Performance of gully pots for road drainage

E J Forty

Report SR 508
October 1998

HR Wallingford

Address and Registered Office: HR Wallingford Ltd. Howbery Park, Wallingford, OXON OX10 8BA
Tel: +44 (0) 1491 835381 Fax: +44 (0) 1491 832233

Contract

This report describes work funded by the Department of the Environment Transport and the Regions under research Contract CI 39/5/95 for which the DETR nominated officer was P Woodhead and the HR nominated officer was WR White. The HR job number was RTS 57. It is published on behalf of the Department of the Environment Transport and the Regions, but any opinions expressed in this report are not necessarily those of the funding Department. The work was carried out by E John Forty and managed by RWP May.

Prepared by ....E John Forty........ *(name)*

........Senior Scientist........ *(Title)*

Approved by ....[signature]........ *(name)*

........Group Manager........ *(Title)*

Date........12-11-98........

Acknowledgements

The author thanks the following for their significant contribution to this project. Mr Keith Barraclough and Naylor Clayware Ltd. and Mr Tony Elliott and Milton Pipes Ltd.

Summary

Performance of gully pots for road drainage

E J Forty

Report SR 508
October 1998

Gully pots are a very important component of surface water drainage systems. Their main purpose is to minimise the amount of sediment entering systems and possibly causing blockages. Associated with this however, they have two further effects due to their design, which has not changed significantly since inception. Gully pots have a limiting flow rate and also retain a certain quantity of water between storm events, the quality of which deteriorates with time. As a result of this, they are believed to be associated with the "first foul flush" phenomenon in which pollutant levels in sewers rise rapidly at the beginning of storms.

This study investigates the present performance criteria for gully pots and endeavours to identify improvements in performance within significant constraints set by cost, construction and maintenance issues.

Various simple modifications to existing designs were tested to try to improve sediment retention ability (trapping efficiency) and two new designs investigated. The hydraulic efficiency (flow capacity) of all designs tested was determined. Scope for further research has been identified.

Contents

Contents *continued*

Figures

Contents continued

Plates

1. INTRODUCTION

1.1 Background

Gully pots represent a very important element of surface water drainage systems especially in urban areas and on roads. Their main function is to prevent the larger solids washed from roads and paved areas entering the drainage system and settling out in vulnerable areas, thus forming blockages. Whilst these blockages may be cleared by storm events it is possible for them to become very dense and semi-permanent and perhaps cause flooding problems. The design of the gully pot itself also determines the maximum inflow rate to the sewer and also the volume of potentially polluted liquor retained between storms.

Apart from the use of alternative production materials the basic design of the gully pot has not changed significantly since its inception. With the ever increasing emphasis on reducing pollution within the environment especially in receiving waters it is important to improve, if possible, any likely source of such pollution. Vast numbers of gully pots are used throughout the UK and any improvement in the hydraulic design and efficiency of these devices would have an impact on manufacturers, users and the environment.

This study, carried out in collaboration with manufacturers, and part of the DETR Construction Research Programme, investigates the present performance criteria for gully pots and endeavours to improve their basic design within the difficult constraints set by the economics of manufacture, installation and maintenance. Obviously any major design change could have a significant bearing on all these issues. It might be possible to produce a very efficient gully pot (in terms of sediment retention) but it would be unlikely to be adopted if it were more difficult to install or maintain or if it were significantly more expensive than existing types.

1.2 Objectives

The main objectives of the present study are:

- To investigate the performance criteria for gully pots
- To improve the sediment retention capability of gully pots (trapping efficiency)
- To identify improvements within constraints set by cost, construction and maintenance issues
- To investigate the hydraulic efficiency of gully pots

1.3 Structure of report

Section 2 describes the present performance criteria for gully pots and includes regulatory, installation, maintenance and manufacturing aspects. Section 3 describes previous and present laboratory studies. Results of this study are discussed in Section 4 and conclusions drawn in Section 5. Recommendations for further studies are given in Section 6.

2. PERFORMANCE CRITERIA

2.1 Regulatory aspects

2.1.1 Current research

Current research is being carried out into the management of gully pots for improved runoff quality under a CIRIA Research Project RP 539 (1) .The aim of this project is to investigate the water quality effects of roadside gully pots and to produce guidance on how runoff quality can be improved through good management practice. This has involved the collection of data from field sites and the development of a numerical model. The main objectives of the study are:

- to identify the nature and scale of water pollution problems linked to the flushing of poor quality liquor from gully pots during cleaning operations and storm flow.
- to investigate the impact of different maintenance practices.
- to produce guidance on good maintenance practice to minimise pollution, taking cost into account.
- to identify criteria for the use of gully pots.

2.1.2 Policy on discharge consent

At the present time there is no legislation relating to the use of, or the discharge from gully pots. The Environment Agency in their Pollution Prevention Guidelines on the use and design of oil separators (2) specifies the use of deep-seal road gullies (to BS5911 1982) "when oil separators are not necessary". This is designated as "on small car parks and most normal stretches of highway". It would seem that at the present time the requirements of the Agency are based very much on a case-by-case consideration.

2.1.3 Design

Information regarding the design of gully pots is presently limited to that given in BS 5911: Part 230: 1994. This states that they " should normally be of adequate size, depending on the use of the area, the type of surface and the frequency of sweeping". There is no method of quantitatively relating size to the factors given in the standard.

2.1.4 Water quality criteria

The water quality criteria presently applicable to gully pots are those commonly associated with contamination of receiving waters. These can be defined as:

- the urban pollution management (UPM) intermittent standards for biochemical oxygen demand (BOD) and ammonia
- the AMP2 guidelines for BOD
- statutory water quality standards

The first of these provide a detailed framework for assessing short – term, acute impacts of oxygen demand and ammonia.

The AMP2 guidelines (intended for interim use only whilst the UPM guidelines become established) were derived for the assessment of pollution from combined sewage overflows and only cover BOD. They are defined as 99 percentile standards which may only be exceeded for 1% of the time.

Statutory water quality standards can cover a range of uses to which water can be put such as abstraction for drinking, boating, fishing, etc. For each type of use water quality standards would be defined for that use. Each use would be designated a number of classes and each class would have pollution limits designated usually based on 90 or 95 percentile values for say BOD, ammonia and metals, etc.

It is presumed that the results of the CIRIA study referred to in 2.1.1 above will in the future be used by the Environment Agency to influence the Highways Agency and the Local Authorities as regards water quality standards for gully pots.

2.1.5 Maintenance

The maintenance of the roadside gully is not well defined in relevant legislation (Water Industry Act, 1991 and Highways Act 1980). Under section S100 (1) of the of the Highways Act, 1980 the highway authority may "Scour, cleanse and keep open all drains situated in the highway". Under a different section of the same Act they have a duty to maintain the highway vested in them.

