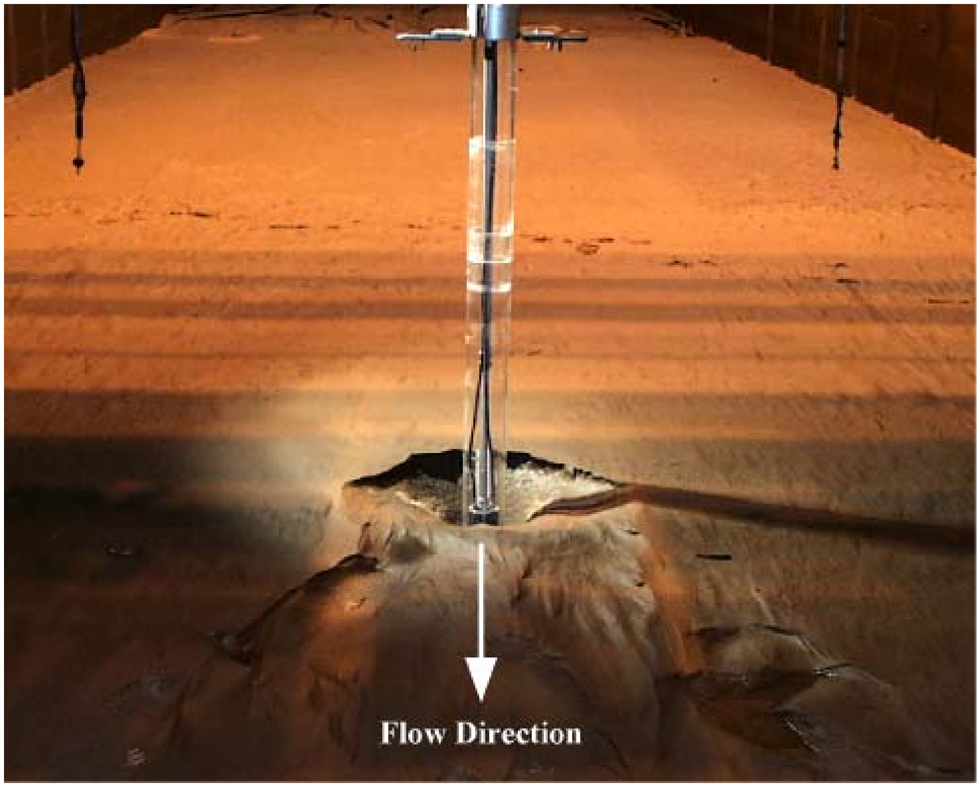

Figure C- 61. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) after test.

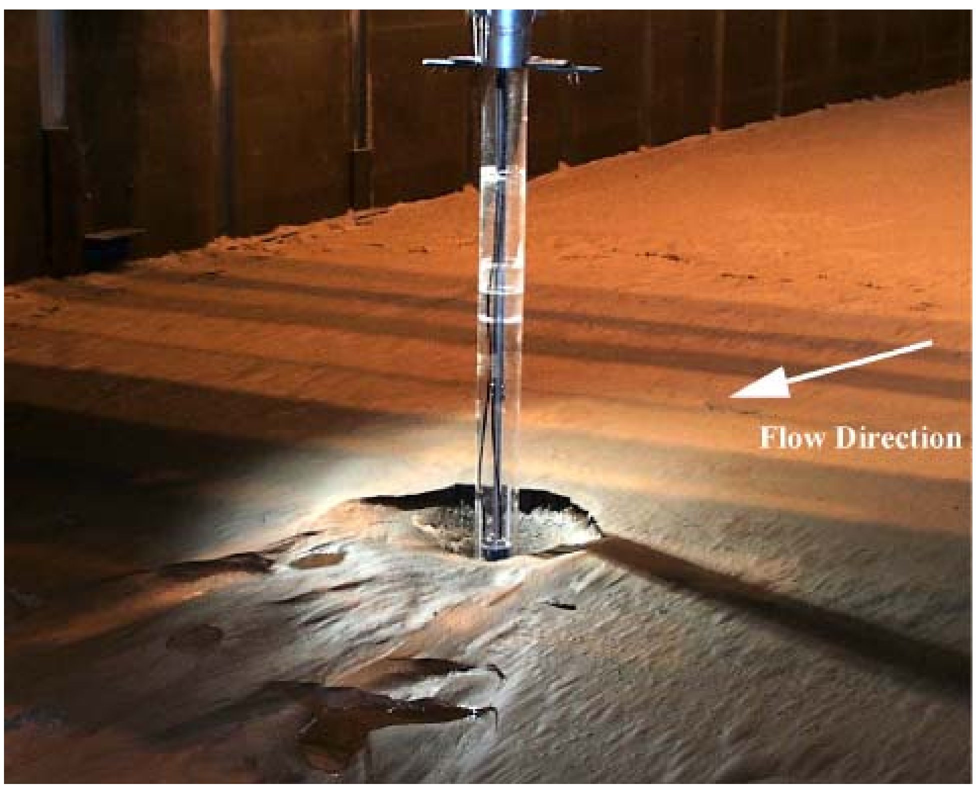

Figure C- 62. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) after test.

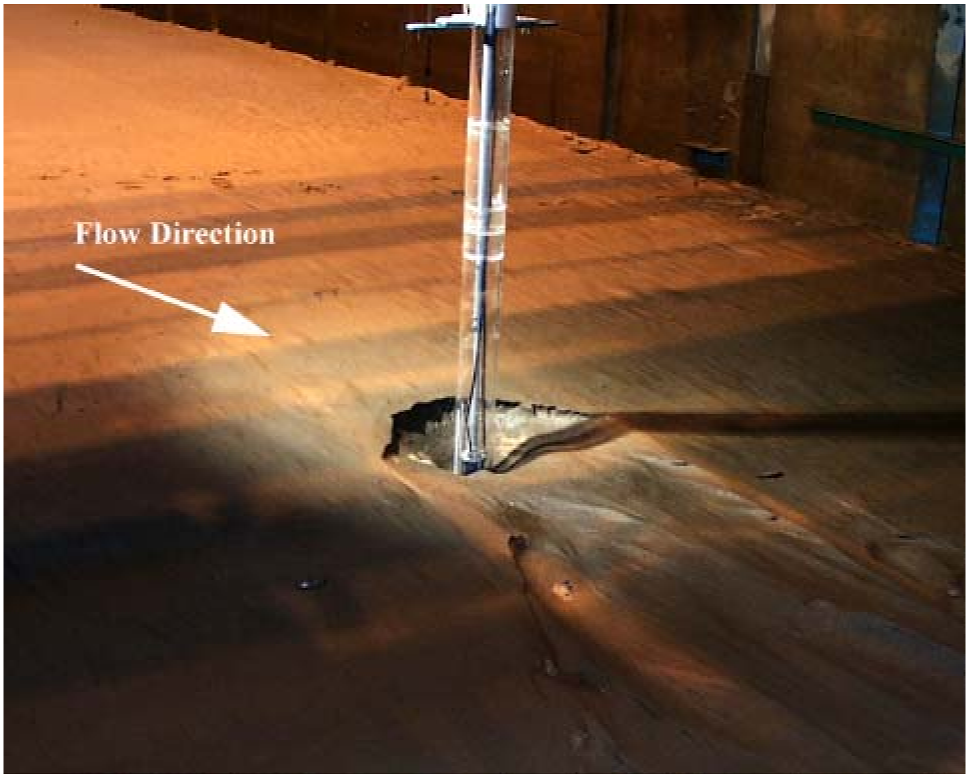

Figure C- 63. Experiment 6 (D = 0.114 m, D_{50} = 0.80 mm) after test.

Experiment 7
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**01/25/2000**	Start Time:	**2:14 PM**
D_{50}(mm):	**2.90**	Stop Date:	**02/04/2000**	Stop Time:	**1:57 PM**
σ:	1.21				
ρ_s (Kg/m^3):	**2650**	Duration:	**188 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.74**	**0.77**
Maximum(m/s):	**0.81**	**0.81**
Minimum(m/s):	**0.69**	**0.67**

Channel average velocity from weir (m/s): **0.68**

Critical (sediment) velocity, V_c (m/s): **0.84**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **1.22**
- Minimum(m): **1.22**
- Maximum(m): **1.24**

Water Temperature:
- Average (degrees C): **0.7**
- Maximum (degrees C): **1.1**
- Minimum (degrees C): **0.7**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m):
- Maximum depth from internal video cameras (m): **1.232**
- Maximum depth from point gauge (m): **1.270**
- Maximum scour depth (m): **1.270**

Dimensionless Parameters:

y_0/D: **1.3** V/V_c: **0.90** D/D_{50}: **316**

d_s/D: **1.39**

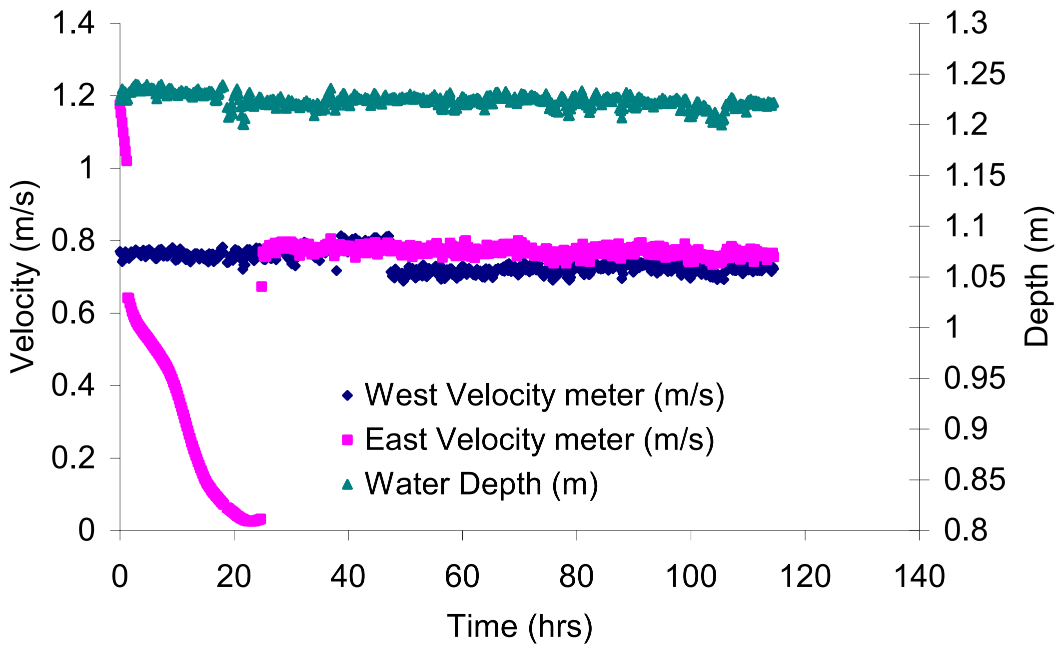

Figure C- 64. Measured velocity and water depth for experiment 7.

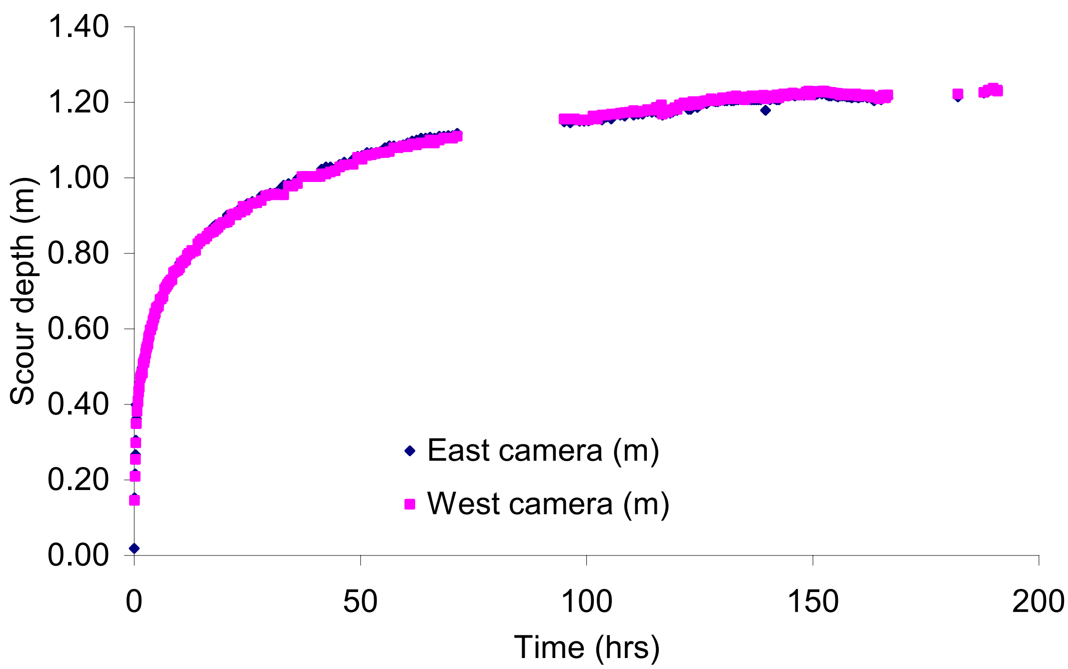

Figure C- 65. Measured local scour data from the internal video cameras for experiment 7.

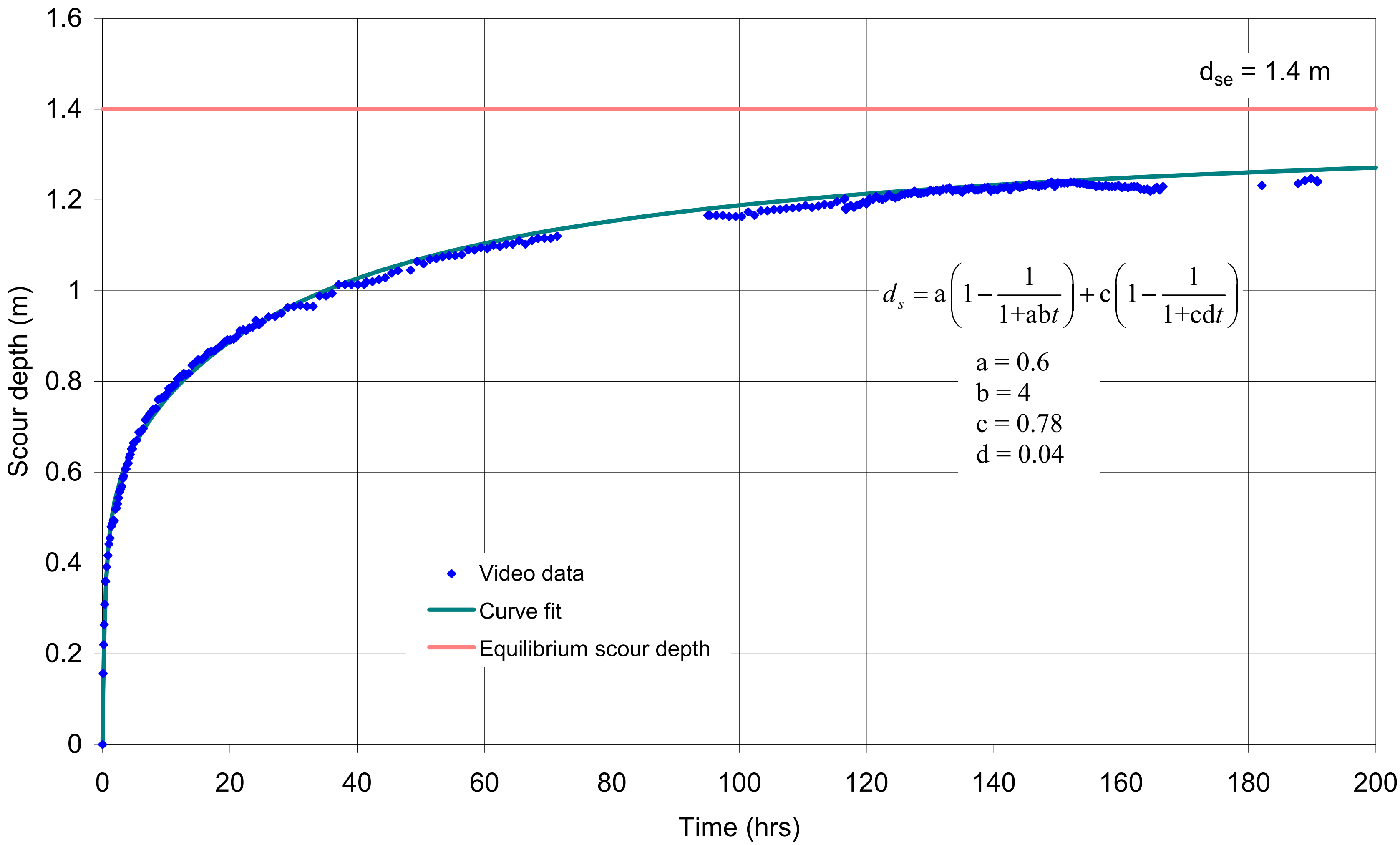

Figure C- 66. Curve fit to the local scour data measured with the internal video cameras for experiment 7.

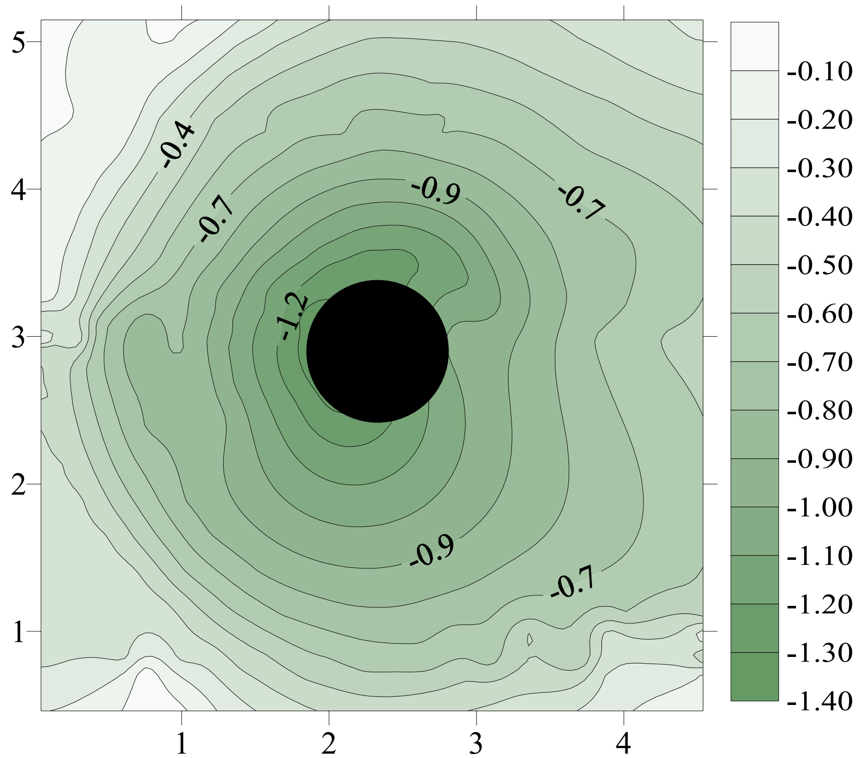

Figure C- 67. Bed elevation contours at completion of experiment 7 referenced to the original bed. All dimensions are in meters.

Table C- 7. The rate of scour depth from the internal video camera for experiment 7.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0.0	0.019	-0.010	6.7	0.699	0.705	22.6	0.904	0.902
0.1	0.152	0.146	7.1	0.705	0.711	23.1	0.915	0.908
0.2	0.216	0.210	7.4	0.708	0.718	23.6	0.921	0.910
0.3	0.267	0.254	7.7	0.724	0.724	24.1	0.922	0.925
0.4	0.305	0.299	8.1	0.729	0.729	24.6	0.927	0.915
0.4	0.399	0.349	8.4	0.737	0.730	25.1	0.932	0.921
0.5	0.362	0.349	8.7	0.743	0.749	26.1	0.938	0.932
0.7	0.396	0.381	9.1	0.755	0.752	27.1	0.935	0.934
0.8	0.419	0.407	9.4	0.749	0.755	28.1	0.953	0.940
1.0	0.445	0.432	9.7	0.756	0.756	29.1	0.955	0.953
1.2	0.457	0.445	10.1	0.775	0.762	30.1	0.959	0.955
1.3	0.470	0.470	10.4	0.775	0.775	31.1	0.959	0.958
1.5	0.476	0.476	10.7	0.777	0.775	32.1	0.968	0.955
1.7	0.495	0.484	11.1	0.780	0.780	33.1	0.981	0.955
1.9	0.499	0.483	11.4	0.783	0.783	34.1	0.985	0.978
2.0	0.508	0.508	11.7	0.794	0.795	35.1	0.983	0.978
2.2	0.523	0.511	12.1	0.800	0.800	36.1	0.997	0.985
2.4	0.527	0.521	12.4	0.800	0.800	37.1	1.004	1.004
2.5	0.546	0.534	12.7	0.808	0.808	38.1	1.004	1.004
2.7	0.553	0.546	13.1	0.807	0.805	39.1	1.004	1.004
2.9	0.553	0.553	13.6	0.813	0.808	40.1	1.004	1.004
3.0	0.572	0.559	14.1	0.826	0.826	41.1	1.004	1.004
3.2	0.578	0.577	14.6	0.832	0.832	41.4	1.023	1.010
3.4	0.584	0.582	15.1	0.838	0.838	42.4	1.029	1.010
3.5	0.597	0.597	15.6	0.845	0.838	43.4	1.029	1.015
3.7	0.597	0.597	16.1	0.851	0.845	44.4	1.024	1.019
3.9	0.610	0.607	16.6	0.856	0.854	45.4	1.035	1.029
4.0	0.610	0.610	17.1	0.864	0.856	46.4	1.042	1.034
4.2	0.616	0.622	17.6	0.871	0.857	48.4	1.049	1.035
4.4	0.629	0.629	18.1	0.877	0.864	49.4	1.057	1.054
4.5	0.629	0.642	18.6	0.877	0.869	50.4	1.059	1.049
4.7	0.634	0.642	19.1	0.882	0.877	51.4	1.067	1.059
4.9	0.648	0.654	19.6	0.884	0.882	52.4	1.067	1.061
5.0	0.648	0.657	20.1	0.889	0.882	53.4	1.067	1.065
5.4	0.661	0.661	20.6	0.902	0.883	54.4	1.070	1.067
5.7	0.678	0.678	21.1	0.902	0.889	55.4	1.080	1.067
6.0	0.686	0.680	21.6	0.902	0.902	56.4	1.085	1.070
6.4	0.686	0.686	22.1	0.904	0.904	57.4	1.085	1.080

Table C-7 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
58.4	1.082	1.080	116.6	1.192	1.193	134.0	1.214	1.212
59.4	1.087	1.085	116.7	1.169	1.171	134.5	1.207	1.212
60.4	1.092	1.082	116.8	1.166	1.169	135.0	1.207	1.207
61.4	1.098	1.090	116.8	1.169	1.173	135.5	1.207	1.214
62.4	1.100	1.087	117.0	1.169	1.174	136.0	1.207	1.214
63.4	1.105	1.092	117.5	1.173	1.178	136.5	1.207	1.217
64.4	1.105	1.092	118.0	1.174	1.174	137.0	1.207	1.212
65.4	1.108	1.100	118.5	1.171	1.179	137.5	1.207	1.212
66.4	1.105	1.092	119.0	1.174	1.180	138.0	1.207	1.214
67.4	1.110	1.100	119.5	1.179	1.185	138.5	1.207	1.217
68.4	1.110	1.105	120.0	1.179	1.181	139.0	1.209	1.218
69.4	1.112	1.105	120.5	1.189	1.193	139.5	1.179	1.209
70.4	1.112	1.105	121.0	1.193	1.192	140.0	1.209	1.213
71.4	1.118	1.110	121.5	1.194	1.198	140.5	1.207	1.212
95.1	1.148	1.156	122.0	1.194	1.193	141.0	1.212	1.217
95.4	1.153	1.156	122.5	1.181	1.192	141.5	1.209	1.217
96.4	1.146	1.156	123.0	1.181	1.194	142.0	1.207	1.220
97.4	1.153	1.156	123.5	1.189	1.202	142.5	1.207	1.212
98.4	1.150	1.153	124.0	1.193	1.197	143.1	1.214	1.220
99.4	1.150	1.153	124.5	1.186	1.194	143.5	1.220	1.222
100.4	1.151	1.153	125.0	1.192	1.197	144.1	1.218	1.217
101.4	1.156	1.164	125.5	1.197	1.202	144.6	1.217	1.220
102.4	1.156	1.156	126.0	1.199	1.203	145.1	1.218	1.222
103.4	1.153	1.166	126.5	1.197	1.204	145.6	1.220	1.225
104.4	1.161	1.166	127.0	1.202	1.204	146.1	1.217	1.222
105.4	1.156	1.169	127.5	1.206	1.209	146.6	1.220	1.222
106.4	1.169	1.169	128.0	1.203	1.204	147.1	1.220	1.220
107.4	1.166	1.171	128.5	1.202	1.204	147.6	1.220	1.222
108.4	1.164	1.173	129.0	1.202	1.206	148.1	1.218	1.222
109.4	1.174	1.174	129.5	1.204	1.207	148.6	1.225	1.227
110.4	1.166	1.178	130.0	1.206	1.212	149.1	1.227	1.230
111.4	1.169	1.174	130.5	1.204	1.209	149.6	1.222	1.220
112.4	1.169	1.176	131.0	1.204	1.212	150.1	1.222	1.228
113.4	1.175	1.180	131.5	1.212	1.209	150.6	1.220	1.227
114.4	1.174	1.179	132.0	1.204	1.214	151.1	1.222	1.227
115.4	1.174	1.186	132.5	1.204	1.214	151.6	1.227	1.227
116.5	1.184	1.192	133.0	1.207	1.217	152.1	1.222	1.230
116.5	1.186	1.192	133.5	1.207	1.209	152.6	1.226	1.230

Table C-7 (continued)

Time (hrs)	East camera (m)	West camera (m)
153.1	1.220	1.227
153.6	1.217	1.226
154.1	1.217	1.226
154.6	1.220	1.225
155.1	1.217	1.223
155.6	1.214	1.223
156.1	1.217	1.220
156.6	1.217	1.222
157.1	1.217	1.220
157.6	1.214	1.222
158.1	1.214	1.220
158.6	1.212	1.220
159.1	1.214	1.220
159.6	1.214	1.222
160.1	1.212	1.217
160.6	1.214	1.220
161.1	1.214	1.217
161.6	1.217	1.220
162.1	1.212	1.220
162.6	1.214	1.220
163.1	1.209	1.214
163.6	1.204	1.213
164.1	1.212	1.214
164.6	1.209	1.209
165.1	1.207	1.212
165.6	1.212	1.218
166.1	1.214	1.212
166.6	1.212	1.220
182.1	1.214	1.222
187.8	1.225	1.226
188.9	1.228	1.232
189.9	1.232	1.237
190.8	1.232	1.232
190.9	1.232	1.230

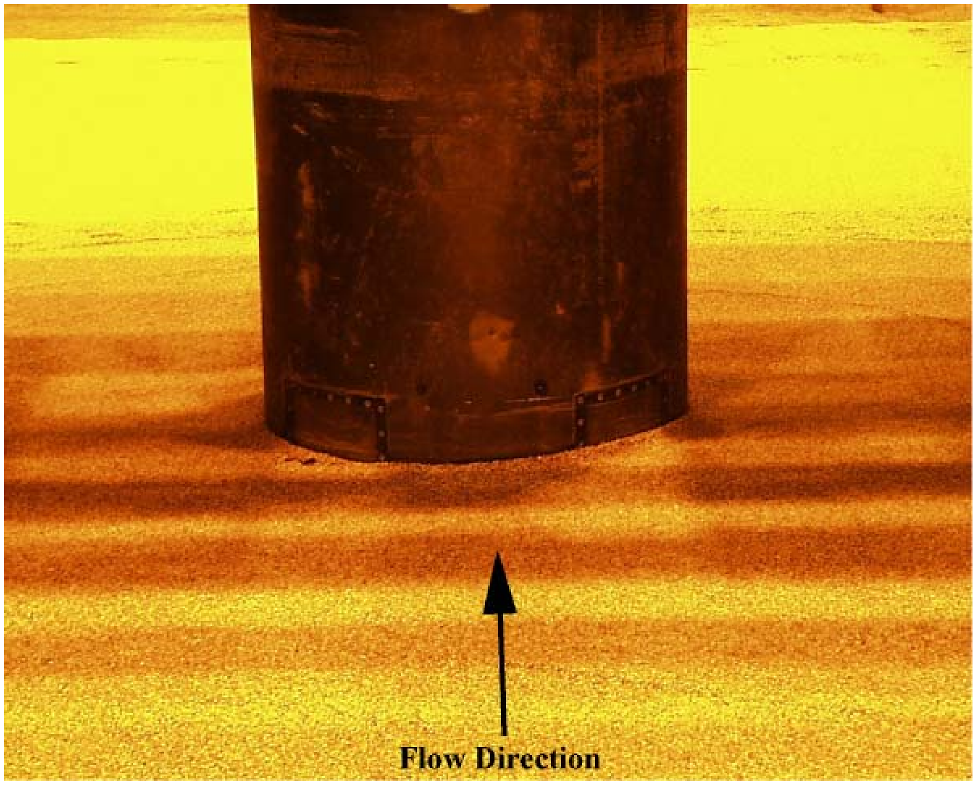

Figure C- 68. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) before test.

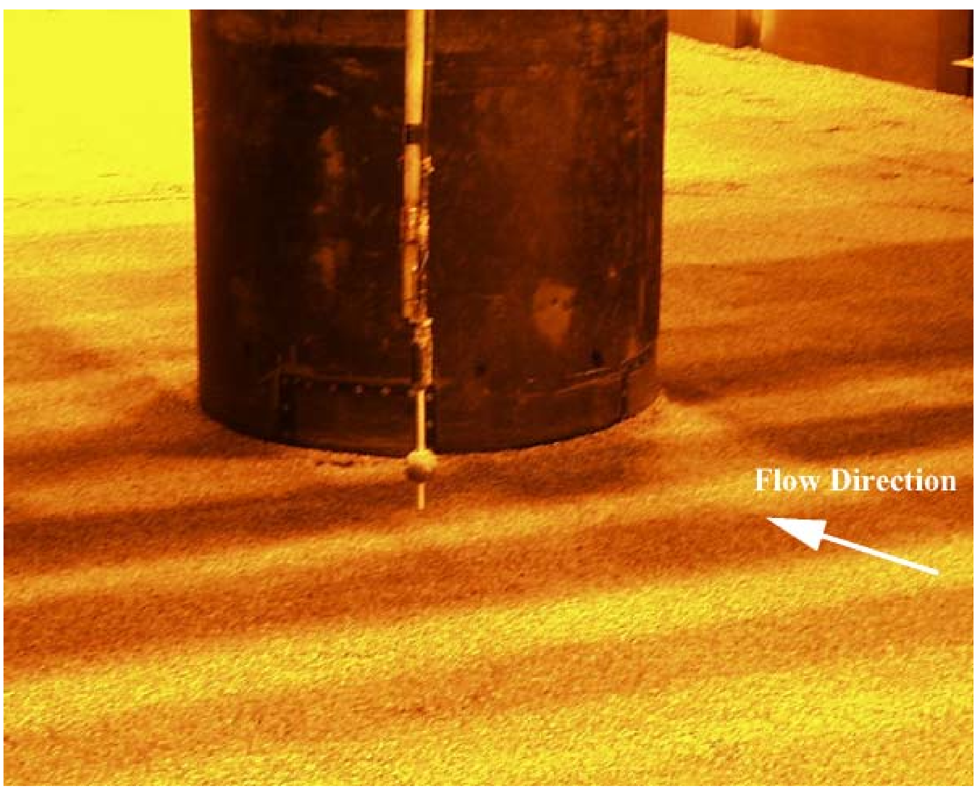

Figure C- 69. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) before test.

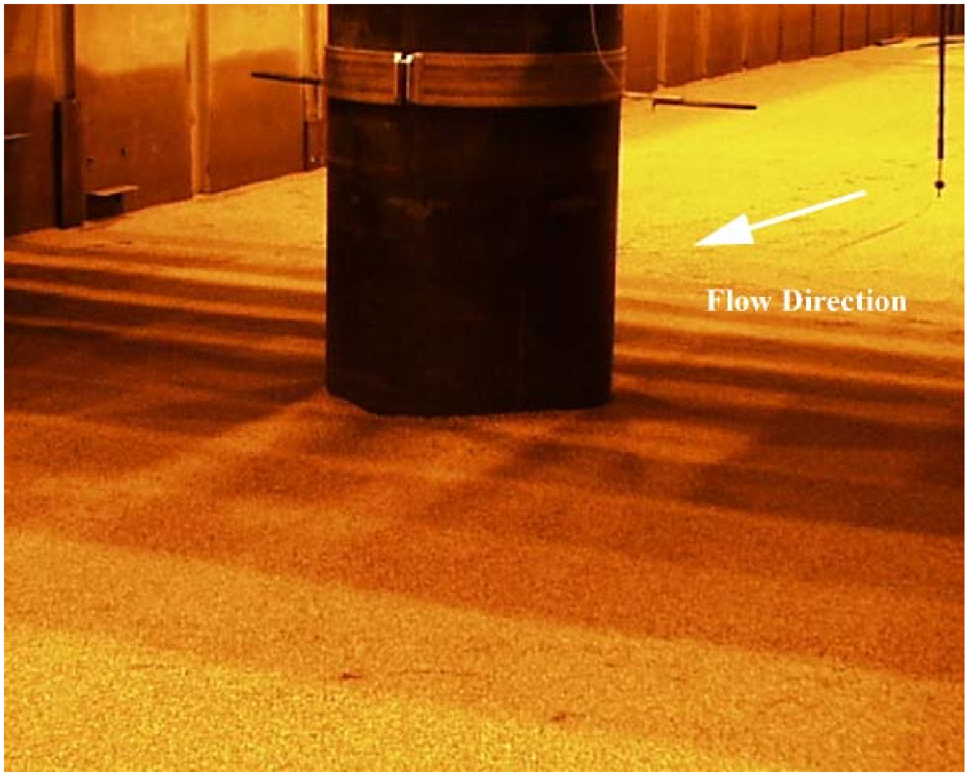

Figure C- 70. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) before test.

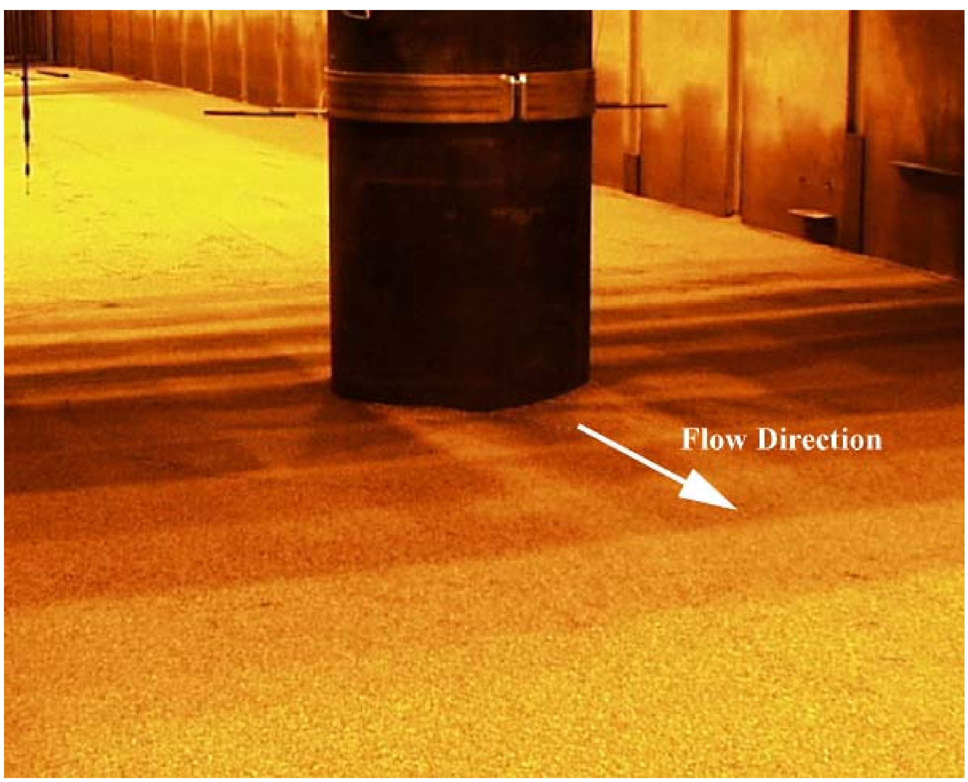

Figure C- 71. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) before test.

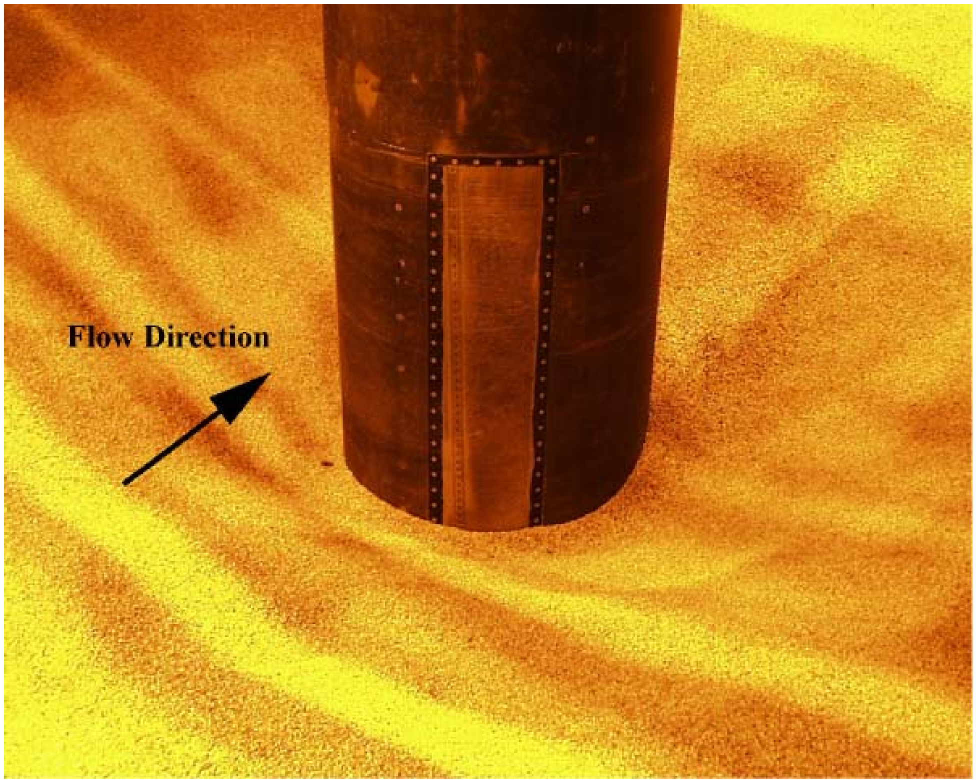

Figure C- 72. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) after test.

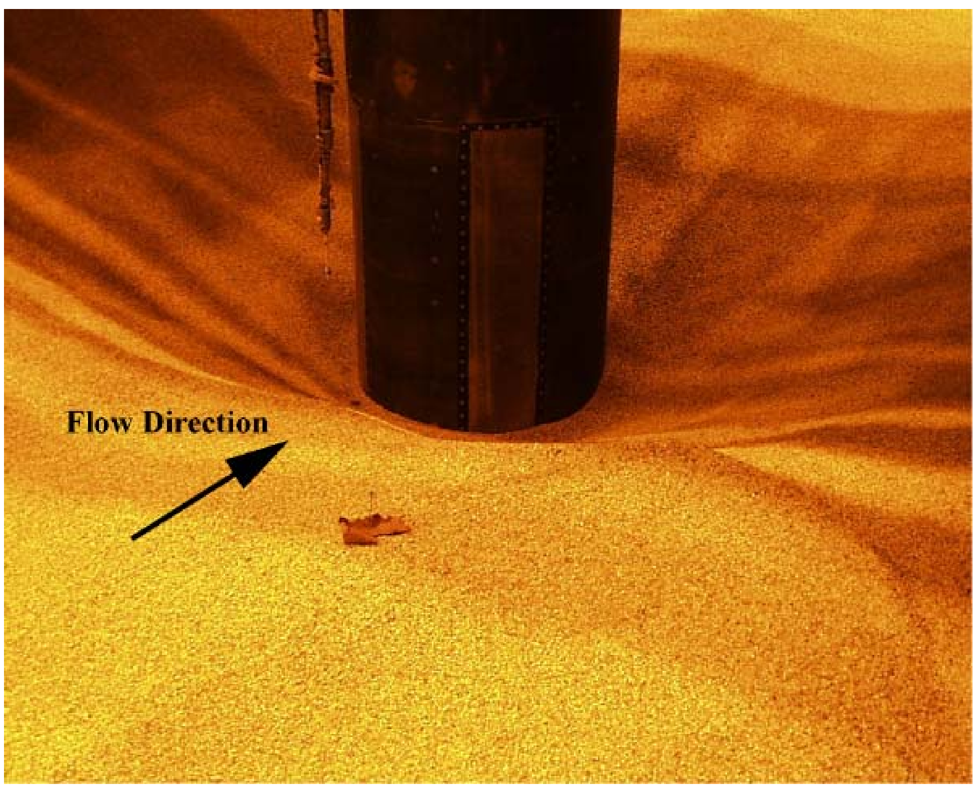

Figure C- 73. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) after test.

