SECOND SERIES OF HYDRAULIC LABORATORY FILTER TESTS FOR CORDELL PUMPING PLANT - OROVILLE-TONASKET UNIT - CHIEF JOSEPH DAM PROJECT, WASHINGTON

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UNITED STATES GOVERNMENT

Memorandum

Memorandum
TO : Chief, Water Conveyance Branch

Denver, Colorado
DATE: October 9, 1980

FROM : Eugene Zeigler, Hydraulics Branch

SUBJECT: Second Series of Hydraulic Laboratory Filter Tests for Cordell Pumping Plant - Oroville-Tonasket Unit - Chief Joseph Dam Project, Washington

BACKGROUND

A filter bed, located in the river bottom, was proposed for a pump intake. Filtration and backwashing (reverse flow) tests were made for a 0.19-m^2 (2-ft^2) area of the upper portion of the filter bed. These hydraulic laboratory tests did not provide a definite answer of whether or not a filter bed would work. The main questions being how long would the filter operate before flow blockage, and the quantity of water needed for backwashing and rejuvenating the filter. A more elaborate test facility was needed which could simulate riverflow with suspended sediment across the filter bed. This type of study was estimated in the range of $75,000, would take some months to do, and would not guarantee a filter with economical backwashing capabilities (memorandum to Chief, Water Conveyance Branch, "Report of Hydraulic Laboratory Filter Tests for Cordell Pumping Plant - Oroville-Tonasket Unit - Chief Joseph Dam Project, Washington," August 9, 1979.) Because of these limitations, a filter bed was not included in the design of the pumping plant intake.

Subsequent to the above tests, Dave Osmundsen from the Pipelines Section requested some additional tests using the same apparatus. He needed data for analytical work with respect to the pumping plant intake design. This memorandum reports on data of his requested tests.

PRELIMINARY WORK

For tests reported in the August memorandum, Dave questioned if a wall effect acted on the piezometer taps. Did the taps, located on the side wall of the plastic box, measure a piezometric head different than what occurred internally within the sand? Thus, three additional piezometer taps were installed. Brass tubes with 1.5 mm (0.06 in) inside diameter were extended into the sand 75 mm (3.0 in) away from the side wall, at the same elevation as the three wall taps. Diameters of the sand particles were from 0.6 to 1.2 mm. Piezometric head measurements were made for seven different discharges through the sand layer. Of the 21 sets of comparable measurements between the wall and internal taps, 11 sets had the same manometer reading, 8 sets were within 3 mm (0.01 ft), and 2 sets were within 6 mm (0.02 ft). These differences were insignificant, indicating that the wall taps were adequate for making the piezometric head measurements, and the three brass tubes were removed.

Modifications were made to improve the test apparatus. Previously water entered the plastic test box from a weir on top of the box, spilled into the box, and entrained air bubbles. The inlet was changed to a pipe which had a deflector for preventing flow impingement upon the filter bed, figure 1a. Plumbing changes were also made in the water storage box. The pump bypass flow pipe was extended 0.46 m (1.5 ft) below the water surface and filtration flow was directed farther from the pump intake. The above changes were made to prevent the minute air bubbles in the water passing through the filter. Six additional piezometer taps were installed on the side wall at 75-mm (3-in) intervals above the previous taps.

A finer sediment was requested for the second series of tests; therefore, a pulverized limestone was obtained. This sediment was similar to cement, and the particle-size analysis had very good agreement to the finer suspended sediment sample, figure 2.

FILTER WITH PROTECTIVE GRAVEL LAYER

Vertical dimensions of sand and gravel layers in the filter and piezometer tap locations are shown in figure 3. Sizes of sand and gravel are shown in figure 2.

Before adding any sediment to the filter, tests were made to establish the clean filter condition. Using the appropriate filtration or backwashing valve, various flows were passed through the test filter. Results of the discharge and head loss measurements are shown in figure 4. The head loss is the difference in the piezometric head between piezometer No. 4 and piezometer No. 8. During the backwashing of February 14, the frictional force of the upward flowing water exceeded the submerged weight of the filter sand and protective gravel layer. The sand and gravel were uplifted in the plastic box, and a horizontal crack formed in the 0.3-m (1-ft) filter sand layer. When continuing the test with higher backwashing discharges, the filter sand below the crack was somewhat fluidized.

The uplifting of sand and gravel affected flow resistance in the 0.3-m (1-ft) thick sand filter layer. Piezometers No. 4 through No. 8 (fig. 3) divide the sand layer into four quarters and flow resistance is shown for these quarters in figure 5. For data of February 14, arrows are placed on figure 5 to show sequence of backwashing valve changes. In the first and second quarters, resistance lowered with increased discharges as fluidization occurred. In the third quarter resistance greatly increased and evidently uplifting compacted the sand. In the fourth quarter resistance also increased, with the exception of the last data point when the discharge was slightly decreased.

Sedimentation tests were made on 3 different days, figure 6. For February 22, 50 mL of sediment were added at four different times, and each time turbidity of the water passing through the filter increased considerably. Much of the sediment evidently passed through the filter and there was only a slight increase of head loss. Some sediment could be seen resting on top of rocks in the protective gravel layer. Therefore, on the March 6 test, the water was agitated 0.15 m (0.5 ft) above the gravel, creating currents that flushed sediment off rocks in the upper portion of the protective gravel layer. Data point 1 was before the agitation and data point 2 after agitation. An additional 200 mL of sediment were added. Turbidity of the filtered water again increased considerably and there was an increase of head loss. On March 7, 300 mL of sediment were added with very little effect on head loss.

Sediment that was trapped by the filter was evidently caught in the upper half of the filter sand. The head loss increased in the third and fourth vertical quarters of the filter but not in the first and second quarters (fig. 7).

The No. 16 to No. 8 screen-size filter sand did not effectively trap the suspended sediment. However, a filter (of the type tested) could develop different filtering characteristics during field use. Over a period of time the No. 50 and larger suspended sediment particles (fig. 2) would be trapped by the filter sand. These smaller-size particles would in turn filter smaller particles of the suspended sediment. The filter was modified to simulate this condition.