Whilst there are at present no defined maintenance standards for gully pots, gully cleaning is usually carried out a predetermined number of times a year. The basis for determining the frequency of cleaning varies depending on the source of advice. Marshal (1970)[3] recommends a minimum frequency of three times a year, with a possible reduction to once a year in rural areas. The Local Authority Associations (1989), Highway Maintenance, Code of good practice suggests a figure of once or twice per year depending on the local situation [4]. The Department of Transport (1985) [5] recommends cleaning not more than once per year for both urban and rural trunk roads except where required by local circumstance.

Again it is likely that the CIRIA study referred to in 2.1.1 above will be used by the Environment Agency to influence the various authorities regarding gully pot maintenance procedures.

2.2 Installation and maintenance aspects for local authorities

2.2.1 Existing situation

The scale of usage of gully pots in the UK is indicated by the case of Oxfordshire where the County Council alone is responsible for approximately 73500 gully pots, the vast majority of which are concrete. The most common size used is 450mm diameter with an outlet pipe of 150mm diameter (trapped or un-trapped depending on the situation).

However, the tendency in new installations is to use plastic gully pots for several reasons as follows:

- Easier to handle, not requiring a heavy lift vehicle to install it and needing fewer people, with resultant savings in costs.
- Potential Health and Safety problems are less serious due to the lower weight
- In urban areas pots can easily be modified to avoid underground services (depth can be simply reduced)
- Similar life span found to date (pots always surrounded in concrete when installed)

It was clear from discussions that the most significant issue for Local Authorities in relation to the installation and maintenance of gully pots was that of cost. Any factors tending to increase cost would not find favour unless demonstrably more cost effective or deemed necessary for a particular situation.

For instance a situation might arise when it is difficult to have the entry point (the gully grating) directly above the collection chamber (the gully pot) such as in the central reservation of a motorway or a roadway used significantly for parking. In this situation normal emptying/ maintenance would be impossible. It is possible that in this case a modified design using a side inlet gully chute could be used.

However, despite the obvious need in a particular situation there were still objections to a "special" type of entry system such as that described above for the following reasons.

- Two manholes to maintain (gully chute and the pot)
- Need to increase number of crew members or time allowed for the emptying process
- Present designs of emptying vehicle would not allow them to reach the pot under the pavement if a vehicle were parked over the chute
- When cleaning the street, the whole length of pavement would need to be closed to pedestrians during the process.

The main design issues for Local Authorities were the need for an increased hydraulic capacity and an improved ability to prevent blockages from coarse sediments but without additional cost implications.

2.2.2 Maintenance

In Oxfordshire the cleaning of gully pots is now sub-contracted to an "in-house privatised" company of the County Council. The company is paid by the number of gullies emptied (around £1.50 per gully in 1996/1997).

Until 1996/1997, gully pots were visited and cleaned two to three times a year. In future, budget constraints will reduce this to once per year. Interest was shown in the possible adoption of a seasonal cleaning scheme (autumn leaves cause significant problems) but again cost implications might prevent the establishment of such a practice.

The cleaning crew is made up of two persons, one driver, and one emptier. The crew logs and reports any problems encountered, identifying blocked or damaged gullies by street and gully number and also those to which they are not able to gain access. These are left to the next campaign. The cleaning practice is not changed according to the type of drainage system since in general the crew is unaware whether a particular gully is connected to a separate, combined or foul sewer.

The Local Authority has a standard procedure contained within its Specification for Highway Works for the cleaning of Gullies. The procedure clearly states that gullies should be backwashed and refilled with clean water, in no case with black water. In practice however, the situation is significantly different at present, for several reasons:

- The design of the emptier vehicle is such that only 25% of its available water volume is clean water (approx 2000l) necessitating either the use of black water or frequent refilling stops.
- The clean water supply is delivered by gravity, providing no pressure for jetting hard solid deposits.
- Black water is expensive to treat or dispose of if not used in the gully pot cleaning process. This cost would be reflected in the charges to the Local Authority.

In reality, backwashing and refilling with black water is current practice. The disposal of the residual arisings also seems to be a little obscure in practice although this is also clearly defined in the Specification for Highway Works provided by the Local Authority.

Generally speaking, the users and maintainers of road gullies are more and more pressured by budget constraints which lead to practices that can become inadequate (cleaning frequency) or can add to the pollution of the drainage system (current practice of backwashing or refilling with black water). However, current research will soon enable the Environment Agency to influence the various authorities on the management of gullies for improvement of runoff quality.

2.3 Manufacturing aspects

With ever increasing budget constraints on specifiers and users of gully pots an important consideration for manufacturers is the cost of the end product. Competition from manufacturers of units utilising materials other than the traditional concrete and clay has heightened this problem. As described in 2.2.1 above there is an increasing move towards lightweight plastic pots for ease of installation and modification reasons. In order to remain competitive in the market place manufacturers are reluctant to alter present designs (produced with expensive tooling and moulds) without good cause. During the course of the present study discussions were held with manufactures /suppliers of several different types of gully pot and it became evident that scope for making major modifications to the present designs was very limited due to significant economic constraints.

3. LABORATORY TESTING

3.1 Definitions

Hydraulic Efficiency is defined as the ability of a gully pot to pass flow without becoming surcharged

Trapping Efficiency / Sediment Retaining Efficiency is defined as dry weight of sediment retained in the pot compared to the dry weight of sediment added to the input flow during a test.

Trapped condition is defined as when flow from the gully pot leaves through a low level outlet via a bend which retains a water seal between the pot and the downstream drainage system at all times.

Un-trapped condition is defined as when flow from the gully pot leaves through a high level outlet (known as the "rodding eye" see Figure 2) and passes directly to the drainage system with no water seal present.

Rodding eye is defined as the high level outlet from a gully pot usually used for cleaning access (see Figure 2). In the trapped condition the rodding eye is sealed with a stopper.

3.2 Previous studies

There have been several laboratory studies to date to investigate the solids retention efficiency of the standard design of gully pot.

Larger et al (1977)[6] reported on tests of North American catch basins. Conclusions drawn were that higher flow rates produced lower solids retention efficiencies and that finer particles were not retained as efficiently as coarse material. Up to a level of 40% of the total height of storage, bed level within the pot was not found to influence the trapping efficiency.

Fletcher et al (1978, 1981)[7] carried out tests on a pot containing a 50mm bed of field sediment. They concluded that re-entrainment of deposits forming the bed depended on the water discharge, accumulated sediment depth and the mass of sediment available for release in the bed. At flow rates up to 1.1 l/s only 0.2% of the basal sediment was removed before running out of suitable material for release. Pratt and Adams (1984)[8] utilised a triangular inflow hydrograph with a peak at 1.1 l/s and recorded trap efficiencies of 89% and 91% for sand particles in the ranges 0.09-0.15mm and 0.15-0.30mm respectively.