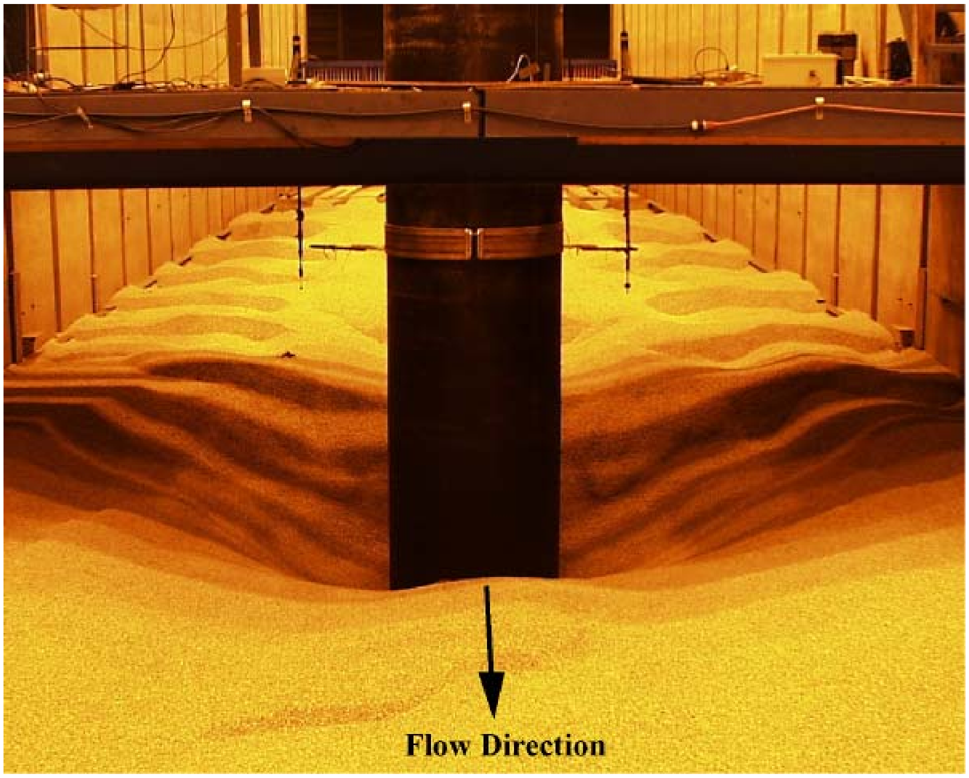

Figure C- 74. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) after test.

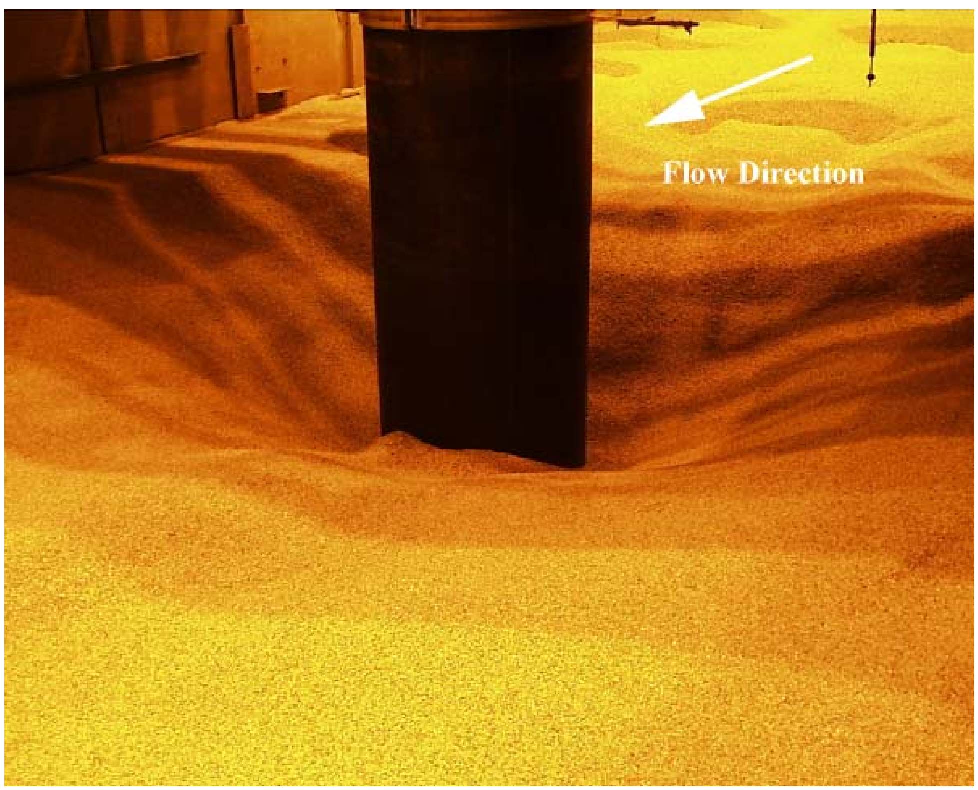

Figure C- 75. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) after test.

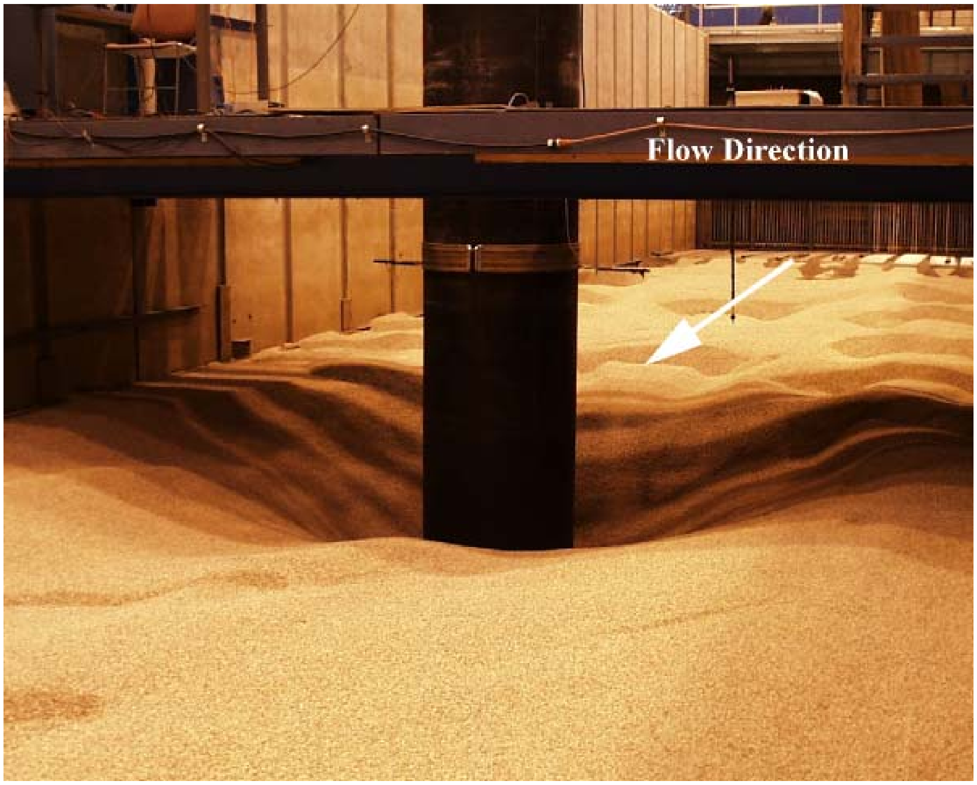

Figure C- 76. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) after test.

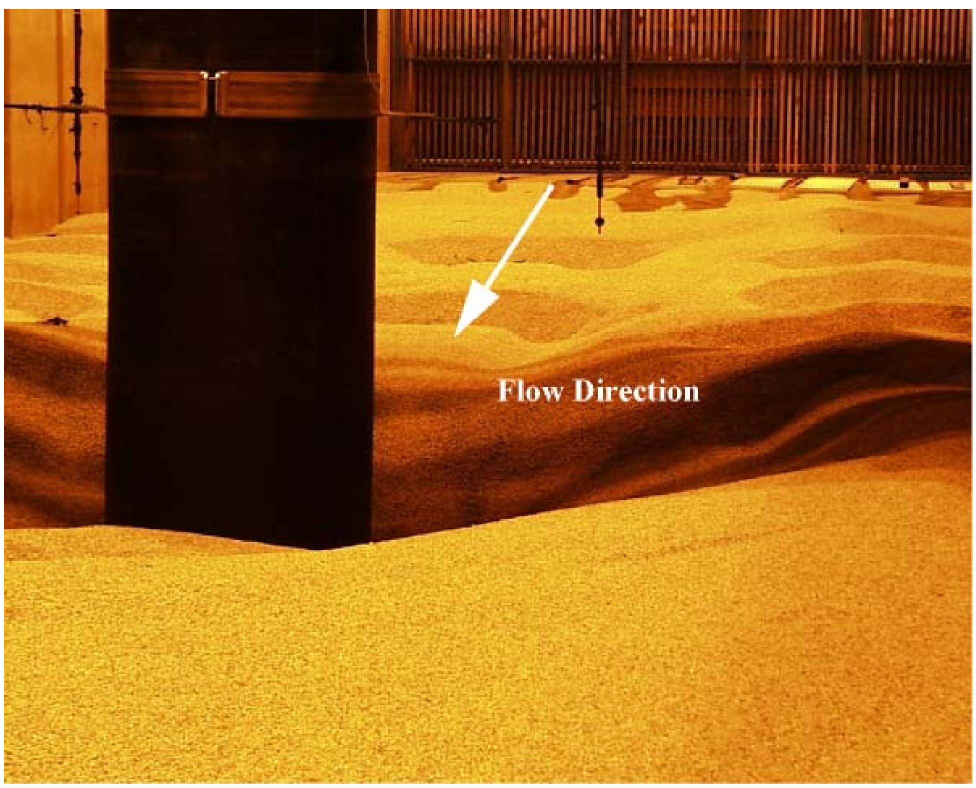

Figure C- 77. Experiment 7 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Experiment 8
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**02/14/2000**	Start Time:	**1:07 PM**
D_{50}(mm):	**2.90**	Stop Date:	**02/28/2000**	Stop Time:	**7:17 AM**
σ:	1.21				
ρ_s (Kg/m^3):	**2650**	Duration:	**330 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.68**	**0.61**
Maximum(m/s):	**0.72**	**0.74**
Minimum(m/s):	**0.54**	**0.57**

Channel average velocity from weir (m/s): **0.60**

Critical (sediment) velocity, V_c (m/s): **0.76**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **0.56**
- Minimum(m): **0.54**
- Maximum(m): **0.57**

Water Temperature:
- Average (degrees C): **1.8**
- Maximum (degrees C): **2.7**
- Minimum (degrees C): **1.0**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.988**
- Maximum depth from internal video cameras (m): **1.023**
- Maximum depth from point gauge (m):
- Maximum scour depth (m): **1.058**

Dimensionless Parameters:

y_0/D: **0.6** V/V_c: **0.85** D/D_{50}: **316**

d_s/D: **1.16**

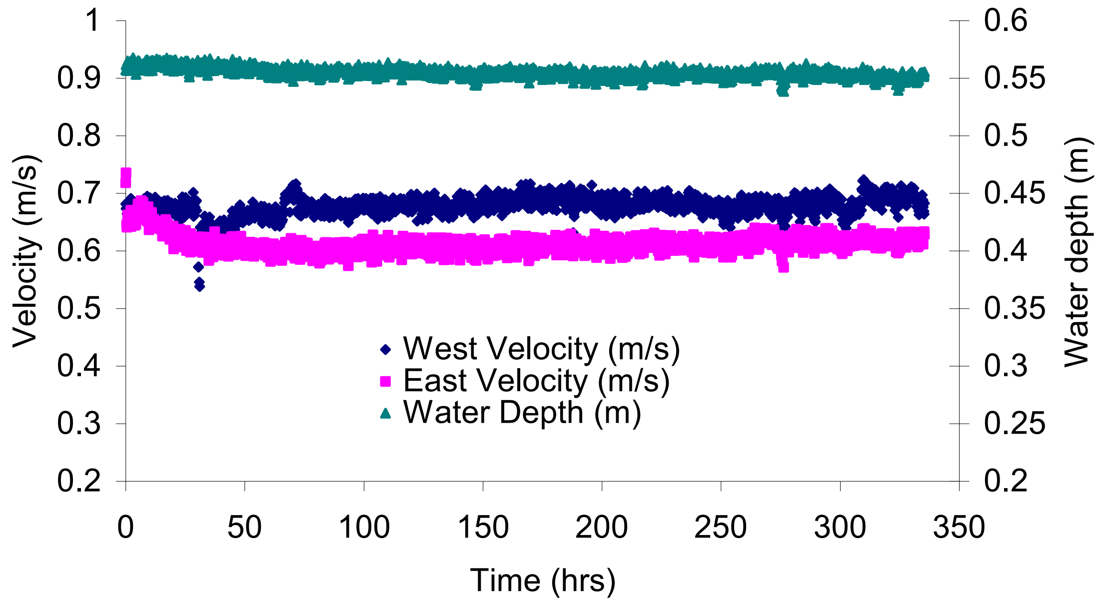

Figure C- 78. Measured velocity and water depth for experiment 8.

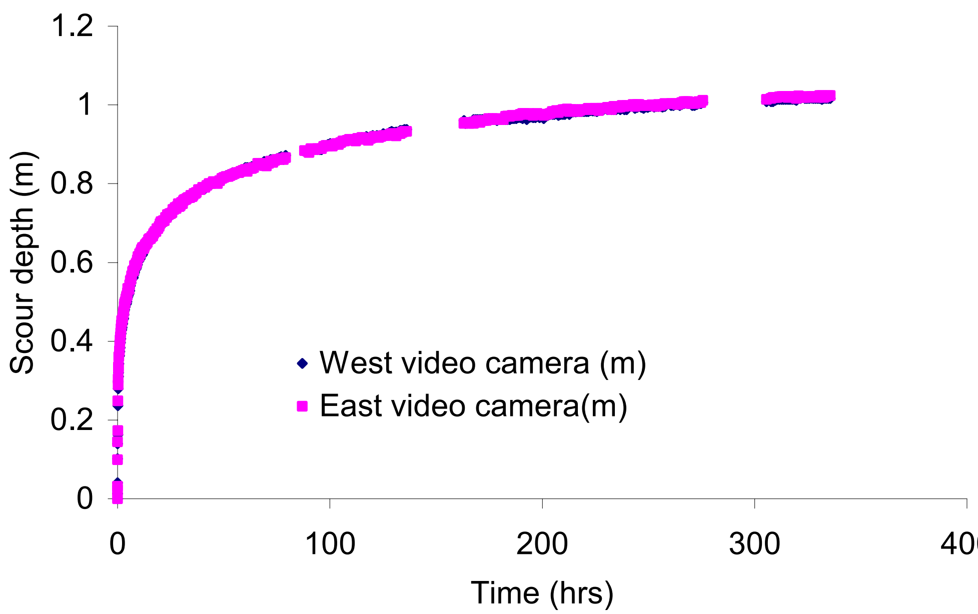

Figure C- 79. Measured local scour data from the internal video camera for experiment 8.

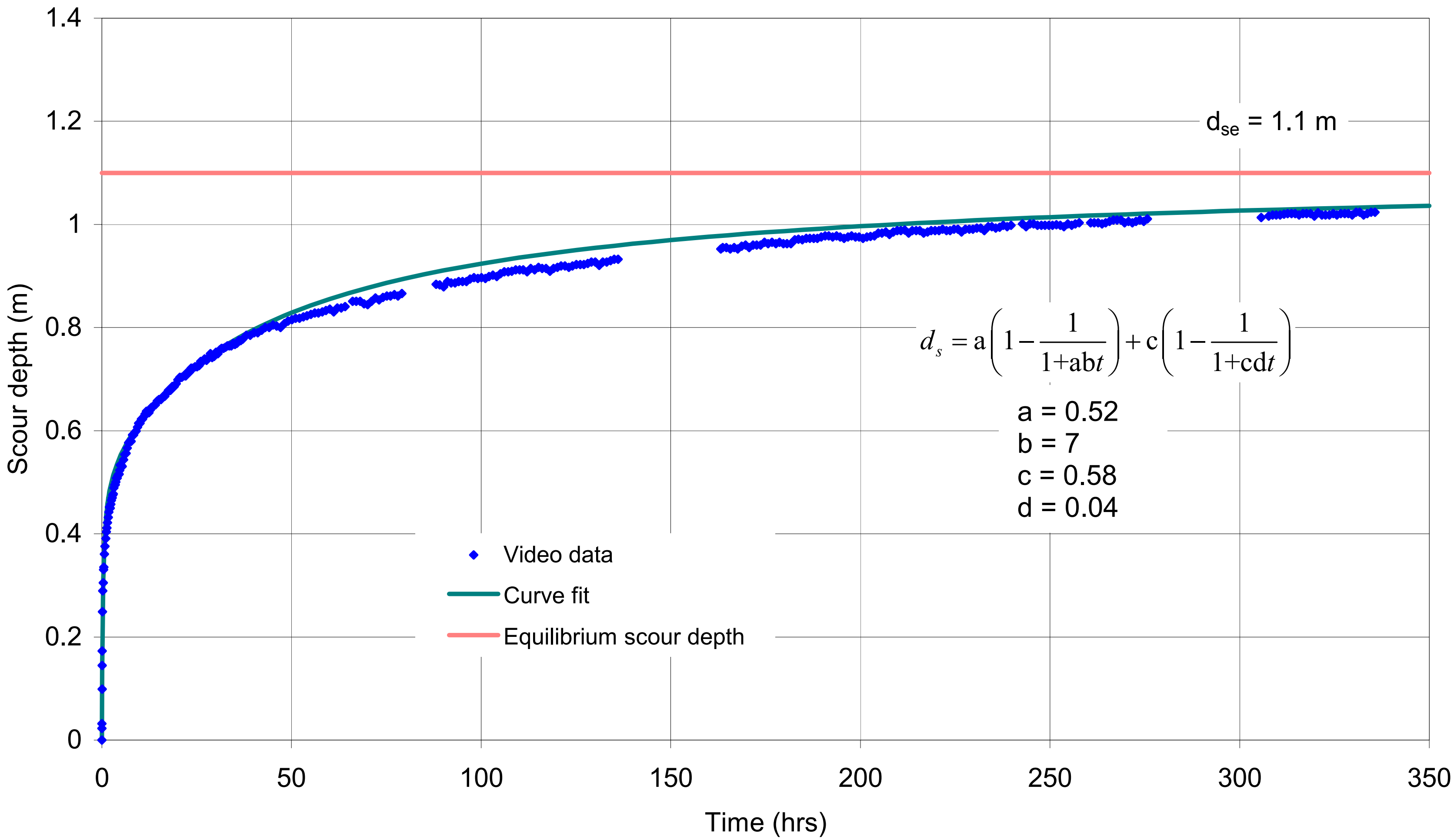

Figure C- 80. Curve fit to the local scour data measured with the acoustic transponder data for experiment 8.

Table C-8. The rate of scour depth from the internal video cameras for experiment 8.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0.0	0.0	0.0	5.4	0.521	0.531	20.6	0.696	0.704
0.0	0.013	0.023	5.7	0.528	0.544	21.1	0.696	0.704
0.0	0.041	0.032	6.0	0.541	0.554	21.6	0.701	0.706
0.1	0.102	0.099	6.4	0.549	0.556	22.1	0.704	0.706
0.1	0.140	0.145	6.7	0.556	0.567	22.6	0.709	0.714
0.1	0.163	0.173	7.0	0.561	0.577	23.1	0.709	0.714
0.2	0.236	0.249	7.4	0.561	0.579	23.6	0.711	0.722
0.3	0.279	0.290	7.7	0.569	0.579	24.1	0.714	0.722
0.3	0.297	0.305	8.1	0.574	0.592	24.6	0.722	0.724
0.4	0.310	0.330	8.4	0.582	0.592	25.1	0.722	0.724
0.5	0.320	0.335	8.7	0.584	0.597	25.6	0.729	0.727
0.7	0.343	0.361	9.1	0.589	0.600	26.1	0.729	0.734
0.8	0.363	0.376	9.4	0.595	0.607	26.6	0.729	0.734
1.0	0.373	0.391	9.7	0.602	0.615	27.1	0.732	0.739
1.2	0.384	0.404	10.1	0.605	0.615	27.6	0.734	0.737
1.3	0.396	0.412	10.4	0.610	0.622	28.1	0.737	0.742
1.5	0.407	0.422	10.7	0.610	0.622	28.6	0.741	0.749
1.7	0.419	0.432	11.1	0.617	0.628	29.1	0.741	0.742
1.8	0.429	0.442	11.4	0.617	0.633	29.6	0.747	0.744
2.0	0.429	0.452	11.7	0.620	0.638	30.1	0.747	0.752
2.2	0.434	0.450	12.1	0.630	0.635	30.6	0.747	0.749
2.4	0.445	0.457	12.4	0.635	0.635	31.1	0.752	0.757
2.5	0.455	0.465	12.7	0.638	0.640	31.6	0.755	0.760
2.7	0.460	0.470	13.1	0.645	0.645	32.1	0.755	0.760
2.9	0.457	0.475	13.6	0.650	0.648	32.6	0.757	0.762
3.0	0.467	0.478	14.1	0.655	0.650	33.1	0.760	0.765
3.2	0.478	0.489	14.6	0.655	0.658	33.6	0.766	0.765
3.4	0.480	0.495	15.1	0.661	0.661	34.1	0.766	0.765
3.5	0.488	0.495	15.6	0.661	0.661	34.6	0.770	0.770
3.7	0.488	0.501	16.1	0.671	0.666	35.1	0.765	0.767
3.9	0.493	0.508	16.6	0.677	0.667	35.6	0.772	0.770
4.0	0.495	0.508	17.1	0.681	0.673	36.1	0.775	0.775
4.2	0.495	0.513	17.6	0.683	0.678	36.6	0.775	0.775
4.4	0.501	0.516	18.1	0.678	0.678	37.1	0.777	0.777
4.5	0.508	0.516	18.6	0.681	0.686	38.1	0.780	0.785
4.7	0.511	0.523	19.1	0.681	0.686	39.1	0.785	0.785
4.9	0.513	0.534	19.6	0.686	0.691	40.1	0.790	0.790
5.0	0.516	0.534	20.1	0.690	0.699	41.1	0.788	0.790

Table C-8 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
42.1	0.795	0.795	89.1	0.884	0.883	127.1	0.927	0.922
43.1	0.798	0.800	90.1	0.884	0.879	128.1	0.930	0.925
44.1	0.798	0.800	91.1	0.887	0.889	129.1	0.932	0.927
45.1	0.803	0.805	92.1	0.887	0.887	130.1	0.930	0.927
46.1	0.803	0.803	93.1	0.887	0.887	131.1	0.931	0.921
47.1	0.803	0.800	94.1	0.887	0.889	132.1	0.931	0.927
48.1	0.810	0.808	95.1	0.887	0.889	133.1	0.935	0.927
49.1	0.816	0.813	96.1	0.887	0.889	134.1	0.935	0.930
50.1	0.817	0.816	97.1	0.897	0.894	135.1	0.938	0.932
51.1	0.821	0.818	98.1	0.897	0.897	136.1	0.938	0.932
52.1	0.823	0.818	99.1	0.899	0.896	163.2	0.960	0.953
53.1	0.823	0.821	100.1	0.902	0.897	163.7	0.953	0.955
54.1	0.828	0.823	101.1	0.899	0.896	164.7	0.955	0.955
55.1	0.828	0.826	102.1	0.897	0.899	165.7	0.957	0.953
56.1	0.828	0.828	103.1	0.902	0.902	166.7	0.955	0.955
57.1	0.831	0.828	104.1	0.904	0.899	167.7	0.963	0.953
58.1	0.831	0.831	105.1	0.904	0.904	168.7	0.963	0.958
59.1	0.836	0.833	106.1	0.907	0.908	169.7	0.963	0.960
60.1	0.841	0.836	107.1	0.907	0.908	170.7	0.963	0.955
61.1	0.841	0.831	108.1	0.910	0.910	171.7	0.963	0.960
62.1	0.841	0.838	109.1	0.912	0.912	172.7	0.963	0.960
63.1	0.843	0.838	110.1	0.910	0.912	173.7	0.963	0.960
64.1	0.843	0.841	111.1	0.910	0.912	174.7	0.965	0.965
66.1	0.849	0.851	112.1	0.912	0.908	175.7	0.963	0.963
67.1	0.851	0.851	113.1	0.912	0.915	176.7	0.963	0.965
68.1	0.851	0.851	114.1	0.912	0.912	177.7	0.963	0.963
69.1	0.856	0.846	115.1	0.917	0.917	178.7	0.960	0.965
70.1	0.856	0.845	116.1	0.915	0.915	179.7	0.963	0.963
71.1	0.856	0.851	117.1	0.920	0.915	180.7	0.963	0.963
72.1	0.861	0.857	118.1	0.917	0.910	181.7	0.963	0.963
73.1	0.861	0.854	119.1	0.920	0.915	182.7	0.963	0.971
74.1	0.861	0.859	120.1	0.922	0.917	183.7	0.963	0.972
75.1	0.864	0.861	121.1	0.920	0.920	184.7	0.963	0.971
76.1	0.866	0.861	122.1	0.922	0.920	185.7	0.965	0.973
77.1	0.869	0.864	123.1	0.920	0.917	186.7	0.965	0.973
78.1	0.861	0.861	124.1	0.922	0.920	187.7	0.965	0.973
79.1	0.871	0.866	125.1	0.927	0.922	188.7	0.968	0.973
88.1	0.882	0.884	126.1	0.925	0.922	189.7	0.968	0.976

Table C-8 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
190.7	0.965	0.978	228.7	0.988	0.991	270.7	0.998	1.006
191.7	0.968	0.978	229.7	0.991	0.991	271.7	0.998	1.004
192.7	0.963	0.976	230.7	0.988	0.993	272.7	1.001	1.006
193.7	0.968	0.978	231.7	0.990	0.993	273.7	1.004	1.009
194.7	0.969	0.976	232.7	0.988	0.988	274.7	1.004	1.006
195.7	0.968	0.973	233.7	0.988	0.996	275.7	1.006	1.011
196.7	0.968	0.976	234.7	0.988	0.996	305.7	1.009	1.014
197.7	0.971	0.978	235.7	0.991	0.993	307.7	1.009	1.016
198.7	0.968	0.976	236.7	0.988	0.995	308.7	1.009	1.019
199.7	0.971	0.976	237.7	0.991	0.998	309.7	1.011	1.019
200.7	0.965	0.973	238.7	0.988	0.996	310.7	1.014	1.019
201.7	0.971	0.976	239.7	0.988	0.998	311.7	1.014	1.020
202.7	0.973	0.977	242.7	0.996	1.001	312.7	1.014	1.021
203.7	0.976	0.978	243.7	0.991	0.996	313.7	1.014	1.021
204.7	0.976	0.983	244.7	0.993	1.001	314.7	1.014	1.021
205.7	0.976	0.983	245.7	0.996	1.001	315.7	1.014	1.019
206.7	0.978	0.986	246.7	0.993	0.998	316.7	1.014	1.021
207.7	0.973	0.981	247.7	0.991	0.998	317.7	1.014	1.021
208.7	0.976	0.986	248.7	0.995	0.998	318.7	1.014	1.021
209.7	0.976	0.988	249.7	0.993	0.998	319.7	1.011	1.016
210.7	0.976	0.988	250.7	0.996	0.998	320.7	1.016	1.023
211.7	0.981	0.990	251.7	0.998	1.000	321.7	1.016	1.019
212.7	0.976	0.983	252.7	0.995	0.998	322.7	1.019	1.019
213.7	0.981	0.988	253.7	0.996	0.996	323.7	1.016	1.019
214.7	0.982	0.988	254.7	0.996	1.001	324.7	1.016	1.021
215.7	0.982	0.988	255.7	0.996	0.998	325.7	1.016	1.019
216.7	0.983	0.983	256.7	0.995	1.001	326.7	1.018	1.021
217.7	0.983	0.986	257.7	0.996	1.004	327.7	1.016	1.021
218.7	0.983	0.988	260.7	0.998	1.004	328.7	1.016	1.021
219.7	0.983	0.988	261.7	0.998	1.004	329.7	1.016	1.019
220.7	0.983	0.988	262.7	1.001	1.004	330.7	1.016	1.024
221.7	0.983	0.991	263.7	1.001	1.001	331.7	1.014	1.024
222.7	0.986	0.988	264.7	0.998	1.004	332.7	1.016	1.019
223.7	0.985	0.988	265.7	1.001	1.006	333.7	1.016	1.021
224.7	0.985	0.991	266.7	1.004	1.009	334.7	1.016	1.024
225.7	0.983	0.991	267.7	1.006	1.009	335.7	1.016	1.024
226.7	0.986	0.986	268.7	1.004	1.009			
227.7	0.988	0.991	269.7	1.004	1.004			

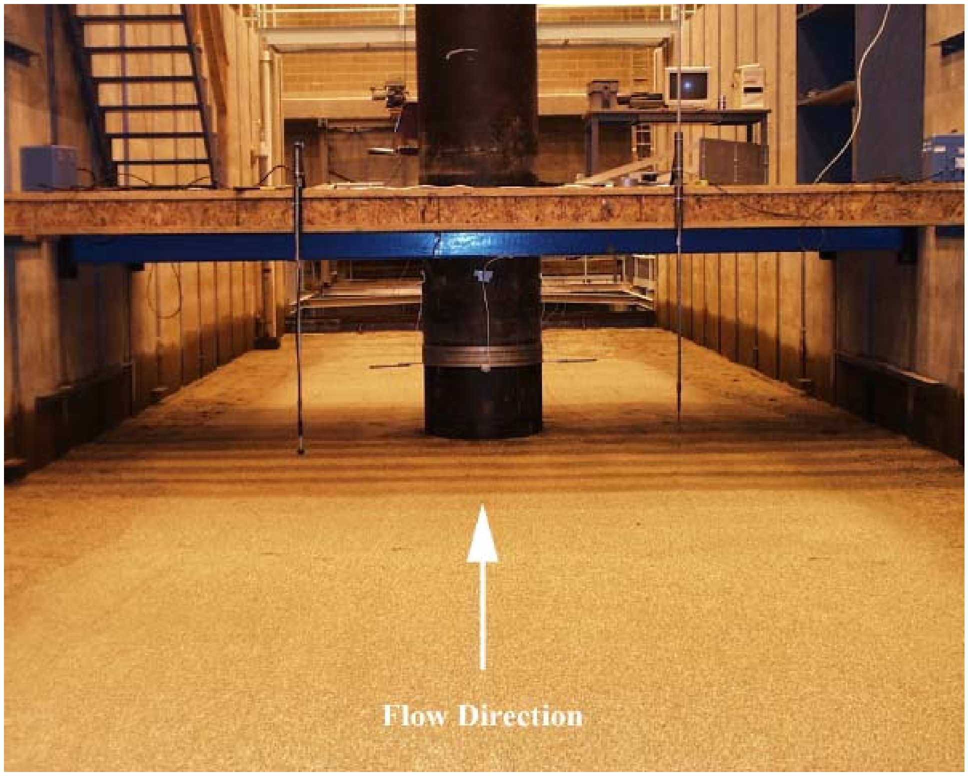

Figure C- 81. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) before test.

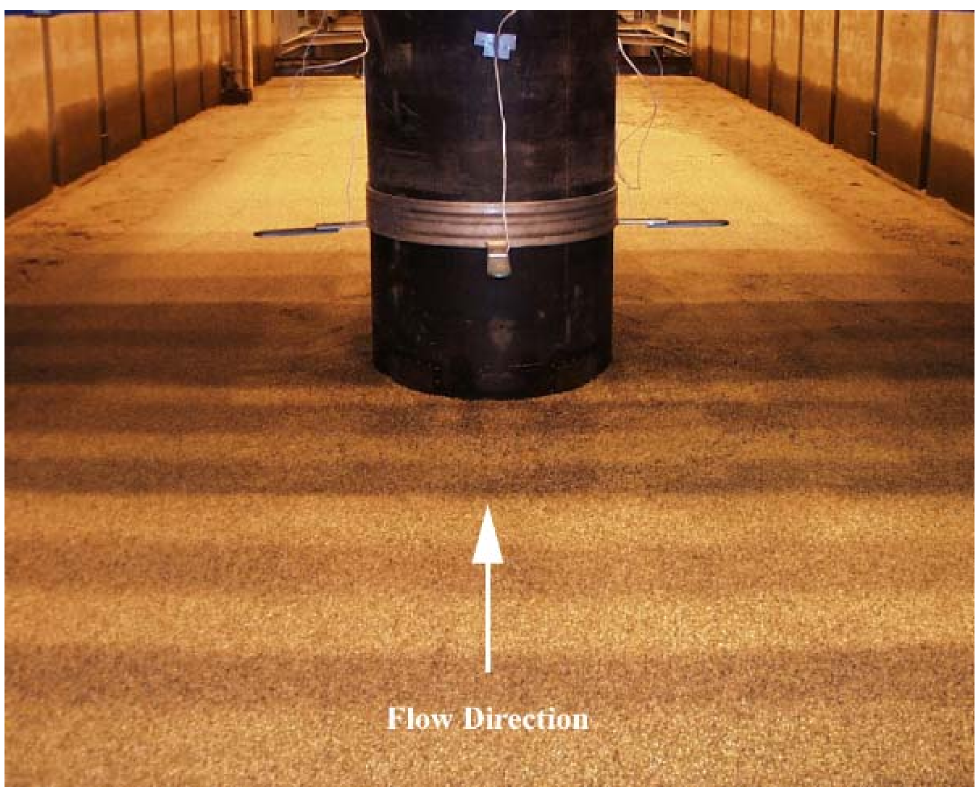

Figure C- 82. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) before test.

Figure C- 83. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) before test.

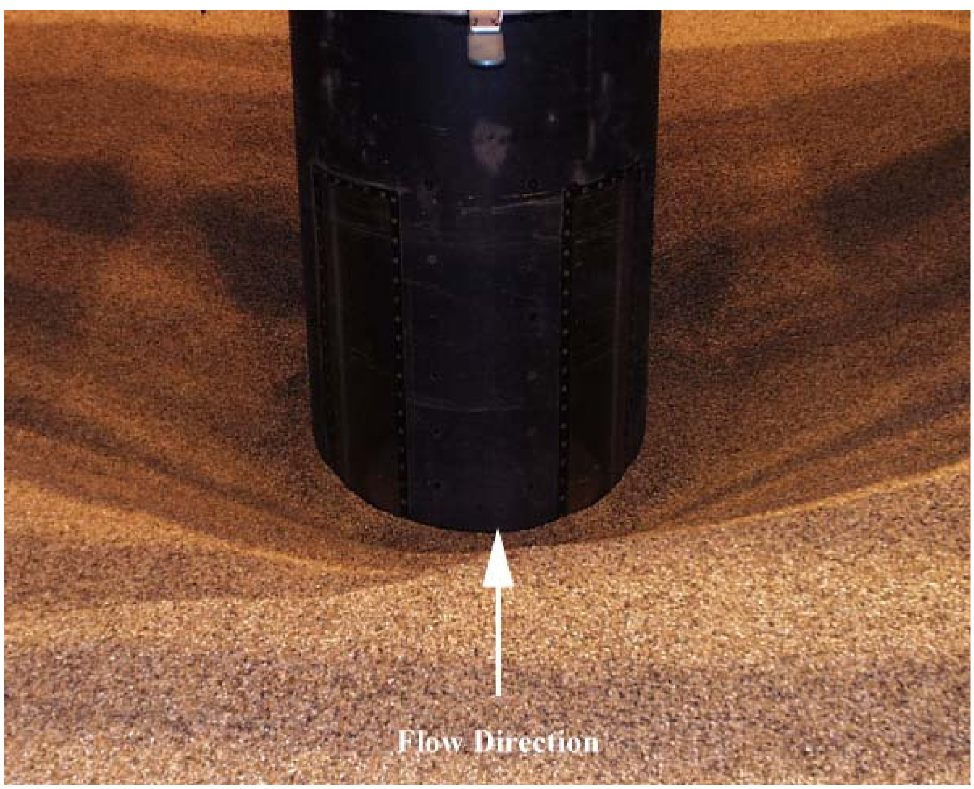

Figure C- 84.   Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 85. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 86. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 87. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 88. Experiment 8 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Experiment 9
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**03/05/2000**	Start Time:	**2:50 PM**
D_{50}(mm):	**2.90**	Stop Date:	**03/24/2000**	Stop Time:	**6:50 AM**
σ:	1.21				
ρ_s (Kg/m^3):	**2650**	Duration:	**448 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):		**0.57**
Maximum(m/s):		**0.60**
Minimum(m/s):		**0.45**

Channel average velocity from weir (m/s): **0.56**

Critical (sediment) velocity, V_c (m/s): **0.69**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **0.29**
- Minimum(m): **0.27**
- Maximum(m): **0.31**

Water Temperature:
- Average (degrees C): **3.1**
- Maximum (degrees C): **7.0**
- Minimum (degrees C): **1.0**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.865**
- Maximum depth from internal video cameras (m): **0.896**
- Maximum depth from point gauge (m):
- Maximum scour depth (m): **0.896**

Dimensionless Parameters:

y_0/D: **0.3** V/V_c: **0.79** D/D_{50}: **316**

d_s/D: **0.98**

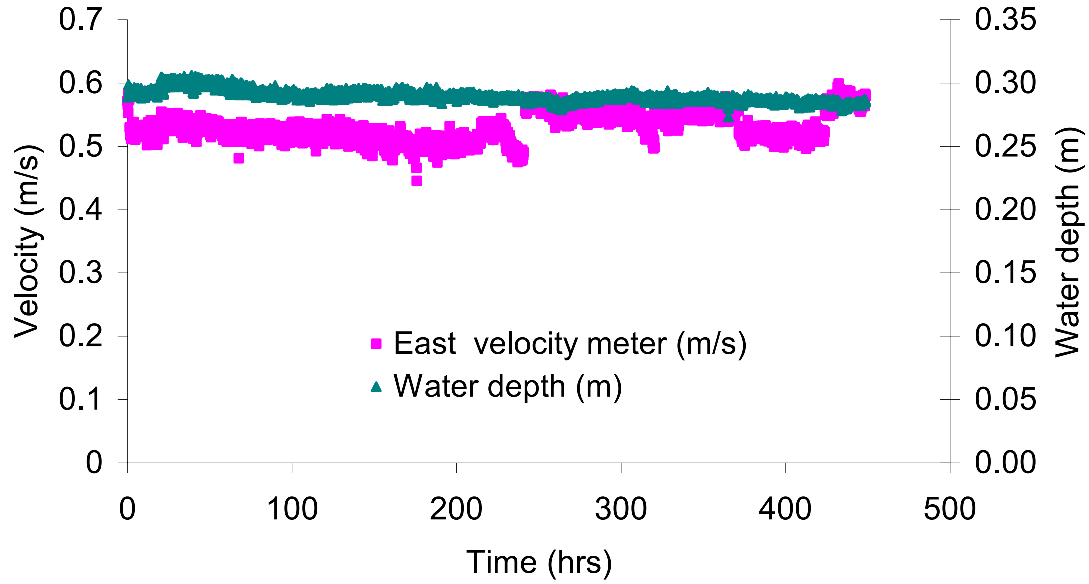

Figure C- 89. Measured velocity and water depth for experiment 9.