FINER SAND FILTER

To capture finer suspended sediment, finer filter sand was required. The protective gravel layer, the intermediate layer, and 0.08 m (3 in) of the filter sand were removed and replaced by two layers of fine sand placed in the test filter-filter configuration II, figures 1b and 3.

During the tests described in the August 9, 1979 memorandum, problems were encountered with air becoming trapped in the finer filter materials. Therefore, preliminary tests were made without adding sediment to the filter. One of the adverse tests showed a 2.7-m (9-ft) head loss in 14 minutes with the discharge decreasing from 48 to 8 L/min (12.8 to 2.1 gal/min). When the filter was backwashed small air bubbles rose from the filter. At this point a critical examination was made of flow in the system. A strong circulation of water, caused by pump recirculation, was noted in the storage box by the pump intake. (For the lower discharges, some pump flow was recirculated to the storage box to prevent overheating of the pump motor.) This pump recirculation was decreased, resulting in a less turbulent water condition near the pump intake. Another test was made with a lower filter discharge. The head loss was 0.3 m (1 ft) in 45 minutes with discharge decreasing from 18 to 17 L/min (4.8 to 4.4 gal/min).

During the preliminary tests, fines were washed from the filter sands, making the water slightly turbid. Some of these fines were trapped when operating in the filtration mode, because when backwashing very turbid water would be flushed upwards from the filter. A backwashing technique was developed which kept the turbid water in the plastic filter box. For a short time the two fine sand layers were vigorously fluidized and then the backwashing stopped. Air bubbles which were purged from the filter rose to the surface, and the turbid water remained within a 0.3- to 0.6-m (1- to 2-ft) distance of the sand surface. Immediately afterwards, when operating in the filtration mode, the head loss rapidly increased. Thus, the finer sand filter caught very small suspended sediment particles resulting in a pronounced increase of head loss.

In preparation for the sedimentation test, the slightly turbid water was drained from both the storage and plastic boxes. The fine sediment in the storage box was allowed to dry and was removed and the system was filled with clean water.

Results of the sedimentation tests for the first day are shown on figure 8; data points are numbered in the sequence they were taken. Test discharges changed because of valve adjustments, filter clogging by trapped sediment, entrapped air, and backwashing effects. Points 1 and 2 are for a clean filter condition with minor valve change between points. Next, 50 grams of sediment were added. Some sediment passed through the filter, because filtered water returning to the storage box made the water cloudy. Points 3 to 6 show effect of trapped sediment while no valve changes were made. Evidently most of the sediment was trapped in one-half hour (point 3), because for the next 1 hour 50 minutes operation there was only a slight increase of head loss (point 6). Valve changes were made and measurements made for points 7 and 8. Another 50 grams of sediment were added with no valve changes. Within 5 minutes the head loss increased by 2.4 m (8 ft) (point 9). Another 30 minutes operation produced slightly more head loss (point 11). Thus, 100 grams of sediment clogged the filter. Our criteria for clogging being a filter passing less than 3.3 L/s per m^2 (5 gal/min per ft^2) with a head loss greater than 3 m (10 ft).

Backwashing tests were also made, figure 8. The filter was backwashed three times, using the technique where sediment particles flushed upward from the filter bed were kept in the plastic box. Numerous air bubbles were purged during the first backwashing. With resumed operation, the filter appeared rejuventated, but when the flushed sediment settled back upon the bed the head loss rapidly increased to that of point 12. With the second backwashing, fewer air bubbles were purged. Resumed filter operation produced a stable head loss-discharge condition, and valve changes were made between measurements of points 13, 14, and 15. With the third backwashing, no air bubbles were purged and head loss rapidly increased to that of point 16. Backwashing effects appeared erratic.

Backwashing tests in which turbid water was kept in the plastic box were made a second day, figure 9. Again, data points are numbered in the sequence they were taken, and for comparison purposes the clean filter condition (measured May 14) was also placed on figure 9. Similar to the May 14 tests, backwashing results were erratic. For points 1, 2, and 3, the filter was backwashed at the end of the May 14 tests and the sediment allowed to settle back upon the bed over a 5-day period without filter operation. Points 1, 2, and 3 fall on the clean filter line. During operation after the fifth backwashing, numerous small cracks were noticed in the fine sediment cake trapped on the filter. Water readily passed through these cracks without producing a high head loss. After the sixth backwashing, a relatively high filtration discharge was established. The head loss rapidly increased with a corresponding decrease in discharge. It appeared that when recapturing the backwashed sediment with a high filtration discharge, head losses were greater than recapturing backwashed sediment with a low filtration discharge.

Test conditions for the seventh backwashing were different, figure 9. A much larger backwash discharge was used and for a longer time period. Sediment which the filter had trapped was flushed out of the plastic box and settled in the storage box except for the very fine particles which remained in the turbid water. Filtration operation was started and during the test there was a steady increase in head loss as the filter captured the very fine sediment from the turbid water. The filter operated 1 hour 20 minutes between points 26 and 32.

Points 7 and 8 of figure 9 show important test results with respect to filter clogging. Fifty grams of sediment were added to the plastic test box for filter flow conditions of point 6. Head loss rapidly increased and discharge decreased to that of point 7. This small addition of suspended sediment effectively clogged the filter and these test results are consistent with those of figure 8. If the filter traps fine suspended sediment as a thin layer deposit then these fine particles create an extremely high flow resistance. Should the fine sediment layer test results that occurred for data of figure 8 occur in the prototype filter, the filter would be uneconomical because of the necessary frequent backwashings. Some idea of the time interval between backwashings can be obtained by examining test conditions for data points 9, 10, and 11 of figure 8. One hundred grams of sediment clogged a filter area of 0.186 m^2 (2 ft^2). The prototype filter may be expected to operate with river water having a suspended sediment concentration of 300 mg/L and a filter discharge of 6.8 L/s per m^2 (10 gal/min per ft^2). For 1 m^3 of water 300 grams of suspended sediment would act upon the filter. In the tests 100 grams of sediment clogged the filter, representing a 0.33 m^3 of river water passing through the test filter. With the expected prototype filter flow rate, 0.33 m^3 of water would pass through the test filter in 4.4 minutes; thus, a 4-minute 24-second time interval between backwashings.