A study of German gully pots was carried out by Grottker (1989, 1990)[9] utilising solid particles ranging in size from 0.025 to 1.6mm. From tests using two sediment levels (250mm and 450mm from the base) a set of empirical equations to predict performance was evolved.

Butler and Karunaratne (1995)[10] carried out tests to investigate the solids trapping efficiency of a 450mm diameter 80 litre volume British Standard gully pot under a variety of typical conditions. Tests utilised water flow rates up to 1.5 l/s combined with sediments ranging from 0.068mm to 0.42mm. The trapping efficiency of the pot due to sedimentation alone was found to vary significantly depending on the size of sediment and the water flow rate. However, the tests suggested that the efficiency was independent of retained bed depth and inflow sediment concentration. At the highest flow rate tested of 1.5 l/s the efficiency varied between 15% and 90% for sediment sizes of 0.068mm and 0.42mm respectively. Using the results, a model of sediment retention efficiency was formulated based on a mass balance approach assuming no bed erosion, complete mixing and settling velocity based on Stokes' law (adjusted for turbulence).

3.3 The present study

The present study involved the design and construction of a purpose built test rig for gully pots with a simulated road surface, kerb and gully grating. The rig was used to investigate the hydraulic and sediment trapping efficiency of four types of gully pot. During the course of the study several simple internal modifications were made to each design within the constraints set by cost, construction and maintenance issues to try to improve the trapping efficiency.

3.3.1 The test rig

A schematic layout of the test rig is shown in Figure 1. A rectangular channel some 2.5m long by 1.25m wide and 0.15m deep was constructed and supported on rollers on a framework approximately 1.5m above ground level. The supporting framework was some 1.2m longer than the channel to enable it to be moved horizontally within the facility to gain access to the top of the pot under test. This channel contained a gully grating outlet towards the downstream right hand corner, see Figure 1. The gully pot under test was placed on supports beneath the framework at the downstream end. A plastic sleeve was formed between the gully grating and the top of the gully pot to prevent any water or sediment loss during a test.

Water supply to the rig was provided by a 30 l/s centrifugal pump through a horizontal manifold designed to provide a uniform flow onto the simulated road surface. Water flow rate was measured using an electro-magnetic flow meter situated in the incoming flow line. Dry sediment was introduced into the flow just upstream of the gully grating using a variable-rate vibrating- screw feeder.

For a particular test different bed levels within the pot were simulated either using loose sediment or a wooden board fixed at the required position to the wall of the pot. The surface of the board was roughened by gluing to it a layer of the sediment being used to simulate the suspended solids.

The outflow from a pot under test was diverted into a sediment collecting chamber containing a number of fine mesh screens designed to retain the particular size of sediment being used. The sediment-free water was then returned to a large sump for re-circulation via the pump.

3.3.2 Test criteria

The performance of individual types of gully pot was measured against two criteria. Firstly, the hydraulic efficiency and maximum flow capacity were determined by measuring the change in water level in the pot with increasing flow rates and various retained sediment levels. Secondly, the sediment retaining efficiency was determined at a particular flow rate and utilising a single sediment supply rate. A limited number of tests were carried out using a fine sand with a d_{50} of 0.12mm but the majority utilised a medium sand with a d_{50} of around 0.84mm. Karunaratne (1992)[11] reported particle size distribution for surface washoff to have a typical d_{50} value of between 0.4mm and 1mm.

3.3.3 Test methods

Tests to determine the hydraulic efficiency of each pot were carried out with no sediment input but with a range of simulated retained sediment depths up to 500mm depending on the pot under test (different pots have outlets at different elevations). The water flow rate into the pot was varied upwards in 1 l/s increments until the pot overflowed. At each increment of flow the water level within the pot was recorded and compared with that of the invert of the outlet. In one case the test was carried out with the pot outlet both in the trapped and un-trapped conditions; in all other cases the pots were tested with the rodding eye stoppered, corresponding to the trapped condition.

The majority of tests to determine the sediment retaining efficiency of a particular design of pot were carried out at an input flow rate of 3 l/s and a supply rate of 1.5 gm/s of the medium sand as specified in 3.3.3 above. Assuming a catchment area of 200 sq. m per gully pot, a flow of 3 l/s represents a rainfall intensity of around 50mm/hr. This is the uniform rate presently used in standards considering flow from paved areas (e.g. BS6367: 1983). The sediment injection rate of 1.5 gm/s relates to a solids concentration of 500 mg/l in the incoming flow a typical value for a Highway drain (after Hall and Ellis 1985)[12]. A few tests were carried out using a fine sand with a d_{50} of 0.12mm, and for one of these the flow rate was reduced to 1.5 l/s (approximately 25mm/h) while the solids concentration was kept the same i.e. 500 mg/l. This was to investigate the relationship between flow rate and efficiency.

Initial tests

Some initial tests were carried out on a continuous basis. This involved collecting, drying and weighing outlet solids caught in the collecting chamber at hourly intervals and allowing the pot to fill over a long period, typically 36 hours. This system proved difficult to manage due to the duration of the test, the large volumes of material being handled, and problems of knowing with a reasonable degree of accuracy, the bulk density of the retained material during the test. The duration of a typical test was then reduced to around 10 hours and involved collecting, drying and weighing the outlet solids every two hours and adding material to the pot at the same time to simulate the filling cycle. However, trying to determine the dry weight of material retained by the pot at specific level increments (to compare with input and collected material) again proved difficult. In order to improve the reliability/certainty of result the test method was further modified.

Test method

Tests were carried out using a rigid board fixed inside the pot to simulate various amounts of accumulated sediment. A number of simulated sediment levels were chosen to represent the filling cycle of the pot. Each test lasted two hours. The sediment input rate from the vibrating feeder was checked at the start, at half hour intervals during a test, and at the end by collecting and weighing a timed sample. Sediment from the pot outlet was collected dried and weighed at the end of the two hour period and similarly sediment accumulated on the rigid board within the pot. Thus, it was possible from these various figures to identify more precisely any losses/errors of measurement.

Tests on individual gully pots were carried out either with the pot in its original condition or utilising one of a number of simple modifications with the aim of increasing pot trapping efficiency. In some cases manufacturers were able to produce a "special" one off pot of a different design for testing purposes in order to compare performance.

3.4 Tests on a concrete gully pot

This series of tests was carried out using Milton Milflex Monolithic gully pot manufactured to BS 5911: Part 230 1994 having an overall height of 900mm with nominal diameter of 450mm see Figure 2.