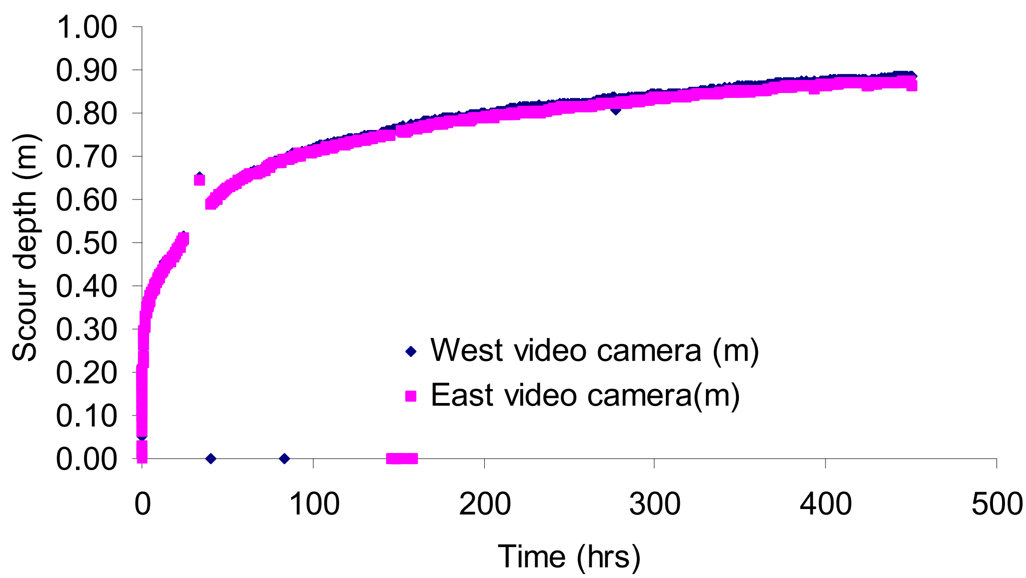

Figure C- 90. Measured local scour data from the internal video camera for experiment 9.

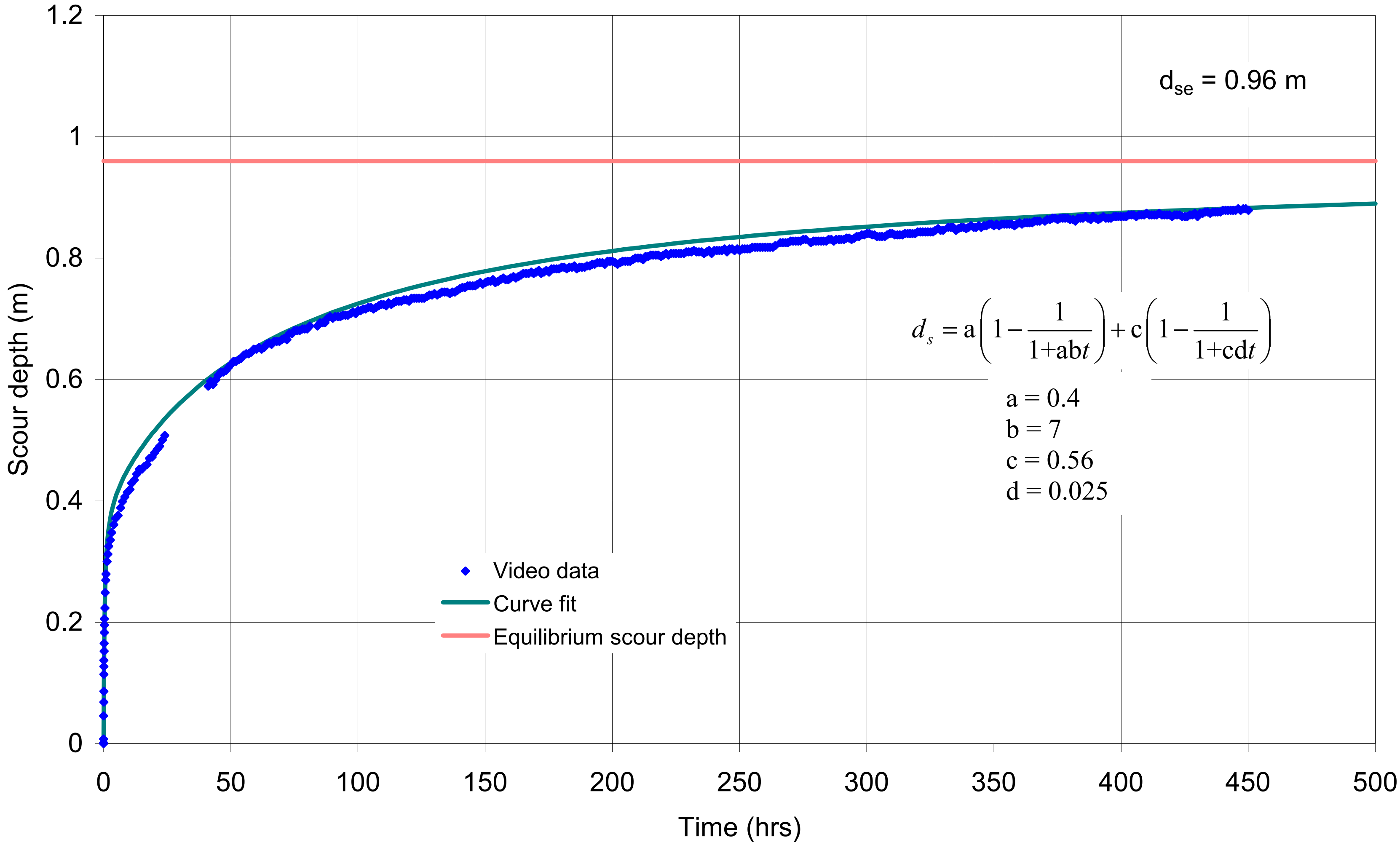

Figure C- 91. Curve fit to the local scour data measured with the internal video cameras for experiment 9.

Table C-9. The rate of scour depth from the internal video cameras for experiment 9.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0.00	0.005	-0.003	2.68	0.340	0.338	13.07	0.450	0.440
0.02	0.006	0.000	2.85	0.343	0.343	13.57	0.455	0.442
0.03	0.013	0.010	3.02	0.348	0.351	14.07	0.457	0.450
0.05	0.051	0.030	3.18	0.353	0.351	14.57	0.457	0.455
0.07	0.074	0.064	3.35	0.353	0.353	15.07	0.457	0.452
0.08	0.091	0.086	3.52	0.356	0.356	15.57	0.460	0.457
0.10	0.028	0.098	3.68	0.356	0.358	16.07	0.462	0.460
0.12	0.119	0.109	3.85	0.358	0.358	16.57	0.462	0.457
0.13	0.132	0.114	4.02	0.366	0.363	17.07	0.465	0.460
0.15	0.142	0.127	4.20	0.368	0.363	17.57	0.470	0.465
0.17	0.150	0.132	4.37	0.371	0.363	18.07	0.475	0.467
0.18	0.158	0.142	4.53	0.373	0.366	18.57	0.475	0.467
0.20	0.163	0.152	4.70	0.376	0.371	19.07	0.478	0.470
0.22	0.170	0.158	4.87	0.376	0.376	19.57	0.483	0.475
0.23	0.175	0.163	5.03	0.376	0.379	20.07	0.485	0.478
0.25	0.178	0.170	5.37	0.381	0.381	20.57	0.485	0.480
0.27	0.188	0.178	5.70	0.381	0.384	21.07	0.490	0.485
0.28	0.188	0.180	6.03	0.389	0.386	21.57	0.493	0.490
0.30	0.193	0.188	6.37	0.386	0.389	22.07	0.495	0.490
0.32	0.201	0.191	6.70	0.394	0.391	22.57	0.501	0.495
0.33	0.203	0.193	7.03	0.396	0.394	23.08	0.506	0.503
0.35	0.208	0.198	7.37	0.404	0.401	23.58	0.508	0.503
0.37	0.211	0.201	7.72	0.404	0.404	24.08	0.513	0.506
0.38	0.213	0.203	8.05	0.407	0.407	24.58	0.516	0.511
0.40	0.211	0.203	8.38	0.412	0.407	40.48	0.000	0.589
0.50	0.229	0.224	8.72	0.412	0.409	41.08	0.595	0.592
0.67	0.254	0.236	9.05	0.417	0.414	42.08	0.602	0.597
0.83	0.274	0.262	9.38	0.419	0.419	43.08	0.597	0.602
1.00	0.285	0.279	9.72	0.422	0.417	44.08	0.605	0.600
1.17	0.292	0.287	10.05	0.424	0.419	45.08	0.612	0.610
1.33	0.305	0.297	10.38	0.424	0.427	46.08	0.617	0.610
1.50	0.313	0.305	10.72	0.432	0.427	47.08	0.617	0.615
1.67	0.318	0.310	11.05	0.434	0.429	48.08	0.620	0.617
1.83	0.323	0.315	11.38	0.434	0.429	49.08	0.625	0.622
2.00	0.330	0.325	11.72	0.437	0.432	50.08	0.630	0.625
2.18	0.333	0.330	12.05	0.440	0.432	51.08	0.635	0.630
2.35	0.338	0.335	12.38	0.442	0.437	52.08	0.635	0.633
2.52	0.338	0.338	12.73	0.447	0.440	53.08	0.638	0.635

Table C-9 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
54.08	0.640	0.638	92.07	0.709	0.706	130.07	0.747	0.737
55.08	0.645	0.638	93.07	0.709	0.701	131.07	0.744	0.737
56.08	0.648	0.643	94.07	0.711	0.706	132.07	0.747	0.739
57.08	0.648	0.645	95.07	0.711	0.709	133.07	0.749	0.739
34.08	0.650	0.645	96.07	0.711	0.709	134.07	0.749	0.742
59.08	0.655	0.648	97.07	0.714	0.709	135.07	0.749	0.742
60.08	0.655	0.650	98.07	0.716	0.711	136.07	0.747	0.744
61.08	0.658	0.650	99.07	0.714	0.709	137.07	0.749	0.744
62.08	0.655	0.655	100.07	0.719	0.711	138.07	0.749	0.744
63.08	0.658	0.658	101.07	0.719	0.711	139.07	0.752	0.744
64.08	0.663	0.658	102.07	0.722	0.711	140.07	0.755	0.747
65.08	0.666	0.661	103.07	0.722	0.714	141.07	0.757	0.747
66.08	0.663	0.661	104.07	0.724	0.714	142.07	0.757	0.747
67.08	0.668	0.661	105.07	0.724	0.716	143.07	0.760	0.749
68.08	0.668	0.663	106.07	0.722	0.714	144.07	0.760	0.749
69.08	0.668	0.663	107.07	0.724	0.716	145.07	0.760	0.749
70.08	0.671	0.666	108.07	0.727	0.722	146.07	0.760	
71.08	0.673	0.668	109.07	0.729	0.722	147.07	0.762	
72.08	0.671	0.668	110.07	0.729	0.722	148.07	0.765	
73.08	0.681	0.673	111.07	0.727	0.719	149.07	0.762	
74.08	0.681	0.678	112.07	0.732	0.722	150.07	0.765	
75.08	0.686	0.673	113.07	0.729	0.724	151.07	0.767	
76.08	0.686	0.681	114.07	0.732	0.724	152.07	0.767	0.760
77.08	0.686	0.683	115.07	0.734	0.724	153.07	0.770	0.757
78.08	0.689	0.683	116.07	0.734	0.727	154.07	0.765	0.757
79.08	0.689	0.683	117.07	0.734	0.727	155.07	0.767	0.760
80.08	0.689	0.686	118.07	0.737	0.729	156.07	0.770	
81.08	0.694	0.686	119.07	0.737	0.727	157.07	0.772	0.762
82.07	0.694	0.691	120.07	0.734	0.729	158.07	0.770	
83.07	0.000	0.691	121.07	0.739	0.729	159.07	0.770	0.762
84.07	0.694	0.691	122.07	0.739	0.732	160.07	0.772	0.762
85.07	0.699	0.694	123.07	0.739	0.734	161.07	0.775	0.765
86.07	0.699	0.694	124.07	0.739	0.734	162.07	0.772	0.767
87.07	0.699	0.696	125.07	0.739	0.734	163.07	0.775	0.767
88.07	0.706	0.696	126.07	0.739	0.737	164.07	0.777	0.767
89.07	0.709	0.699	127.07	0.742	0.737	165.07	0.780	0.770
90.07	0.706	0.699	128.07	0.744	0.737	166.07	0.780	0.770
91.07	0.709	0.699	129.07	0.744	0.737	167.07	0.780	0.767

Table C-9 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
168.07	0.783	0.770	206.07	0.800	0.790	244.07	0.821	0.810
169.07	0.780	0.772	207.07	0.800	0.795	245.07	0.816	0.813
170.07	0.783	0.772	208.07	0.803	0.795	246.07	0.821	0.813
171.07	0.785	0.772	209.07	0.805	0.795	247.07	0.821	0.810
172.07	0.780	0.775	210.07	0.805	0.795	248.07	0.818	0.813
173.07	0.783	0.775	211.07	0.805	0.795	249.07	0.821	0.813
174.07	0.785	0.777	212.07	0.803	0.798	250.07	0.818	0.810
175.07	0.783	0.777	213.07	0.808	0.798	251.07	0.821	0.813
176.07	0.788	0.775	214.07	0.808	0.798	252.07	0.821	0.813
177.07	0.788	0.777	215.07	0.810	0.798	253.07	0.821	0.813
178.07	0.788	0.777	216.07	0.810	0.800	254.07	0.821	0.813
179.07	0.788	0.777	217.07	0.810	0.800	255.07	0.823	0.816
180.07	0.790	0.780	218.07	0.810	0.798	256.07	0.823	0.816
181.07	0.790	0.780	219.07	0.808	0.800	257.07	0.823	0.816
182.07	0.788	0.780	220.07	0.810	0.800	258.07	0.823	0.816
183.07	0.790	0.783	221.07	0.813	0.800	259.07	0.823	0.816
184.07	0.790	0.783	222.07	0.810	0.800	260.07	0.823	0.813
185.07	0.793	0.783	223.07	0.813	0.803	261.07	0.823	0.816
186.07	0.788	0.783	224.07	0.813	0.800	262.07	0.823	0.816
187.07	0.790	0.783	225.07	0.813	0.800	263.07	0.823	0.816
188.07	0.790	0.785	226.07	0.813	0.800	264.07	0.826	0.818
189.07	0.790	0.785	227.07	0.813	0.800	265.05	0.823	0.818
190.07	0.793	0.785	228.07	0.813	0.803	266.05	0.831	0.818
191.07	0.793	0.785	229.07	0.816	0.803	267.05	0.831	0.818
192.07	0.795	0.783	230.07	0.816	0.803	268.05	0.831	0.818
193.07	0.795	0.785	231.07	0.816	0.803	269.05	0.831	0.821
194.07	0.798	0.788	232.07	0.818	0.803	270.05	0.833	0.821
195.07	0.798	0.788	233.07	0.816	0.800	271.05	0.833	0.821
196.07	0.798	0.790	234.07	0.816	0.803	272.05	0.833	0.823
197.07	0.795	0.788	235.07	0.816	0.803	273.05	0.833	0.823
198.07	0.800	0.788	236.07	0.813	0.803	274.05	0.833	0.821
199.07	0.800	0.790	237.07	0.816	0.805	275.05	0.836	0.823
200.07	0.800	0.790	238.07	0.818	0.808	276.05	0.836	0.823
201.07	0.798	0.793	239.07	0.813	0.808	277.05	0.808	0.823
202.07	0.795	0.793	240.07	0.818	0.808	278.05	0.831	0.823
203.07	0.798	0.793	241.07	0.818	0.810	279.05	0.833	0.823
204.07	0.800	0.793	242.07	0.818	0.808	280.05	0.833	0.826
205.07	0.800	0.793	243.07	0.818	0.810	281.05	0.833	0.821

Table C-9 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
282.05	0.833	0.826	320.05	0.849	0.841	359.05	0.861	0.851
283.05	0.833	0.826	321.05	0.849	0.841	360.05	0.864	0.851
284.05	0.833	0.823	322.05	0.849	0.841	361.05	0.861	0.851
285.05	0.836	0.826	323.05	0.849	0.841	362.05	0.864	0.854
286.05	0.836	0.826	324.05	0.849	0.843	363.05	0.864	0.851
287.05	0.833	0.826	325.05	0.849	0.843	364.05	0.864	0.854
288.05	0.836	0.828	326.05	0.849	0.843	365.05	0.864	0.854
289.05	0.836	0.826	327.05	0.851	0.843	366.05	0.866	0.856
290.05	0.836	0.828	328.05	0.854	0.843	367.05	0.866	0.856
291.05	0.836	0.826	329.05	0.851	0.843	368.05	0.866	0.856
292.05	0.838	0.828	330.05	0.851	0.843	369.03	0.866	0.856
293.05	0.838	0.828	332.05	0.856	0.843	370.03	0.866	0.859
294.05	0.836	0.828	333.05	0.856	0.846	371.03	0.869	0.859
295.05	0.838	0.828	334.05	0.856	0.846	372.03	0.869	0.859
296.05	0.841	0.831	335.05	0.851	0.846	373.03	0.871	0.859
297.05	0.841	0.831	336.05	0.854	0.846	374.03	0.871	0.859
298.05	0.843	0.833	337.05	0.856	0.846	375.03	0.869	0.859
299.05	0.843	0.833	338.05	0.856	0.849	376.03	0.871	0.861
300.05	0.846	0.836	339.05	0.854	0.849	377.03	0.871	0.861
301.05	0.846	0.833	340.05	0.856	0.849	378.03	0.871	0.859
302.05	0.843	0.836	341.05	0.859	0.849	379.03	0.871	0.861
303.05	0.843	0.836	342.05	0.856	0.849	380.03	0.869	0.859
304.05	0.841	0.833	343.05	0.856	0.849	381.03	0.869	0.861
305.05	0.841	0.833	344.05	0.859	0.851	382.03	0.866	0.861
306.05	0.841	0.833	345.05	0.856	0.849	383.03	0.871	0.861
307.05	0.841	0.836	346.05	0.859	0.849	384.03	0.871	0.861
308.05	0.843	0.836	347.05	0.859	0.849	385.03	0.871	0.861
309.05	0.846	0.836	348.05	0.861	0.851	386.03	0.874	0.864
310.05	0.846	0.836	349.05	0.861	0.851	387.03	0.871	0.864
311.05	0.843	0.836	350.05	0.859	0.849	388.03	0.869	0.864
312.05	0.843	0.836	351.05	0.861	0.849	389.03	0.874	0.864
313.05	0.843	0.838	352.05	0.859	0.851	390.03	0.871	0.864
314.05	0.843	0.838	353.05	0.861	0.851	391.03	0.869	0.864
315.05	0.846	0.838	354.05	0.861	0.851	392.03	0.871	0.864
316.05	0.846	0.841	355.05	0.861	0.851	393.03	0.874	0.856
317.05	0.846	0.841	356.05	0.861	0.849	394.03	0.871	0.861
318.05	0.846	0.838	357.05	0.861	0.851	395.03	0.871	0.864
319.05	0.846	0.841	358.05	0.859	0.851	396.03	0.871	0.864

Table C-9 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
397.03	0.874	0.866	435.03	0.879	0.871
398.03	0.874	0.866	436.03	0.882	0.869
399.03	0.874	0.866	437.03	0.882	0.871
400.03	0.874	0.866	438.03	0.882	0.869
401.03	0.874	0.864	439.03	0.882	0.871
402.03	0.874	0.866	440.03	0.884	0.871
403.03	0.877	0.866	441.03	0.884	0.871
404.03	0.877	0.866	442.03	0.884	0.871
405.03	0.877	0.866	443.03	0.884	0.871
406.03	0.874	0.866	444.03	0.884	0.871
407.03	0.877	0.866	445.03	0.884	0.874
408.03	0.877	0.869	446.03	0.887	0.871
409.03	0.877	0.869	447.03	0.884	0.874
410.03	0.879	0.869	448.03	0.887	0.874
411.03	0.877	0.869	449.03	0.887	0.874
412.03	0.877	0.869	450.03	0.884	0.864
413.03	0.877	0.869			
414.03	0.877	0.869			
415.03	0.879	0.869			
416.03	0.877	0.871			
417.03	0.877	0.871			
418.03	0.877	0.871			
419.03	0.877	0.869			
420.03	0.874	0.869			
421.03	0.877	0.871			
422.03	0.877	0.869			
423.03	0.877	0.869			
424.03	0.874	0.864			
425.03	0.874	0.864			
426.03	0.874	0.869			
427.03	0.877	0.869			
428.03	0.877	0.869			
429.03	0.879	0.866			
430.03	0.874	0.866			
431.03	0.879	0.869			
432.03	0.879	0.869			
433.03	0.882	0.869			
434.03	0.882	0.871			

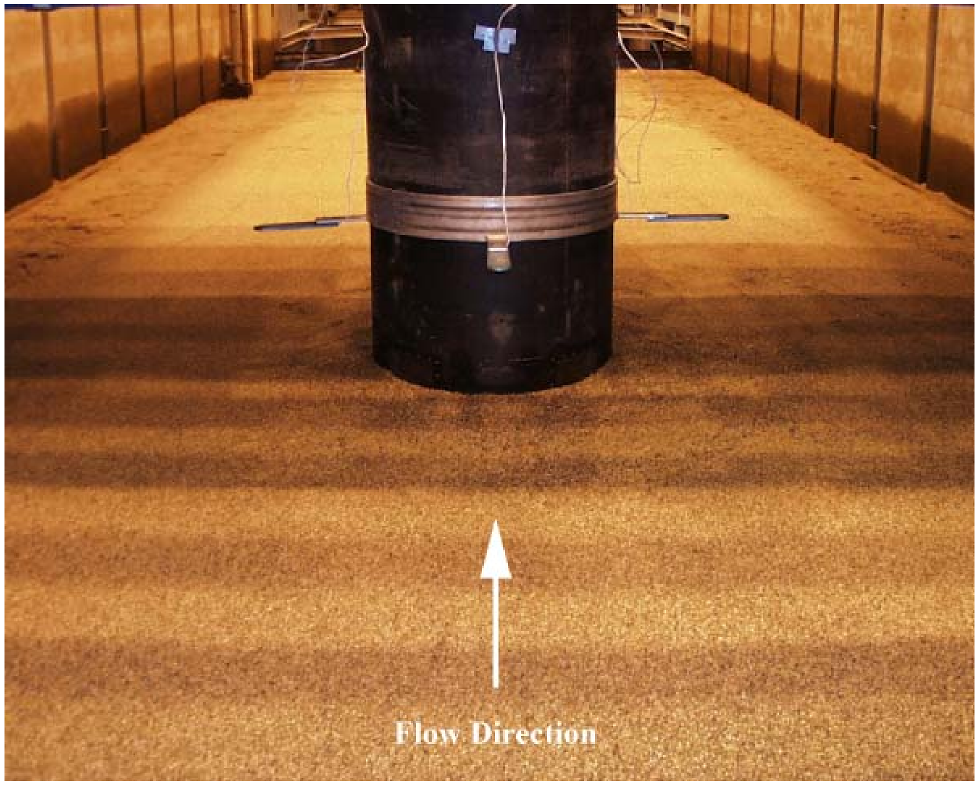

Figure C- 92. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) before test.

Figure C- 93. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 94. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

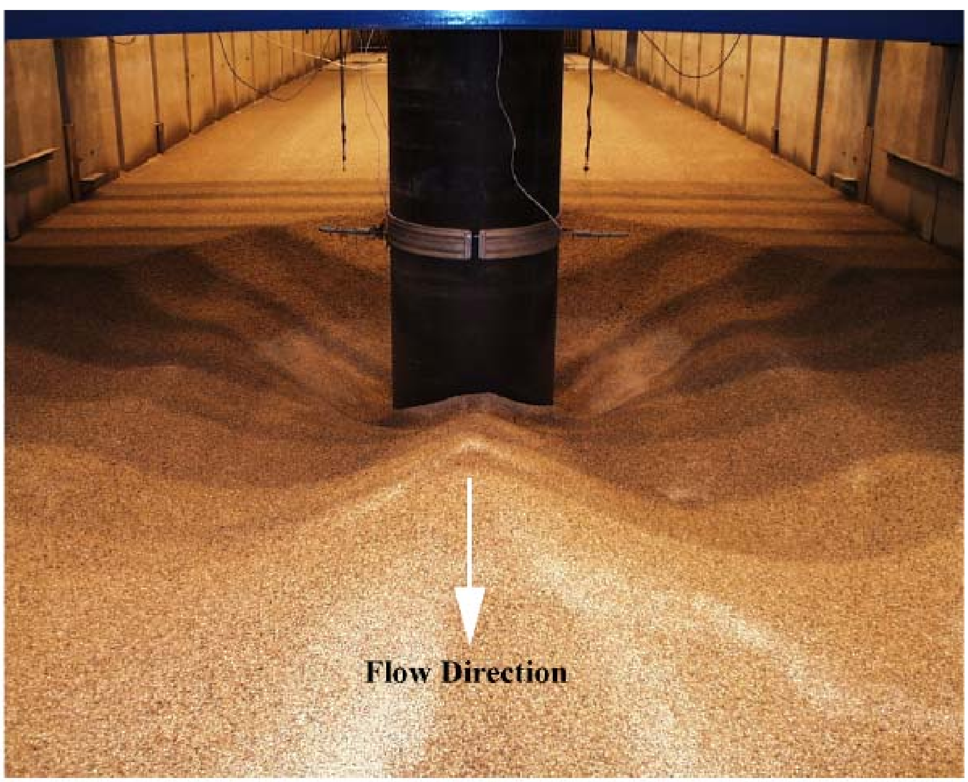

Figure C- 95. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 96. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 97. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 98. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

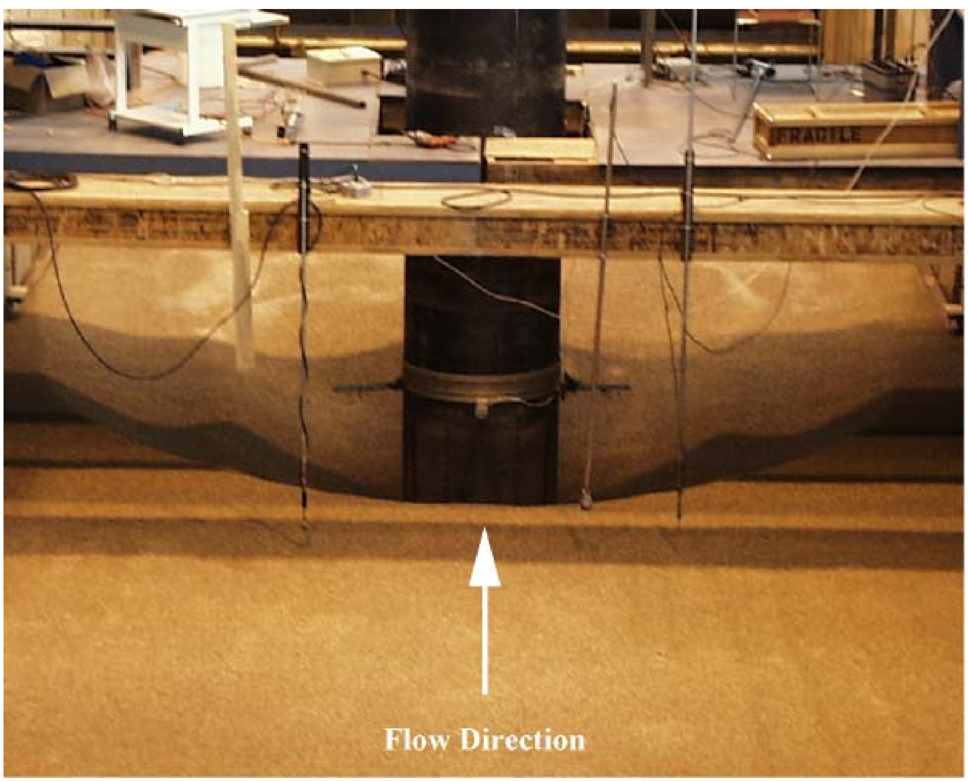

Figure C- 99. Experiment 9 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Experiment 10
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**04/05/2000**	Start Time:	**2:15 PM**
D_{50}(mm):	**2.90**	Stop Date:	**05/01/2000**	Stop Time:	**6:17 AM**
σ:	1.21				
ρ_s (Kg/m^3):	**2650**	Duration:	**616 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.43**	**0.50**
Maximum(m/s):	**0.72**	**0.55**
Minimum(m/s):	**0.15**	**0.45**

Channel average velocity from weir (m/s): **0.48**

Critical (sediment) velocity, V_c (m/s): **0.65**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **0.17**
- Minimum(m): **0.16**
- Maximum(m): **0.18**

Water Temperature:
- Average (degrees C): **6.1**
- Maximum (degrees C): **8.0**
- Minimum (degrees C): **4.3**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.624**
- Maximum depth from internal video cameras (m): **0.650**
- Maximum depth from point gauge (m):
- Maximum scour depth (m): **0.659**

Dimensionless Parameters:

y_0/D: **0.2** V/V_c: **0.76** D/D_{50}: **316**

d_s/D: **0.72**

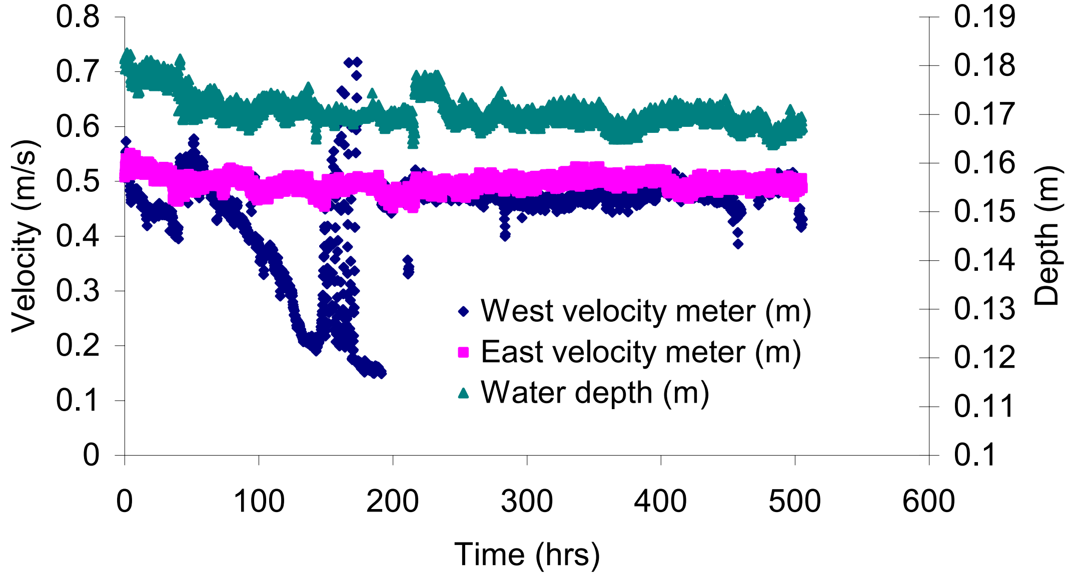

Figure C- 100. Measured velocity and water depth for experiment 10.

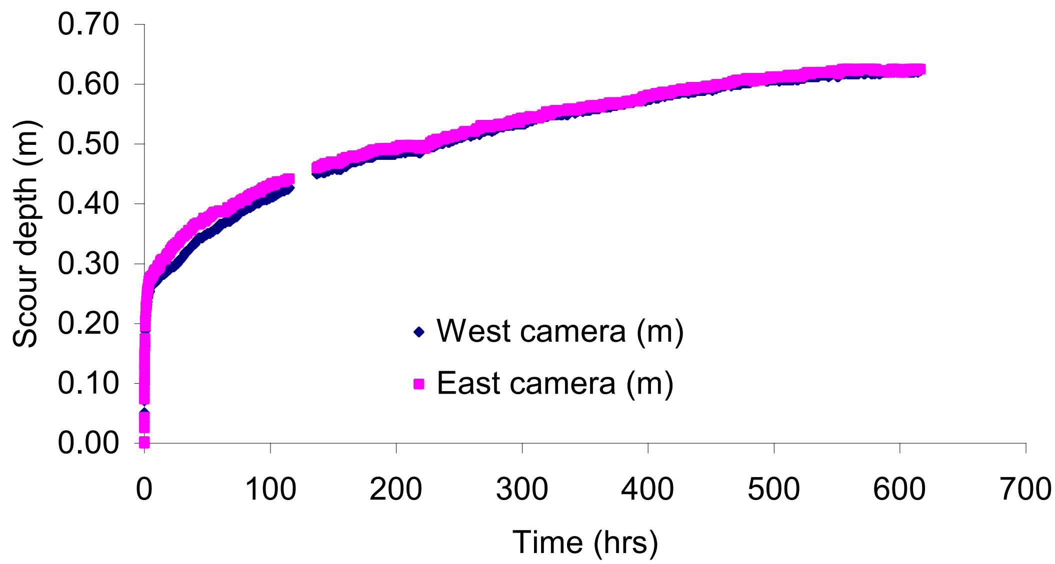

Figure C- 101. Measured local scour data from the internal video camera for experiment 10.

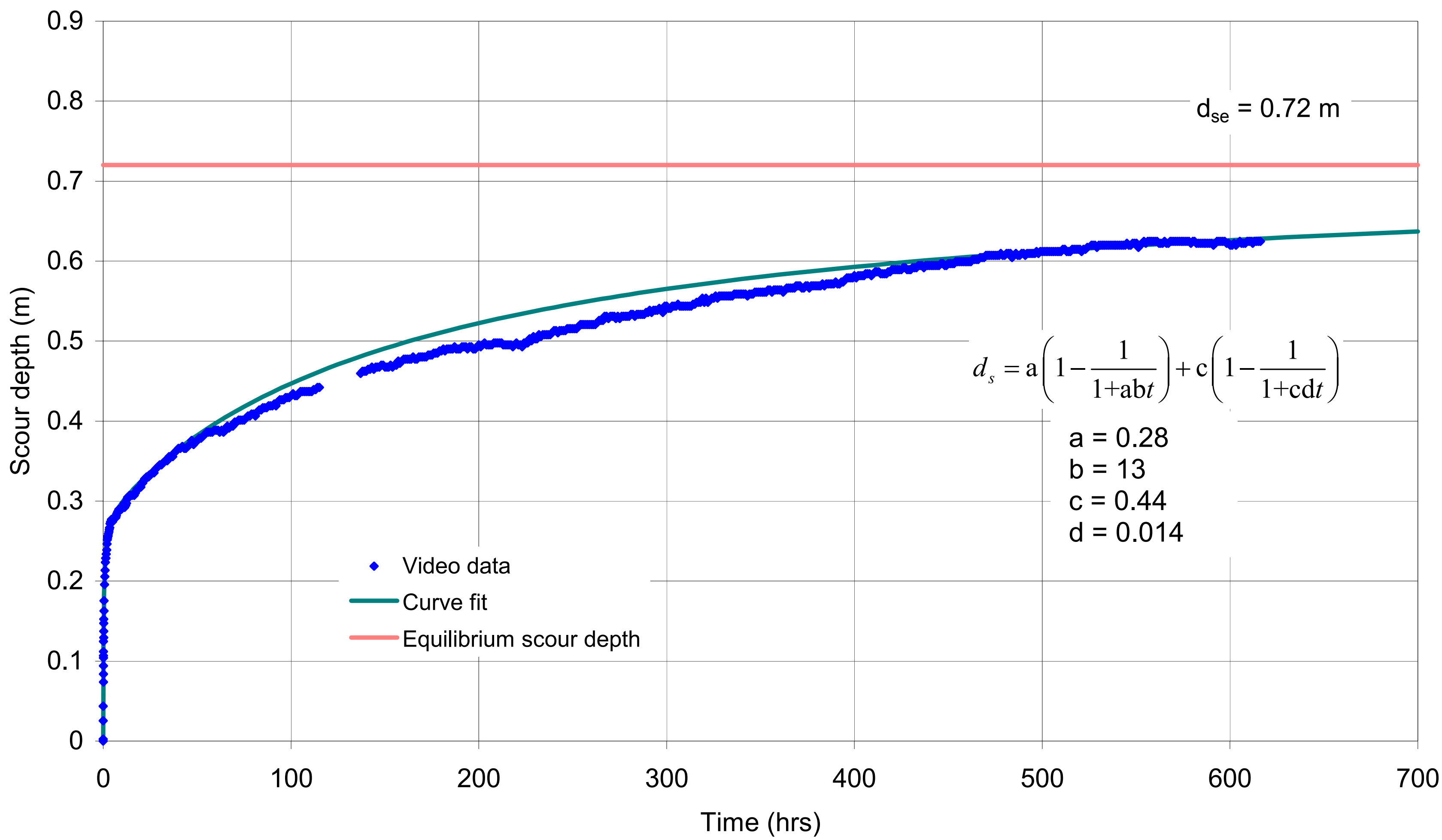

Figure C- 102. Curve fit to the local scour data measured with the internal video cameras for experiment 10.