Consideration should be given that the preceding filter test conditions may have been overly stringent. Experience of city water systems recognizes that "blinding" (deposit of fine sediment layer on a filter) is very uneconomical and trapping particles along a greater depth of the filter is better. Note that our test sediment, figure 2, did not have the coarse-size suspended sediment particles. If these size particles had been included, possibly the trapped sediment layer would have been thicker and less resistant to flow. Also, precise information about sediment size that damages sprinkler heads is not available. If larger sediment can be tolerated, possibly economical filtration can be achieved. These arguments are not given with the viewpoint that further research should be done at this time for a prototype filter, but with the viewpoint our organization should maintain an open mind toward future filter research.

E. R. ZEIGLER

Copy to: Regional Director, Boise, Idaho, Attention: PN-200

Blind to: D-270 (Carlson)
D-272 (Anderson)
D-272 (Osmundsen)
D-1530
D-210

ERZeigler:pmd-V6

Calhoun
10-20-80

Fig. 1a. Inlet pipe with flow deflector.

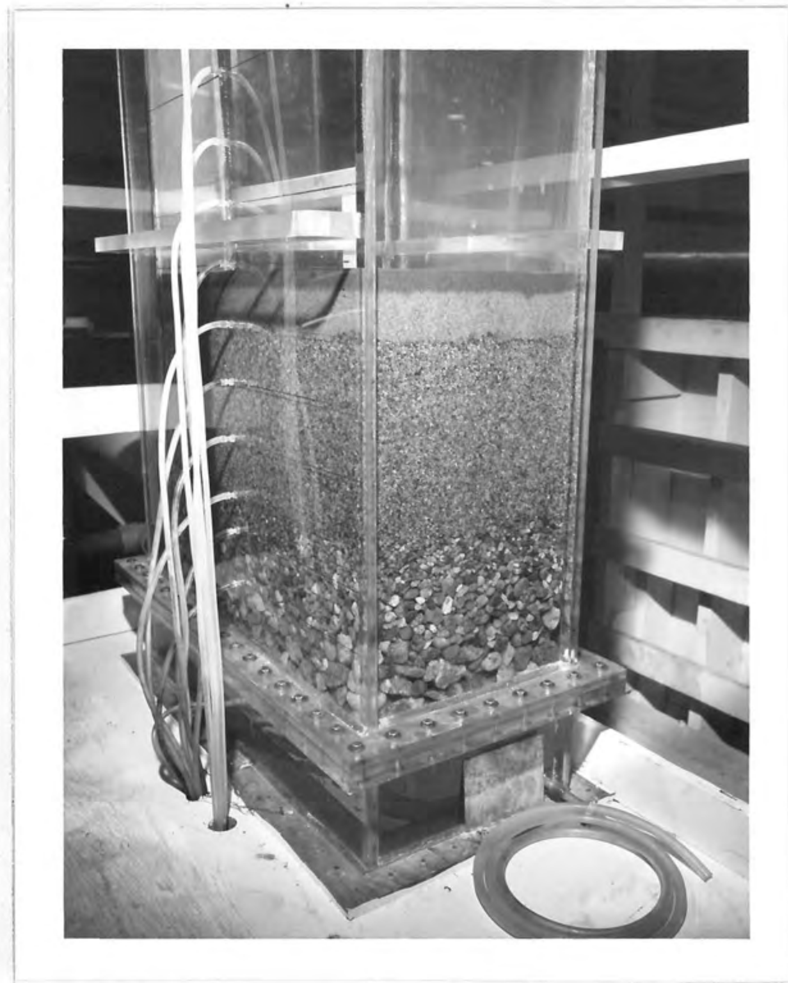

Fig. 1b. Filter configuration II.

Figure 1. - Plastic test box.