3.4.1 Hydraulic efficiency of original design (trapped)

For this test (HT1) the gully pot was mounted on the test rig and the rodding eye stopper inserted in order to provide a trapped outlet. The incoming flow rate was varied in 1 l/s increments until the pot overflowed. At each value of flow rate the water level in the pot was recorded and compared with the outlet level of the invert. In order to investigate the variation of hydraulic efficiency as the pot fills this procedure was carried out at five accumulated sediment levels.

Results of this test (HT1) are shown on Figure 3. It can be seen that this standard pot in trapped mode will take a flow of approximately 11 l/s before overflowing (i.e. this was the flow when the water level reached the top of the pot 245mm above the outlet invert see Figure 2). The influence of bed height within the pot was minimal.

3.4.2 Hydraulic efficiency of original design (not trapped)

The above test was repeated with the pot in the un–trapped condition that is to say, with the rodding eye stopper removed and the trapped outlet sealed allowing flow to pass to the downstream pipework directly and not via the trap. Flow was again raised in 1 l/s increments and the water level within the pot recorded

Results are shown on Figure 4. With the pot in the un-trapped mode the flow capacity was increased from 11 l/s to 18 l/s before overtopping took place (i.e. when the water level was some 245mm above the outlet invert). Again, as can be seen, the accumulated sediment level had little influence on performance.

3.4.3 Trapping efficiency of original design (trapped)

Tests to investigate the trapping efficiency of the concrete gully pot in its original condition were carried out using both the fine sediment (d_{50} 0.12mm) and the medium sediment (d_{50} 0.84mm).

Fine sediment

For this test (CF1) an inflow rate of 3 l/s was used together with a sediment supply rate of 1.5 gm/s. The test was started with no sediment in the pot and water and sediment supplied for a two hour period. At the start and at half hour intervals the sediment supply rate was checked by taking and weighing a 5 minute sample. After 2 hours the test was suspended and the sediment removed from the collecting chamber connected to the outlet pipe. This sediment was then dried and weighed. At this stage the test was resumed for a further two hours and the procedure repeated. The depth of the accreted sediment within the pot was noted. In order to speed up the process sand was then placed in the pot by hand to increase the bed level by some 100mm (to a level of 186mm above the base) and the test resumed. This procedure was repeated until the accumulated sediment level in the pot reached 486mm. The total duration of the test was some 12 hours. Tests were carried out to determine the efficiency of the collecting chamber (connected to the outlet of the pot) and it was found that due to the nature of the material some minor loss occurred whilst collecting took place. It was decided therefore, to compensate for this loss by adding 4% to all collected weights of fine sand.

From an analysis of the dry weights of sand input and collected it can be seen (Figure 5) that up to an accumulated sediment level of 286mm the mean trapping efficiency was found to be around 36 % At this point efficiency started to reduce until it became virtually zero at an accumulated sediment level of 486mm.

In order to assess the effect of input flowrate on the trapping efficiency a further test (CF2) was carried out with the non-modified pot this time using a flowrate of 1.5 l/s. The sand input rate was reduced to 0.75 gm/s to maintain the same sediment supply rate. For this test, only the highest accumulated sediment level was used i.e. 486mm due to the difficulty in operating the rig with this material. As can be seen from Figure 5 trapping efficiency increased from virtually zero to around 30% as a result of the reduced flowrate.

Medium sediment

A similar test (CM1) to that described above was then carried out using the medium sand. The rig was again operated for a series of 2 hour periods, the sand collected from the outlet, and the bed raised at the end of each period. In this case however, slightly different bed elevations were used with only four increments above a completely empty pot. Plate 1 shows the accreted sediment following the two hour period starting at a bed level of 400mm.

Again from an analysis of collected weights of dry sand it can be seen (Figure 6) that from an initial high value of trapping efficiency with an empty pot (nearly 100%) this figure reduces to around 80% at bed elevations between 200 and 400mm before dropping off to only just over 20% at an elevation of 500mm. In the case of the medium sand the collecting chamber was found to lose some 1%. This figure was added to all collected weights before the calculation of trapping efficiency was made.

As described earlier (3.3.3) results from the above test method are subject to some degree of uncertainty due to the fact that it is very difficult to measure the quantity of dry solids remaining in the pot after each time period.

At this point it was decided to investigate the use of a board fixed in the pot to simulate the various degrees of accumulated sediment. At the end of each time period it was therefore possible to remove, dry and weigh the material collected on this board. It was therefore possible to define more precisely any losses of material.

A second test (CM2) was carried out therefore with the pot in its original condition but using the board to simulate accreted sediment. Results of this test are shown on Figure 7. Apart from the empty pot situation, trapping efficiencies were between 6 and 22% higher using this method of testing.

3.4.4 Trapping efficiency of original design incorporating baffle 1 (trapped)

Fine sediment

For the next test (CF3) the concrete gully pot was modified to incorporate a baffle plate suspended vertically in front of the trapped outlet see Figure 8. The plate measuring some 400mm vertically by some 310mm horizontally was designed to help prevent sediment-laden water leaving the pot before the sediment has had time to settle out. The baffle was supported using a bracket attached to the rodding eye stopper in order to keep additional costs to a minimum. This test was carried out using a natural bed to simulate accreted sediment (no baseboard in pot). At the end of each two hour time period as before, sand was added to the pot to raise the accumulated sediment level to the required position. For this test only three levels of sediment were used 0, 286 and 386mm above the base. It was not possible to increase the bed level further since it would then have interfered with the baffle arrangement preventing flow to the outlet.

Results are shown on Figure 5. It can be seen that this arrangement of baffle considerably reduced the trapping efficiency of the pot as it began to fill. At a level of 386mm efficiency was zero.

3.4.5 Trapping efficiency of original design incorporating baffle 2 (trapped)

Medium sediment

The baffle arrangement was then changed. The design of baffle 1 produced vertical flow in the vicinity of the pot outlet and probably encouraged settled sediment to be re–entrained and removed. Baffle 2 as shown on Figure 9 and Plate 2 was designed to prevent vertical flow in the vicinity of the outlet but allow horizontal movement at a higher level. Again in order to keep manufacturing costs to a minimum the baffle was attached to the rodding eye stopper.

This test (CM3) was carried out at an input flow rate of 3 l/s and a sediment supply rate of 1.5 gm/s. As before the rig was operated for a series of 2 hour periods and sand collected from the outlet. The natural bed within the pot was raised at the end of each period.

Results are shown on Figure 6. It can be seen from a comparison with results of test CM1 that at most accumulated sediment levels efficiencies were very similar to the "no baffle" case. Only at an accumulated sediment level of 200mm was there a significant apparent increase of around 12%.