Table C-10. The rate of scour depth from the internal video cameras for experiment 10.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0	0	0	4.18	0.254	0.274	18.07	0.290	0.315
0.03	0	0.003	4.35	0.259	0.277	18.57	0.290	0.315
0.05	0.036	0.025	4.53	0.262	0.274	19.07	0.290	0.318
0.07	0.051	0.043	4.70	0.262	0.274	19.57	0.290	0.318
0.08	0.071	0.074	4.87	0.262	0.274	20.07	0.292	0.318
0.10	0.081	0.084	5.03	0.262	0.274	20.57	0.292	0.323
0.12	0.091	0.094	5.37	0.264	0.277	21.07	0.295	0.323
0.13	0.099	0.104	5.70	0.264	0.279	21.57	0.295	0.325
0.15	0.104	0.107	6.03	0.264	0.279	22.07	0.295	0.328
0.17	0.109	0.112	6.37	0.267	0.279	22.57	0.295	0.328
0.20	0.119	0.124	6.70	0.267	0.279	23.07	0.295	0.330
0.23	0.124	0.130	7.03	0.267	0.282	23.57	0.295	0.330
0.27	0.130	0.137	7.37	0.267	0.285	24.07	0.297	0.330
0.30	0.140	0.147	7.70	0.267	0.287	24.57	0.297	0.333
0.33	0.150	0.152	8.03	0.269	0.287	25.08	0.300	0.333
0.40	0.163	0.163	8.37	0.269	0.290	26.08	0.300	0.335
0.50	0.168	0.175	8.70	0.269	0.290	27.08	0.305	0.335
0.67	0.188	0.196	9.05	0.269	0.290	28.08	0.305	0.340
0.83	0.201	0.206	9.38	0.272	0.290	29.08	0.307	0.343
1.00	0.206	0.213	9.72	0.272	0.290	30.08	0.310	0.346
1.17	0.213	0.224	10.05	0.272	0.292	31.08	0.313	0.346
1.33	0.221	0.229	10.38	0.274	0.292	32.08	0.318	0.348
1.50	0.224	0.229	10.72	0.274	0.295	33.08	0.320	0.351
1.67	0.226	0.234	11.05	0.274	0.297	34.08	0.320	0.351
1.83	0.229	0.239	11.38	0.277	0.292	35.08	0.323	0.356
2.00	0.231	0.246	11.72	0.279	0.295	36.08	0.325	0.356
2.17	0.236	0.252	12.05	0.282	0.295	37.08	0.328	0.356
2.33	0.241	0.254	12.38	0.282	0.297	38.08	0.330	0.361
2.50	0.244	0.257	12.72	0.282	0.302	39.08	0.333	0.363
2.68	0.244	0.257	13.05	0.282	0.305	40.08	0.333	0.366
2.85	0.246	0.259	13.55	0.282	0.305	41.08	0.338	0.366
3.02	0.249	0.262	14.05	0.282	0.307	42.08	0.340	0.368
3.18	0.254	0.264	14.55	0.282	0.307	43.08	0.343	0.366
3.35	0.254	0.267	15.05	0.282	0.307	44.08	0.343	0.366
3.52	0.252	0.267	15.55	0.282	0.307	45.08	0.343	0.368
3.68	0.254	0.272	16.57	0.285	0.307	46.08	0.343	0.371
3.85	0.254	0.272	17.07	0.285	0.310	47.08	0.346	0.376
4.02	0.254	0.274	17.57	0.290	0.313	48.08	0.348	0.371

Table C-10 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
49.08	0.348	0.373	87.07	0.399	0.417	146.05	0.455	0.467
50.08	0.351	0.376	88.07	0.401	0.419	147.05	0.457	0.467
51.08	0.351	0.379	89.07	0.401	0.419	148.05	0.460	0.470
52.08	0.351	0.379	90.07	0.401	0.419	149.05	0.457	0.470
53.08	0.353	0.381	91.07	0.401	0.422	150.05	0.460	0.467
54.08	0.353	0.384	92.07	0.404	0.419	151.05	0.460	0.467
55.08	0.356	0.386	93.07	0.407	0.424	152.05	0.460	0.467
56.08	0.358	0.386	94.07	0.407	0.427	153.05	0.457	0.470
57.08	0.358	0.386	95.07	0.407	0.427	154.05	0.460	0.467
58.08	0.358	0.386	96.07	0.409	0.427	155.05	0.457	0.470
59.08	0.361	0.389	97.07	0.407	0.429	156.05	0.457	0.470
60.08	0.366	0.389	98.07	0.409	0.429	157.05	0.462	0.475
61.08	0.366	0.389	99.07	0.409	0.429	158.05	0.465	0.473
62.08	0.366	0.386	100.07	0.414	0.432	159.05	0.465	0.475
63.08	0.368	0.389	101.07	0.412	0.434	160.05	0.462	0.478
64.07	0.368	0.386	102.07	0.412	0.432	161.05	0.465	0.478
65.07	0.371	0.389	103.07	0.414	0.432	162.05	0.467	0.478
66.07	0.371	0.394	104.07	0.414	0.434	163.05	0.467	0.478
67.07	0.371	0.391	105.07	0.417	0.437	164.05	0.470	0.478
68.07	0.371	0.394	106.07	0.417	0.437	165.05	0.470	0.480
69.07	0.376	0.394	107.07	0.419	0.437	166.05	0.470	0.478
70.07	0.376	0.399	108.07	0.419	0.437	167.05	0.470	0.478
71.07	0.376	0.399	109.07	0.422	0.437	168.05	0.470	0.480
72.07	0.379	0.401	110.07	0.422	0.437	169.05	0.473	0.480
73.07	0.379	0.401	111.07	0.422	0.437	170.05	0.473	0.480
74.07	0.381	0.401	112.07	0.424	0.440	171.05	0.475	0.480
75.07	0.384	0.401	113.07	0.424	0.440	172.05	0.473	0.480
76.07	0.386	0.404	114.07	0.424	0.442	173.05	0.475	0.483
77.07	0.391	0.407	115.07	0.427	0.442	174.05	0.475	0.483
78.07	0.389	0.407	137.05	0.450	0.460	175.05	0.478	0.483
79.07	0.389	0.409	138.05	0.452	0.462	176.05	0.478	0.485
80.07	0.391	0.409	139.05	0.452	0.462	177.05	0.478	0.485
81.07	0.391	0.407	140.05	0.455	0.462	178.05	0.478	0.485
82.07	0.396	0.412	141.05	0.455	0.465	179.05	0.478	0.488
83.07	0.394	0.414	142.05	0.452	0.465	180.05	0.478	0.488
84.07	0.394	0.414	143.05	0.452	0.467	181.05	0.478	0.490
85.07	0.396	0.417	144.05	0.455	0.465	182.05	0.480	0.488
86.07	0.396	0.417	145.05	0.455	0.467	183.05	0.480	0.490

Table C-10 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
184.05	0.483	0.490	222.05	0.493	0.495	260.05	0.516	0.521
185.05	0.483	0.490	223.05	0.493	0.493	261.05	0.516	0.521
186.05	0.483	0.490	224.05	0.493	0.498	262.05	0.516	0.521
187.05	0.483	0.493	225.05	0.493	0.498	263.05	0.518	0.523
188.05	0.483	0.490	226.05	0.495	0.498	264.05	0.518	0.526
189.05	0.483	0.490	227.05	0.495	0.503	265.05	0.518	0.526
190.05	0.483	0.490	228.05	0.495	0.501	266.05	0.516	0.526
191.05	0.483	0.493	229.05	0.495	0.506	267.05	0.521	0.531
192.05	0.483	0.493	230.05	0.495	0.503	268.03	0.521	0.531
193.05	0.483	0.493	231.05	0.498	0.503	269.03	0.521	0.528
194.05	0.483	0.490	232.05	0.498	0.508	270.03	0.521	0.531
195.05	0.483	0.493	233.05	0.501	0.506	271.03	0.523	0.531
196.05	0.483	0.493	234.05	0.501	0.508	272.03	0.523	0.531
197.05	0.483	0.490	235.05	0.503	0.508	273.03	0.523	0.528
198.05	0.483	0.490	236.05	0.501	0.508	274.03	0.523	0.531
199.05	0.483	0.493	237.05	0.501	0.508	275.03	0.526	0.528
200.05	0.485	0.495	238.05	0.506	0.508	276.03	0.521	0.531
201.05	0.485	0.493	239.05	0.506	0.511	277.03	0.523	0.531
202.05	0.485	0.495	240.05	0.506	0.513	278.03	0.523	0.531
203.05	0.485	0.498	241.05	0.503	0.513	279.03	0.528	0.531
204.05	0.485	0.495	242.05	0.503	0.511	280.03	0.526	0.531
205.05	0.488	0.495	243.05	0.506	0.513	281.03	0.528	0.534
206.05	0.488	0.495	244.05	0.506	0.513	282.03	0.528	0.534
207.05	0.485	0.495	245.05	0.506	0.513	283.03	0.531	0.531
208.05	0.488	0.498	246.05	0.508	0.513	284.03	0.528	0.534
209.05	0.488	0.498	247.05	0.508	0.516	285.03	0.528	0.534
210.05	0.488	0.498	248.05	0.508	0.516	286.03	0.531	0.534
211.05	0.488	0.498	249.05	0.511	0.516	287.03	0.531	0.534
212.05	0.488	0.498	250.05	0.511	0.516	288.03	0.531	0.534
213.05	0.488	0.495	251.05	0.511	0.516	289.03	0.531	0.536
214.05	0.488	0.495	252.05	0.511	0.516	290.03	0.531	0.536
215.05	0.488	0.495	253.05	0.513	0.518	291.03	0.534	0.539
216.05	0.488	0.495	254.05	0.513	0.521	292.03	0.531	0.536
217.05	0.488	0.495	255.05	0.516	0.521	293.03	0.531	0.539
218.05	0.485	0.493	256.05	0.516	0.521	294.03	0.534	0.539
219.05	0.485	0.495	257.05	0.516	0.521	295.03	0.534	0.539
220.05	0.488	0.498	258.05	0.516	0.521	296.03	0.534	0.541
221.05	0.490	0.495	259.05	0.513	0.521	297.03	0.534	0.539

Table C-10 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
298.03	0.534	0.536	336.03	0.549	0.559	374.02	0.564	0.569
299.03	0.534	0.544	337.03	0.554	0.559	375.02	0.564	0.569
300.03	0.534	0.544	338.03	0.554	0.559	376.02	0.567	0.567
301.03	0.534	0.541	339.03	0.554	0.559	377.02	0.567	0.569
302.03	0.534	0.541	340.03	0.556	0.559	378.02	0.567	0.569
303.03	0.536	0.544	341.03	0.554	0.559	379.02	0.567	0.569
304.03	0.536	0.544	342.03	0.551	0.559	380.02	0.567	0.569
305.03	0.539	0.544	343.03	0.554	0.556	381.02	0.567	0.569
306.03	0.541	0.546	344.03	0.554	0.559	382.02	0.569	0.569
307.03	0.539	0.544	345.03	0.556	0.559	383.02	0.569	0.572
308.03	0.539	0.544	346.03	0.556	0.559	384.02	0.569	0.569
309.03	0.541	0.544	347.03	0.556	0.561	385.02	0.569	0.572
310.03	0.544	0.544	348.03	0.554	0.561	386.02	0.569	0.572
311.03	0.541	0.544	349.03	0.556	0.561	387.02	0.572	0.572
312.03	0.544	0.544	350.03	0.556	0.561	388.02	0.569	0.572
313.03	0.546	0.544	351.03	0.556	0.561	389.02	0.572	0.572
314.03	0.544	0.546	352.03	0.556	0.561	390.02	0.572	0.574
315.03	0.544	0.546	353.03	0.556	0.561	391.02	0.572	0.572
316.03	0.544	0.549	354.03	0.556	0.564	392.02	0.572	0.572
317.03	0.546	0.549	355.03	0.559	0.564	393.02	0.572	0.574
318.03	0.546	0.549	356.03	0.559	0.561	394.02	0.572	0.574
319.03	0.546	0.554	357.03	0.559	0.564	395.02	0.572	0.577
320.03	0.546	0.549	358.03	0.559	0.564	396.02	0.574	0.579
321.03	0.549	0.554	359.03	0.559	0.564	397.02	0.574	0.579
322.03	0.549	0.549	360.03	0.559	0.564	398.02	0.572	0.579
323.03	0.549	0.551	361.03	0.559	0.564	399.02	0.574	0.579
324.03	0.549	0.554	362.02	0.561	0.561	400.02	0.574	0.582
325.03	0.549	0.554	363.02	0.564	0.564	401.02	0.574	0.579
326.03	0.549	0.556	364.02	0.564	0.567	402.02	0.574	0.582
327.03	0.549	0.554	365.02	0.561	0.567	403.02	0.577	0.582
328.03	0.549	0.556	366.02	0.561	0.567	404.02	0.579	0.582
329.03	0.551	0.556	367.02	0.561	0.567	405.02	0.579	0.582
330.03	0.549	0.556	368.02	0.561	0.567	406.02	0.577	0.584
331.03	0.549	0.556	369.02	0.564	0.569	407.02	0.577	0.584
332.03	0.549	0.556	370.02	0.561	0.569	408.02	0.577	0.584
333.03	0.551	0.556	371.02	0.564	0.569	409.02	0.579	0.582
334.03	0.551	0.556	372.02	0.564	0.567	410.02	0.579	0.584
335.03	0.549	0.556	373.02	0.564	0.567	411.02	0.582	0.587

Table C-10 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
412.02	0.582	0.587	450.02	0.592	0.597	488.00	0.607	0.607
413.02	0.579	0.587	451.02	0.589	0.597	489.00	0.607	0.610
414.02	0.582	0.584	452.02	0.592	0.597	490.00	0.607	0.610
415.02	0.582	0.584	453.00	0.595	0.597	491.00	0.607	0.607
416.02	0.582	0.584	454.00	0.592	0.600	492.00	0.607	0.610
417.02	0.582	0.584	455.00	0.597	0.600	493.00	0.607	0.610
418.02	0.582	0.587	456.00	0.595	0.600	494.00	0.605	0.610
419.02	0.582	0.587	457.00	0.595	0.600	495.00	0.605	0.610
420.02	0.584	0.589	458.00	0.597	0.600	496.00	0.607	0.610
421.02	0.584	0.589	459.00	0.597	0.600	497.00	0.607	0.612
422.02	0.584	0.589	460.00	0.597	0.600	498.00	0.607	0.610
423.02	0.584	0.589	461.00	0.597	0.600	499.00	0.607	0.612
424.02	0.584	0.589	462.00	0.600	0.600	500.00	0.607	0.612
425.02	0.584	0.589	463.00	0.600	0.602	501.00	0.607	0.612
426.02	0.587	0.592	464.00	0.600	0.602	502.00	0.610	0.612
427.02	0.587	0.592	465.00	0.600	0.602	503.00	0.610	0.612
428.02	0.587	0.589	466.00	0.597	0.602	504.00	0.605	0.612
429.02	0.587	0.589	467.00	0.600	0.605	505.00	0.607	0.612
430.02	0.587	0.589	468.00	0.600	0.605	506.00	0.610	0.612
431.02	0.587	0.592	469.00	0.600	0.605	507.00	0.607	0.612
432.02	0.584	0.592	470.00	0.600	0.607	508.00	0.607	0.612
433.02	0.587	0.592	471.00	0.600	0.607	509.00	0.607	0.612
434.02	0.587	0.595	472.00	0.600	0.607	510.00	0.607	0.612
435.02	0.587	0.595	473.00	0.600	0.607	511.00	0.607	0.615
436.02	0.587	0.595	474.00	0.602	0.607	512.00	0.607	0.615
437.02	0.587	0.592	475.00	0.602	0.607	513.00	0.607	0.612
438.02	0.589	0.595	476.00	0.602	0.607	514.00	0.607	0.612
439.02	0.589	0.595	477.00	0.602	0.607	515.00	0.607	0.612
440.02	0.589	0.595	478.00	0.602	0.610	516.00	0.610	0.615
441.02	0.589	0.595	479.00	0.602	0.607	517.00	0.610	0.615
442.02	0.589	0.595	480.00	0.602	0.607	518.00	0.607	0.615
443.02	0.589	0.595	481.00	0.602	0.610	519.00	0.607	0.615
444.02	0.589	0.595	482.00	0.605	0.610	520.00	0.610	0.615
445.02	0.589	0.595	483.00	0.605	0.610	521.00	0.610	0.612
446.02	0.592	0.597	484.00	0.605	0.605	522.00	0.610	0.615
447.02	0.592	0.597	485.00	0.605	0.607	523.00	0.610	0.615
448.02	0.592	0.595	486.00	0.607	0.610	524.00	0.610	0.617
449.02	0.592	0.595	487.00	0.607	0.607	526.15	0.612	0.620

Table C-10 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
527.15	0.612	0.620	565.13	0.617	0.625	603.13	0.620	0.620
528.15	0.612	0.620	566.13	0.617	0.622	604.13	0.622	0.622
529.15	0.612	0.617	567.13	0.617	0.622	605.13	0.622	0.625
530.15	0.612	0.620	568.13	0.620	0.625	606.13	0.620	0.622
531.15	0.612	0.620	569.13	0.620	0.625	607.13	0.620	0.622
532.15	0.612	0.620	570.13	0.620	0.625	608.13	0.620	0.622
533.15	0.612	0.620	571.13	0.617	0.625	609.13	0.620	0.625
534.15	0.612	0.620	572.13	0.617	0.625	610.13	0.620	0.625
535.15	0.612	0.620	573.13	0.620	0.625	611.13	0.620	0.625
536.15	0.615	0.620	574.13	0.620	0.625	612.13	0.622	0.622
537.15	0.615	0.620	575.13	0.620	0.625	613.13	0.622	0.625
538.15	0.615	0.620	576.13	0.620	0.625	614.13	0.620	0.625
539.15	0.615	0.620	577.13	0.617	0.625	615.13	0.622	0.625
540.15	0.615	0.620	578.13	0.617	0.625	616.13	0.622	0.625
541.15	0.615	0.620	579.13	0.620	0.622			
542.15	0.615	0.620	580.13	0.617	0.625			
543.15	0.612	0.620	581.13	0.620	0.625			
544.15	0.615	0.620	582.13	0.620	0.622			
545.15	0.615	0.622	583.13	0.617	0.622			
546.15	0.617	0.620	584.13	0.617	0.622			
547.15	0.617	0.620	585.13	0.620	0.622			
548.15	0.617	0.622	586.13	0.620	0.622			
549.15	0.617	0.622	587.13	0.620	0.622			
550.15	0.612	0.622	588.13	0.620	0.622			
551.15	0.612	0.617	589.13	0.620	0.622			
552.15	0.615	0.620	590.13	0.620	0.622			
553.15	0.617	0.622	591.13	0.620	0.620			
554.15	0.617	0.625	592.13	0.622	0.622			
555.15	0.617	0.622	593.13	0.620	0.625			
556.15	0.617	0.625	594.13	0.622	0.625			
557.15	0.620	0.625	595.13	0.620	0.625			
558.15	0.617	0.625	596.13	0.622	0.625			
559.15	0.617	0.625	597.13	0.622	0.625			
560.15	0.617	0.625	598.13	0.622	0.622			
561.15	0.617	0.625	599.13	0.622	0.622			
562.13	0.617	0.622	600.13	0.620	0.620			
563.13	0.617	0.622	601.13	0.622	0.620			
564.13	0.617	0.622	602.13	0.622	0.622			

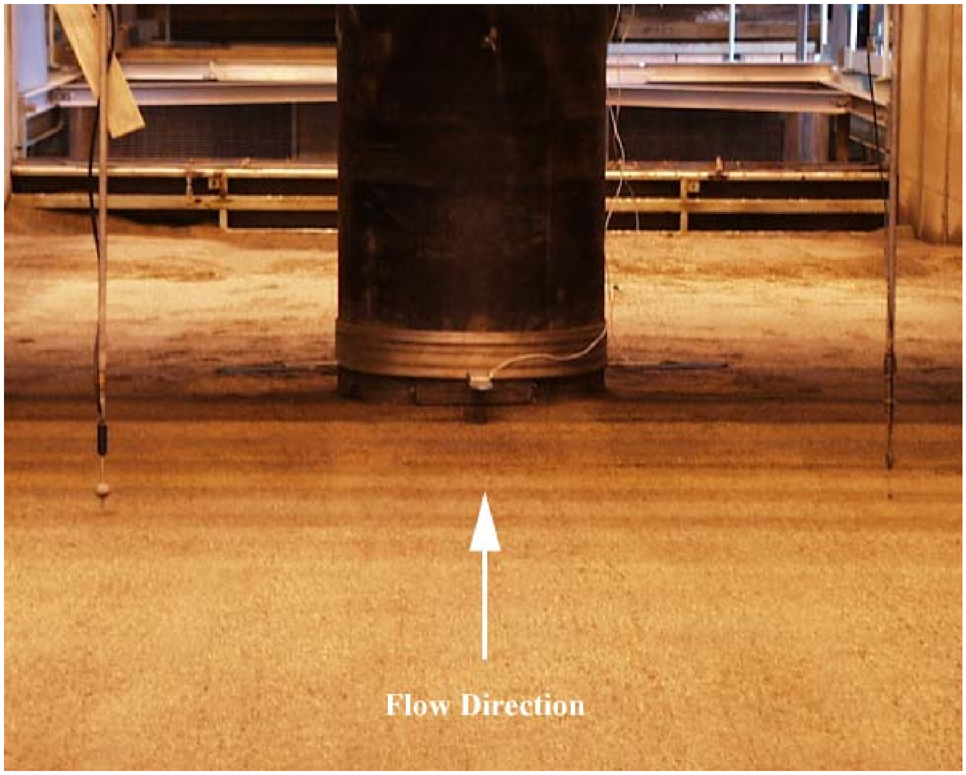

Figure C- 103. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) before test.

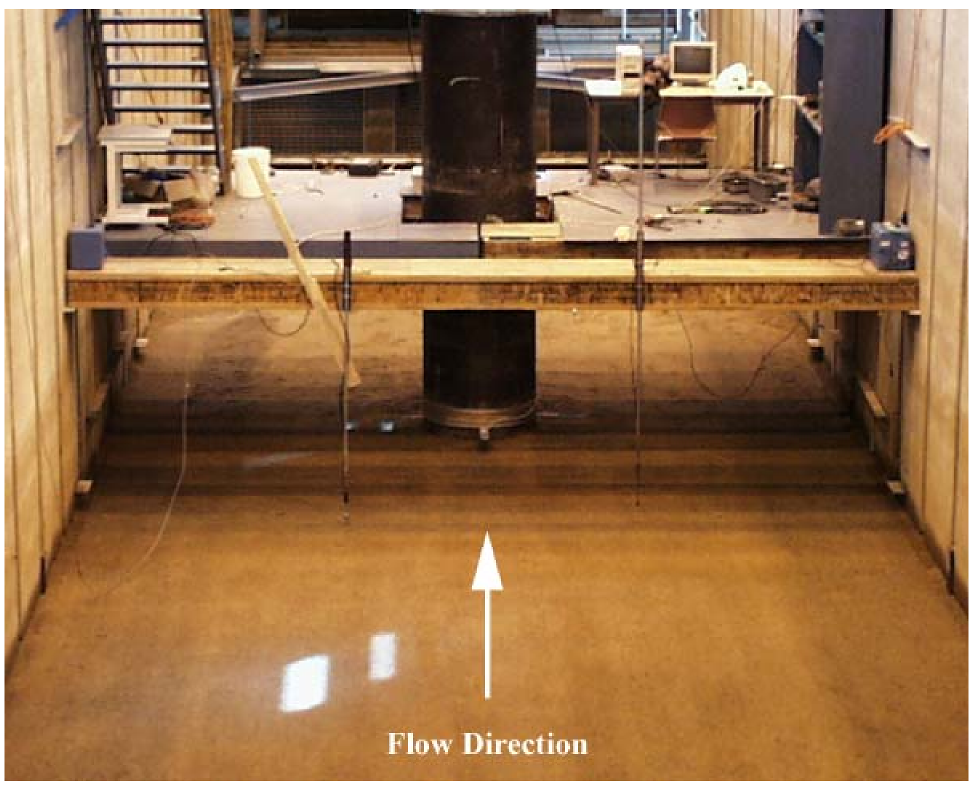

Figure C- 104. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) before test.

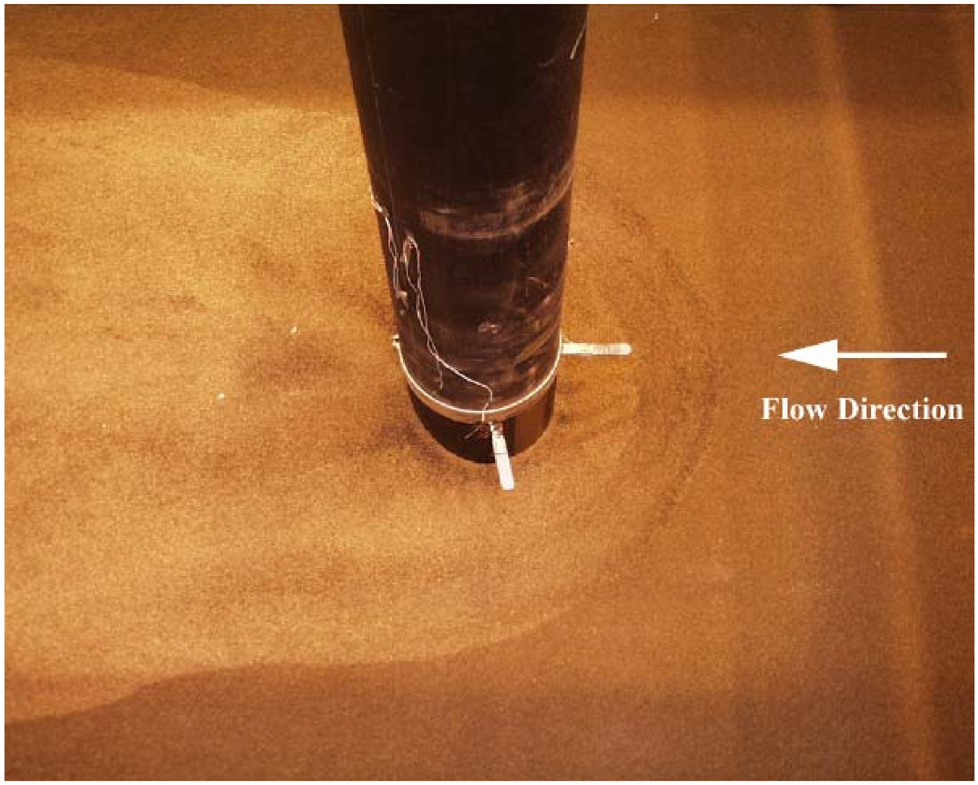

Figure C- 105. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) after test.

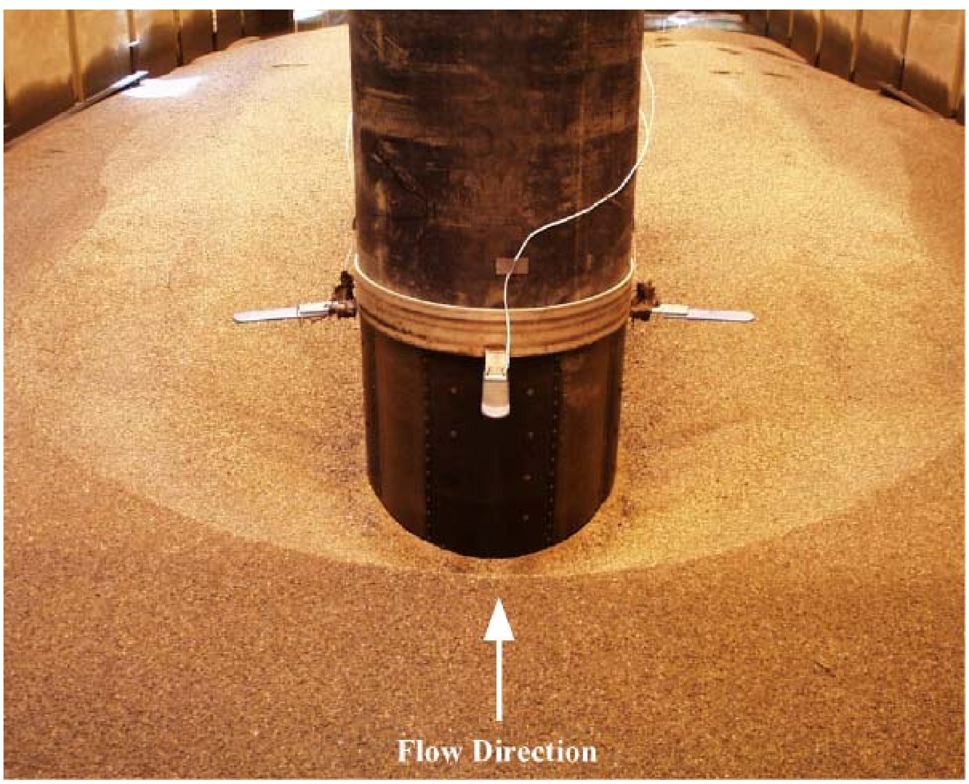

Figure C- 106. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) after test.

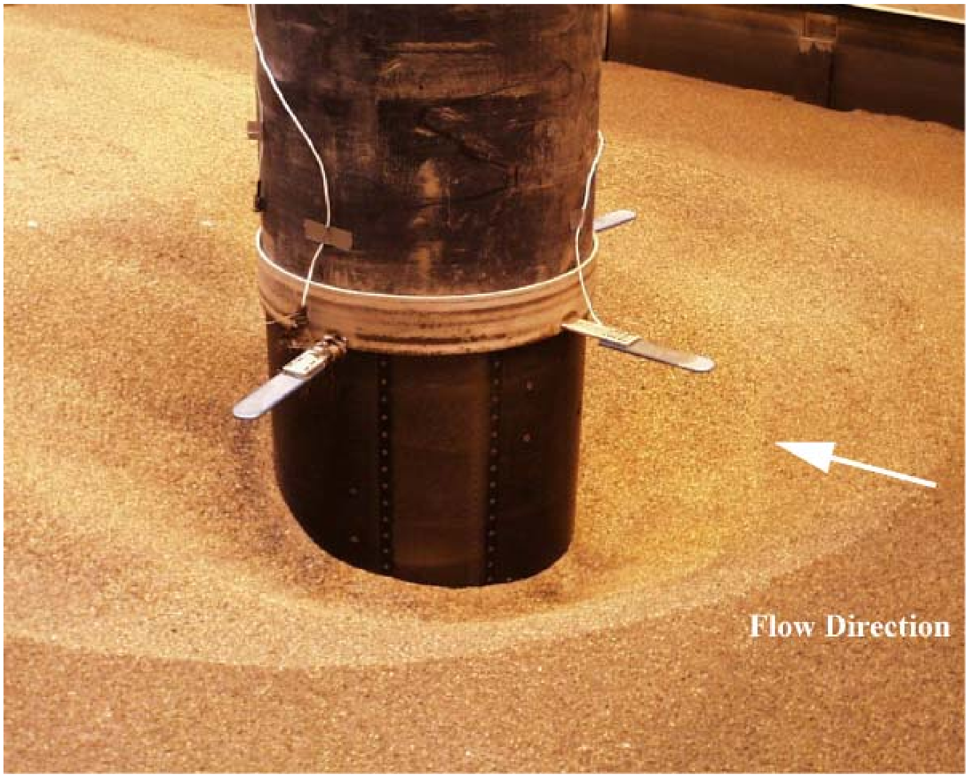

Figure C- 107. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) after test.

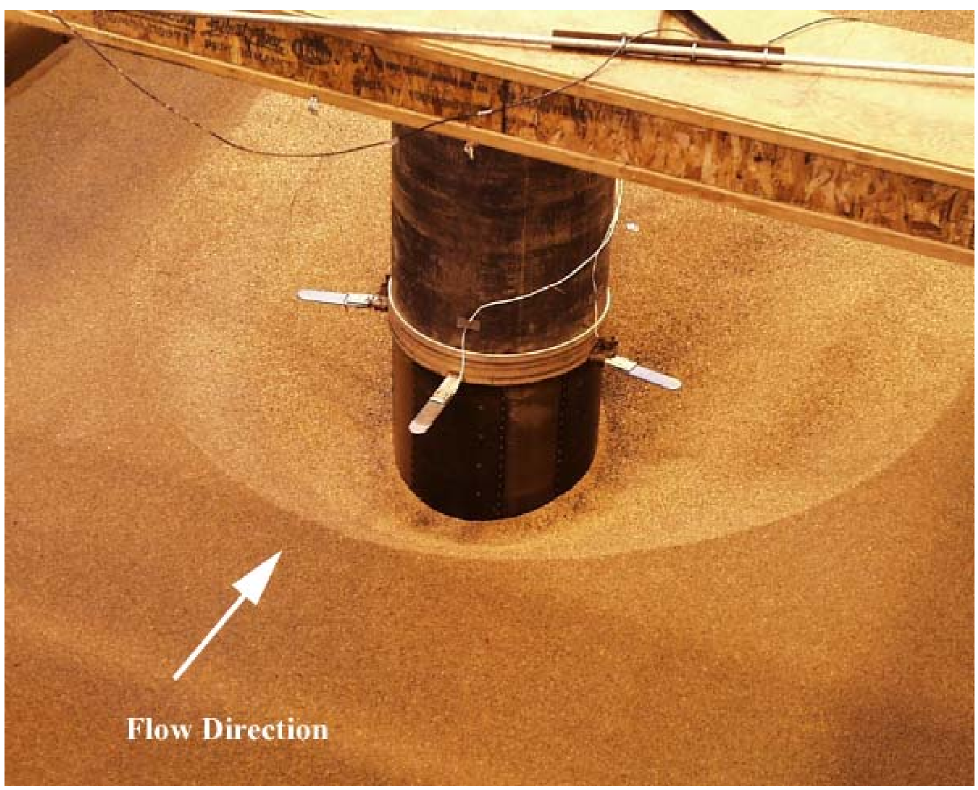

Figure C- 108. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) after test.

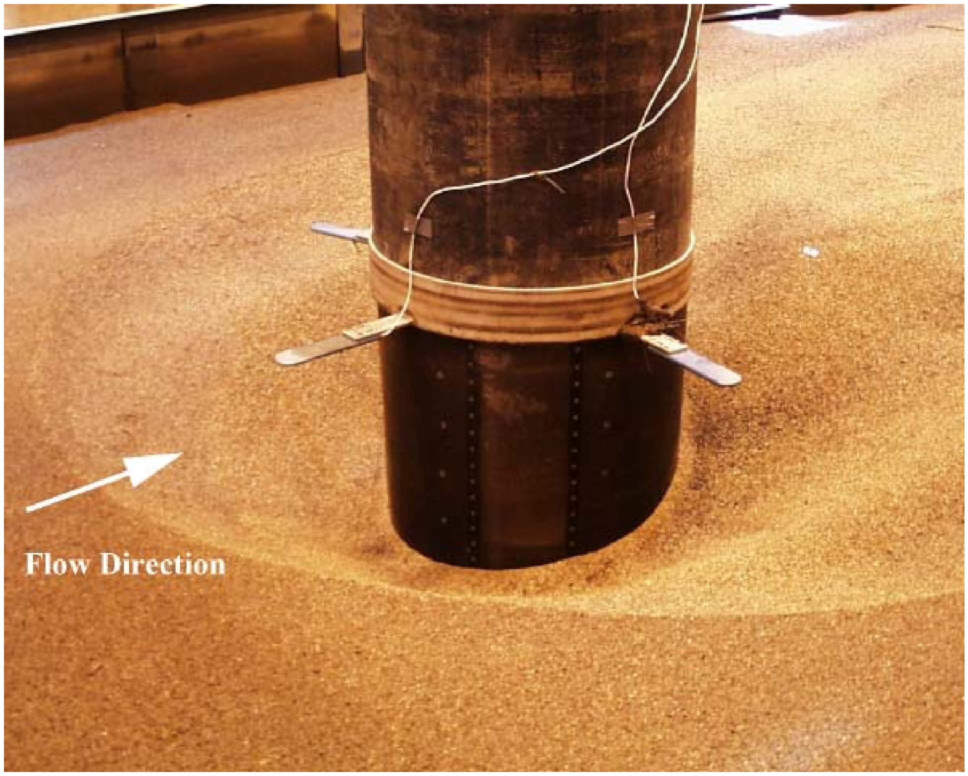

Figure C- 109. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) after test.

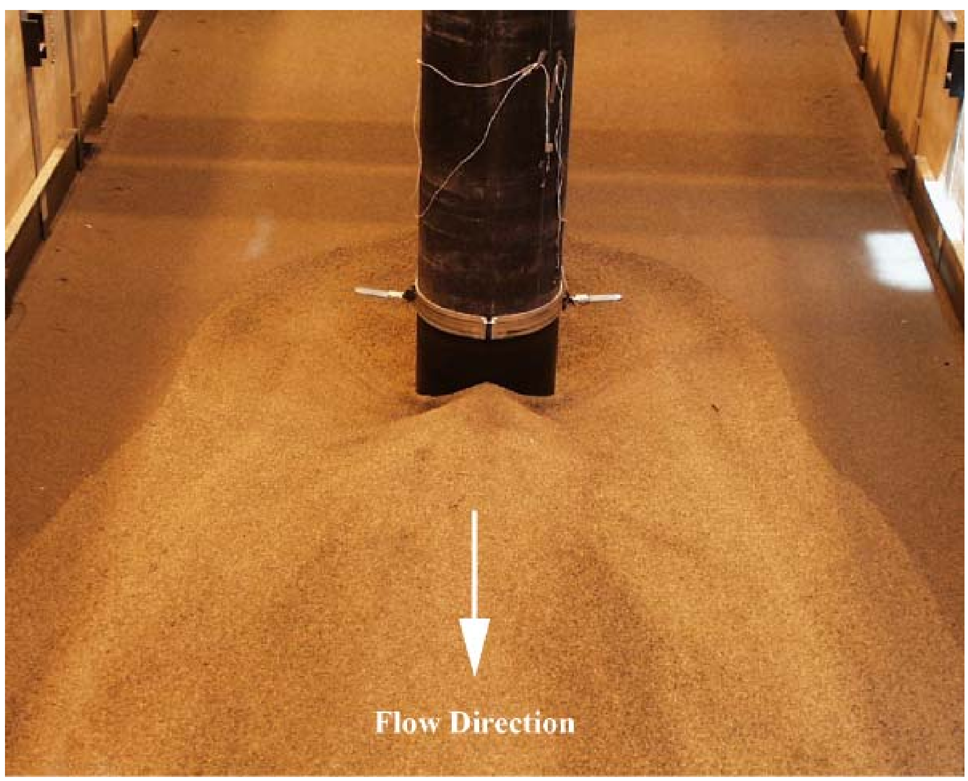

Figure C- 110. Experiment 10 (D = 0.915 m, D_{50} = 2.90 mm) after test

Experiment 11
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**05/02/2000**	Start Time:	**4:18 PM**
D_{50}(mm):	**2.90**	Stop Date:	**05/17/2000**	Stop Time:	**6:35 AM**
σ:	1.21				
ρ_s (Kg/m^3):	**2650**	Duration:	**350 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.65**	**0.67**
Maximum(m/s):	**0.94**	**1.01**
Minimum(m/s):	**0.47**	**0.45**

Channel average velocity from weir (m/s): **0.60**

Critical (sediment) velocity, V_c (m/s): **0.93**

Bed Relative Roughness, RR: **2**

Water depth, y_0 :
- Average water depth(m): **1.90**
- Minimum(m): **1.73**
- Maximum(m): **1.93**

Water Temperature:
- Average (degrees C): **11.8**
- Maximum (degrees C): **14.8**
- Minimum (degrees C): **8.6**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.960**
- Maximum depth from internal video cameras (m): **0.968**
- Maximum depth from point gauge (m):
- Maximum scour depth (m): **1.004**

Dimensionless Parameters:

y_0/D: **2.1** V/V_c: **0.75** D/D_{50}: **316**

d_s/D: **1.10**

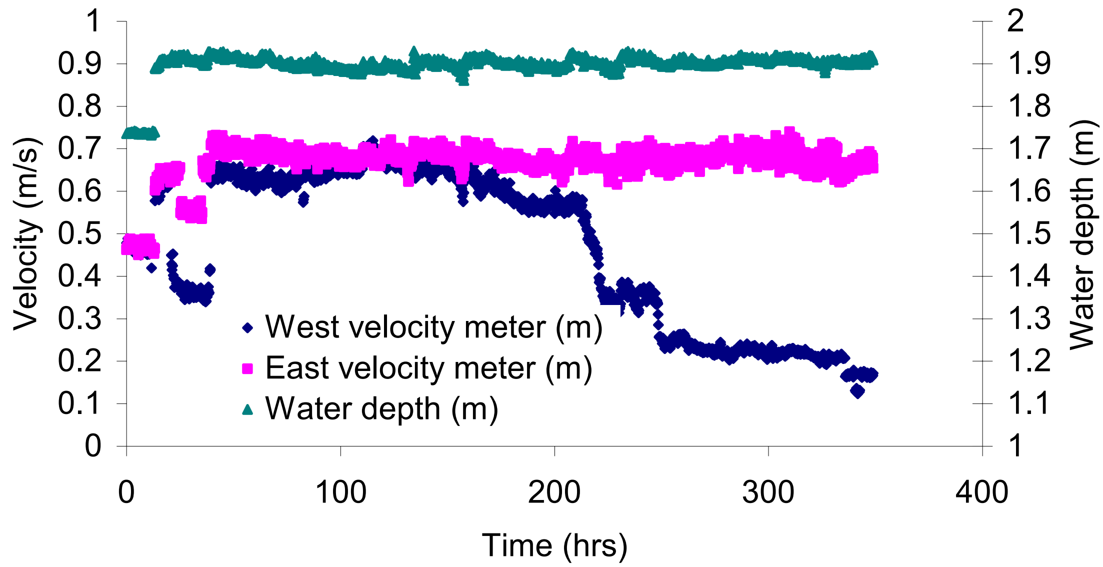

Figure C- 111. Measured velocity and water depth for experiment 11.

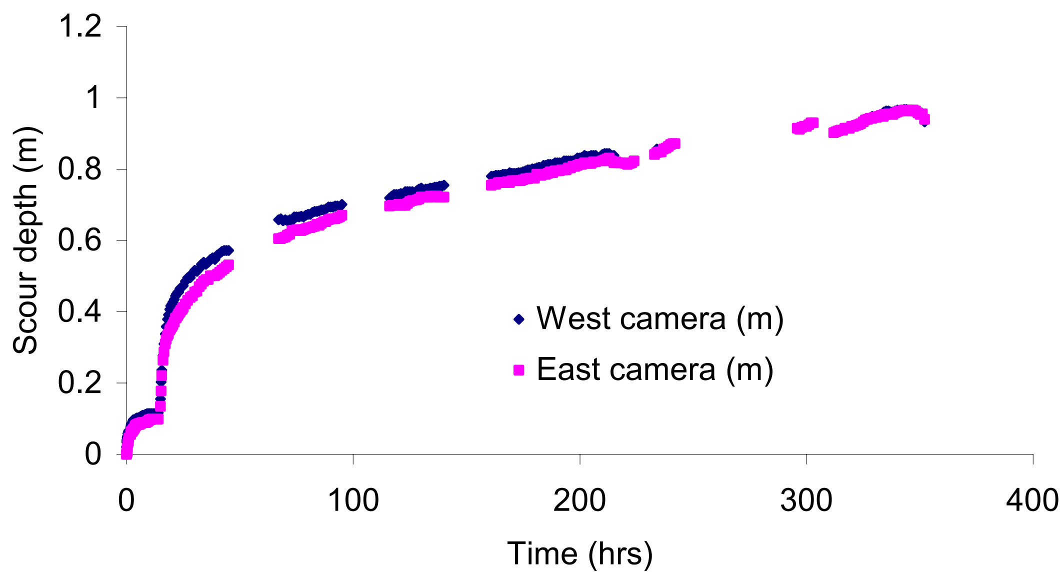

Figure C- 112. Measured local scour data from the internal video cameras for experiment 11.