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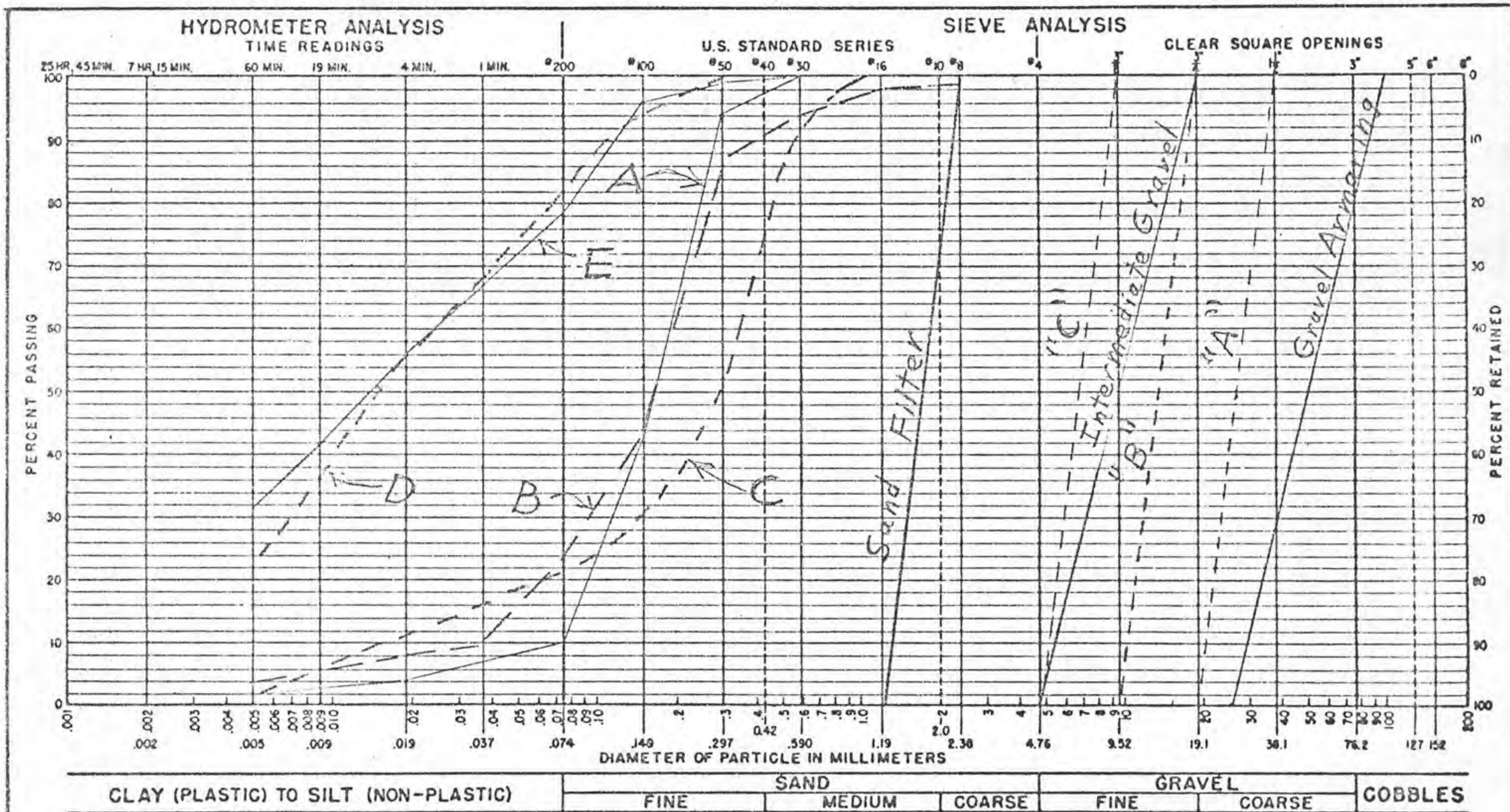

NOTES:

GRADATION TEST

A - First sediment used in lab tests
B - Sediment received from Okanogan River
C & D - Suspended sediment samples taken June 1978, Okanogan River
E - Pulverized limestone, sediment used in 2nd series lab tests

...TION ______ EXCAVATION No. ______ DEPTH ______ FT.

Figure 2. Size analysis of filter and sediment materials.

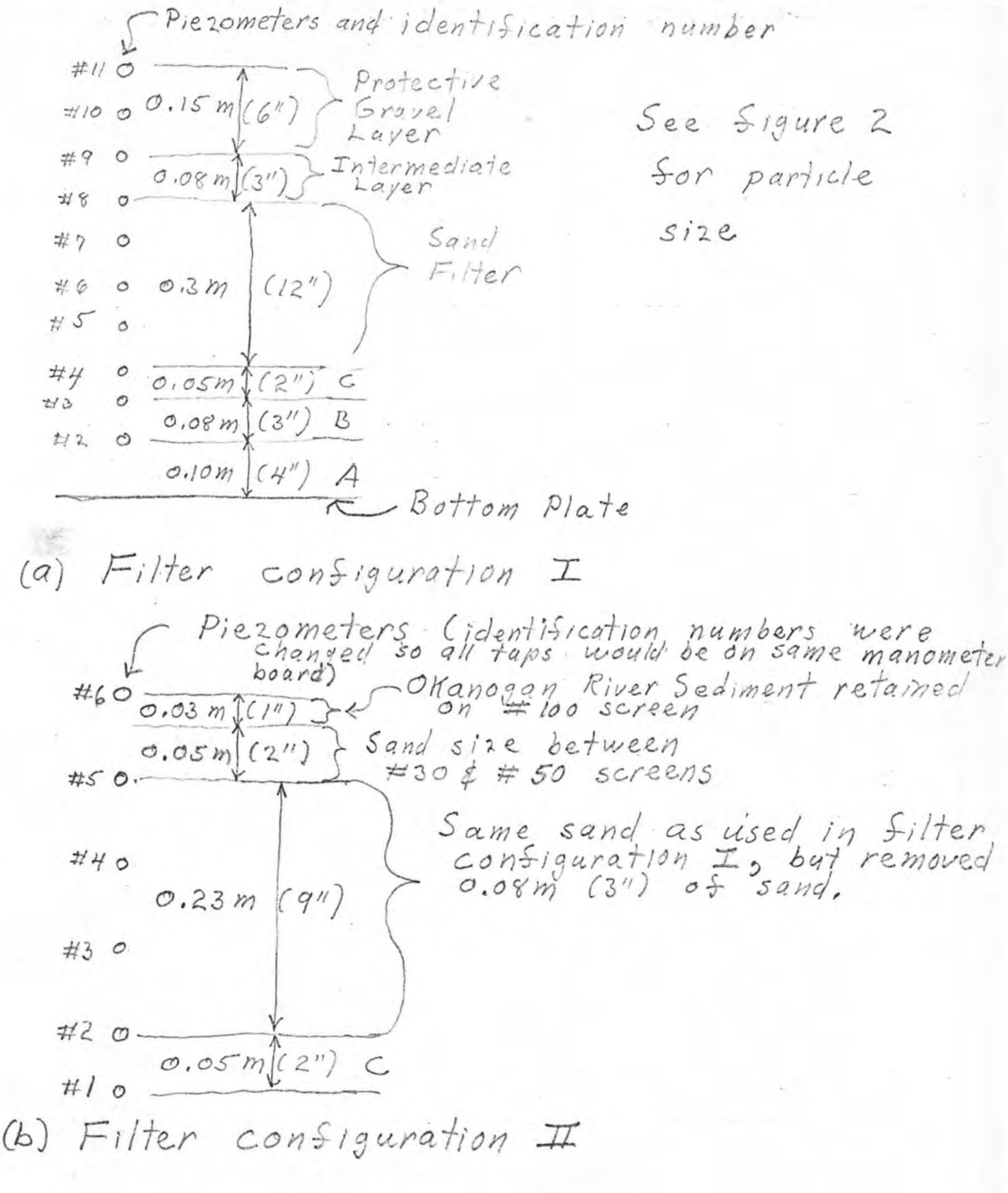

Figure 3. Vertical filter dimensions and piezometer tap locations.