Fine sediment

In order to compare the likely effect of this modified baffle on the trapping efficiency of finer material a single test (CF4) was carried out using the same configuration of flow and sediment rate and with an accumulated bed level of 386mm (the level used in previous fine sediment tests). The result is shown on Figure 5. It can be seen from a comparison with tests CF1 and CF3 that this modified baffle improved trapping efficiency for the finer material at this accumulated sediment level (386mm). A value of around 20% was obtained compared with Zero for baffle 1 (CF3) and 15% for the basic design of pot (CF1).

3.4.6 Trapping efficiency of original design incorporating baffle 3 (trapped)

Medium sediment

It was then decided to investigate the performance of a third type of baffle as shown on Figure 10 and Plate 3. This was in the form of a horizontal plate fixed to the wall of the gully pot some 375mm above the base (just below the level of the trapped outlet). As with baffle 2 it was designed to prevent the vertical movement of flow and hence sediment in the area immediately in front of the pot outlet.

This test (CM4) was carried out at the standard input flow rate of 3l/s and sediment supply rate of 1.5gm/s. Again the rig was operated for a series of 2 hour periods. After each period the sand was collected from the outlet and from within the pot. For this test three accumulated sediment levels were investigated using the board to simulate accreted bed as described earlier. It was not possible to carry out tests with a bed level above 300mm due to the configuration of the revised baffle.

Results are shown on Figure 7. Comparing the results of this test with those of test CM2 (no baffle with board) efficiency was lower at all three bed levels tested

Fine sediment

Due to the relatively poor results obtained with baffle 3 no tests were carried out using the fine sediment.

3.4.7 Hydraulic efficiency of larger outlet design (trapped)

Since there was no significant improvement in the trapping efficiency of the standard gully pot using various different arrangements of baffle plate it was decided to investigate the effect of a modification to the outlet pipe. Whilst the internal diameter of the gully pot outlet (that connecting to the surface water drainage system) was approximately 150mm the design of the trap was such that there was a considerable reduction in cross–sectional area through the trap and at the inner wall of pot. At this position, the outlet consisted of a square hole approximately 106mm by 106mm Thus, the cross–sectional area internally was some 60% less that that of the external pipe.

The trapped outlet was increased in size to approximately 170mm by 106mm (keeping the square/rectangular shape) until the cross-sectional area matched that of the external pipe, see Plate 4. At the same time a small radius bellmouth entrance was formed to reduce the separation of flow and hence turbulence at this position.

The hydraulic efficiency test as described in 3.3.1 above was repeated. The input flow was increased in 1 l/s increments and water level measured in the pot until the pot overflowed. As before this procedure was repeated at four additional accreted sediment levels.

Results are shown on Figure 11. It can be seen that the accreted sediment level had little influence on hydraulic efficiency at a particular flow rate. However, with the enlarged outlet, as would be expected the maximum through flow was increased from 11 to 14l/s before overtopping took place.

3.4.8 Larger outlet – trapped – trapping efficiency

Medium sediment

This test (CM5) was carried out with the standard inflow rate of 3 l/s and sediment supply rate of 1.5gm/s. As previously, the rig was operated for a series of 2 hour periods at each accreted sediment bed level and sand collected from the outlet at the end of each period. In this case accreted sediment levels were simulated with the board fixed at appropriate levels within the pot. After each 2 hour period sediment retained within the pot was removed, dried and weighed and the board re- positioned. Plate 5 shows accreted sediment after the two hour period starting at a bed level of 200mm.

Results of this test are shown on Figure 7. It can be seen that trapping efficiencies with this configuration were higher at every accreted sediment level that all other tests. The most significant increase was when the pot was virtually full (bed level of 500mm) where the efficiency increased from around 20 % to over 90%.

3.5 Tests on a clay gully pot

This series of tests was carried out using three designs of clay gully pot manufactured by Naylor Clayware. Whilst the three designs varied in terms of inlet and outlet details they were all based around the nominal 450mm diameter 900mm high unit see Figure 12. All tests were carried out using the medium sand and the standard test conditions (water inflow rate 3l/s and sediment supply rate 1.5 gm/s). In all cases the rig was operated for a series of 2 hour periods and sediment collected from the outlet and inside the pot at the end of the period for drying and weighing. In all tests a board was used to represent the various levels of accreted sediment.

3.5.1 Hydraulic efficiency of original design (trapped)

The hydraulic efficiency test (HT2) for this design of clay pot was carried out in a similar way to that described in 3.4.1 above for the concrete pot. Results are shown on Figure 13. As can be seen in this case the through flow capacity was significantly higher than that of the concrete pot reaching 19 l/s before overtopping took place (i.e. when the water level was some 285mm above the outlet invert see Figure 12) However, increased turbulence at the higher flow rates of 15 to 17 l/s caused a larger variation at differing accreted sediment levels than previously observed.

3.5.2 Trapping efficiency of original design (trapped)

This test (CLM1) was carried out with the gully pot in two conditions, empty and with accreted sediment up to a level of 400mm (maximum possible before inundation of outlet). Plate 6 shows the accreted sediment following the test at 400mm. Results are shown on Figure 14. As can be seen trapping efficiency at both conditions was around 94%. In this make of pot, the cross–sectional area of the outlet pipe was similar throughout and so the gain in efficiency made to the concrete pot by modifying the outlet would not be applicable here. Discussion with the manufacturer suggested several possible alterations to the construction of the pot which, it was hoped would improve the trapping efficiency even further.

3.5.3 Hydraulic efficiency of swirl design (trapped)

The basic configuration of this design is shown on Figure 15. The concept is to provide a swirling action within the pot by using a tangential side inlet in order to assist the separation and settlement of the solids within the flow. In this case the feed to the pot was via a gully chute mounted below the gully grating and connected to the pot inlet with a short tube see Plate 7. It was envisaged that this layout would be useful in the situation where a benefit would arise from having the gully pot offset a distance from the grating.

The hydraulic efficiency test (HT3) for this design of pot was carried out in the standard way as described in 3.4.1 above. However, in this case overtopping took place when the water level was some 270mm above the outlet invert see Figure 15. Results are shown on Figure 16. In this case there was no significant variation in hydraulic efficiency with accreted bed level. However, with this design of clay pot the through flow capacity was reduced from 19l/s (original design) to 15 l/s.

3.5.4 Trapping efficiency of swirl design (trapped)

This test (CLM2) was carried out in the standard way as described at the start of this section on the clay pots. Results are shown on Figure 14. Unfortunately it can be seen that trapping efficiency with this design of pot was significantly lower that with the original design. At accreted levels of up to 200mm efficiency was some 18% lower at around 76% and between 300 and 400mm the efficiency was almost 30% lower at around 64%. Plate 8 shows the accreted sediment at the end of the test. Close inspection of this original swirl design of pot during a test suggested that sediment entering through the tangential inlet was being drawn out before having time to settle below the outlet level.