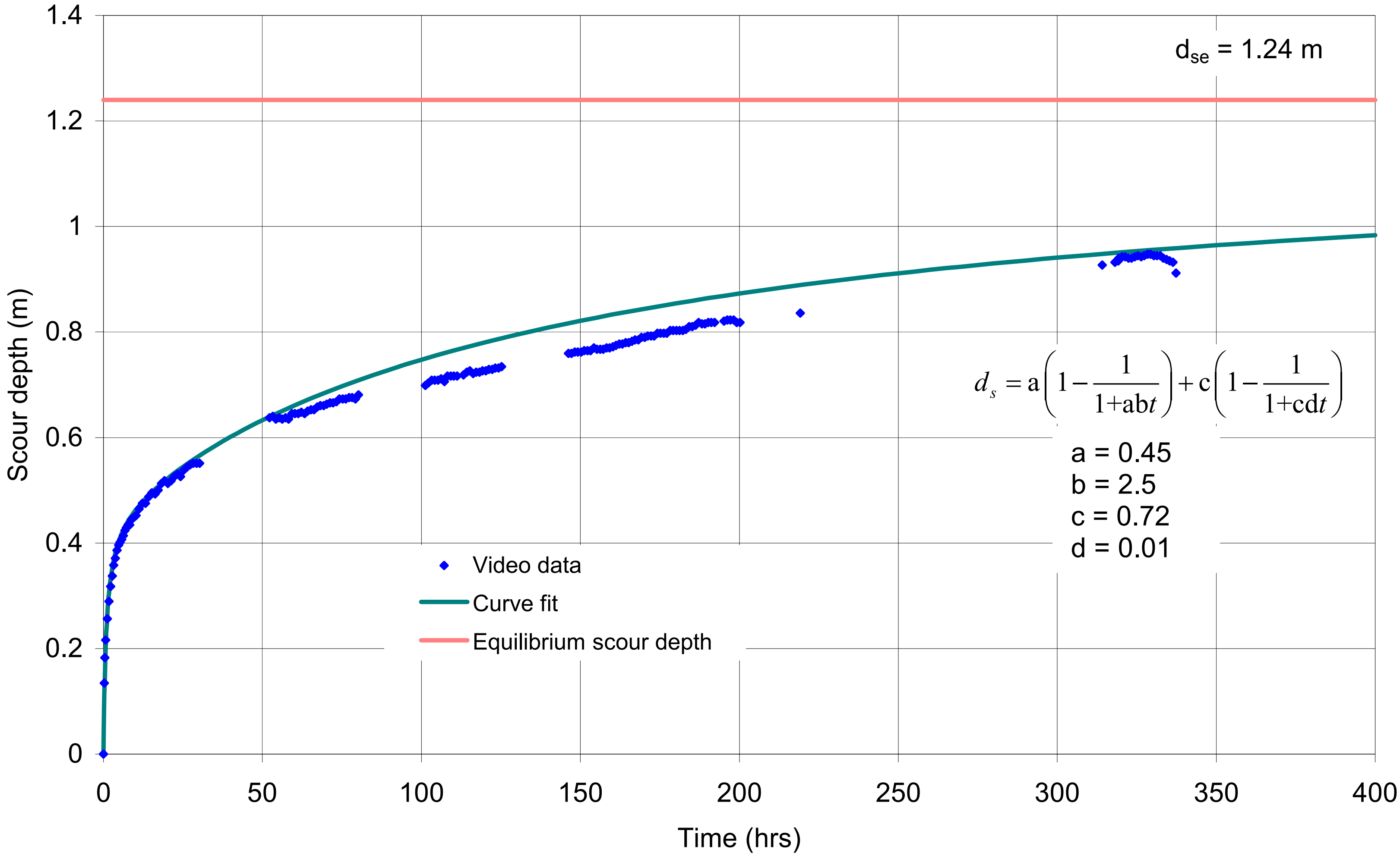

Figure C- 113. Curve fit to the local scour data measured with the internal video camera for experiment 11.

Table C-11. The rate of scour depth from the internal video cameras for experiment 11.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0.00	0.020	-0.003	6.33	0.107	0.086	22.03	0.450	0.384
0.03	0.020	0.000	6.67	0.107	0.089	22.53	0.455	0.389
0.07	0.020	0.000	7.00	0.109	0.089	23.03	0.455	0.394
0.15	0.033	0.003	7.33	0.109	0.089	23.53	0.465	0.399
0.17	0.036	0.005	7.67	0.109	0.089	24.03	0.467	0.404
0.18	0.038	0.010	8.00	0.109	0.089	24.53	0.470	0.407
0.20	0.041	0.010	8.33	0.112	0.089	25.03	0.473	0.412
0.22	0.041	0.010	8.67	0.112	0.089	26.03	0.485	0.422
0.23	0.041	0.008	9.00	0.114	0.091	27.03	0.495	0.432
0.32	0.046	0.010	9.35	0.114	0.091	28.03	0.495	0.440
0.35	0.048	0.015	9.68	0.114	0.094	29.03	0.508	0.445
0.47	0.051	0.018	10.02	0.114	0.097	30.03	0.516	0.455
0.63	0.058	0.030	10.35	0.114	0.097	31.03	0.513	0.457
0.80	0.064	0.036	10.68	0.114	0.097	32.03	0.521	0.470
0.97	0.066	0.046	11.02	0.114	0.099	33.03	0.534	0.478
1.80	0.076	0.056	11.35	0.114	0.099	34.03	0.539	0.485
1.97	0.081	0.061	11.68	0.114	0.099	35.03	0.534	0.490
2.13	0.086	0.064	12.02	0.114	0.099	36.03	0.539	0.490
2.30	0.086	0.064	12.35	0.114	0.099	37.03	0.546	0.501
2.48	0.086	0.064	12.68	0.114	0.099	38.03	0.551	0.501
2.65	0.091	0.066	13.02	0.114	0.099	39.03	0.546	0.501
2.82	0.094	0.069	13.52	0.117	0.099	40.03	0.559	0.506
2.98	0.097	0.069	14.02	0.117	0.099	41.03	0.564	0.511
3.15	0.097	0.071	15.02	0.155	0.135	42.03	0.569	0.516
3.32	0.097	0.071	15.22	0.203	0.178	43.03	0.572	0.521
3.48	0.097	0.074	15.52	0.236	0.221	44.03	0.572	0.526
3.65	0.097	0.076	16.03	0.277	0.264	45.03	0.572	0.531
3.82	0.099	0.079	16.53	0.310	0.287	67.03	0.658	0.605
3.98	0.099	0.079	17.03	0.338	0.310	68.03	0.661	0.605
4.15	0.099	0.081	17.53	0.358	0.323	69.03	0.655	0.607
4.32	0.102	0.081	18.03	0.379	0.333	70.03	0.658	0.610
4.48	0.102	0.084	18.53	0.391	0.338	71.03	0.655	0.615
4.65	0.102	0.084	19.03	0.407	0.348	72.03	0.658	0.617
4.82	0.102	0.084	19.53	0.417	0.353	73.03	0.655	0.628
5.00	0.102	0.084	20.03	0.422	0.358	74.03	0.666	0.628
5.33	0.102	0.086	20.53	0.427	0.363	75.03	0.666	0.630
5.67	0.104	0.084	21.03	0.434	0.371	76.03	0.666	0.630
6.00	0.104	0.086	21.53	0.445	0.381	77.03	0.668	0.628

Table C-11 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
78.03	0.666	0.630	137.02	0.749	0.724	194.98	0.823	0.803
79.03	0.671	0.633	138.02	0.752	0.722	195.98	0.823	0.803
80.03	0.673	0.635	139.02	0.752	0.722	196.98	0.823	0.808
81.03	0.673	0.635	140.02	0.755	0.722	197.98	0.826	0.808
82.03	0.678	0.638	161.00	0.780	0.755	198.98	0.831	0.810
83.03	0.681	0.640	162.00	0.780	0.757	199.98	0.831	0.813
84.03	0.681	0.645	163.00	0.783	0.757	200.98	0.833	0.813
85.03	0.683	0.643	164.00	0.783	0.762	201.98	0.838	0.818
86.03	0.686	0.648	165.00	0.783	0.762	202.98	0.836	0.816
87.03	0.686	0.653	166.00	0.785	0.762	203.98	0.836	0.816
88.03	0.689	0.653	167.00	0.785	0.762	204.98	0.838	0.816
89.03	0.694	0.658	168.00	0.785	0.765	205.98	0.838	0.821
90.03	0.694	0.661	169.00	0.790	0.762	206.98	0.838	0.821
91.03	0.694	0.661	170.00	0.788	0.767	209.98	0.841	0.823
92.03	0.696	0.661	171.00	0.788	0.767	210.98	0.843	0.826
93.03	0.696	0.663	172.00	0.788	0.767	211.98	0.843	0.828
94.03	0.694	0.666	173.00	0.790	0.767	212.98	0.843	0.831
95.03	0.701	0.671	174.00	0.790	0.767	213.98	0.838	0.823
116.02	0.719	0.696	175.00	0.793	0.770	214.98	0.838	0.818
117.02	0.724	0.699	176.00	0.795	0.772	215.98		0.821
118.02	0.729	0.699	177.00	0.798	0.772	216.98		0.818
119.02	0.729	0.699	178.00	0.798	0.775	217.98		0.818
120.02	0.729	0.701	179.00	0.800	0.775	218.98		0.818
121.02	0.732	0.699	180.00	0.800	0.775	219.98		0.816
122.02	0.727	0.699	181.00	0.803	0.785	220.98		0.813
123.02	0.737	0.699	182.00	0.805	0.783	221.98		0.816
124.02	0.737	0.704	183.00	0.805	0.783	222.98		0.818
125.02	0.737	0.709	184.00	0.810	0.785	223.98		0.823
126.02	0.737	0.711	185.00	0.810	0.785	232.98		0.841
128.02	0.739	0.714	186.00	0.813	0.788	233.98	0.856	0.846
129.02	0.744	0.716	187.00	0.813	0.793	234.98		0.849
130.02	0.747	0.722	188.00	0.813	0.790	235.98		0.849
131.02	0.742	0.722	189.00	0.818	0.795	236.98		0.856
132.02	0.744	0.722	189.98	0.818	0.795	237.98		0.859
133.02	0.744	0.722	190.98	0.818	0.795	238.98		0.864
134.02	0.747	0.724	191.98	0.818	0.798	239.98		0.869
135.02	0.747	0.722	192.98	0.823	0.798	240.98		0.871
136.02	0.749	0.724	193.98	0.823	0.798	241.98		0.871

Table C-11 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
242.98			280.98			326.97		0.940
243.98			281.98			327.97		0.943
244.98			282.98			328.97	0.948	0.943
245.98			283.98			329.97		0.945
246.98			284.98			330.97		0.945
247.98			285.98			331.97		0.948
248.98			286.98			332.97	0.953	0.950
249.98			287.98			333.97	0.955	0.948
250.98			288.98			334.15	0.960	0.953
251.98			289.98			335.15	0.963	0.953
252.98			290.98			336.15	0.963	0.955
253.98			291.98			337.15	0.960	0.955
254.98			292.98			338.15	0.960	0.953
255.98			293.98			339.15	0.963	0.958
256.98			294.98			340.15	0.965	0.960
257.98			295.98		0.915	341.15	0.963	0.963
258.98			296.98		0.912	342.15	0.965	0.963
259.98			297.98		0.917	343.15	0.968	0.965
260.98			298.98		0.920	344.15	0.968	0.965
261.98			299.98		0.920	345.15	0.965	0.965
262.98			300.98		0.925	346.15	0.965	0.963
263.98			301.98		0.930	347.15	0.965	0.965
264.98			302.98		0.930	348.15	0.960	0.963
265.98			311.97		0.902	349.15	0.958	0.958
266.98			312.97		0.904	350.15	0.955	0.953
267.98			313.97		0.907	351.15	0.953	0.955
268.98			314.97		0.910	352.10	0.932	0.940
269.98			315.97		0.910			
270.98			316.97		0.915			
271.98			317.97		0.915			
272.98			318.97		0.915			
273.98			319.97		0.920			
274.98			320.97		0.920			
275.98			321.97		0.922			
276.98			322.97		0.925			
277.98			323.97		0.927			
278.98			324.97		0.932			
279.98			325.97		0.938			

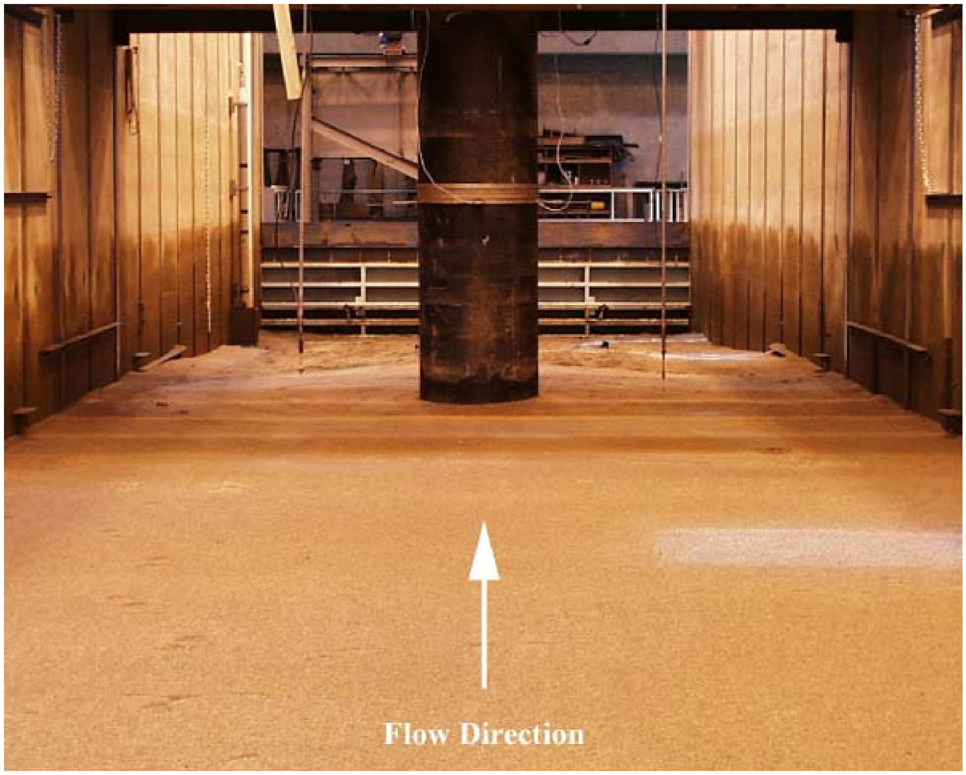

Figure C- 114. Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) before test.

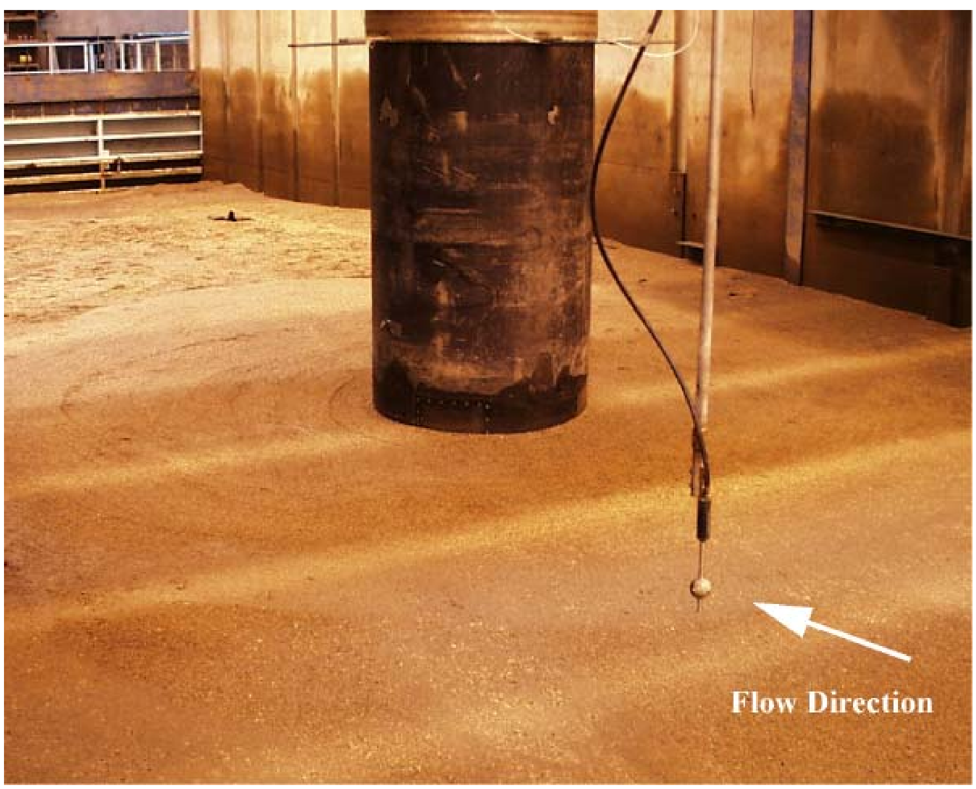

Figure C- 115. Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) before test.

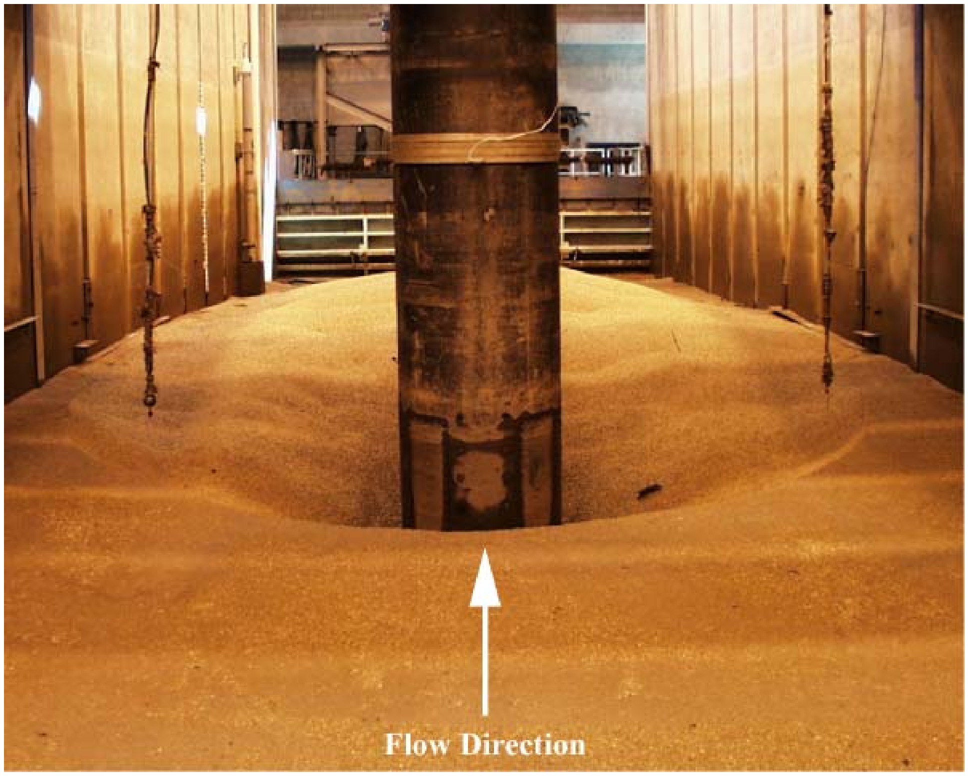

Figure C- 116. Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 117. Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 118. Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 119. Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 120.   Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Figure C- 121.   Experiment 11 (D = 0.915 m, D_{50} = 2.90 mm) after test.

Experiment 12
Scour Summary Form

Circular Pile diameter, D: **0.305 m**

Sediment:

Type:	**Quartz**	Start Date:	**10/05/2000**	Start Time:	**3:00 PM**
D_{50}(mm):	**0.22**	Stop Date:	**10/17/00**	Stop Time:	**9:00 AM**
σ:	1.51				
ρ_s (Kg/m^3):	**2650**	Duration:	**256 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):		**0.37**
Maximum(m/s):		**0.41**
Minimum(m/s):		**0.32**

Channel average velocity from weir (m/s): **0.31**

Critical (sediment) velocity, V_c (m/s): **0.33**

Bed Relative Roughness, RR: **5**

Water depth, y_0 :
- Average water depth(m): **1.22**
- Minimum(m):
- Maximum(m):

Water Temperature:
- Average (degrees C): **15.0**
- Maximum (degrees C): **17.2**
- Minimum (degrees C): **14.4**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.385**
- Maximum depth from internal video cameras (m): **0.370**
- Maximum depth from point gauge (m): **0.377**
- Maximum scour depth (m): **0.377**

Dimensionless Parameters:
- y_0/D: **4.0** V/V_c: **1.23** D/D_{50}: **1386**

d_s/D: **1.24**

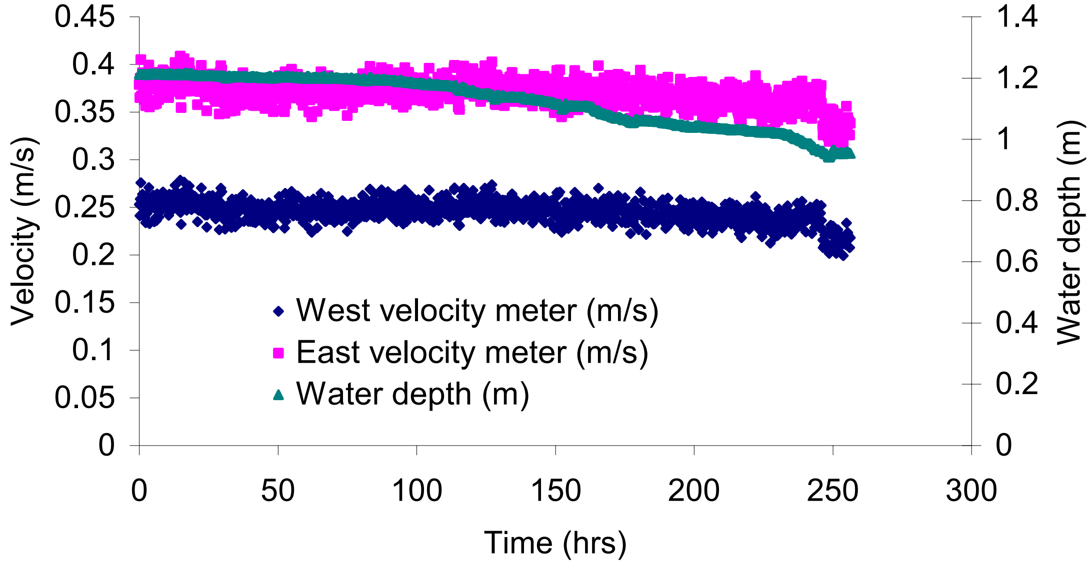

Figure C- 122. Measured velocity and water depth for experiment 12.

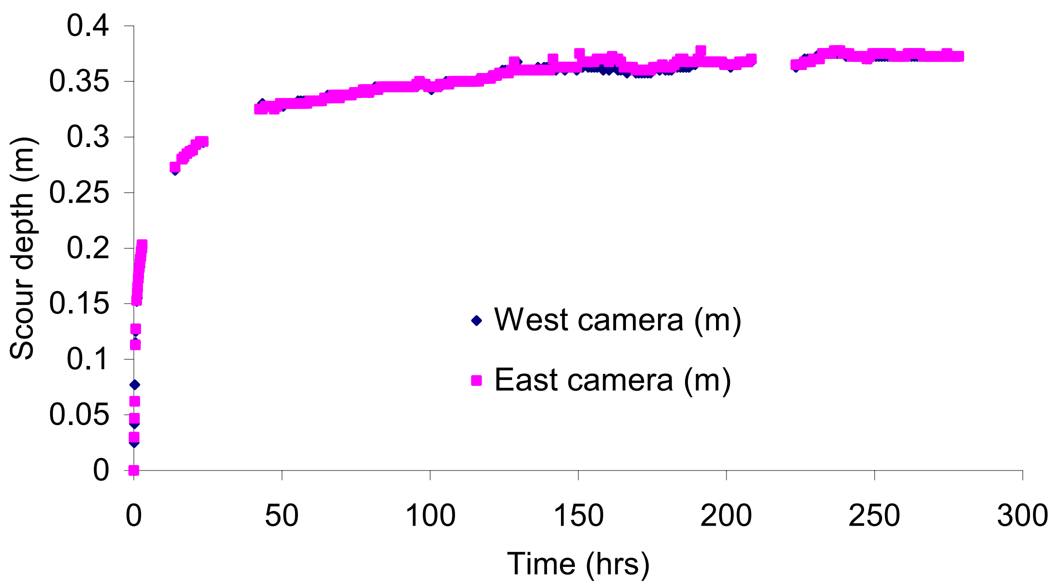

Figure C- 123. Measured local scour data from the internal video cameras for experiment 12.

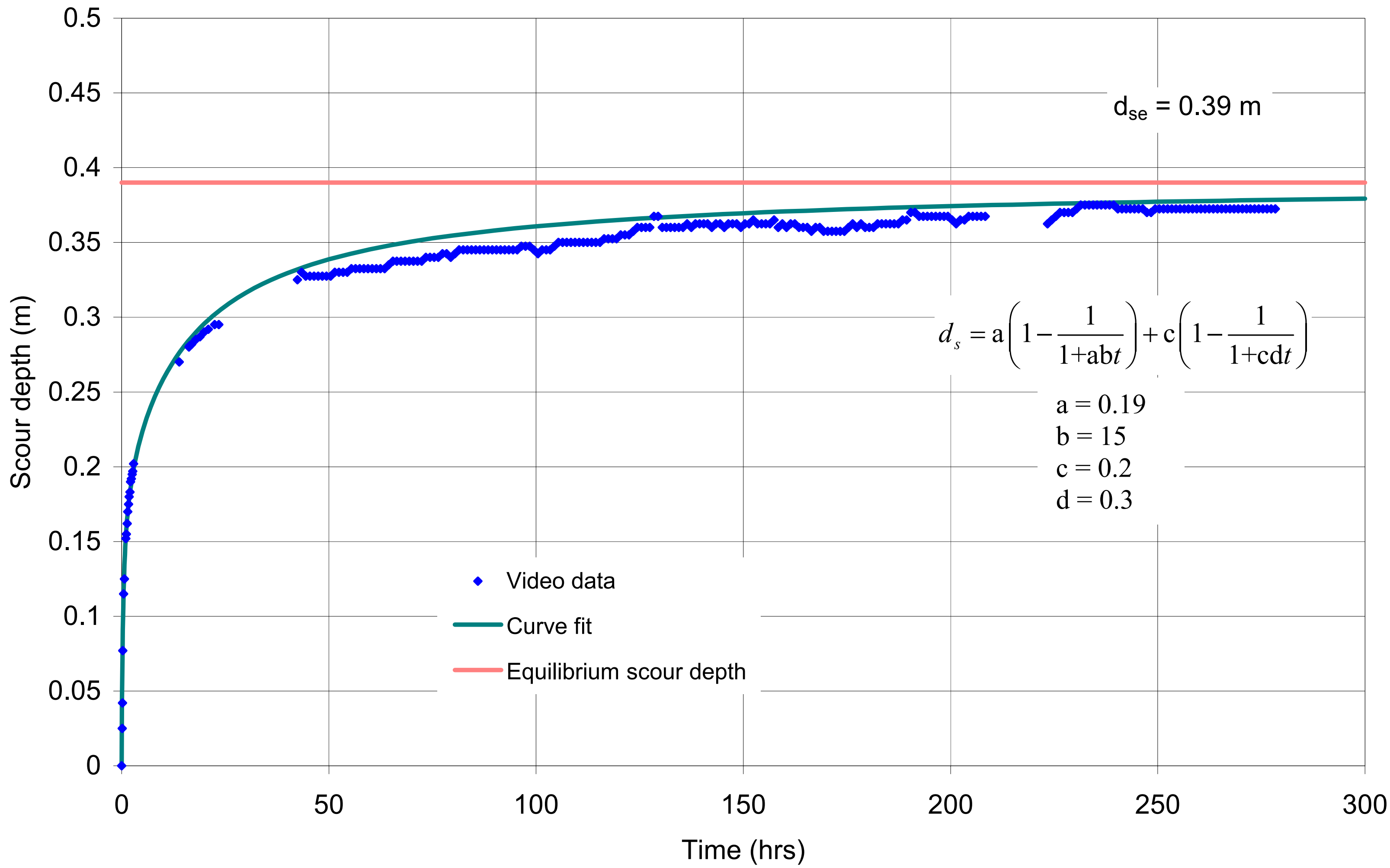

Figure C- 124. Curve fit to the local scour data measured with the internal video camera for experiment 12.

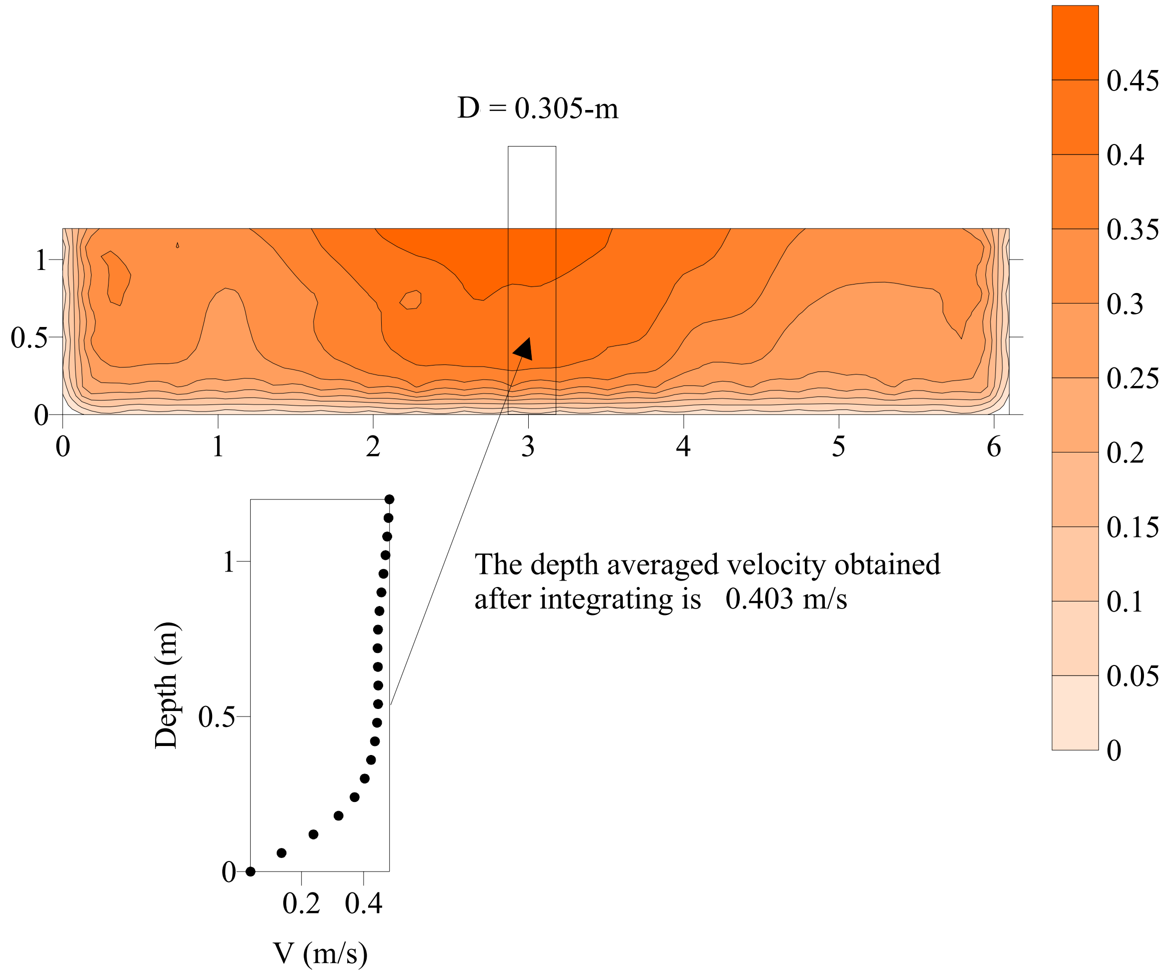

Figure C- 125. Velocity profile for experiment 12 taken at the end of the experiment. All dimensions are in meters and the velocity is in meters / second.

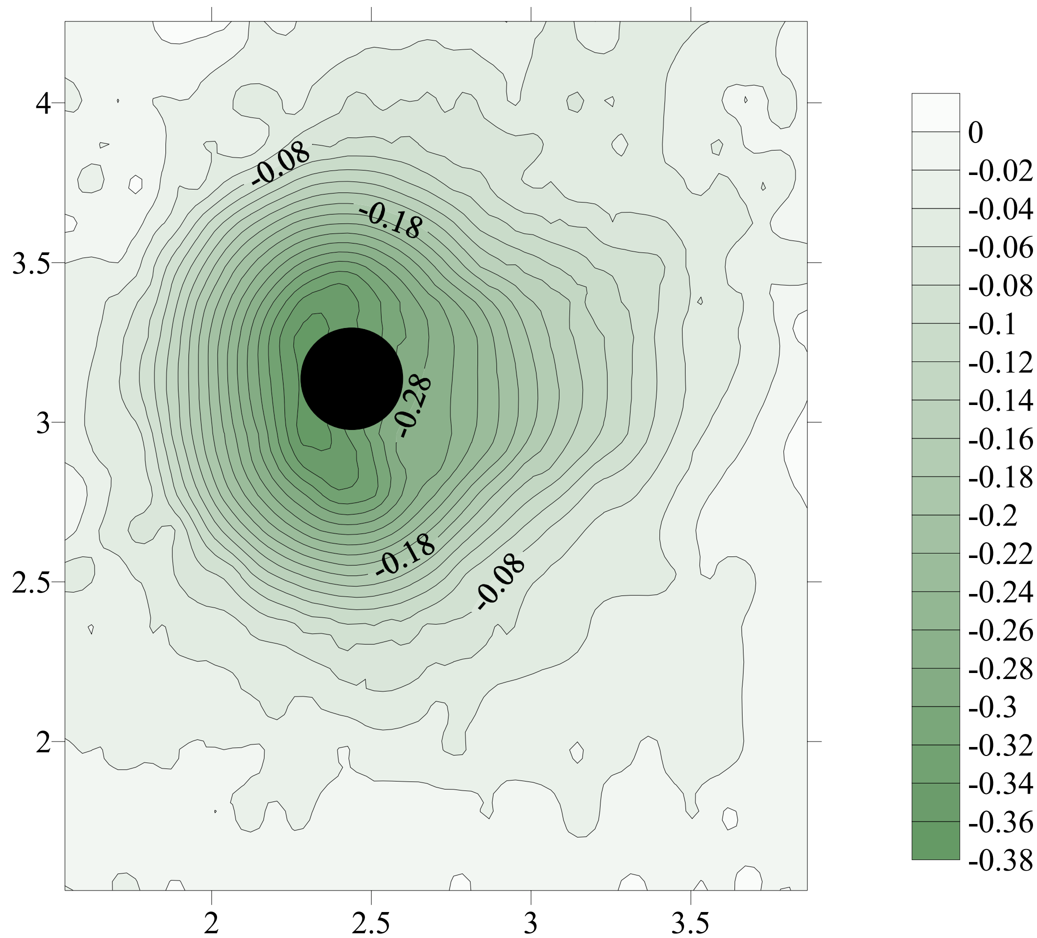

Figure C- 126. Bed elevation contours at completion of experiment 12 referenced to the original bed. All dimensions are in meters.

Table C-12. The rate of scour depth from the internal video camera for experiment 12.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0	0	0	52.42	0.330	0.330	90.42	0.345	0.345
0.13	0.025	0.030	53.42	0.330	0.330	91.42	0.345	0.345
0.18	0.042	0.047	54.42	0.330	0.330	92.42	0.345	0.345
0.30	0.077	0.062	55.42	0.333	0.330	93.42	0.345	0.345
0.50	0.115	0.113	56.42	0.333	0.330	94.42	0.345	0.345
0.67	0.125	0.128	57.42	0.333	0.330	95.42	0.345	0.348
1.00	0.152	0.153	58.42	0.333	0.330	96.42	0.348	0.350
1.17	0.155	0.160	59.42	0.333	0.333	97.42	0.348	0.348
1.33	0.162	0.165	60.42	0.333	0.333	98.42	0.348	0.348
1.50	0.170	0.173	61.42	0.333	0.333	99.42	0.345	0.345
1.67	0.175	0.176	62.42	0.333	0.333	100.42	0.343	0.345
1.83	0.180	0.182	63.42	0.333	0.333	101.42	0.345	0.345
2.00	0.183	0.186	64.42	0.335	0.335	102.42	0.345	0.345
2.17	0.190	0.190	65.42	0.338	0.335	103.42	0.345	0.348
2.33	0.192	0.193	66.42	0.338	0.335	104.42	0.348	0.348
2.52	0.195	0.197	67.42	0.338	0.338	105.42	0.350	0.348
2.67	0.197	0.200	68.42	0.338	0.338	106.42	0.350	0.348
2.85	0.202	0.203	69.42	0.338	0.335	107.42	0.350	0.350
13.92	0.270	0.273	70.42	0.338	0.338	108.42	0.350	0.350
16.25	0.280	0.280	71.42	0.338	0.338	109.42	0.350	0.350
16.42	0.281	0.280	72.42	0.338	0.338	110.42	0.350	0.350
16.92	0.282	0.282	73.42	0.340	0.338	111.42	0.350	0.350
17.92	0.285	0.285	74.42	0.340	0.340	112.42	0.350	0.350
18.92	0.287	0.287	75.42	0.340	0.340	113.42	0.350	0.350
19.92	0.290	0.288	76.42	0.340	0.340	114.42	0.350	0.350
20.92	0.292	0.293	77.42	0.343	0.343	115.42	0.350	0.350
22.42	0.295	0.296	78.42	0.343	0.343	116.42	0.353	0.350
23.43	0.295	0.296	79.42	0.340	0.340	117.42	0.353	0.353
42.42	0.325	0.325	80.42	0.343	0.343	118.42	0.353	0.353
43.42	0.330	0.325	81.42	0.345	0.343	119.42	0.353	0.353
44.42	0.328	0.328	82.42	0.345	0.343	120.42	0.355	0.353
45.42	0.328	0.328	83.42	0.345	0.345	121.42	0.355	0.355
46.42	0.328	0.328	84.42	0.345	0.345	122.42	0.355	0.355
47.42	0.328	0.325	85.42	0.345	0.345	123.42	0.358	0.358
48.42	0.328	0.328	86.42	0.345	0.345	124.42	0.360	0.358
49.42	0.328	0.330	87.42	0.345	0.345	125.42	0.360	0.358
50.42	0.328	0.330	88.42	0.345	0.345	126.42	0.360	0.358
51.42	0.330	0.330	89.42	0.345	0.345	127.42	0.360	0.360

Table C-12 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
128.42	0.368	0.368	166.40	0.358	0.363	204.38	0.368	0.368
129.42	0.368	0.360	167.40	0.360	0.363	205.38	0.368	0.368
130.42	0.360	0.360	168.40	0.360	0.363	206.38	0.368	0.368
131.42	0.360	0.360	169.40	0.358	0.360	207.38	0.368	0.368
132.42	0.360	0.360	170.40	0.358	0.360	208.38	0.368	0.370
133.42	0.360	0.360	171.40	0.358	0.360	223.38	0.363	0.365
134.42	0.360	0.360	172.40	0.358	0.360	224.38	0.365	0.365
135.42	0.360	0.360	173.40	0.358	0.360	225.38	0.368	0.365
136.42	0.363	0.360	174.40	0.358	0.360	226.38	0.370	0.368
137.42	0.360	0.360	175.40	0.360	0.363	227.38	0.370	0.368
138.42	0.363	0.360	176.40	0.363	0.363	228.38	0.370	0.368
139.42	0.363	0.360	177.40	0.360	0.363	229.38	0.370	0.370
140.42	0.363	0.360	178.40	0.363	0.365	230.38	0.373	0.370
141.42	0.363	0.370	179.40	0.360	0.363	231.38	0.375	0.370
142.42	0.360	0.363	180.40	0.360	0.363	232.38	0.375	0.375
143.42	0.363	0.363	181.40	0.360	0.363	233.38	0.375	0.375
144.42	0.363	0.363	182.40	0.363	0.365	234.42	0.375	0.375
145.42	0.360	0.363	183.40	0.363	0.368	235.38	0.375	0.375
146.42	0.363	0.363	184.40	0.363	0.370	236.38	0.375	0.378
147.42	0.363	0.363	185.40	0.363	0.370	237.38	0.375	0.378
148.42	0.363	0.363	186.40	0.363	0.368	238.38	0.375	0.378
149.42	0.360	0.363	187.40	0.363	0.368	239.38	0.375	0.375
150.42	0.363	0.375	188.40	0.365	0.368	240.38	0.373	0.375
151.40	0.363	0.368	189.40	0.365	0.368	241.38	0.373	0.375
152.40	0.365	0.368	190.40	0.370	0.370	242.38	0.373	0.373
153.40	0.363	0.368	191.40	0.370	0.378	243.38	0.373	0.373
154.40	0.363	0.368	192.40	0.368	0.368	244.38	0.373	0.373
155.40	0.363	0.368	193.40	0.368	0.368	245.38	0.373	0.373
156.40	0.363	0.370	194.40	0.368	0.368	246.38	0.373	0.373
157.38	0.365	0.370	195.40	0.368	0.368	247.38	0.370	0.370
158.40	0.360	0.370	196.40	0.368	0.368	248.38	0.370	0.373
159.40	0.363	0.370	197.40	0.368	0.368	249.38	0.373	0.375
160.40	0.360	0.368	198.40	0.368	0.368	250.38	0.373	0.375
161.40	0.363	0.373	199.38	0.368	0.365	251.38	0.373	0.375
162.40	0.363	0.370	200.38	0.365	0.365	252.38	0.373	0.375
163.40	0.360	0.370	201.38	0.363	0.365	253.38	0.373	0.375
164.40	0.360	0.368	202.38	0.365	0.365	254.38	0.373	0.375
165.40	0.360	0.363	203.38	0.365	0.365	255.38	0.373	0.375

Table C-12 (continued)

Time (hrs)	East camera (m)	West camera (m)
256.38	0.373	0.373
257.38	0.373	0.373
258.38	0.373	0.373
259.38	0.373	0.373
260.38	0.373	0.373
261.38	0.373	0.375
262.38	0.373	0.375
263.38	0.373	0.375
264.38	0.373	0.375
265.38	0.373	0.375
266.38	0.373	0.373
267.38	0.373	0.373
268.38	0.373	0.373
269.38	0.373	0.373
270.38	0.373	0.373
271.38	0.373	0.373
272.37	0.373	0.373
273.37	0.373	0.373
274.37	0.373	0.375
275.37	0.373	0.373
276.37	0.373	0.373
277.37	0.373	0.373
278.37	0.373	0.373

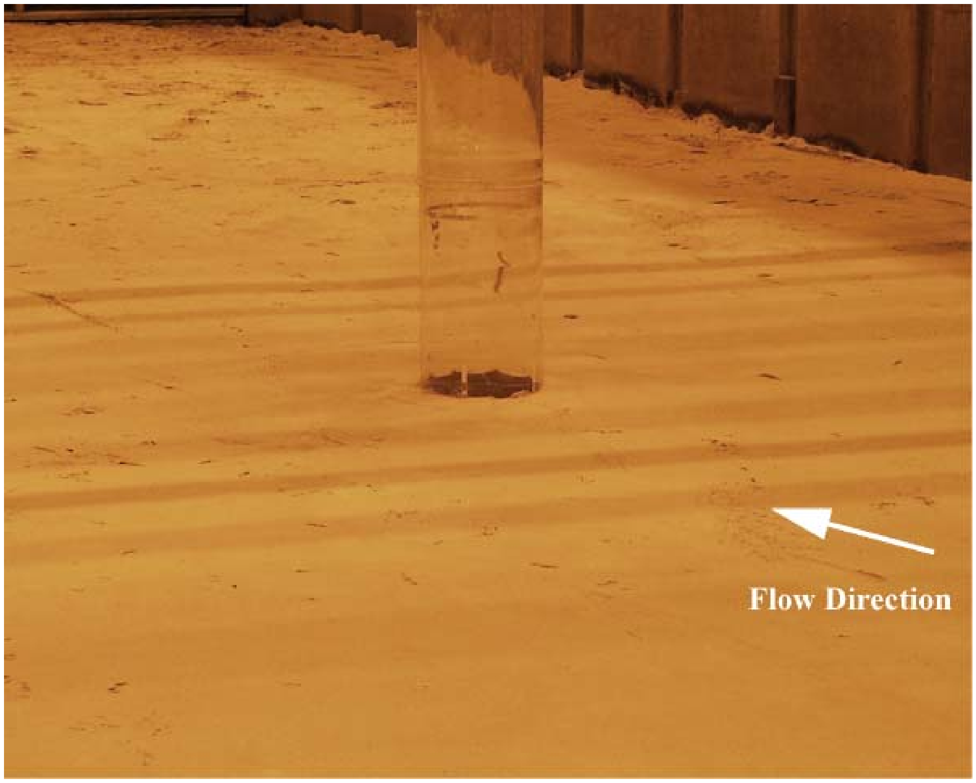

Figure C- 127. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) before test.