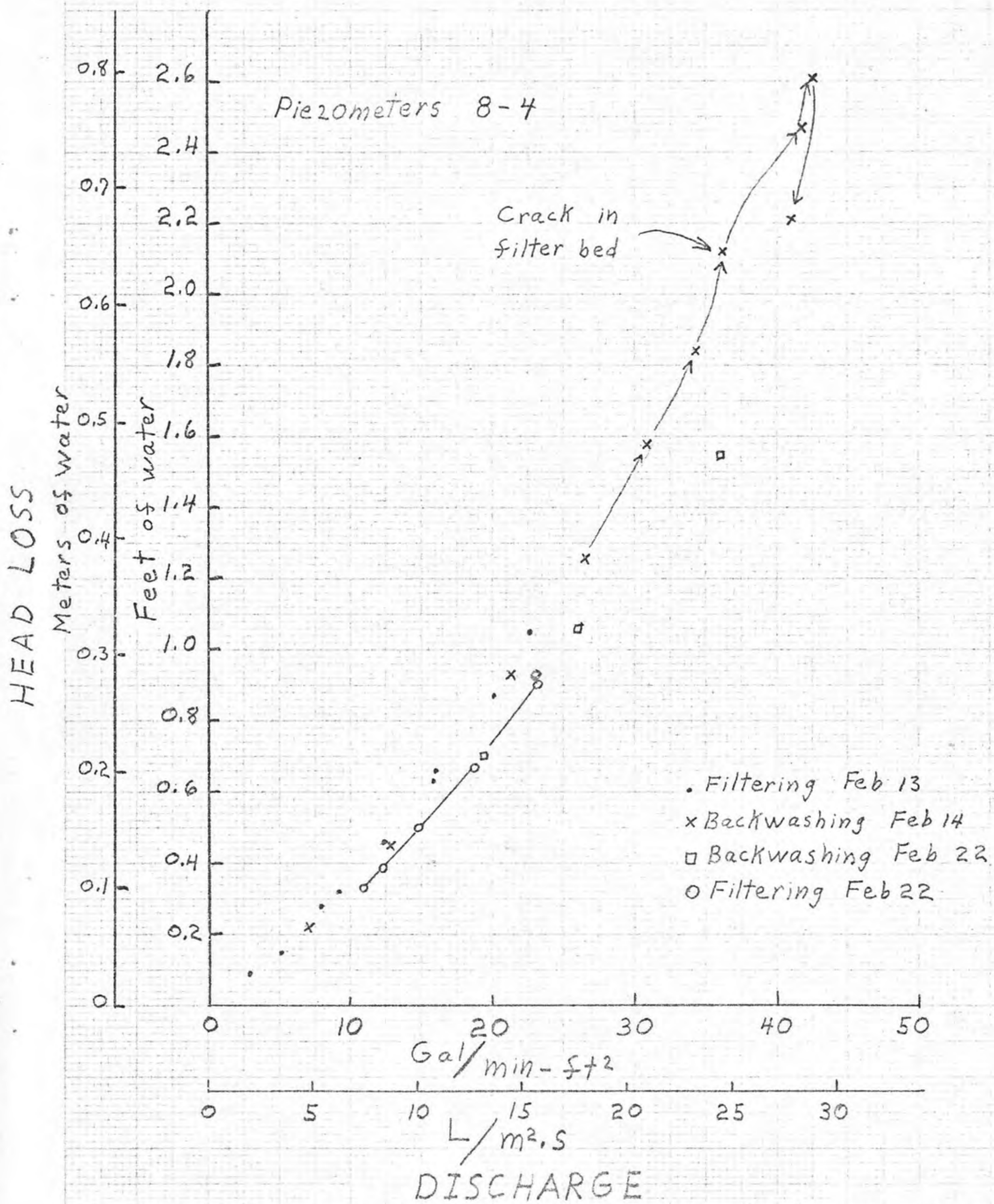

Figure 4. Clean filter (configuration I).