3.5.5 Hydraulic efficiency of swirl design incorporating a modified outlet (trapped)

The existing outlet as constructed in this new design was provided with a streamlined entrance see Plate 8, which also assisted the removal of sediment-laden water. In the first instance this streamlined/tangential entrance was modified to provide a square edged outlet normal to the inner wall of the pot see Plate 9. The resultant cross – sectional area for flow at the entrance was reduced by some 12% with this configuration.

The hydraulic efficiency test (HT4) for this modified design was carried out according to paragraph 3.3.1 above. Results are shown on Figure 17. Again it can be seen that accreted bed level had little effect on performance. With this modified design of outlet, not unexpectedly, through flow capacity was reduced slightly to 14 l/s.

3.5.6 Trapping efficiency of swirl design incorporating modified outlet (trapped)

The test (CLM3) on this design of outlet was only carried out with the pot in the empty state, since it became obvious during the course of the test that the trapping efficiency of this modified design was significantly worse that with the original swirl pattern. Results are shown on Figure 14. Trapping efficiency of only 49% was obtained with this modified design of outlet.

3.5.7 Trapping efficiency of swirl design incorporating modified outlet and baffle 1 (trapped)

In an effort to improve the trapping efficiency of this design of pot a vertical baffle plate was fixed to the inner wall adjacent to the outlet pipe as shown on Figure 18 and Plate 10. This plate measured some 0.17m (vertically) by 0.1m (horizontally) and was designed to divert sediment-laden flow away from the outlet. Of course its presence unfortunately also disturbed the swirling action of the flow at that point. An initial test (CLM4) was carried out on this configuration with the pot empty. The result is shown on Figure 14. Whilst there was some improvement on the previous test with the modified outlet (increased efficiency from 49 to 59%) it was felt that further observations with higher bed levels were not worthwhile.

3.5.8 Trapping efficiency of swirl design incorporating modified outlet and baffle 2 (trapped)

This test (CLM5) was carried out with a revised design of baffle plate (similar to that used as baffle 2 with the concrete pot shown on Figure 9). As above, an initial test was carried out with the pot empty to assess its performance. Unfortunately little improvement was obtained as shown on Figure 14. Trapping efficiency with this second type of baffle was of the order of only 59% compared to over 75% obtained with the "no baffle" situation. No further observations were made with this design of baffle.

Since generally, the swirl design of clay pot with the original outlet design performed better than the modified pot with or without baffle arrangements (see Figure 14) two further tests were carried out on this original design but incorporating each baffle in turn. However results were significantly worse than without baffles and so no further work was carried out on this type of pot.

3.5.9 Hydraulic efficiency of long path outlet design (trapped)

From the results of all previous tests it was apparent that the placing of various baffle arrangements within the gully pot in the vicinity of the outlet whilst being simple and economic did not significantly improve the trapping efficiency of any of the designs. Following deliberations and further discussions with the manufacturer of the clay pot a third design was evolved.

The aim was to modify the trapped outlet to provide a longer path, whilst including additional vertical movement of the sediment laden water. This resulted in the design shown on Figure 19. A significant element of this design is the invert level of the outlet pipe within the pot which is some 260mm above that of the original clay pot. Because of this the long path outlet design has potentially 65% more volume available for accumulated sediment before it reaches the outlet pipe. A second benefit of this design is the configuration of the trapped outlet which is constructed on the outside of the pot accessed via a high level inlet. This being so the water seal to the downstream pipework is maintained whatever the water level within the gully pot. Thus, following the emptying process there is no need to re-fill the pot with clean or black water to maintain the drain seal.

Results of the hydraulic efficiency test (HT5) are shown on Figure 20. As with most of the previous tests of this type efficiency did not vary significantly with accreted sediment level. For this arrangement of outlet the maximum through flow before overtopping took place (water level some 270mm above the outlet invert) was around 15 l/s. This was some 4 l/s less than with the standard arrangement of pot outlet.

3.5.10 Trapping efficiency long path outlet design (trapped)

This test (CLM6) was carried out in the standard way described at the start of this section and utilised three accreted bed levels plus the empty pot condition. Plate 11 shows the accreted sediment following the two hour period at the start of the test. Results are shown on Figure 14. As can be seen trapping efficiencies were very consistent throughout the range of bed levels at around 94%. This is the same as for the standard design of pot. It must be remembered however, that this long path outlet pot has considerable more volume available for sediment (approximately 65%) below the invert level of the outlet. Thus, for a similar overall size of pot the emptying / maintenance cycle could be extended without reducing the trapping efficiency.

4. DISCUSSION OF RESULTS

4.1 Hydraulic efficiency of concrete pot

Hydraulic efficiency tests were carried out on the original concrete pot both in the trapped and un-trapped condition since some situations allow un-trapped pot to be used particularly in rural areas. A test was also carried out following the modification of the pot to provide a larger outlet. Results for the test on the original pot in the trapped condition indicated that the through flow capacity was in the region of 11 l/s before overtopping took place. It was also evident that accreted bed level within the pot of up to 500mm had little if any effect on its hydraulic performance. With the pot in the un-trapped condition, that is to say with the rodding eye stopper removed and the lower outlet blocked, through flow capacity was increased to around 18 l/s. This significant change was due to the increase in flow area of some 23% between the trapped and un-trapped outlets and to a reduction in friction loss in the latter situation.

When the trapped outlet was modified to provide a larger cross–sectional area the through flow capacity in this situation was around 14 l/s. As in the previous case there was no significant variation with different accreted bed levels within the pot.

4.2 Trapping efficiency of concrete pot

Tests to investigate the trapping efficiency of the concrete pot were carried out both in its original condition and also with several internal modifications. The variation of efficiency with accreted bed level was also investigated. Most of the tests utilised a medium sand with a d_{50} of around 0.84mm but a few were carried out with a fine sand of d_{50} 0.12mm. Unfortunately, operational difficulties restricted the use of this finer material.

As described earlier the tests to investigate the variation of trapping efficiency with accreted sediment levels were carried out in two ways. Initially, the various sediment levels within the pot were simulated using a full depth of natural sediment. Subsequently, due to significant difficulties ascertaining the retained weights of dry sediment, a board was used to simulate depths of sediment which was fixed at the required test level.

In order to investigate the two methods, the test on the original design of concrete pot was carried out using both. Results are compared on Figure 21. It can be seen that, generally, efficiencies obtained with the bed simulated with a board were higher than with the natural bed. The most likely reason for this is that, with a natural bed, scour can occur to a level below that at which the test is started. If part or all of this scoured material in suspension subsequently leaves the pot through the outlet it adds to that supplied from the sand injection system and is included in the calculation of efficiency. However, since, with this method of testing, it was not possible to ascertain precisely the quantity of material remaining in the pot at the end of each test, one could not check if any of the original contents had been removed during the test period. Additional material collected from the outlet due to scouring below the start level would therefore reduce the apparent efficiency of the pot for a particular bed level.