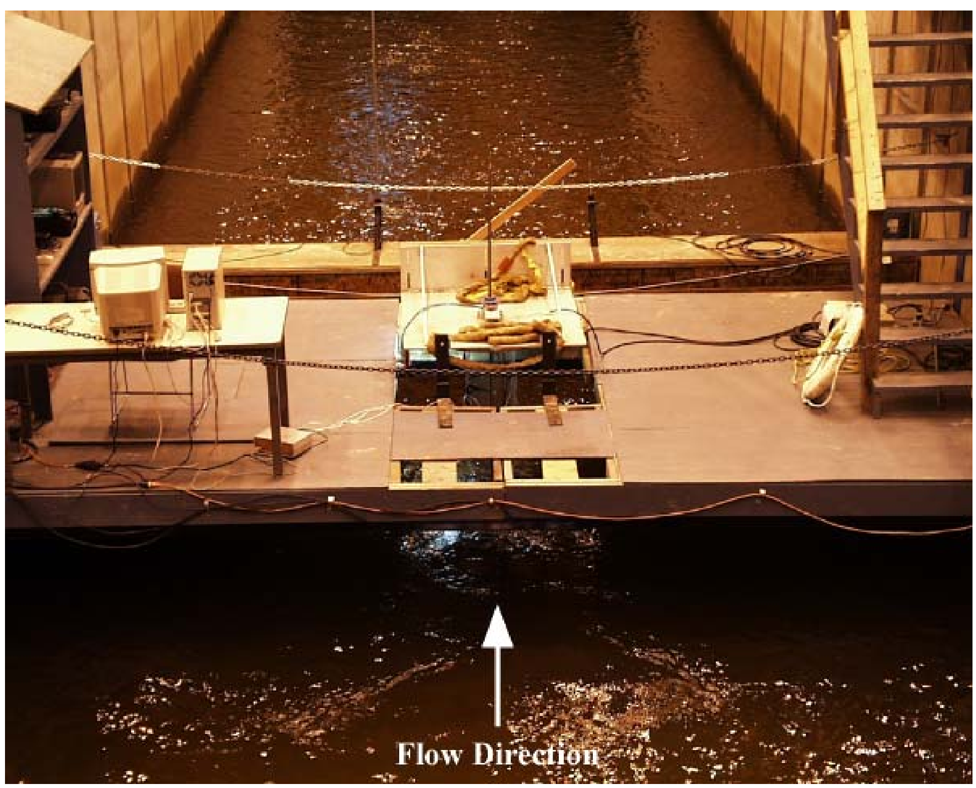

Figure C- 128. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) during the test.

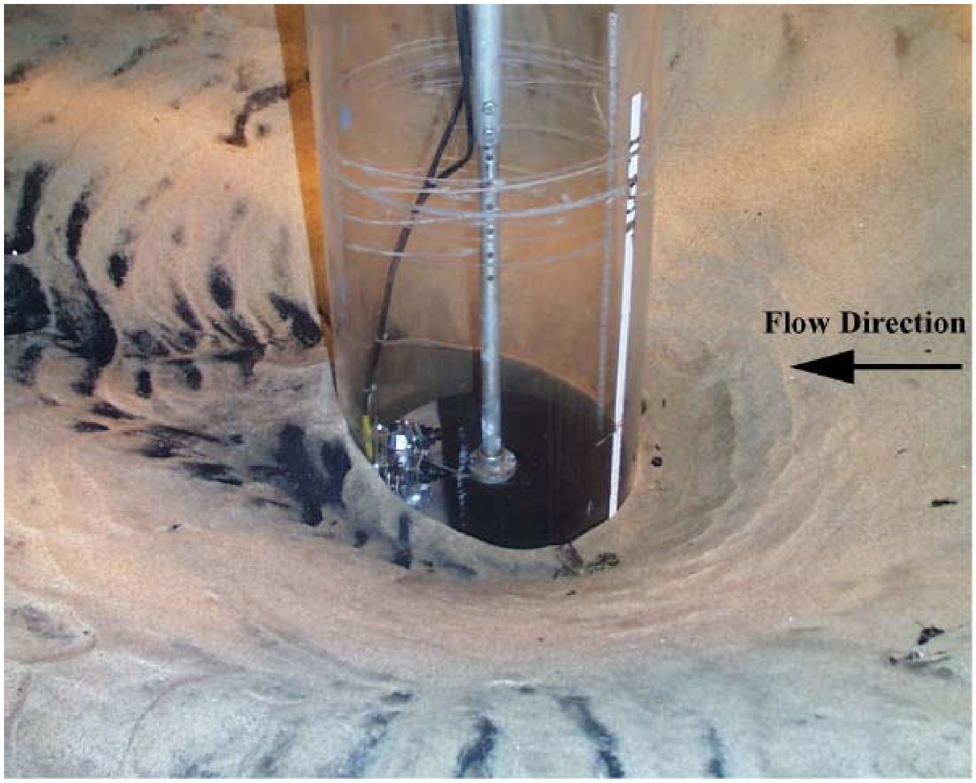

Figure C- 129. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

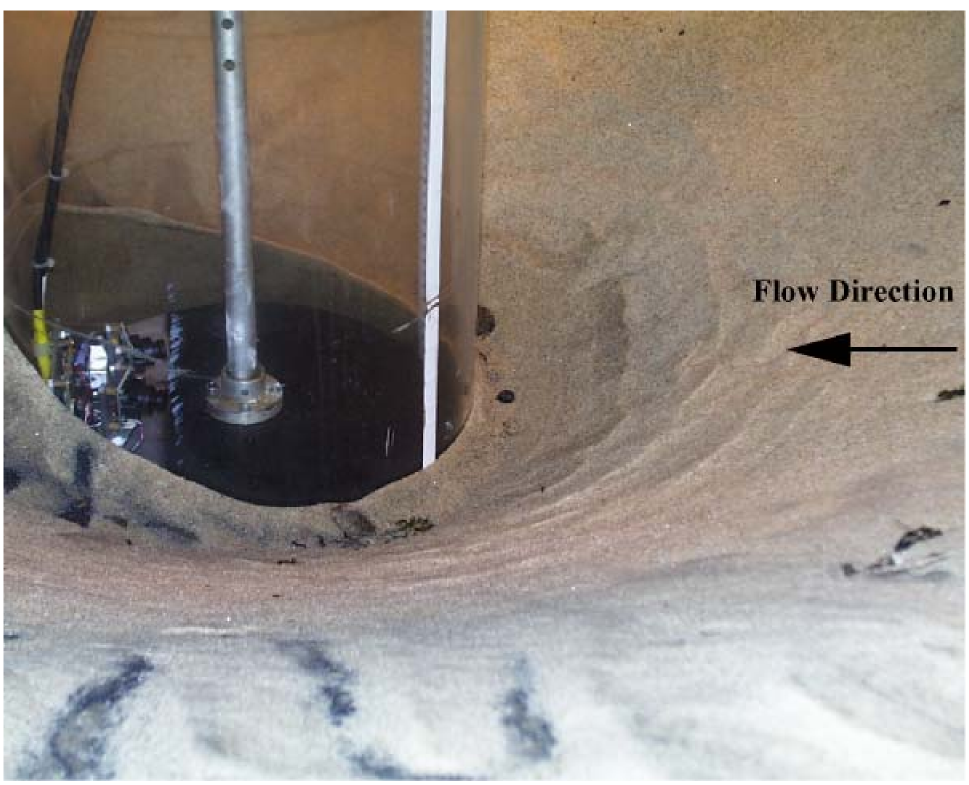

Figure C- 130. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

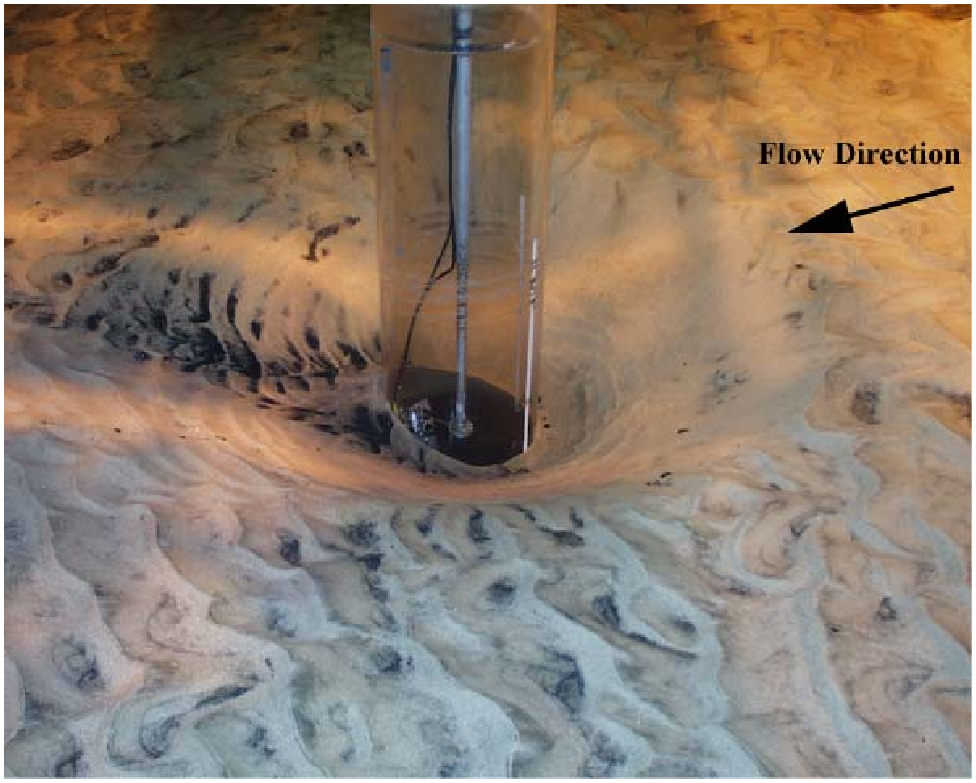

Figure C- 131. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

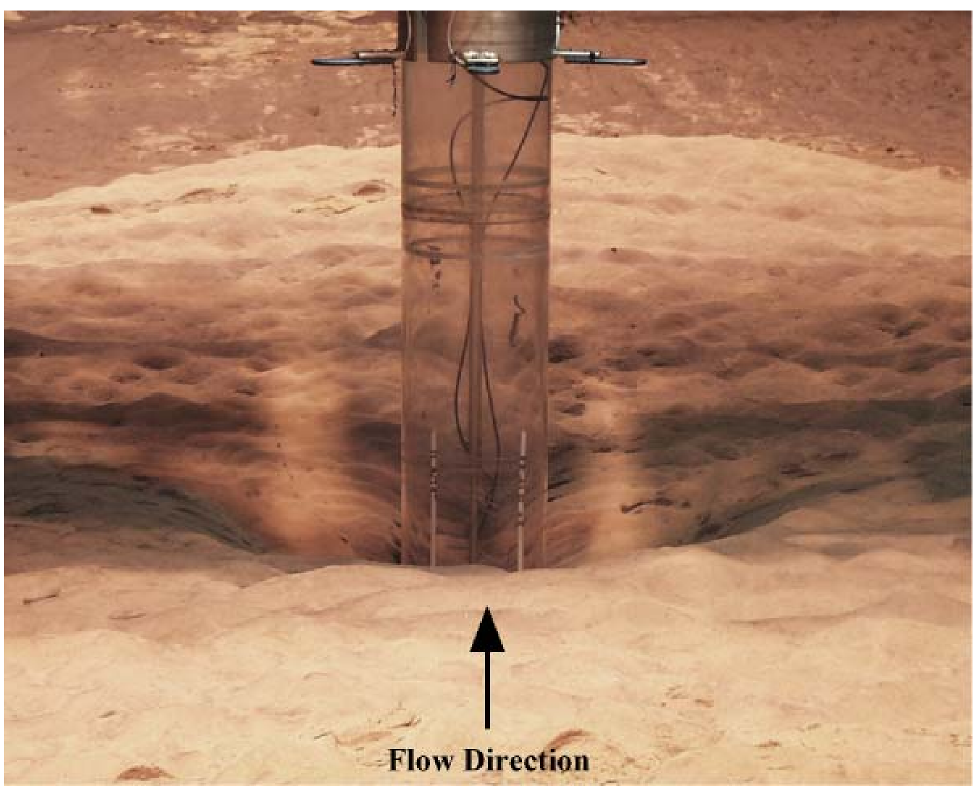

Figure C- 132. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

Figure C- 133. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

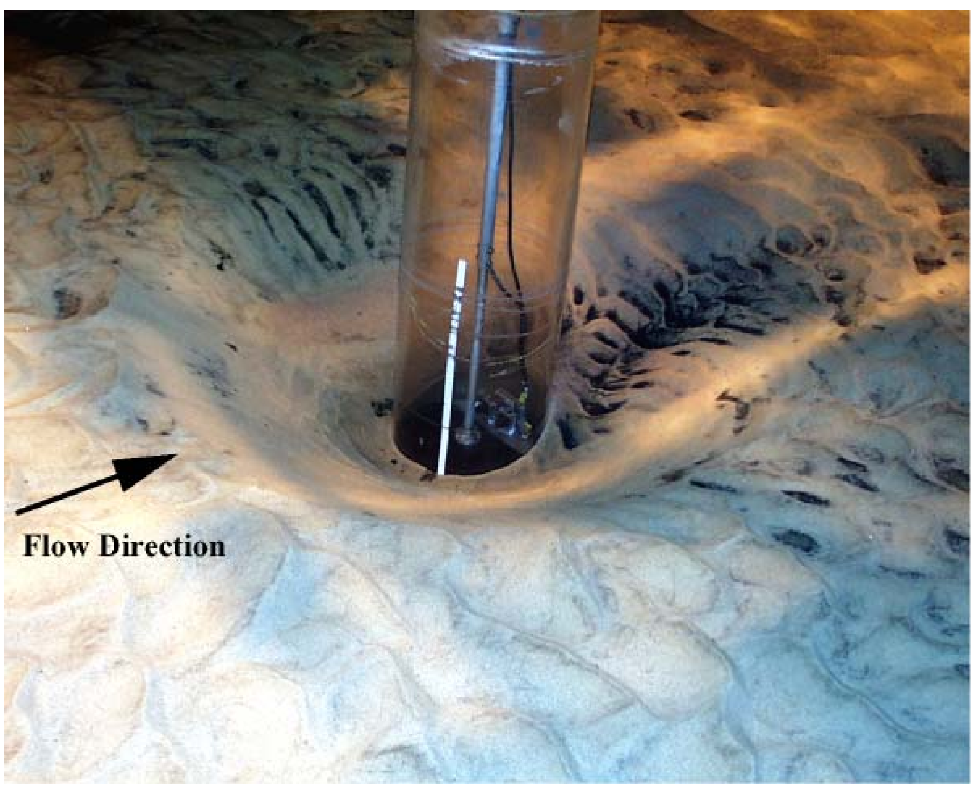

Figure C- 134. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

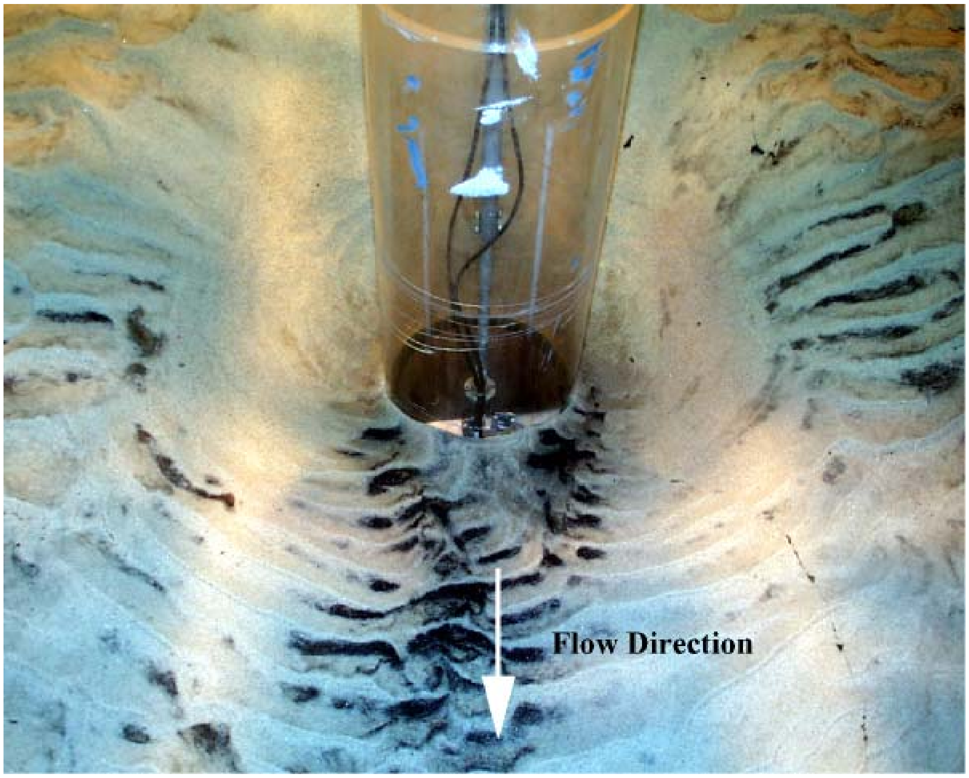

Figure C- 135. Experiment 12 (D = 0.305 m, D_{50} = 0.22 mm) after test.

Experiment 13
Scour Summary Form

Circular Pile diameter, D: **0.305 m**

Sediment:

Type:	**Quartz**	Start Date:	**10/20/2000**	Start Time:	**3:00 PM**
D_{50}(mm):	**0.22**	Stop Date:	**10/29/2000**	Stop Time:	**2:05 PM**
σ:	1.51				
ρ_s (Kg/m^3):	**2650**	Duration:	**215 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.30**	
Maximum(m/s):	**0.38**	
Minimum(m/s):	**0.24**	

Channel average velocity from weir (m/s): **0.27**

Critical (sediment) velocity, V_c (m/s): **0.27**

Bed Relative Roughness, RR: **5**

Water depth, y_0 :
- Average water depth(m): **0.18**
- Minimum(m): **0.17**
- Maximum(m): **0.19**

Water Temperature:
- Average (degrees C): **12.7**
- Maximum (degrees C): **14.8**
- Minimum (degrees C): **9.3**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m):
- Maximum depth from internal video cameras (m): **0.265**
- Maximum depth from point gauge (m): **0.296**
- Maximum scour depth (m): **0.296**

Dimensionless Parameters:

y_0/D: **0.6** V/V_c: **1.11** D/D_{50}: **1386**

d_s/D: **0.97**

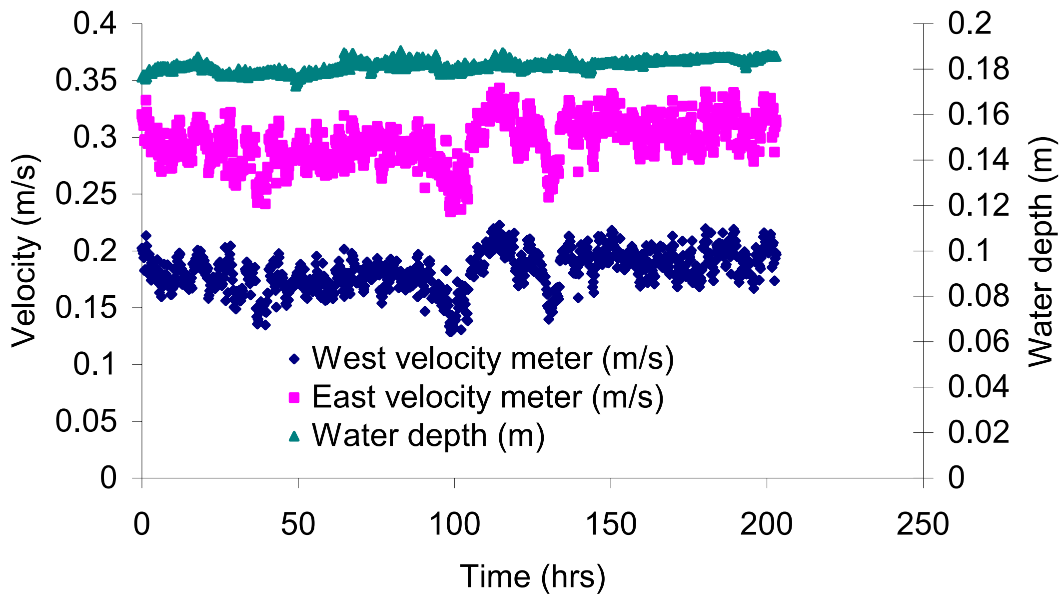

Figure C- 136. Measured velocity and water depth for experiment 13.

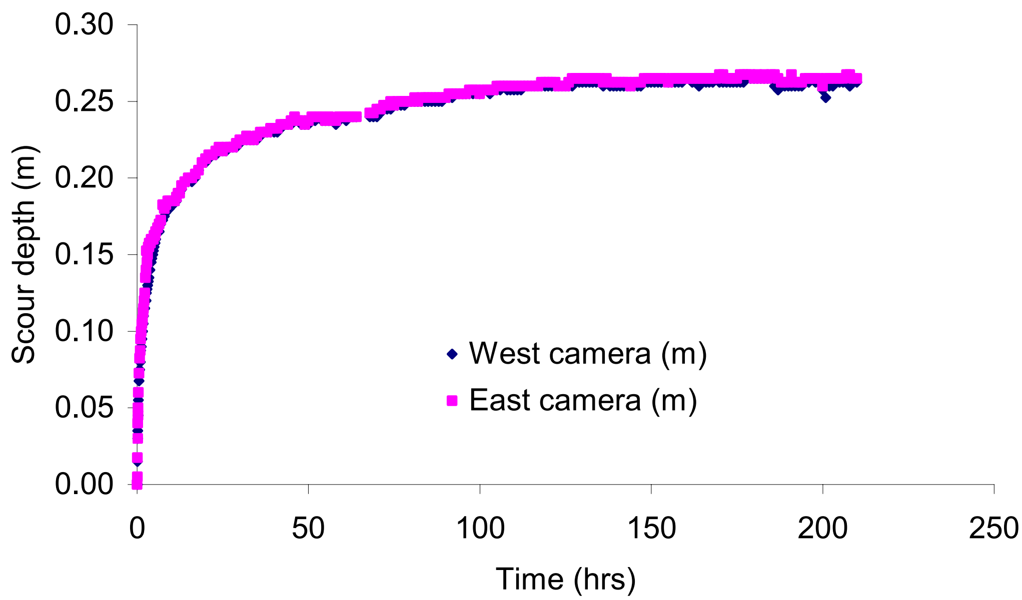

Figure C- 137. Measured local scour data from the internal video cameras for experiment 13.

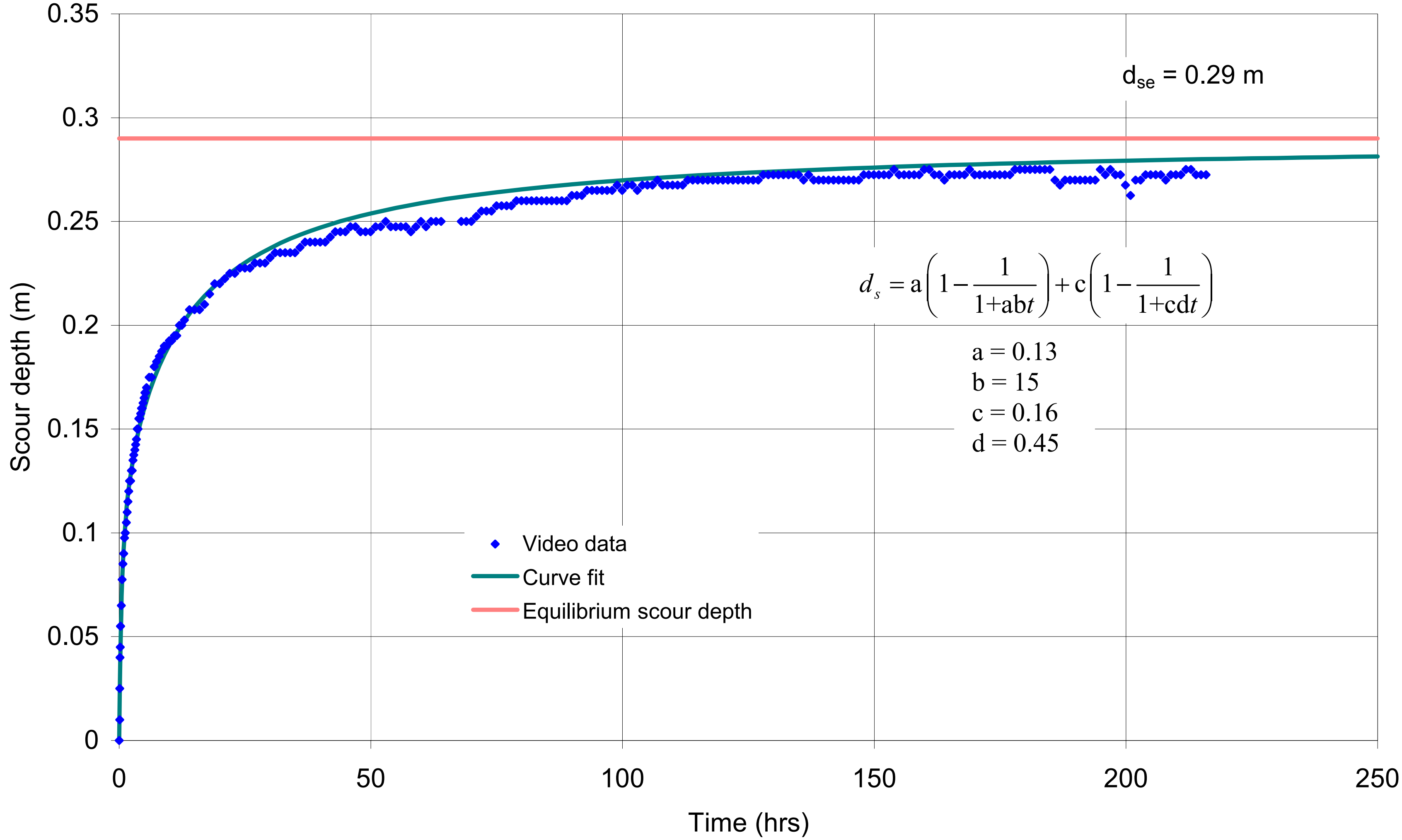

Figure C- 138. Curve fit to the local scour data measured with the internal video camera for experiment 13.

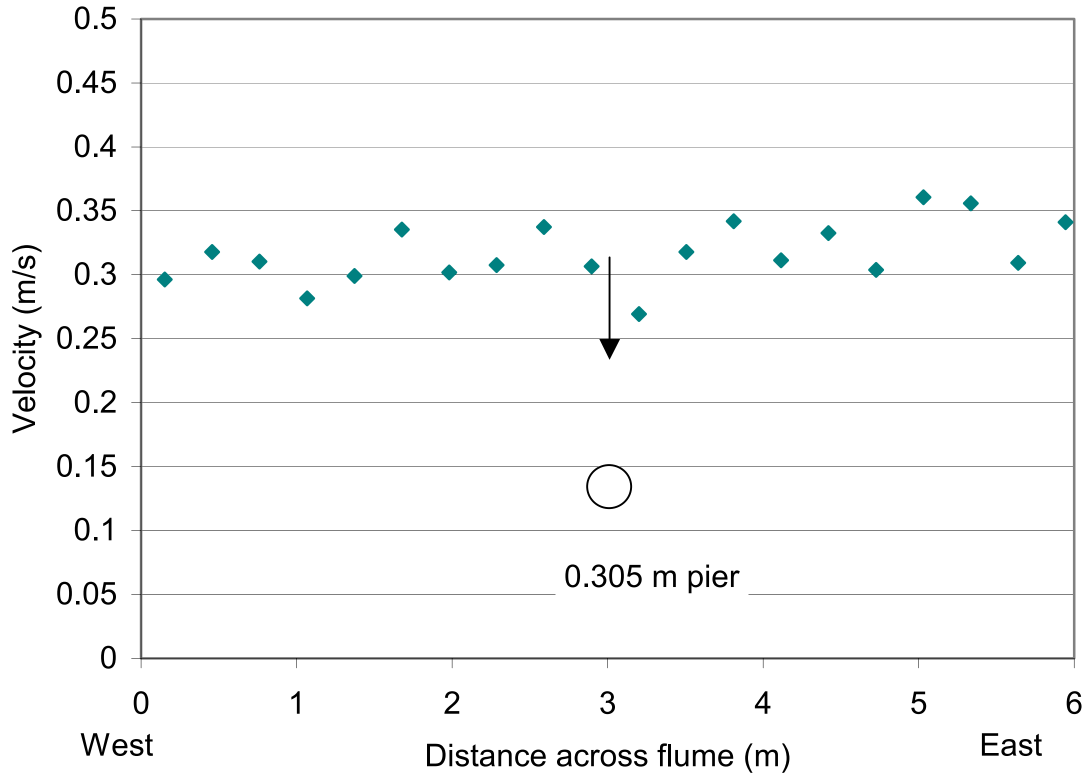

Figure C- 139. Velocity traverse across the flume at the 0.09 m elevation above the bed for experiment 13.

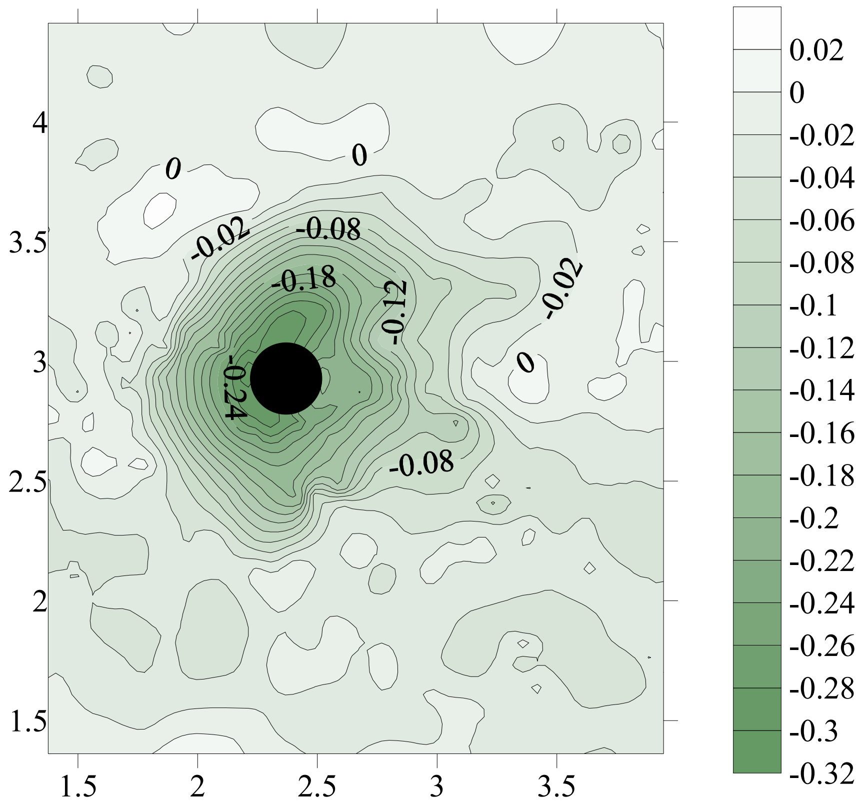

Figure C- 140. Bed elevation contours at completion of experiment 13 referenced to the original bed. All dimensions are in meters.