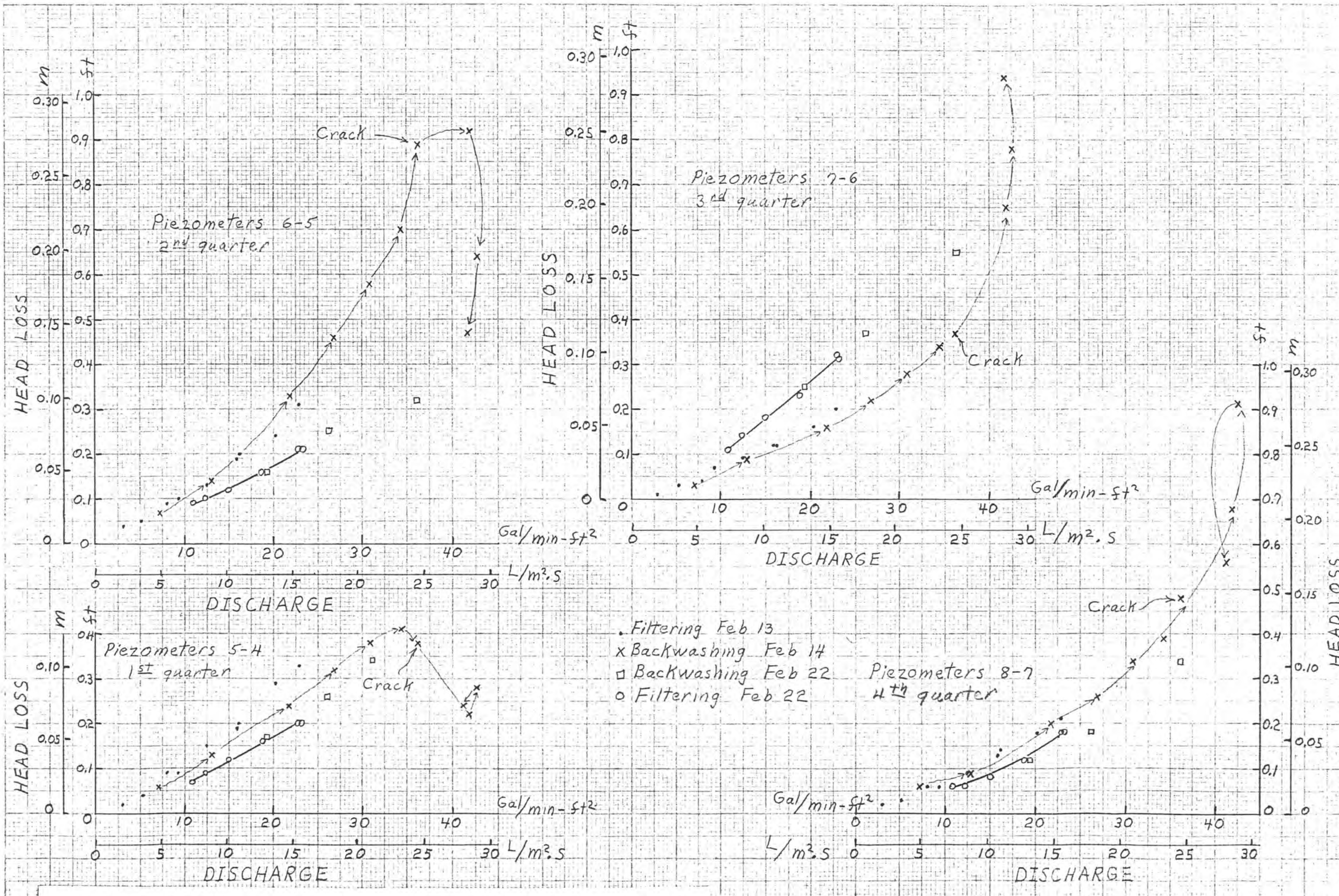

Figure 5. Flow resistance for quarters of the filter sand layer (configuration I).

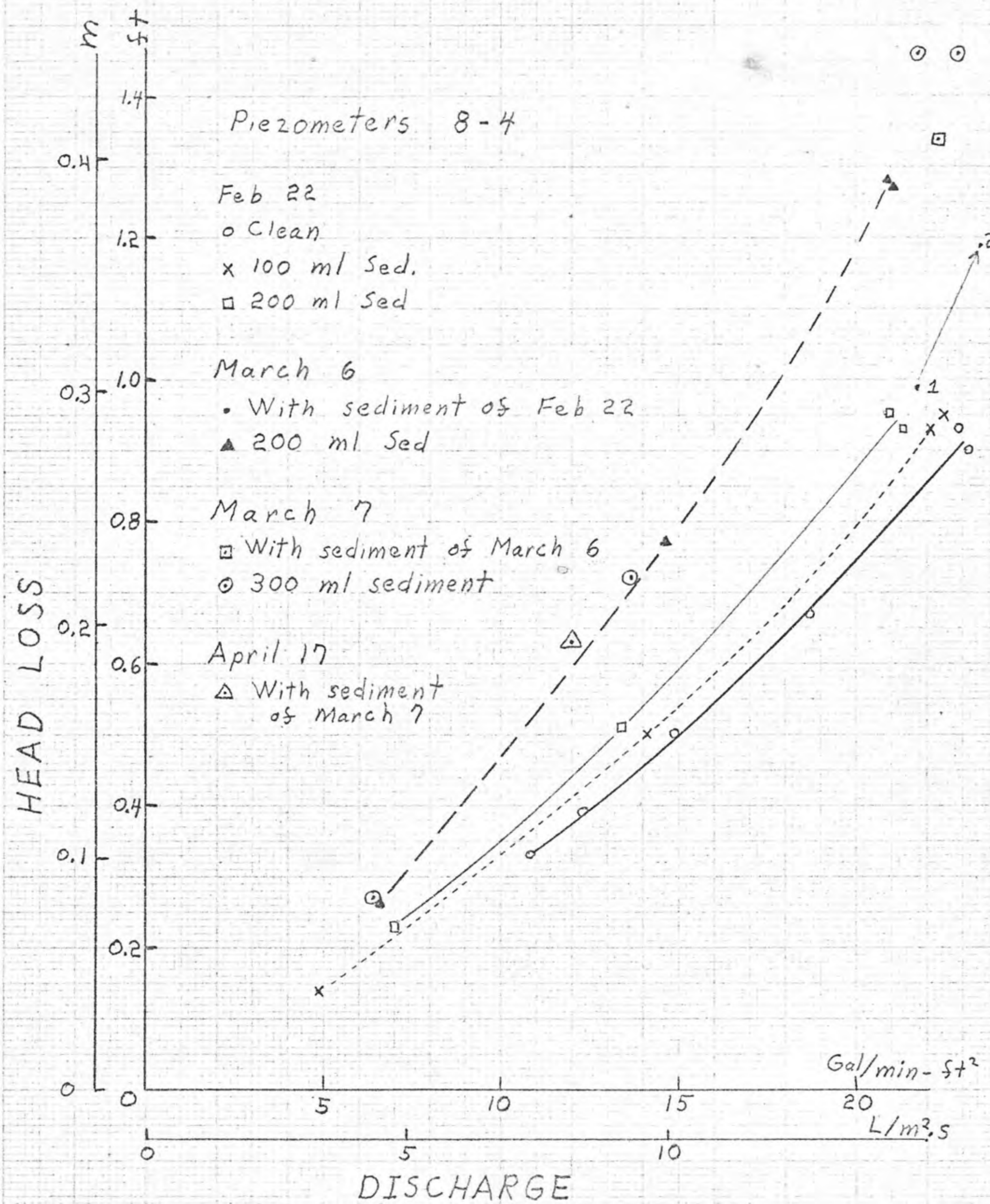

Figure 6. Sedimentation tests (configuration I).