During this investigation of the two methods, photographs were taken of the inside of the pot for each method at several bed elevations. Plates 12 and 13 show the accreted bed for the natural condition and the board respectively at an elevation of 200mm. Viewed carefully it can be seen that whilst the bed forms are similar in both cases (a build up of sediment in the area of the outlet), a small area of board is exposed as shown on Plate 13, suggesting that in this case little or no scour would have occurred below the level of the board. However, with the natural bed it is possible that additional scour has taken place. Plates 14 and 15 show the accreted bed for the natural condition and with the board respectively at an elevation of 500mm. At this elevation due to the proximity of the bed to the water surface and outlet one would expect that any difference between the two methods might be highlighted. Whilst it can be seen on Plate 15 that a considerable area of base board remained exposed results would indicate (see Figure 21) that little additional sediment had been scoured out from the natural bed since the difference in trapping efficiency for the two tests was only some 6%.

Fine sand

All trapping efficiency tests using the fine sand were carried out using the natural material to simulate accreted bed levels. The results could therefore be less reliable due to the reasons described in the above paragraph

With the pot in its original condition and at a flow rate of 3l/s the trapping efficiency of the fine sand was found to be of the order of 36% at accreted sediment levels up to 300mm (Figure 5). Above this level efficiency was seen to reduce rapidly to virtually zero when the accreted bed reached the level of the outlet pipe. With the flow rate reduced to 1.5 l/s efficiency with retained sediment at outlet level (500mm) was seen to increase from almost zero to around 30%. Butler and Karunaratne (1994) [10] recorded trap efficiencies of just over 40% for a similar size of sand at the same flow rate (1.5l/s) and a significant variation of trapping efficiency with flow rate for a particular size of sediment.

With the pot modified by the addition of internal baffle 1 (see Figure 8) a second test (CF3) was carried out using the fine sand and a flow rate of 3l/s. In this case, with the pot in the empty condition trapping efficiency was around 35%. However, this rapidly decreased to zero with a bed level around 400mm. As described earlier this initial baffle encouraged the upward movement of sediment-laden flow towards the outlet resulting in a relatively poor performance. A second baffle arrangement (see Figure 9) was investigated with the pot containing sediment up to a level of almost 400mm. With this arrangement trapping efficiency (at a flow rate of 3l/s) was around 21% some 6% higher than the no – baffle situation and 20% better than baffle 2 at this retained sediment level, see Figure 5.

Medium sand

Some tests utilising the medium sand in the concrete pot were carried out using two methods as described in 3.2.3 above. Although it is considered that in one case results might be less reliable than the other; they have all been reported for completeness. In one case the accreted sand bed within the pot was simulated using a wooden board covered with a thin layer of sand and supported at the required bed level. In the second case a full bed of natural sand was used for each level. However, as described earlier, problems were encountered concerning the accurate assessment of material retained within the gully pot after each two hour run when a full natural bed was used. Therefore, for the purpose of analysis like will be compared with like. Tests carried out using a natural bed are compared as are the tests carried out with the simulated bed. This will remove any inaccuracies due to the comparison of different methods of testing.

With the concrete pot in its original condition and using the natural bed method of testing, trapping efficiency was seen to vary considerably in relation to accreted sediment level, see Figure 6. With an empty pot efficiency was almost 100% reducing to around 80% for retained sediment levels between 200 and 400mm. After 400mm efficiency was seen to fall to 20%. The addition of baffle 2 did not significantly improve efficiency.

With the pot in its original condition but using the board to simulate accreted sediment, trapping efficiency for bed levels between 0 and 400mm varied between 88% and 98% see Figure 7. However, as before, above 400mm the efficiency quickly dropped to around 30%. The addition of baffle 3 unfortunately lowered the efficiency in most cases. It was not possible to investigate the effect of bed levels above 300mm with type of baffle due to its location within the pot.

Having had no significant success improving the trapping efficiency of the concrete pot utilising several different types of internal baffle a modification was made to the square trapped outlet through the pot wall. In its original condition this outlet (formed automatically as part of the construction process) was considerably smaller in cross – sectional area than that of the external pipe. In order to maintain the same cross – sectional area for flow, this square section tube was enlarged and a small radius bellmouth entrance was formed to reduce turbulence at the entrance, see Plate 5. The effect of these modifications was to increase trapping efficiency throughout the range of accreted bed elevations to between 95 and 99%, see Figure 7. The most marked increase was at an accreted bed level of 500mm (a full pot) where the increase was over 70%. Thus, it was evident, that the increase in cross-sectional area and subsequent reduction in the velocity of flow through the outlet had a significant effect on trapping efficiency when the pot approached its full condition.

Comparison of medium and fine sand

In the above series of tests on the concrete pot a limited comparison can be drawn between the trapping efficiency of the standard concrete pot for two different sizes of sediment under the same conditions of water flow and sediment input rate. It can be see with reference to Figure 22 that for a water flowrate of 3l/s and a sediment input rate of 1.5gm/s the trapping efficiency of the medium sand was between 75 and 100% for retained sediment levels up to 400mm falling to almost 20% above this level. Using the fine sand, trapping efficiency was around 36% up to a retained sediment level of 300mm reducing to 15% at 400mm and virtually zero above this level.

Thus, for accreted sediment levels of up to 300mm, trapping efficiency of fine sand (d_{50} of 0.12mm) was some 40% less than that of a medium sand (d_{50} of 0.84mm). This is in general agreement with Butler and Karunaratne who recorded differences of up to 70% with material ranging in size from 0.068 to 0.23mm. at sediment bed heights ranging from 0 to 400mm.

4.3 Hydraulic efficiency of clay pot

Hydraulic efficiency tests were carried out on four different types of clay gully pot. Initially the standard design with trap was investigated. This was shown to have a through flow capacity of around 19 l/s before overtopping took place. The water level / discharge relationship had previously been found to be reasonably independent of accreted bed level with the concrete pot. In this case however, whilst at flows of less than 15 l/s the variation in water level for the 5 bed levels investigated was only around 20mm, between 15 and 17 l/s this increased to around 80mm, see Figure 13. It is not certain why in this case; the variation with bed level was so large although at the higher bed levels conditions within the pot were more turbulent and water level subject to significant vertical variation.

The second hydraulic efficiency test was carried out on the swirl design of pot with trapped outlet. In this case through flow capacity was around 15 l/s and the variation in water level within the pot for various simulated bed levels at a particular flow was only of the order of 10 to 20mm, see Figure 16.