Table C-13. The rate of scour depth from the internal video cameras for experiment 13.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0.0	0.0	0.0	5.93	0.165	0.168	36.95	0.230	0.230
0.08	0.0	0.005	6.43	0.165	0.170	37.95	0.230	0.230
0.12	0.015	0.018	6.93	0.170	0.173	38.95	0.230	0.233
0.17	0.030	0.030	7.43	0.173	0.183	39.95	0.230	0.233
0.20	0.035	0.040	7.93	0.175	0.180	40.95	0.230	0.233
0.25	0.045	0.045	8.43	0.178	0.183	41.95	0.233	0.235
0.28	0.045	0.050	8.95	0.180	0.185	42.95	0.235	0.235
0.40	0.055	0.060	9.45	0.180	0.185	43.95	0.235	0.235
0.57	0.068	0.073	9.95	0.183	0.185	44.95	0.235	0.238
0.73	0.075	0.083	10.45	0.183	0.185	45.95	0.238	0.240
0.90	0.080	0.088	10.95	0.185	0.185	46.95	0.238	0.238
1.07	0.088	0.095	11.45	0.185	0.188	47.95	0.235	0.238
1.23	0.090	0.100	11.95	0.190	0.190	48.95	0.235	0.235
1.40	0.095	0.105	12.45	0.190	0.190	49.95	0.235	0.238
1.57	0.100	0.108	12.95	0.193	0.195	50.95	0.238	0.240
1.73	0.105	0.113	13.95	0.198	0.198	51.95	0.238	0.240
1.90	0.110	0.115	14.95	0.198	0.200	52.95	0.240	0.240
2.07	0.115	0.120	15.95	0.198	0.200	53.95	0.238	0.240
2.25	0.115	0.125	16.95	0.200	0.203	54.95	0.238	0.238
2.42	0.120	0.135	17.95	0.205	0.205	55.95	0.238	0.240
2.58	0.120	0.140	18.95	0.210	0.210	56.95	0.238	0.238
2.75	0.125	0.153	19.95	0.210	0.213	57.95	0.235	0.238
2.92	0.128	0.145	20.95	0.213	0.215	58.95	0.238	0.240
3.08	0.130	0.150	21.95	0.215	0.215	59.95	0.240	0.240
3.25	0.133	0.155	22.95	0.215	0.218	60.95	0.238	0.240
3.42	0.135	0.155	23.95	0.218	0.220	61.95	0.240	0.240
3.58	0.140	0.158	24.95	0.218	0.218	62.95	0.240	0.240
3.75	0.140	0.158	25.95	0.218	0.220	63.95	0.240	0.240
3.92	0.145	0.158	26.95	0.220	0.220	67.93	0.240	0.243
4.08	0.145	0.160	27.95	0.220	0.220	68.93	0.240	0.243
4.25	0.148	0.160	28.95	0.220	0.223	69.93	0.240	0.245
4.42	0.150	0.160	29.95	0.223	0.225	70.93	0.243	0.245
4.58	0.150	0.160	30.95	0.225	0.225	71.93	0.245	0.248
4.77	0.153	0.160	31.95	0.225	0.228	72.93	0.245	0.248
4.93	0.155	0.163	32.95	0.225	0.225	73.93	0.245	0.250
5.10	0.158	0.163	33.95	0.225	0.225	74.93	0.248	0.248
5.27	0.158	0.163	34.95	0.225	0.228	75.93	0.248	0.250
5.43	0.160	0.165	35.95	0.228	0.230	76.93	0.248	0.250

Table C-13 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
77.93	0.248	0.250	115.93	0.260	0.260	153.92	0.265	0.265
78.93	0.250	0.250	116.93	0.260	0.260	154.92	0.263	0.263
79.93	0.250	0.250	117.93	0.260	0.263	155.92	0.263	0.265
80.93	0.250	0.253	118.93	0.260	0.263	156.92	0.263	0.265
81.93	0.250	0.250	119.93	0.260	0.263	157.92	0.263	0.265
82.93	0.250	0.253	120.93	0.260	0.263	158.92	0.263	0.265
83.93	0.250	0.253	121.93	0.260	0.263	159.92	0.265	0.265
84.93	0.250	0.253	122.93	0.260	0.260	160.92	0.265	0.265
85.93	0.250	0.253	123.93	0.260	0.260	161.92	0.263	0.265
86.93	0.250	0.253	124.93	0.260	0.260	162.92	0.263	0.265
87.93	0.250	0.253	125.93	0.260	0.263	163.92	0.260	0.265
88.93	0.250	0.253	126.93	0.260	0.265	164.92	0.263	0.265
89.93	0.253	0.253	127.93	0.263	0.265	165.92	0.263	0.265
90.93	0.253	0.255	128.93	0.263	0.265	166.92	0.263	0.265
91.93	0.253	0.255	129.93	0.263	0.265	167.92	0.263	0.265
92.93	0.255	0.255	130.93	0.263	0.265	168.92	0.265	0.265
93.93	0.255	0.255	131.93	0.263	0.265	169.92	0.263	0.268
94.93	0.255	0.255	132.93	0.263	0.265	170.92	0.263	0.268
95.93	0.255	0.255	133.93	0.263	0.265	171.92	0.263	0.265
96.93	0.255	0.258	134.93	0.263	0.265	172.92	0.263	0.265
97.93	0.255	0.258	135.93	0.260	0.263	173.92	0.263	0.265
98.93	0.258	0.258	136.93	0.263	0.265	174.92	0.263	0.265
99.93	0.255	0.255	137.93	0.260	0.263	175.92	0.263	0.268
100.93	0.258	0.258	138.93	0.260	0.263	176.92	0.263	0.268
101.93	0.258	0.258	139.93	0.260	0.263	177.92	0.265	0.268
102.93	0.255	0.258	140.93	0.260	0.263	178.92	0.265	0.268
103.93	0.258	0.258	141.93	0.260	0.263	179.92	0.265	0.265
104.93	0.258	0.260	142.93	0.260	0.263	180.92	0.265	0.268
105.93	0.258	0.260	143.93	0.260	0.260	181.92	0.265	0.265
106.93	0.260	0.260	144.93	0.260	0.263	182.92	0.265	0.268
107.93	0.258	0.260	145.93	0.260	0.263	183.92	0.265	0.265
108.93	0.258	0.260	146.93	0.260	0.263	184.92	0.265	0.268
109.93	0.258	0.260	147.93	0.263	0.265	185.92	0.260	0.268
110.93	0.258	0.260	148.93	0.263	0.265	186.92	0.258	0.265
111.93	0.258	0.260	149.93	0.263	0.265	187.92	0.260	0.263
112.93	0.260	0.260	150.93	0.263	0.265	188.92	0.260	0.263
113.93	0.260	0.260	151.93	0.263	0.265	189.92	0.260	0.263
114.93	0.260	0.260	152.92	0.263	0.265	190.92	0.260	0.268

Table C-13 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
191.92	0.260	0.263	229.92	0.278	0.278
192.92	0.260	0.263	230.92	0.278	0.278
193.92	0.260	0.263	231.92	0.278	
194.92	0.265	0.265	232.92	0.283	0.283
195.92	0.263	0.265	233.92	0.283	0.283
196.92	0.265	0.265	234.92	0.283	0.283
197.92	0.263	0.265	235.92	0.285	0.285
198.92	0.263	0.265	236.92	0.285	0.285
199.92	0.258	0.260	237.92	0.285	0.285
200.92	0.253	0.265	238.92	0.285	0.285
201.92	0.260	0.265	239.92	0.285	0.285
202.92	0.260	0.265	240.92	0.285	0.288
203.92	0.263	0.265	241.92	0.285	0.288
204.92	0.263	0.265	242.92	0.288	0.290
205.92	0.263	0.265	243.92	0.285	0.288
206.92	0.263	0.268	244.92	0.288	0.290
207.92	0.260	0.268	245.92	0.288	0.290
208.92	0.263	0.265	246.92	0.288	0.290
209.92	0.263	0.265	247.92	0.288	0.290
210.92	0.263	0.265	248.90	0.288	0.290
211.92	0.265	0.265	249.90	0.288	0.290
212.92	0.265	0.265	250.90	0.285	0.288
213.92	0.263	0.265	251.90	0.288	0.290
214.92	0.263	0.265	252.90	0.288	0.290
215.92	0.263	0.265	253.90	0.288	0.288
216.92	0.275	0.265	254.90	0.285	0.288
217.92	0.270	0.265	255.90	0.285	0.288
218.92	0.273	0.275	256.90	0.288	0.290
219.92	0.275	0.275	257.90	0.288	0.293
220.92	0.275	0.280			
221.92	0.270	0.278			
222.92	0.270	0.273			
223.92	0.273	0.275			
224.92	0.275	0.275			
225.92	0.275	0.275			
226.92	0.278	0.278			
227.92	0.278	0.278			
228.92	0.278	0.278			

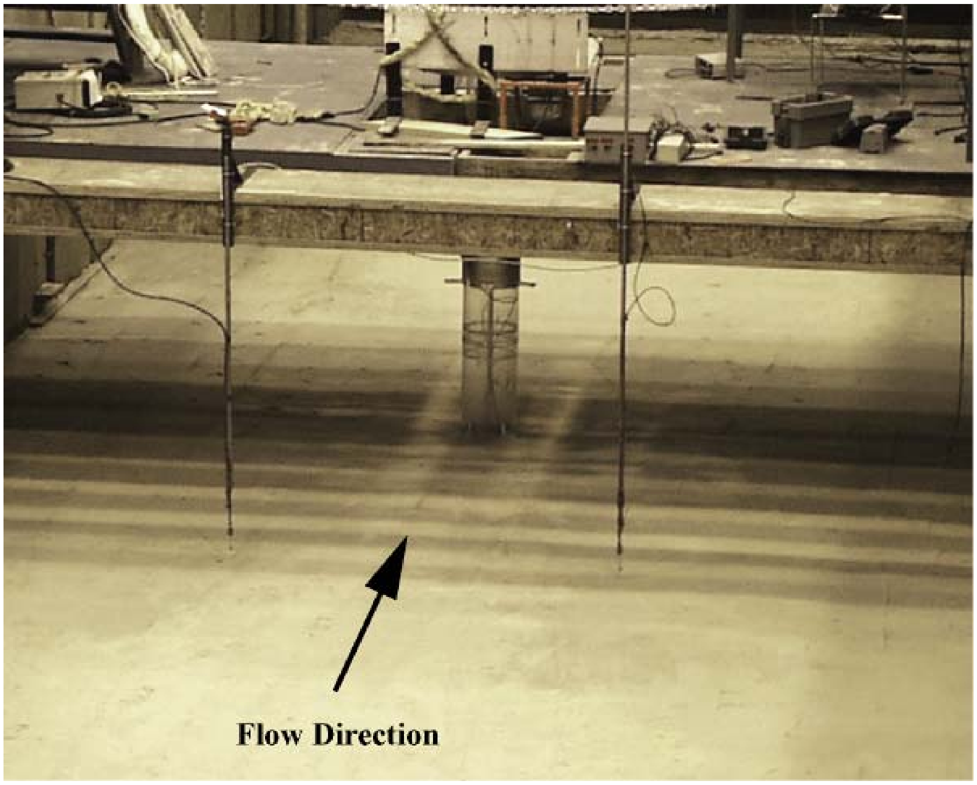

Figure C- 141. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) before test.

Figure C- 142. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) before the test.

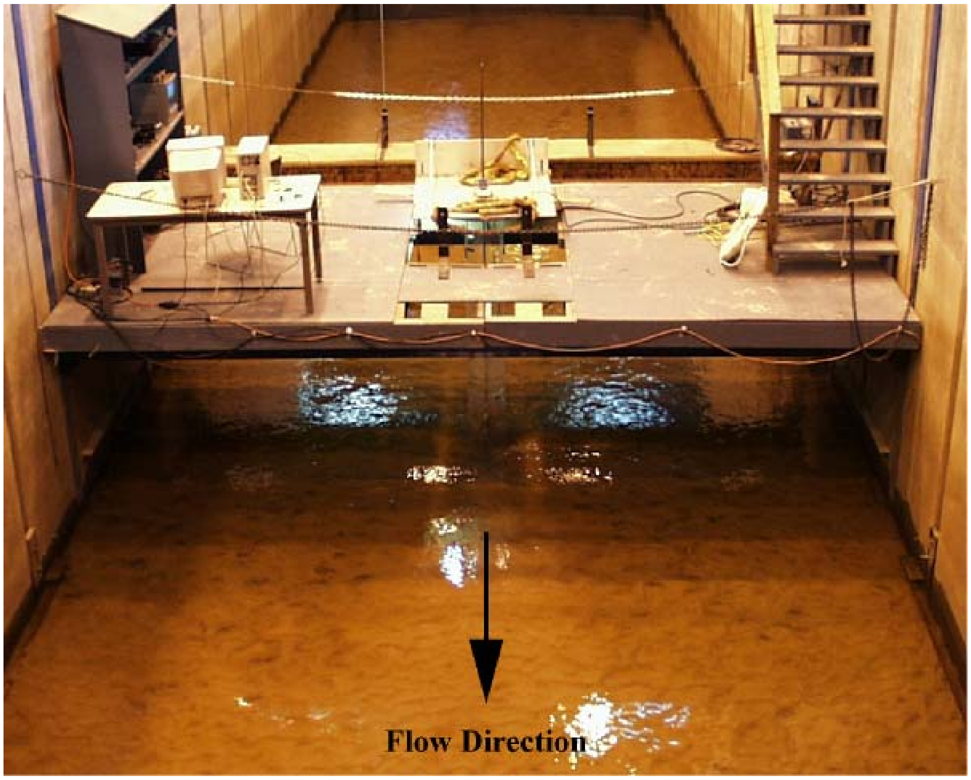

Figure C- 143. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) during test.

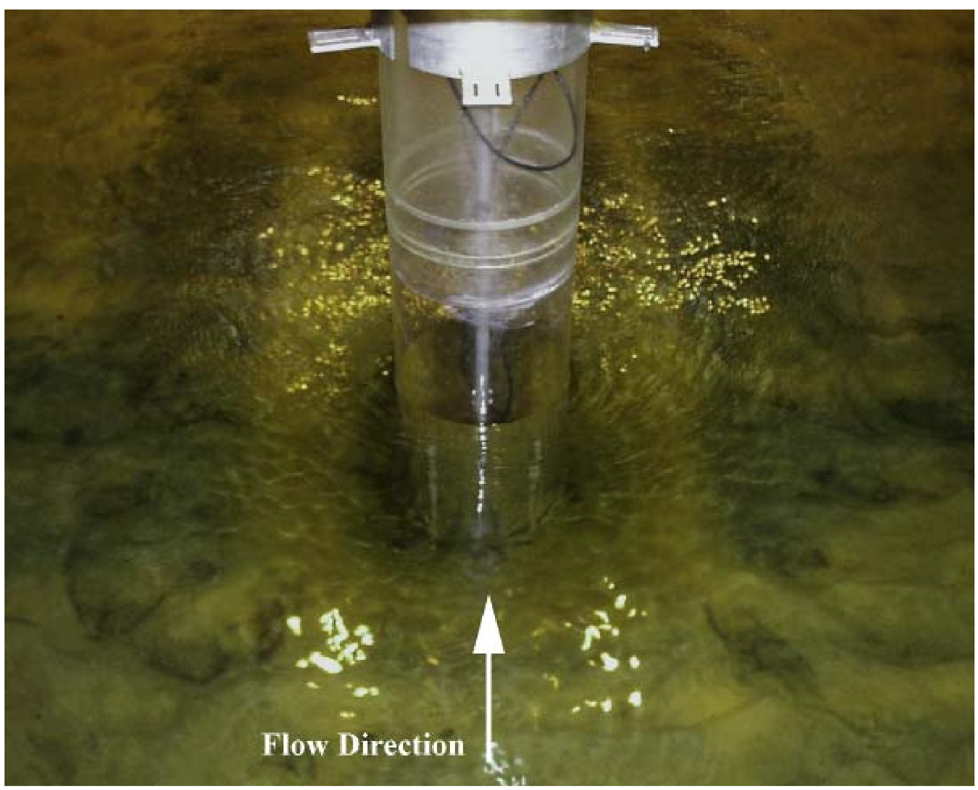

Figure C- 144. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) during the test.

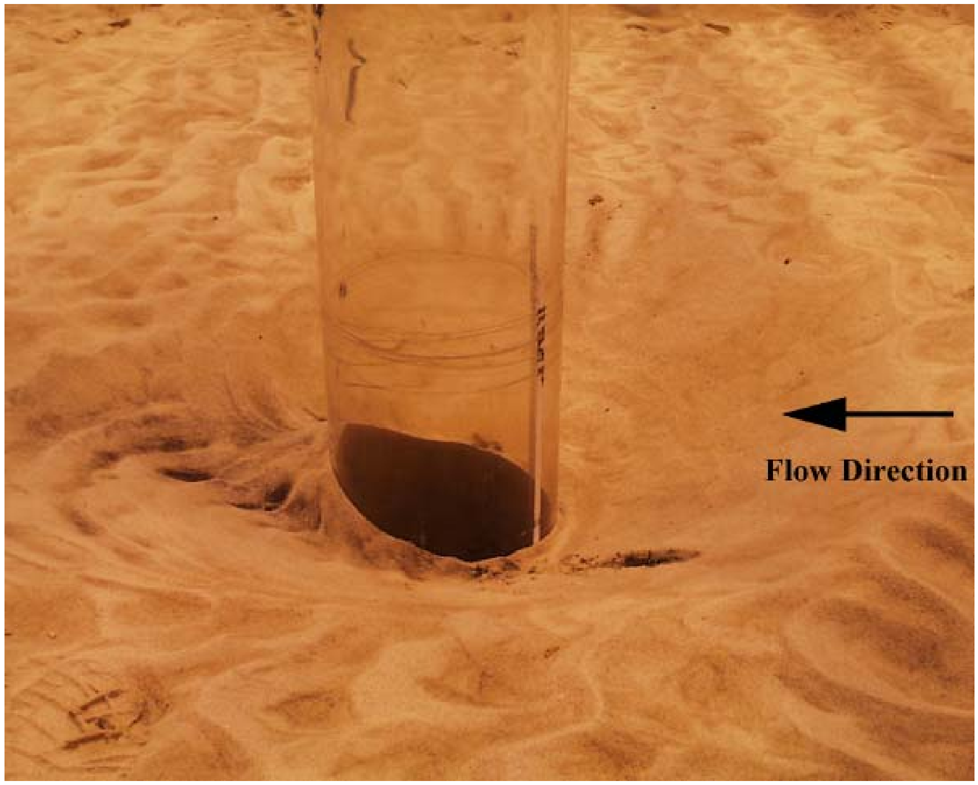

Figure C- 145. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) after test.

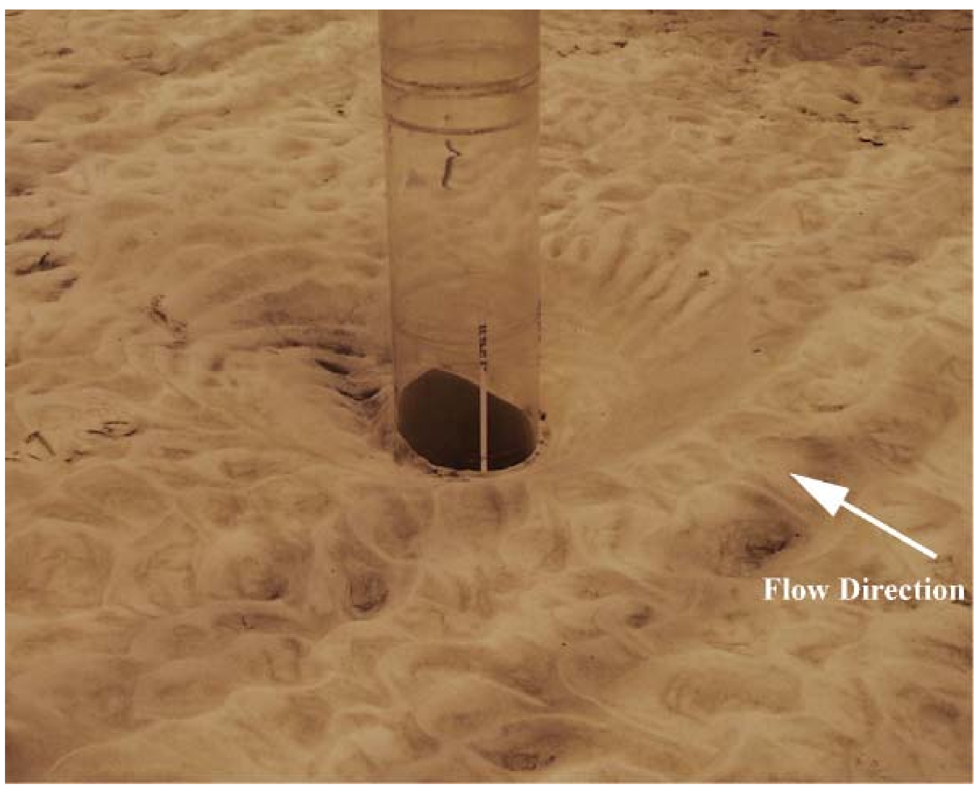

Figure C- 146. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) after the test.

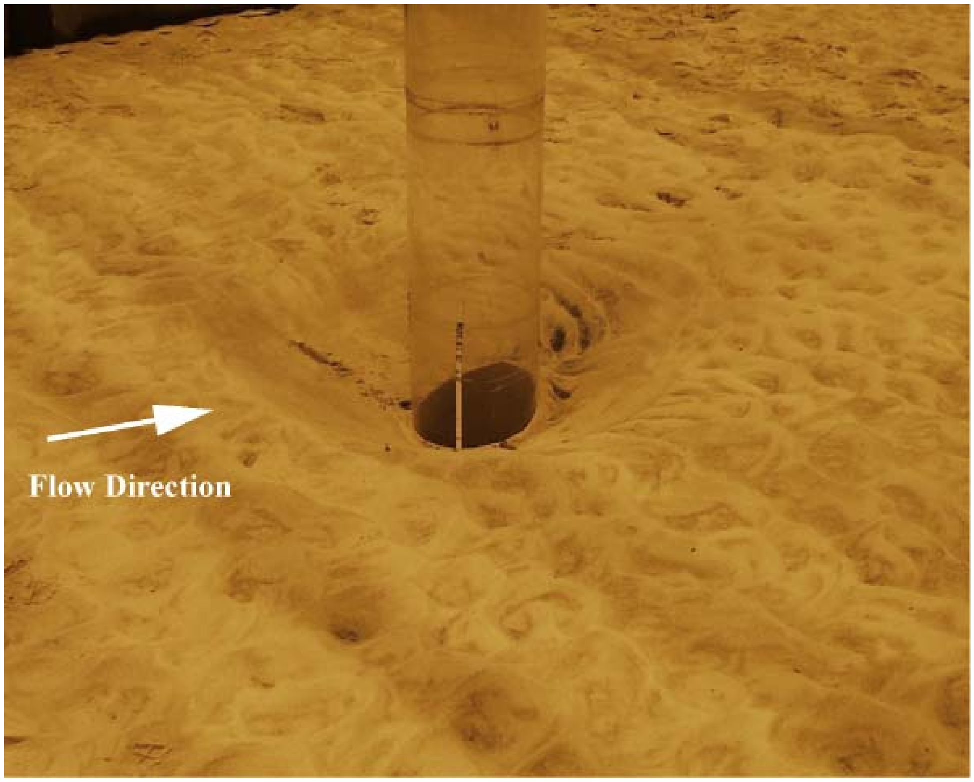

Figure C- 147. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) after test.

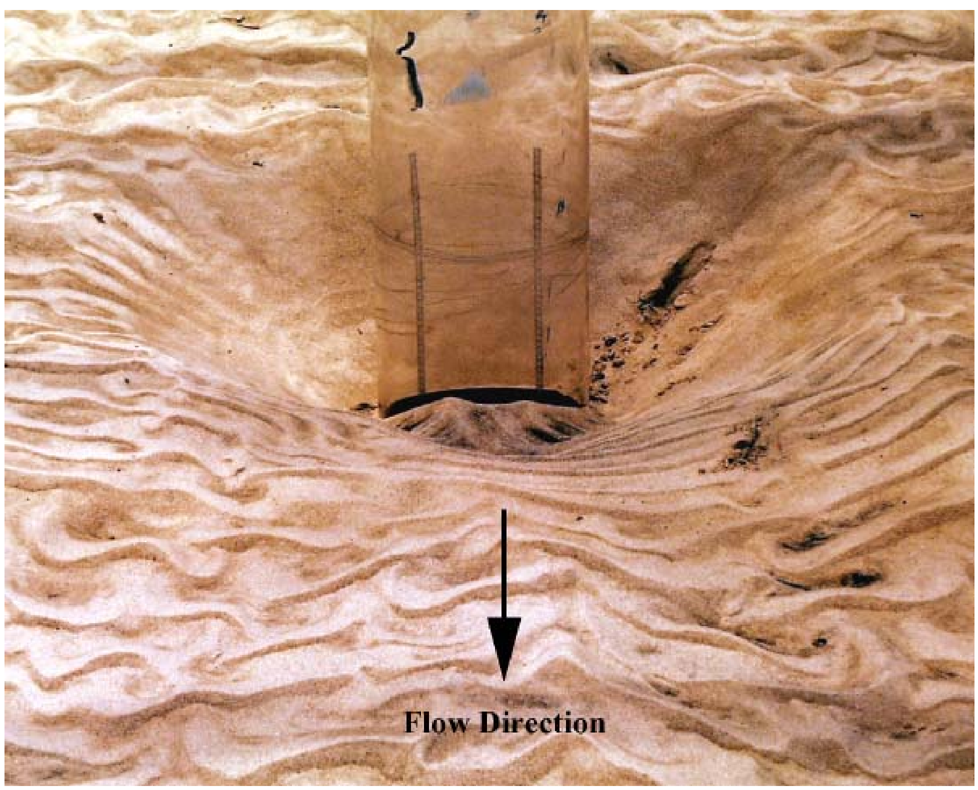

Figure C- 148. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) after the test.

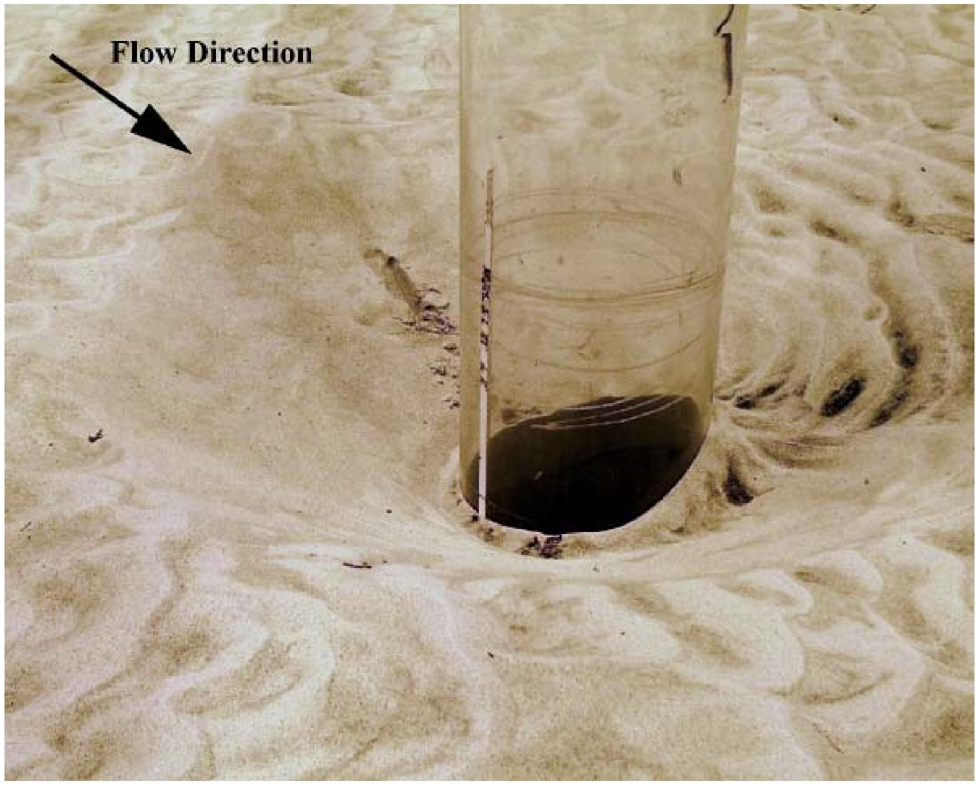

Figure C- 149. Experiment 13 (D = 0.305 m, D_{50} = 0.22 mm) after the test.

Experiment 14
Scour Summary Form

Circular Pile diameter, D: **0.915 m**

Sediment:

Type:	**Quartz**	Start Date:	**06/28/2001**	Start Time:	**9:50 AM**
D_{50}(mm):	**0.22**	Stop Date:	**07/22/2001**	Stop Time:	**2:25 PM**
σ:	1.51				
ρ_s (Kg/m^3):	**2650**	Duration:	**579 hrs**		

Flow Variables:

	West Velocity Meter	East Velocity Meter
Average(m/s):	**0.32**	**0.28**
Maximum(m/s):	**0.67**	**0.42**
Minimum(m/s):	**0.22**	**0.22**

Channel average velocity from weir (m/s): **0.21**

Critical (sediment) velocity, V_c (m/s): **0.32**

Bed Relative Roughness, RR: **5**

Water depth, y_0 :
- Average water depth(m): **1.81**
- Minimum(m): **1.78**
- Maximum(m): **1.83**

Water Temperature:
- Average (degrees C): **23.0**
- Maximum (degrees C): **24.4**
- Minimum (degrees C): **20.8**

Local Equilibrium Scour Depth, d_s:
- Maximum depth from acoustic transponders (m): **0.787**
- Maximum depth from internal video cameras (m): **0.749**
- Maximum depth from point gauge (m): **0.778**
- Maximum scour depth (m): **0.787**

Dimensionless Parameters:

y_0/D: **2.0** V/V_c: **0.94** D/D_{50}: **4159**

d_s/D: **0.86**

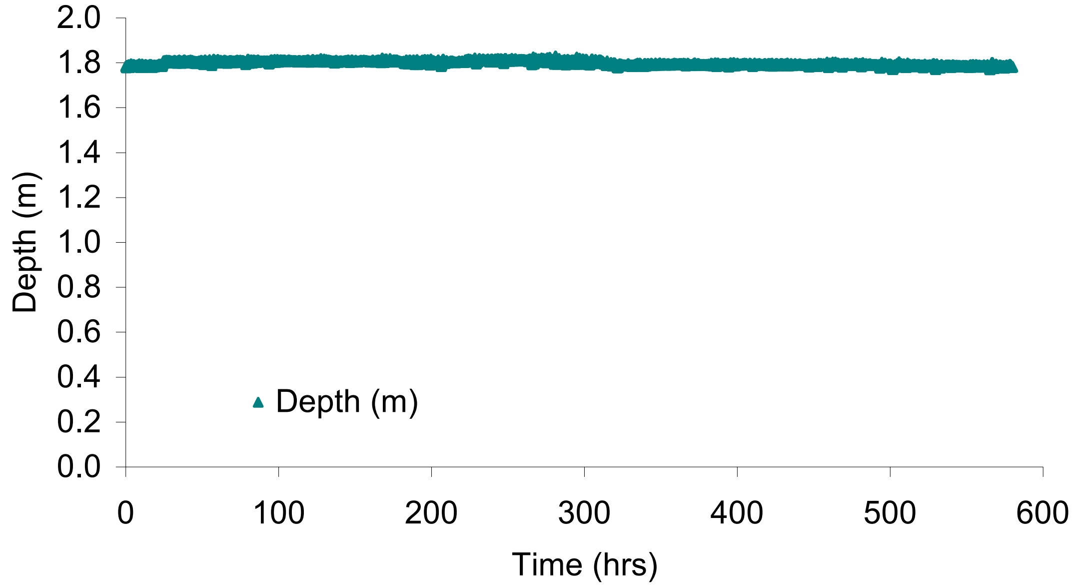

Figure C- 150. Measured water depth for experiment 14.

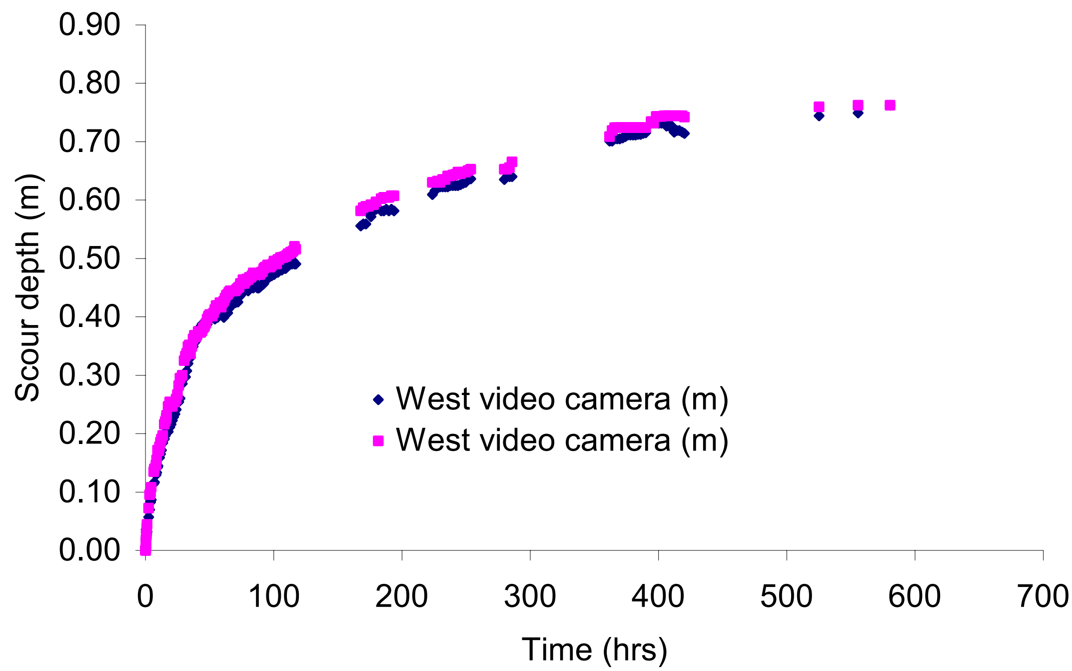

Figure C- 151. Measured local scour data from the internal video cameras for experiment 14.

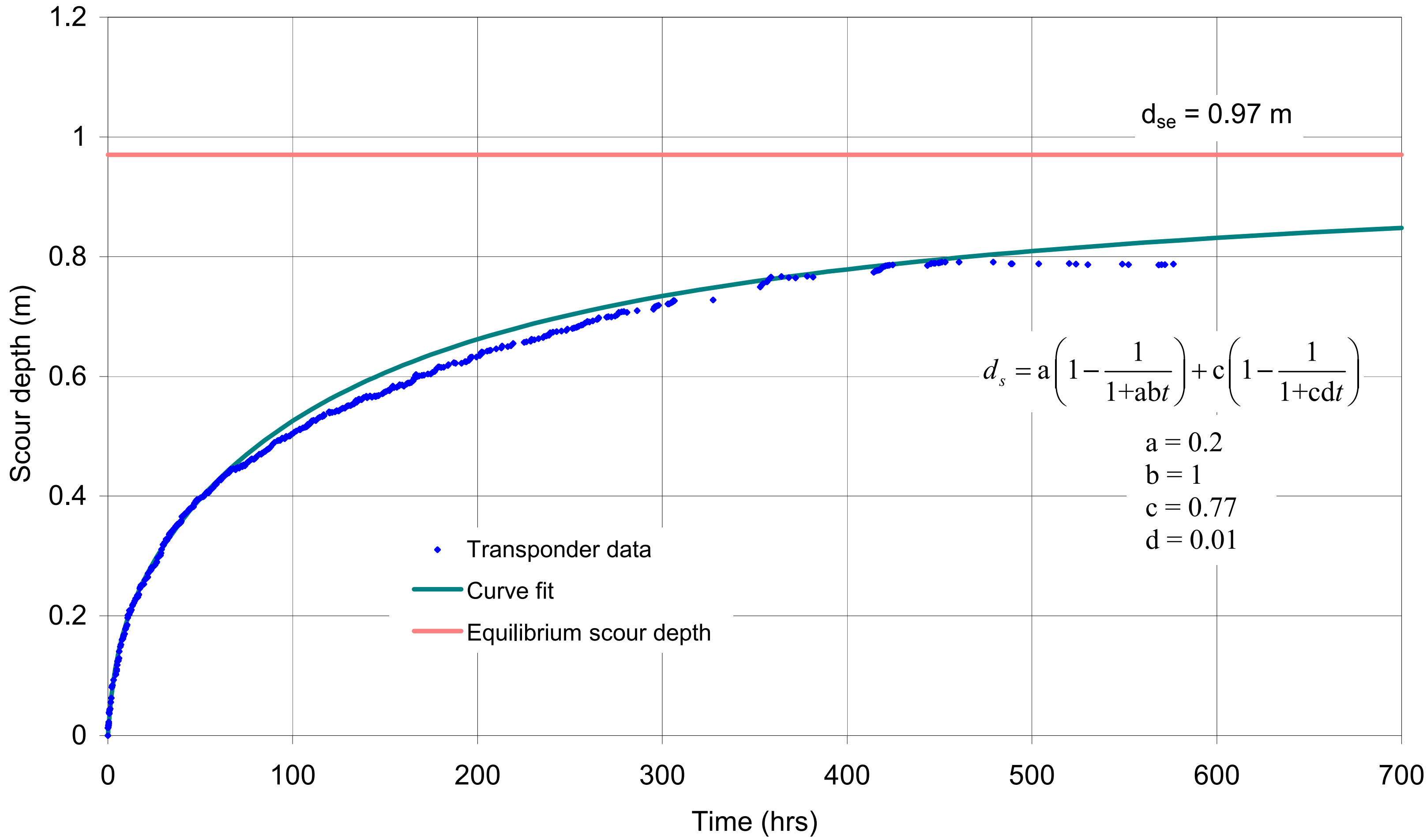

Figure C- 152. Curve fit to the local scour data measured with the acoustic transponder data for experiment 14.

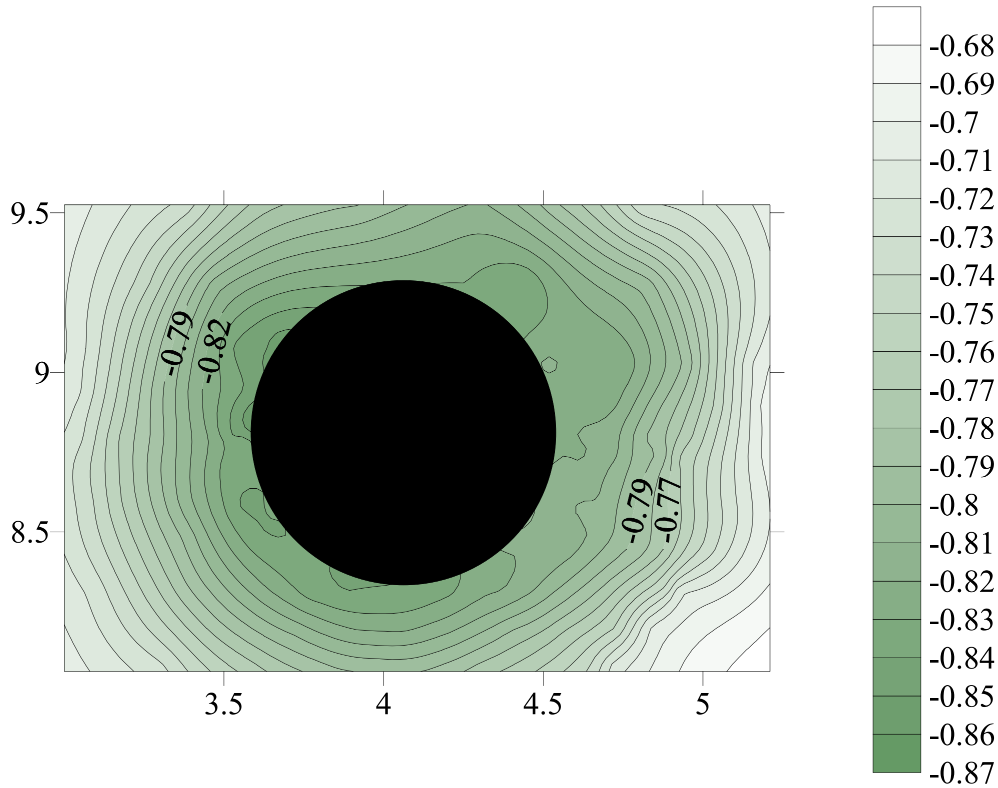

Figure C- 153. Bed elevation contours at completion of experiment 14 referenced to the original bed. All dimensions are in meters.

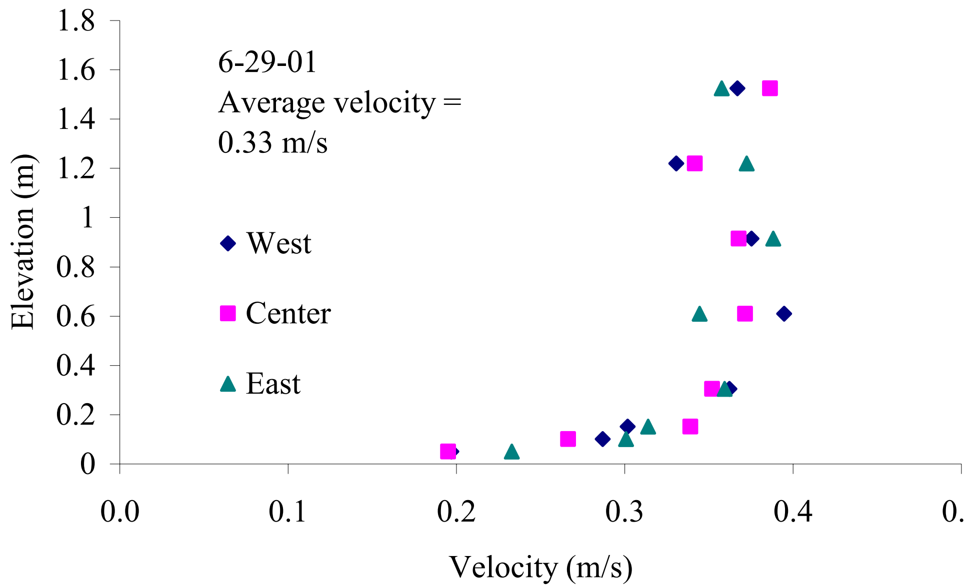

Figure C- 154. Velocity profiles taken at the center of the flume, 0.46 m East of center and 0.46 m West of flume center on 6/29/2001.

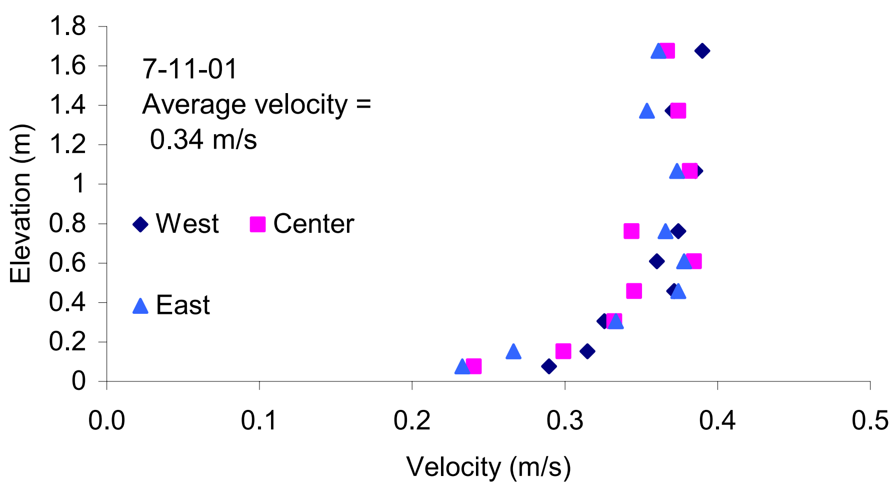

Figure C- 155. Velocity profiles taken at the center of the flume, 0.46 m East of center and 0.46 m West of flume center on 7/11/2001.

Table C-14. The rate of scour depth from the internal video cameras for experiment 14.