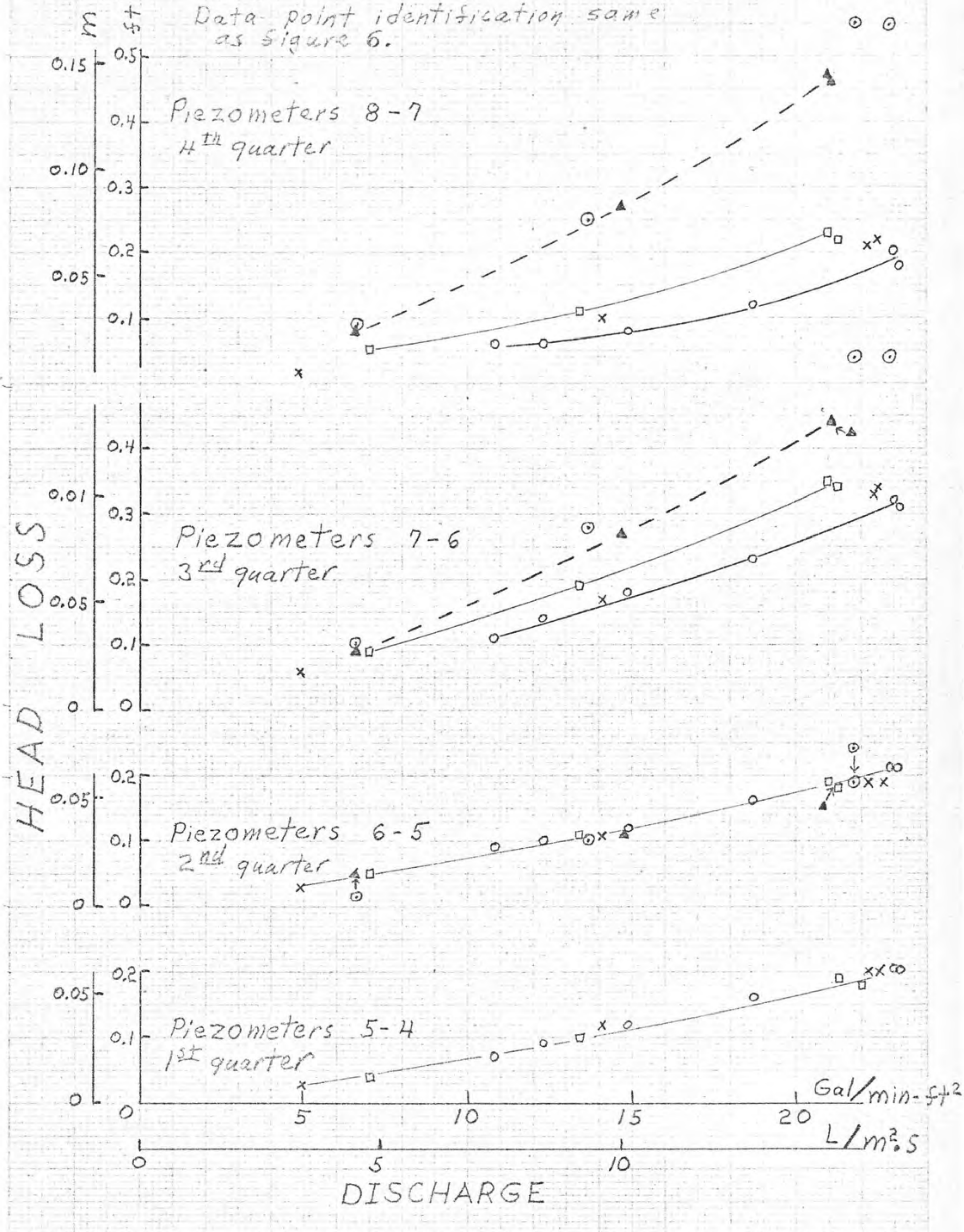

Figure 7. Flow resistance for quarters of the sand layer - sedimentation tests (configuration I).

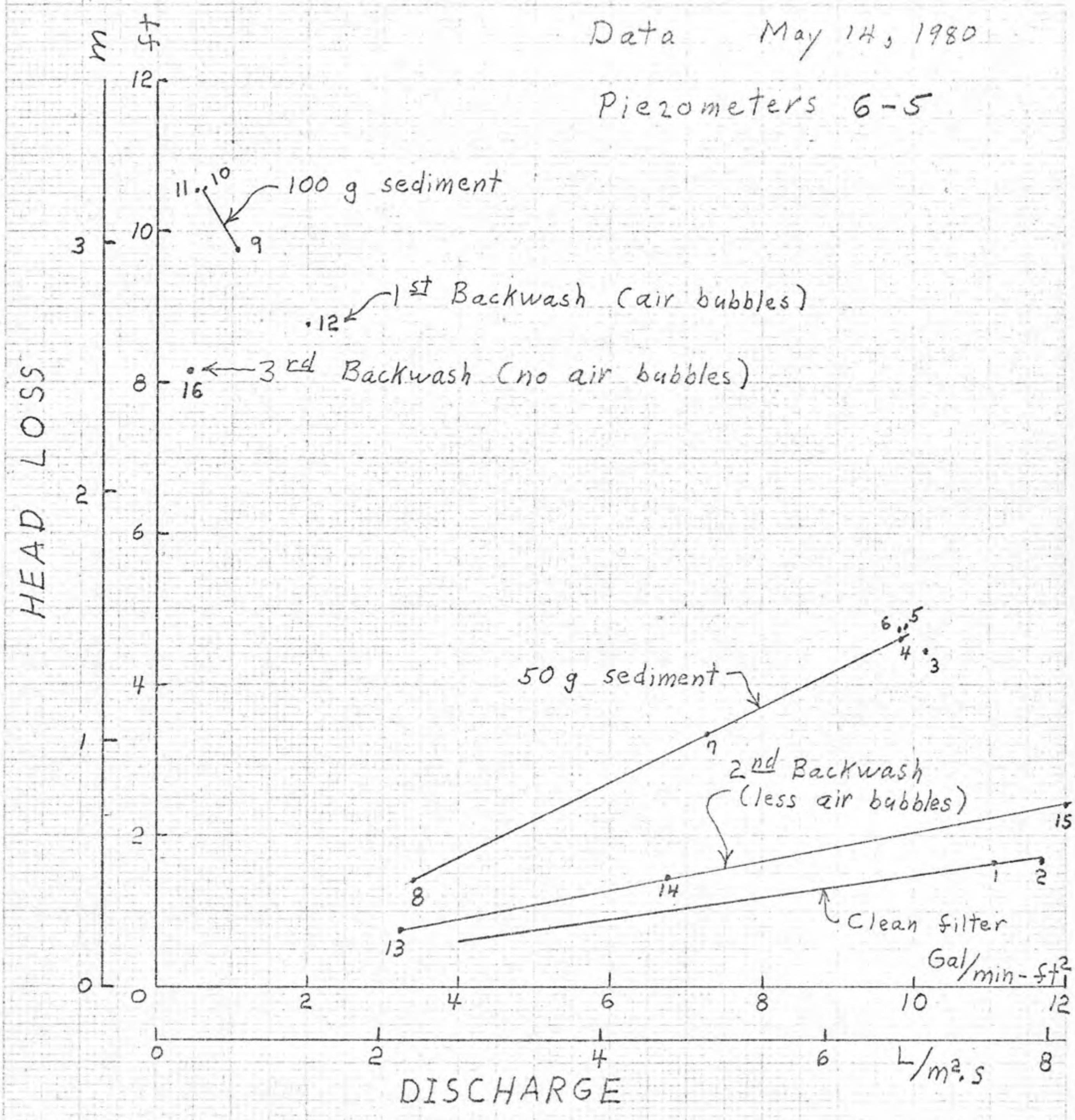

Figure 8. Sedimentation tests (configuration II).

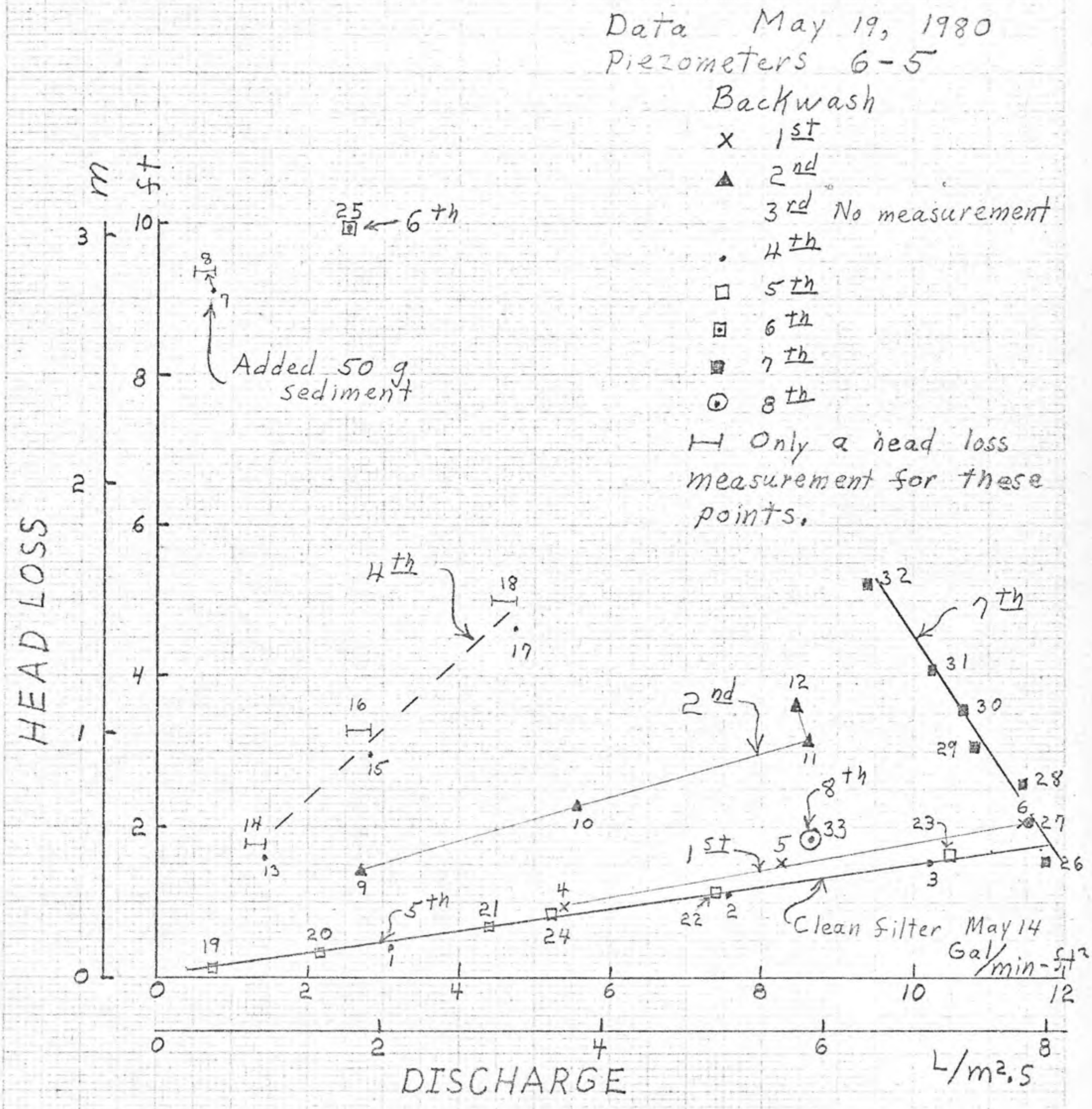

Figure 9. Additional backwashing tests (configuration II).