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
0.00	0.000	0.000	25.90	0.254	0.282	65.15	0.414	0.442
0.08	0.000	0.000	26.92	0.260	0.295	66.15	0.419	0.445
0.22	0.008	0.000	28.65	0.286	0.300	67.15	0.419	0.445
0.30	0.019	0.003	30.15	0.299	0.325	68.15	0.427	0.445
0.38	0.023	0.009	31.13	0.297	0.333	69.15	0.427	0.445
0.48	0.032	0.015	32.13	0.307	0.338	70.15	0.424	0.445
0.58	0.036	0.019	33.15	0.320	0.349	71.15	0.427	0.447
0.67	0.025	0.025	34.13	0.337	0.352	72.15	0.426	0.450
0.83	0.028	0.028	35.15	0.330	0.337	73.15	0.434	0.451
1.02	0.028	0.038	36.15	0.346	0.349	74.15	0.437	0.457
1.17	0.032	0.044	37.15	0.349	0.362	75.15	0.440	0.457
2.38	0.057	0.072	38.15	0.356	0.368	76.15	0.442	0.464
3.23	0.070	0.095	39.15	0.358	0.366	77.15	0.445	0.457
4.08	0.083	0.099	40.15	0.368	0.368	78.15	0.447	0.461
4.57	0.086	0.108	41.15	0.371	0.375	79.15	0.447	0.465
6.60	0.114	0.135	42.15	0.381	0.373	80.15	0.445	0.464
7.10	0.117	0.140	43.15	0.384	0.373	81.15	0.450	0.467
8.33	0.130	0.146	44.15	0.387	0.376	82.15	0.450	0.467
8.85	0.133	0.155	45.15	0.381	0.381	83.15	0.452	0.470
9.60	0.142	0.171	46.15	0.389	0.384	84.15	0.450	0.475
9.85	0.145	0.171	47.15	0.389	0.389	85.15	0.460	0.473
10.35	0.159	0.170	48.15	0.387	0.396	86.20	0.455	0.473
10.87	0.159	0.178	49.15	0.399	0.401	87.20	0.450	0.473
11.60	0.165	0.185	50.15	0.400	0.404	88.20	0.450	0.473
12.35	0.171	0.191	51.15	0.400	0.401	89.22	0.451	0.473
13.35	0.184	0.197	52.15	0.399	0.401	90.22	0.455	0.476
14.62	0.191	0.216	53.15	0.399	0.407	91.22	0.455	0.478
15.37	0.197	0.221	54.15	0.396	0.413	92.22	0.457	0.483
16.13	0.203	0.226	55.15	0.399	0.419	93.22	0.462	0.485
16.38	0.203	0.231	56.15	0.399	0.419	94.22	0.467	0.485
17.65	0.203	0.246	57.15	0.407	0.419	95.22	0.466	0.489
18.90	0.211	0.254	58.15	0.407	0.424	96.22	0.467	0.488
19.90	0.216	0.246	59.15	0.407	0.417	97.22	0.470	0.485
20.90	0.222	0.246	60.15	0.407	0.424	98.22	0.470	0.488
21.90	0.229	0.254	61.15	0.399	0.427	99.22	0.473	0.490
22.90	0.234	0.254	62.15	0.404	0.432	100.22	0.473	0.495
23.90	0.241	0.259	63.15	0.407	0.437	101.22	0.475	0.493
24.90	0.254	0.267	64.15	0.407	0.438	102.22	0.476	0.490

Table C-14 (continued)

Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)	Time (hrs)	East camera (m)	West camera (m)
103.22	0.476	0.498	243.72	0.625	0.648	420.18	0.714	0.742
104.22	0.480	0.498	245.72	0.626	0.645	525.18	0.744	0.760
105.22	0.483	0.502	247.72	0.629	0.648	555.60	0.749	0.762
106.22	0.480	0.502	249.70	0.630	0.648	580.60	0.762	0.762
107.22	0.483	0.502	251.70	0.635	0.650			
108.22	0.483	0.503	253.70	0.636	0.653			
109.22	0.483	0.503	279.70	0.635	0.653			
110.23	0.485	0.506	281.70	0.640	0.653			
111.23	0.490	0.508	283.70	0.640	0.655			
112.23	0.489	0.508	285.70	0.640	0.666			
113.23	0.495	0.511	361.93	0.701	0.709			
114.23	0.490	0.511	363.95	0.701	0.719			
115.23	0.495	0.513	365.95	0.705	0.724			
116.23	0.490	0.521	367.95	0.705	0.724			
117.23	0.490	0.516	369.95	0.705	0.724			
167.80	0.556	0.582	371.95	0.706	0.724			
169.80	0.5589	0.587	373.95	0.709	0.724			
171.78	0.5589	0.589	376.03	0.711	0.724			
173.80	0.5780	0.589	378.03	0.711	0.724			
175.82	0.5716	0.592	380.03	0.711	0.724			
177.82	0.5818	0.592	382.08	0.711	0.724			
179.78	0.5843	0.597	384.08	0.713	0.724			
183.78	0.5818	0.602	386.10	0.713	0.724			
185.80	0.5818	0.605	388.12	0.714	0.724			
187.80	0.5843	0.605	390.13	0.715	0.724			
189.80	0.5818	0.605	394.17	0.732	0.734			
191.80	0.5843	0.607	396.18	0.734	0.732			
193.80	0.5818	0.607	398.18	0.734	0.743			
223.72	0.6098	0.630	400.20	0.732	0.743			
225.72	0.6161	0.630	402.20	0.732	0.743			
227.72	0.6225	0.633	404.22	0.732	0.744			
229.72	0.6225	0.630	406.23	0.727	0.744			
231.72	0.6225	0.635	408.25	0.727	0.744			
233.72	0.6225	0.635	410.27	0.727	0.744			
235.72	0.6225	0.642	412.30	0.716	0.744			
237.72	0.625	0.642	414.30	0.719	0.744			
239.72	0.625	0.643	416.32	0.719	0.744			
241.72	0.625	0.644	418.33	0.716	0.744			

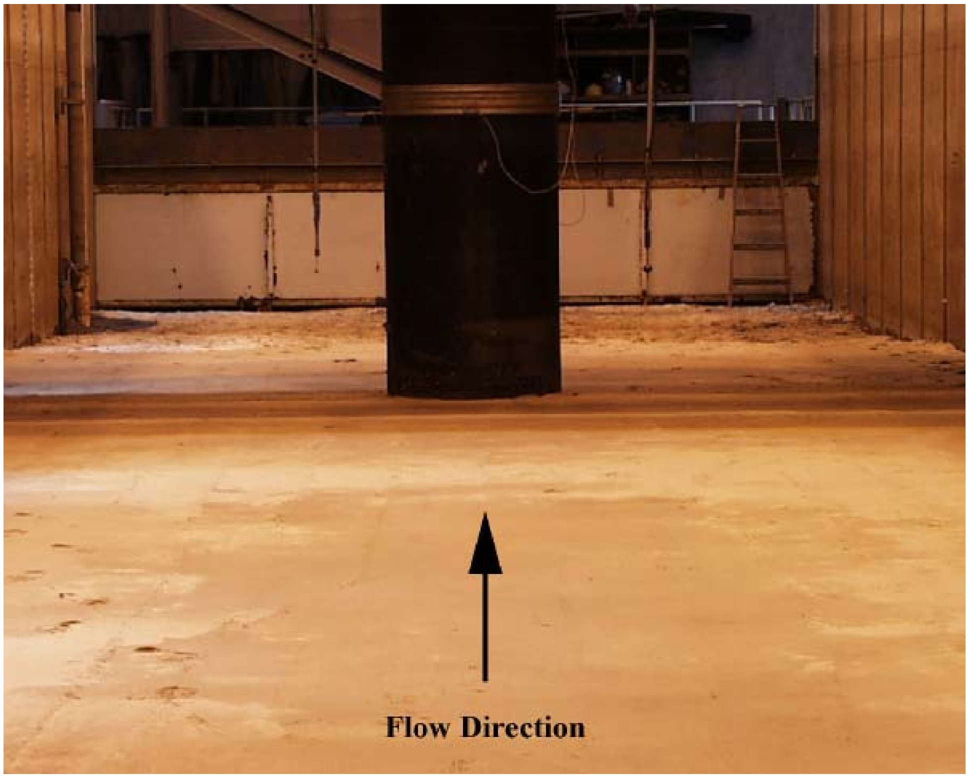

Figure C- 156. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) before test.

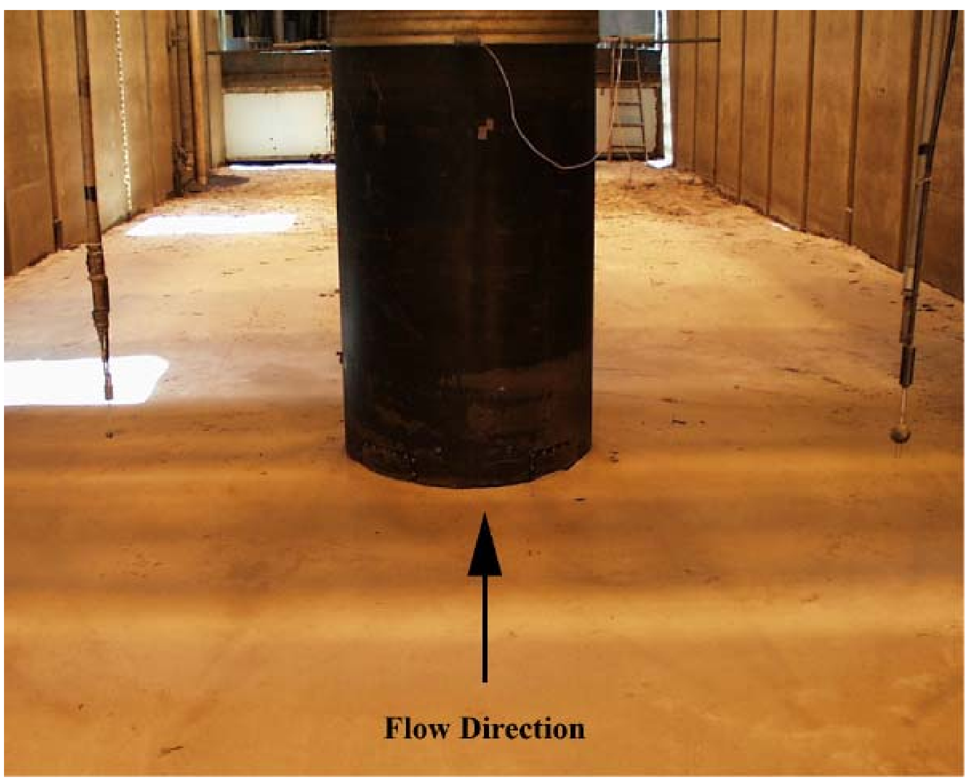

Figure C- 157. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) before the test.

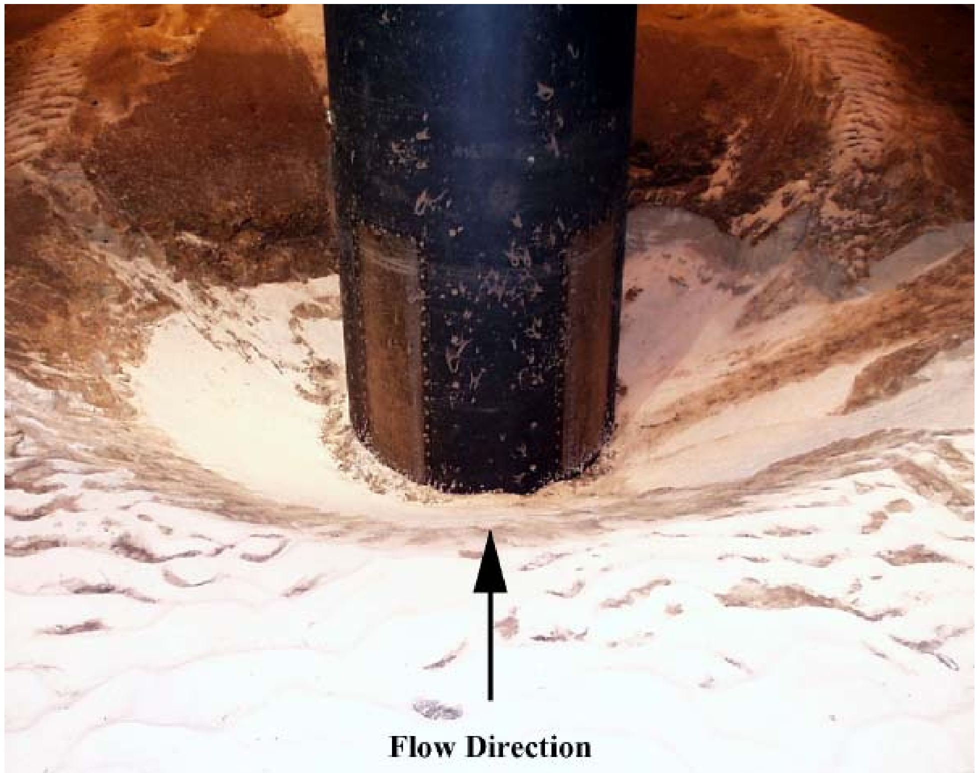

Figure C- 158. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after test.

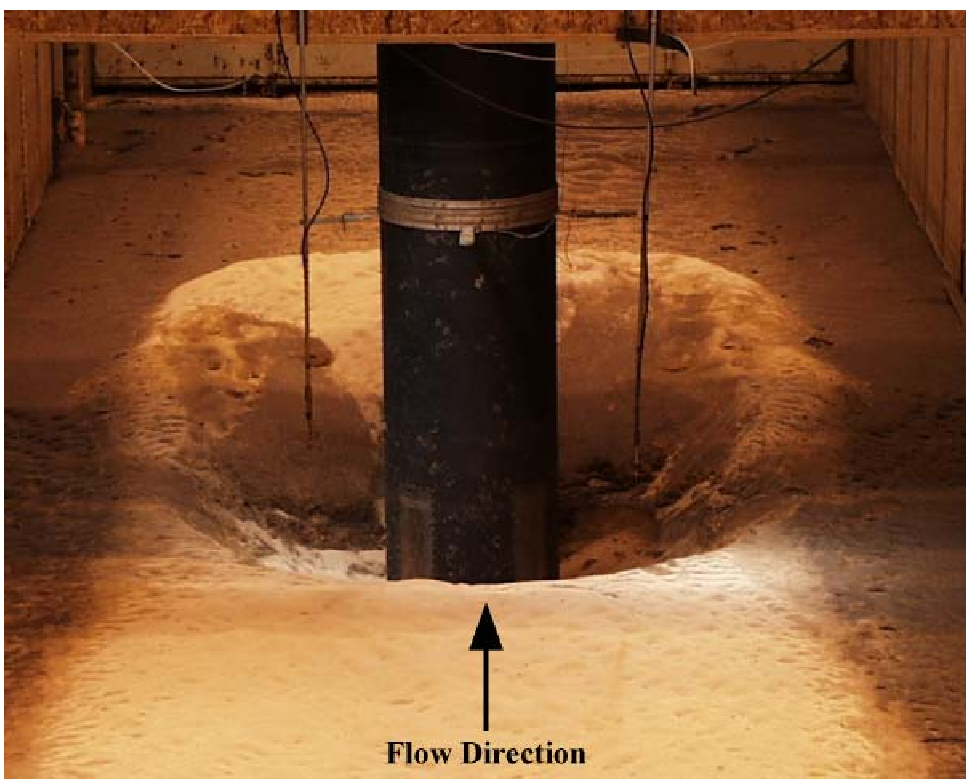

Figure C- 159. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after the test.

Figure C- 160. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after test.

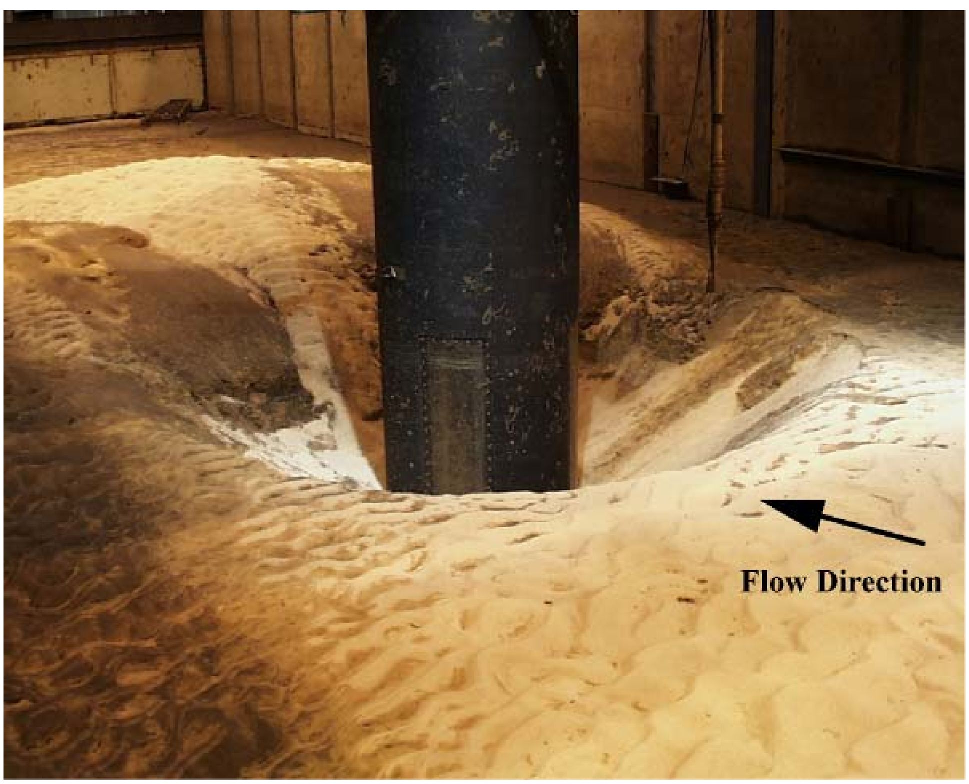

Figure C- 161. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after the test.

Figure C- 162. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after test.

Figure C- 163. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after the test.

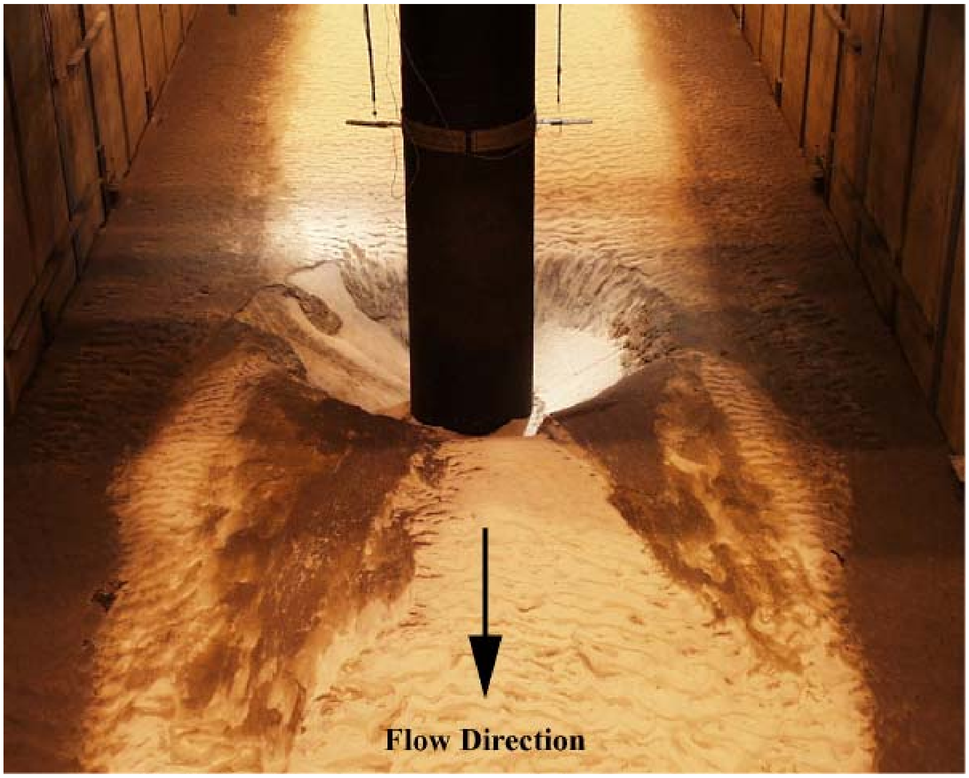

Figure C- 164. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after test.

Figure C- 165. Experiment 14 (D = 0.915 m, D_{50} = 0.22 mm) after the test.

APPENDIX D
RECOMMENDED EXPERIMENTAL PROCEDURE

This appendix outlines a recommended experimental procedure for conducting clearwater local sediment scour experiments. Local scour depths are influenced by many flow, sediment and structure parameters, thus care must be taken when conducting experiments to isolate those quantities being investigated. The precise procedure that should be followed will, of course, depend on the design of the flume, type of test structure, sediment type, etc. but the general philosophy presented here can be followed. These procedures are intended for local scour experiments with cohesionless sediments only. For cohesive sediments (muds, clays, etc.) and rock materials these procedures must be modified and extended. Some items discussed are basic and apply to any scientific experiment but are included for completeness.

The primary objective of most clearwater local scour experiments conducted to date has been to determine the dependence of equilibrium scour depth on upstream (depth-averaged) velocity, water depth, sediment size and density and structure size and shape. The vast majority of these tests have been performed with cohesionless sediments (sand). As would be expected for such complex processes there is scatter in the published data, but perhaps this could have been reduced if more strict procedures were followed. Even though extensive research has been conducted in the field of sediment transport much work is still needed before precise predictions can be made.

At this time equilibrium scour depth is thought to be dependent on the following flow, sediment and structure properties:

Water/Flow

1. water mass density, ρ_w,

2. water viscosity, μ,

3. water depth, y_0, and

4. bed shear stress, τ (depth averaged velocity, V).

Sediment

1. sediment mass density, ρ_s,

2. sediment size, D_{50},

3. size distribution, σ, and

4. compaction.

Structure

1. size (effective diameter/width), D,

2. shape and

3. orientation to the flow.

In addition it has been observed that equilibrium scour depth depends on dimensionless combinations of the properties listed above, namely:

1. aspect ratio, $\frac{y_0}{D}$,

2. shear stress (velocity) ratio, $\frac{\tau}{\tau_c}$ or $\frac{V}{V_c}$, and

3. normalized sediment size ratio, $\frac{D_{50}}{D}$, or its reciprocal, $\frac{D}{D_{50}}$.

The τ_c and V_c above refer to the critical shear stress and velocity respectively, i.e., the shear stress (velocity) required to initiate sediment motion on the flat bed just upstream of the structure. Equilibrium scour depth, d_{se}, has commonly been normalized by either the structure size, D, or the water depth, y_0. The scour depth is highly dependent on both quantities but this dependence decreases with increased values of depth and structure size. Which quantity is the better normalizing parameter depends on the situation. For large structures (large compared to the sediment size) in shallow water (shallow compared to the structure size) the water depth is probably more appropriate. For small structures in deep water the structure size is more appropriate.

For laboratory experiments designed to measure the dependence of equilibrium scour depth on one of these quantities it is important to maintain the other quantities as constant as possible. Thus much of the discussion below is directed at assuring that the desired quantities are produced in the flume and that the quantities not being investigated are constant (or at least known).

During the course of the clearwater scour experiments conducted during this study it became clear that the level of suspended fine sediments in the water column has an impact on equilibrium scour depth. There are probably other water/flow properties (e.g., water salinity, ph, etc.) that effect scour depth to varying degrees that are not known at this time. For this reason the more information obtained about the water/flow/sediment used in the experiment the better. Obviously the more control over these parameters the better. The advantage of the flume used in the experiments reported here was its size, which allowed structures as large as 0.915 m (3 ft) in diameter to be tested. The disadvantage was that there was no control on the water supply. In particular, the water temperature and suspended sediment concentration varied significantly. The effect of temperature was known and thus was measured and accounted for in the data reduction/analysis process. The importance of suspended sediment concentration was not known until late in the study and, therefore, suspended sediment concentrations were not measured until near the end of the study. The reason for this discussion is to stress the importance of measuring as many properties as practical in order to ensure accurate and useful data from the experiment.

The recommended procedures are divided into pre-, during- and post-experiment categories and as stated above apply to local clearwater scour experiments with cohesionless sediments.

Pre-experiment

These procedures are designed to produce a known uniform flow in the flume and a flat, evenly compacted sediment bed that is free of entrapped air.

1. For many flumes the (vertical) velocity profile at the entrance is near uniform and thus the shear stress exerted on the bed is greater than that downstream where the profile is fully developed. For this reason the bed at and near the entrance should be fixed (i.e., not erodible). The fixed bed should extend at least one channel width down the channel. If practical, the level of the bed should be lowered to produce a larger cross-section and lower mean velocity. The roughness of the fixed bed should be close to that of the rest of the sediment to reduce change in bed shear stress at the transition from fixed to movable bed. The absence of such an arrangement will result in the production of bed forms (ripples and sand waves) at the entrance that propagates down the flume and eventually into the scour hole. The closer the flow velocity is to the critical value in the test area of the flume, the more acute the problem.

2. Some type of (preferably adjustable) flow straightener should be installed at the flume entrance. This will produce a more uniform flow across the channel and more homogeneous turbulence. Vertical velocity profiles at increments across the channel should be taken and flow straightener adjustments made to produce a flow that is as uniform as practical.
3. The bed should be compacted to ensure uniform compaction of the sediment. The level of compaction can be measured with a nuclear density probe.
4. The flume should be slowly filled with water and allowed to sit for an extended period of time to allow air entrapped in the soil to escape. The time required depends on the depth of the sediment and moisture content prior to filling the flume. If the sediment in the flume is initially dry the sediment should be compacted, filled, drained and compacted once again prior to filling and starting the test.
5. The test section of the flume should be located sufficiently far downstream of the entrance that the flow will be fully developed at the test structure for the range of flow conditions desired (otherwise, it is difficult to compute the bed shear stress in the test section). In determining this distance the greatest water depth and lowest velocity to be investigated should be used.
6. The instrumentation used to monitor the various parameters is important. It is always helpful to build in redundancy so in case unexpected values are obtained there is verification that they are real and not a faulty instrument. It is even better to measure the same parameter by two different methods.

In this study the time varying scour depth was measured by two different methods and the final value measured by a third method. During the test scour depth was measured by 12 acoustic transponders and two video cameras located inside the test cylinders. When the test was stopped and the flume drained the scour hole was surveyed with a point gauge. Measurement of the scour depth during the test is necessary in order to determine when the test can be stopped. This data also provides valuable rate of local scour information. The water depth also needs to be monitored throughout the experiment. There are a number of accurate instruments available for measuring water depth. An instrument utilizing a near bottom mounted pressure transducer was used in this study with periodic visual checks using elevation markings on the flume wall.

Bed shear stress is extremely difficult to measure; thus, most researchers resort to measuring flow discharge and computing a sectional-averaged velocity from which they estimate bed shear stress. Others measure vertical velocity profiles from which they compute depth-averaged velocities. In this study the depth-averaged velocity (and bed shear stress) was attained by several different methods. For a fully developed velocity profile the velocity at a point four tenths of the water depth from the bed is approximately equal to the depth averaged velocity at that location for the tests conducted in this study. Two small electromagnetic current meters were positioned 2 m (6.6 ft) upstream and 1.0 m (3.3 ft) to the side of the center of the test structure and 0.4 times the water depth from the bed.

The discharge in the flume was computed using calibrated weir equations and the measured water depth, upstream of the weir. Vertical velocity profiles across the flume (near the electromagnetic flow meters) were obtained near the beginning and end of the tests.

Water temperature was measured with a commercial instrument and checked with a mercury-in-glass thermometer.

In the instrument calibration phase it is important to run the flume near the velocities to be used in the scour tests to establish such things as the duration of the velocity measurement over which to average, etc. If using high frequency narrow beam acoustic transponders to measure scour depths, the blanking distance (distance from the transponder where acoustic returns are not measured) and return signal sensitivity (threshold voltage) must be set. Even for clearwater scour there is suspended sediment near the structure and the return signal sensitivity must be set properly in order to accurately measure the bed level.

7. Prior to filling the tank it is recommended that photographs of the bed and test structure be taken from locations where photographs will be taken after the test has been completed. This will provide documentation for the pre-experiment bed condition and aid in the presentation of the test results.

During Experiment

1. Before starting the experiment all instrumentation and data acquisition systems should be calibrated, tested and initialized.
2. The flume should be filled slowly and allowed to stand for some period of time as described in the pre-experiment section. Once the flow is started the desired

water depth and flow velocity should be achieved as soon as possible (without exceeding the desired velocity). Velocities higher than the critical value will produce bed forms that will impact the critical shear stress (and velocity).

3. It is important to monitor the scour depth throughout the experiment in order to know when the scour hole has progressed to the point where the experiment can be stopped.
4. If the objective of the experiment is to investigate equilibrium scour depth for a given set of steady flow conditions, then it is important to maintain a steady flow throughout the test. In flow-through flume systems the incoming flow conditions can change due to clogged filters, changes in reservoir levels, etc. For closed recirculating flume systems, the water temperature usually increases with time and there can be variations in pump speeds resulting in changes in flow velocity and water depth.

Post-experiment

1. The flow should be stopped in such a manner that the flow conditions being tested are not exceeded. That is, the flow velocity and/or water depths being tested are not exceeded by, for example surface waves generated by stopping the pumps too abruptly.
2. The drains in the flume should not all be located in the test section. Otherwise, most of the suspended sediment at the end of the test will be deposited in the test area. An even distribution of drains will reduce drainage time and avoid the deposition problem.

3. An accurate survey of the scour hole is desirable. This ensures that the maximum depth in the scour hole is measured. The importance of this measurement depends on the instrument(s) used to measure scour depth during the experiment but in all cases the survey provides an independent check. If there is a problem with the results, having an accurate map of the scour hole can be helpful in analyzing the problem.
4. High resolution photographs of the scour hole, and upstream bed (preferably taken from the same locations as the pre-experiment photographs) is desirable. These photographs can be helpful in analyzing and presenting the data. If bed forms are present on the upstream bed these should be photographed and sand wave heights and lengths measured. This can be useful in estimating the bed roughness, which is required in the computation the critical bed shear stress and velocity.

This recommended procedure is intended as a guide for those not experienced in performing clearwater local scour experiments in cohesionless sediments. They will have to be modified to accommodate the design of the flume and the specific objectives of the experiments. With the equilibrium scour depth dependent on so many quantities care must are taken to ensure that all parameters are according to the test specifications and that as many of the variables as practical be measured. The greater the accuracy and number of quantities measured the more valuable and useful the data.

APPENDIX E
IMPACT OF SUSPENDED SEDIMENT ON LOCAL SCOUR

The CAFRC Laboratory flume is a flow-through type flume with the water supply being a hydroelectric power plant reservoir connected to the Connecticut River in Turners Falls, Massachusetts. The flume is gravity driven and uses a downstream control structure (sharp crested weir) to control the water level in and flow discharge through the flume. Water from the flume is discharged into the Connecticut River downstream of control structures in the river. The advantage of this type of flume is that large discharges can be obtained without the use of pumps. The disadvantage is that there is little control on the water properties. In particular, the water temperature and the constituents in the water cannot be controlled. At this location the drainage area for the river is approximately 20,515 km^2 (7,860 mi^2). When there is a heavy rain or snowmelt, large quantities of fine sediment are transported to the river where they remain in suspension for several days. The water temperature ranges from slightly above freezing in the winter months to a high of about 26°C (79°F) in the summer.

If properly accounted for when computing viscosity, the extreme water temperatures appear to have little impact on the accurate prediction of local scour. However, the presence of suspended fine sediment in the water column was found to alter equilibrium scour depths. This dependence can greatly impact scour research being performed in flow-through type flumes and can also be a problem in the interpretation of field data where the level of suspended fine sediment is usually not known.

The sensitivity of scour depth to suspended fine sediment concentration was not known to the authors prior to these experiments and thus, with the exception of one experiment, suspended sediment concentrations were not measured. For many of the experiments the water was clear and thus the suspended sediment concentrations were low. In some of the experiments, however, there were changes in the level of suspended fine sediment during the test. One of the experiments that experienced large increases was repeated with the same structure and sediment but with slightly different water depth and flow velocity. The suspended fine sediment concentration was very low in the repeated experiment. Local scour depth time history plots for both tests are presented in Figure E-1 along with a plot of the repeated test results adjusted to the water depth and flow velocity of the original test. The experiment with the suspended sediment is referred to as Experiment A and the repeated experiment by Experiment B. The photograph of the structure and surrounding sediment in Figure E-2 shows the conditions prior to Experiments A and B. Figures E-3 and E-4 are photographs of the scour holes following Experiments A and B respectively. Contour plots of the scour holes for Experiments A and B are presented in Figures E-5 and E-6. Unfortunately, the suspended sediment concentration was only measured for one test. In this case water samples were collected at different elevations in the flow. These samples were analyzed resulting in a depth-averaged concentration of 29 mg/l of suspended fine sediment.

To the knowledge of the authors, the effects of suspended sediment in the water column on local scour depth have not been reported prior to this time. The precise reason for the reduced scour is not known, but it is possibly due to a reduction in bed shear stress caused by the suspended fine sediment. There did not appear to be fine sediment deposition adjacent to the structure during the tests with the high concentrations. However, there was deposition in the scour hole out away from the structure after the experiment was stopped.

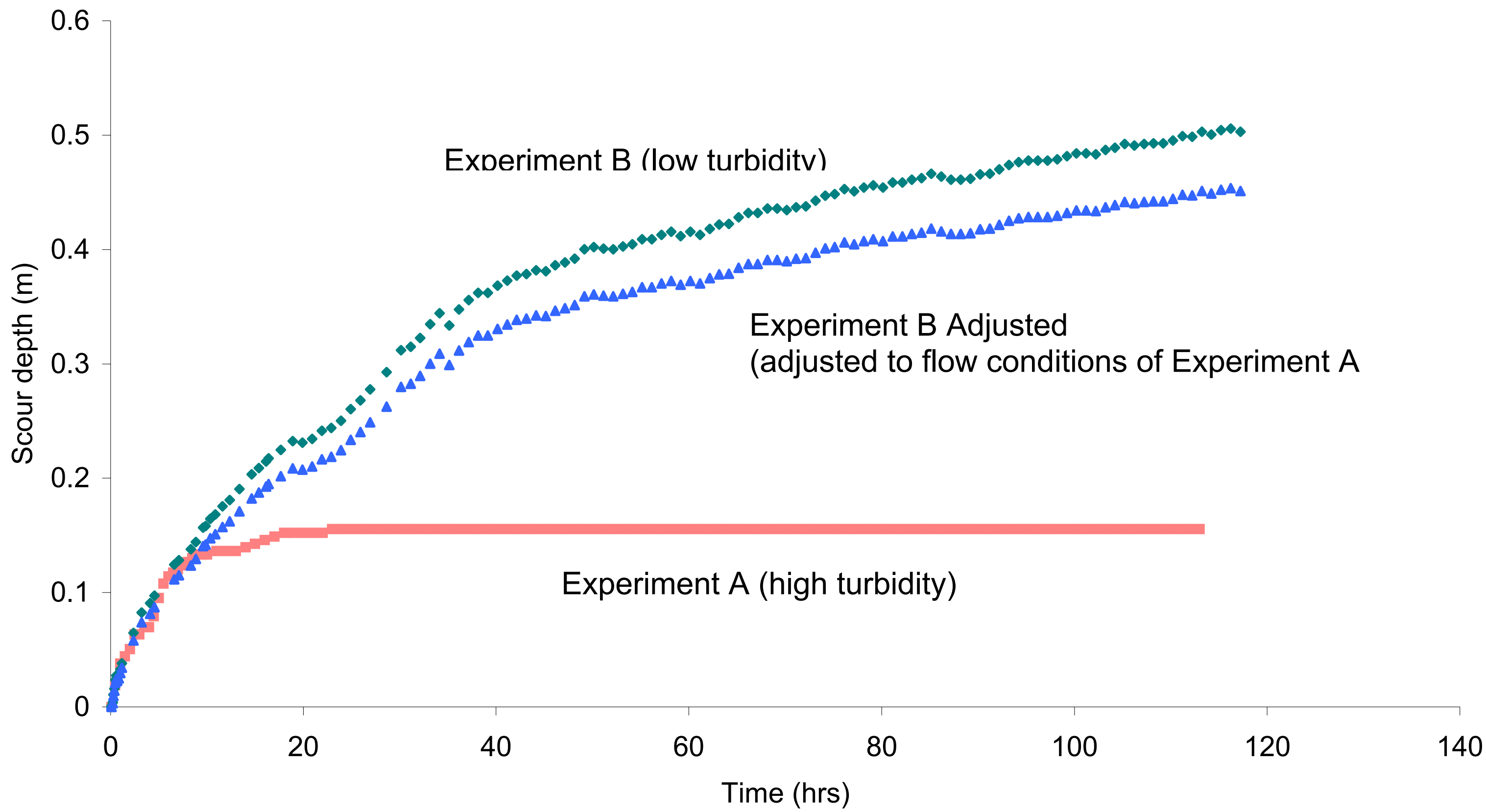

Figure E- 1. Graph illustrating the impact of suspended fine sediment on equilibrium local scour depths under clearwater scour conditions. Experiment A experienced a sudden increase in suspended fine sediment about 10 hours into the test. Experiment B was with the same sediment and structure but with a slightly higher velocity and a deeper water depth. In the Experiment B Adjusted plot the data for Experiment B has been analytically adjusted to the flow conditions of Experiment A (with the exception of the suspended fine sediment).

Figure E- 2. Pre-test photograph of test bed (D = 0.915 m, D_{50} = 0.22 mm).

Figure E- 3. Scour hole after high suspended fine sediment experiment (Experiment A) (D = 0.915m, D_{50} = 0.22 mm, y_o = 1.22 m, V/V_c = 0.92).

Figure E- 4. Scour hole after low suspended fine sediment experiment (Experiment B) (D = 0.915 m, D_{50} = 0.22 mm, y_o = 1.8 m, V/V_c = 0.97).

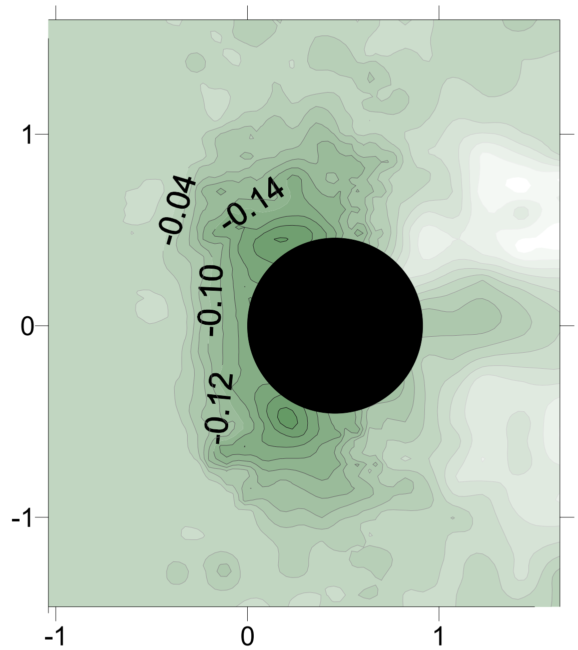

Figure E- 5. Contour plot of scour hole for the high suspended sediment level experiment (Experiment A) (D = 0.915 m, D_{50} = 0.22 mm, y_o = 1.22 m, V/V_c = 0.92).

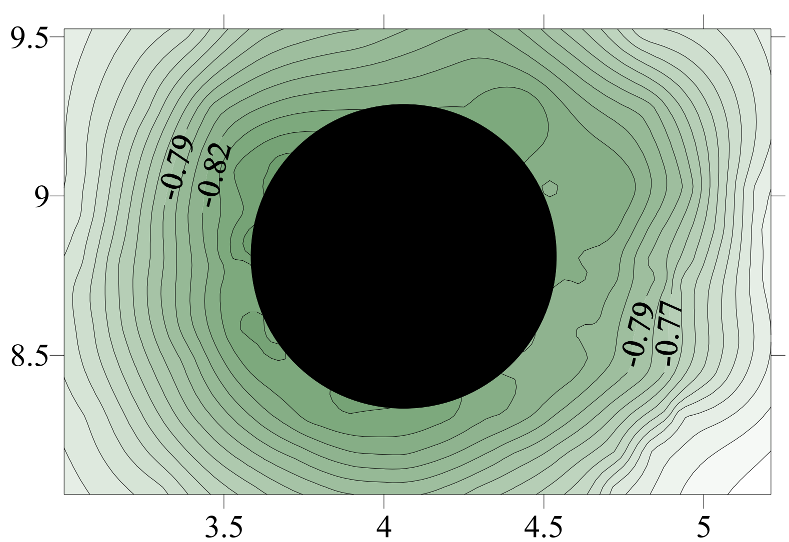

Figure E- 6. Contour plot of scour hole for the low suspended sediment level experiment (Experiment B) (D = 0.915 m, D_{50}= 0.22 mm, y_o =1.8 m, V/V_c = 0.97).

The mechanisms causing the reduction in scour by the suspended fine sediment are currently under investigation by the lead author.