When the swirl design of pot was modified in order to try to improve its trapping ability the hydraulic efficiency test was repeated. With the modified outlet, as described earlier, through flow capacity was further reduced to around 14 l/s. The variation of water level within the pot at various bed levels for a particular flow rate was only of the order of 15 to 20mm, see Figure 17. Since the modified outlet to the swirl design of pot had reduced the flow area by some 12% and also removed the streamlined entrance, the loss of flow capacity was to be expected.

The final hydraulic efficiency test was carried out on the long path outlet design. This design of pot had a through flow capacity of around 15 l/s, see Figure 20. The variation of water level within the pot at various bed levels for a constant flowrate was again only some 15 to 20mm. The 3 l/s reduction in the maximum flow rate compared with the standard design of clay pot was almost certainly due to the increased losses through the outlet system.

4.4 Trapping efficiency of clay pot

During the course of the study in addition to the standard clay pot two alternative designs were evolved, aimed at improving trapping efficiency. These were the swirl type pot with flow entering tangentially and the long path outlet pot with normal top entry but an extended path outlet. In addition to tests on these three designs, the swirl pot was tested with a number of internal baffles to try to improve its performance. All tests were carried out with the medium sand and a board to simulate the accreted sediment levels. Thus, a direct comparison of results can be made throughout.

The test on the standard design of clay gully pot empty and with a depth of accreted sediment of 400mm achieved trapping efficiencies of 93 and 94% respectively, see Figure 14. In order to try to improve this and also investigate a type of pot suitable for side entry, the swirl design was evolved. This was based around an idea originating many years ago and well before trapping efficiency became a major concern. Tests on the basic design of this pot unfortunately produced trapping efficiencies of only between 63 and 77% depending on the retained sediment depth. To try to improve this, a small modification was made to the outlet configuration replacing the streamlined entrance with one having a square corner. However, the improvement expected with this configuration was more than counterbalanced by the subsequent slight reduction in cross – sectional area of the outlet as a result of this modification. When tested with the pot empty the efficiency was found to be only 50% as shown on Figure 14.

In a further effort to increase efficiency, the modified swirl type pot was tested using two alternative types of internal baffle. Unfortunately, neither of these modifications significantly improved the trapping efficiency, an increase of only around 10% being obtained (Figure 14, tests CLM4 and CLM5). It became obvious that the swirl type pot with or without modification would not achieve trapping efficiencies better than the standard design. However, if side entry is seen as a benefit in a particular situation this study has provided some data on the performance of a pot with this configuration.

Following further discussion between the manufacturer and HR, a final design of pot evolved, which utilised a long path outlet. This design of outlet incorporated a trap attached to the outside of the pot that remained sealed when the pot was emptied thus preventing the need to re-fill the pot with water following the cleaning process. In this type of pot the position of the outlet was such that there was an additional 65% of volume available for sediment before it became inundated and trapping efficiency subsequently significantly reduced. Trapping efficiency of this design was consistently high at around 94% over the range of accreted sediment levels tested (0 to 400mm). Results were similar to the standard design of pot (Figure 14, test CLM6) but of course the long path outlet pot had the advantage of additional sediment capacity and the independent trap.

5. CONCLUSIONS

The general conclusions to be drawn from the study are as follows:

1. At present there is no UK legislation on the use or discharge from gully pots
2. Present legislation does not define maintenance standards for gully pots
3. The only water quality criteria presently applicable to gully pots are those associated with contamination of receiving waters.
4. Information regarding the design of gully pots is presently limited to that given in BS5911 i.e. of adequate size depending on use of the area, the type of surface and the frequency of cleaning.
5. Through flow capacity (hydraulic efficiency) of the standard designs of gully pot used in these experiments varied between 11 and 19l/s.
6. For a particular design of gully pot hydraulic efficiency was almost without exception found to be independent of accreted sediment level.
7. The standard design of concrete gully pot has a trapping efficiency for a medium sediment (D_{50} of 0.8mm) of between 95 and 99% at retained sediment levels up to 400mm. The trapping efficiency drops to about 25% at a retained sediment level of 500mm, the maximum level before blockage of the outlet begins to occur.
8. Limited testing with a fine sediment (d_{50} of 0.12mm) has indicated that trapping efficiency is very dependent on sediment size and is around 40% in this case. The trapping efficiency is also affected by flow rate.
9. Increasing the area of the trapped outlet of a concrete pot to that of the receiving pipe was found to increase trapping efficiency. For a high accreted sediment level of 500mm the trapping efficiency increased from about 30% to over 90%.
10. The long path outlet pot was found to be as efficient at trapping sediment as the standard design. It also has the following benefits :
    - greater volume for sediment retention
    - no requirement to refill after cleaning
11. Various designs of internal baffle reduced the trapping efficiency. In addition, the swirl design used for the clay gully pot also reduced trapping efficiency. However, whilst generally not recommended the swirl type pot with its side entry via a gully chute can be advantageous in some applications.

6. RECOMMENDATIONS

The following modifications to gully pot designs should be investigated further:

1. Increasing the area of the trapped outlet (concrete pot only). This was shown to increase trapping efficiency at high sediment levels. Clearly the pot must be cleaned before the maximum sediment level is reached or once the pot is full; sediment will pass through into the drainage system.

2. Introduction of the long path outlet. Not only is this as efficient as the standard design, but it also has a higher sediment capacity and has no requirement to refill after cleaning. This would lead to a significant reduction in maintenance requirements. It will also reduce pollution resulting from the current practice of refilling gully pots with black water.

Consideration should also be given to the introduction of legislation on the use or discharge from gully pots and the definition of maintenance standards.

7. REFERENCES

1 Osborne M, Butler D, Clark P, Memon F, 1997, Management of gully pots for improved run off quality. Ciria . Funders Report/IP/23

2 Environment Agency, Pollution Prevention Guidelines, The Use and Design of Oil Separators in Surface Water Drainage Systems PPG3 1994

3 Marshall Committee, Report of the Committee on Highway Maintenance, HMSO, London, 1970

4 Local Authority Associations. Highway Maintenance. A Code of Good Practice, Association of County Councils, London 1989

5 Department of Transport, Code of Practice for Routine Maintenance: Motorways and all purpose trunk roads. HMSO, London 1985

6 Larger J A, Smith W G, and Tchobanoglous G, Catchbasin technology overview and assessment, USEPA Report 600/2-77-051, 1977

7 Fletcher I J, Pratt C J, and Elliot G E P, An assessment of the importance of roadside gully pots in determining the quality of stormwater. In Proceedings of the first international conference on urban storm drainage Southampton, England pp. 586-602, 1978

8 Fletcher I J and Pratt C J, mathematical simulation of pollution contributions to urban runoff from Roadside gully pots. In Proceedings of the second international conference on urban storm drainage Urbana, Illinois, USA 1981

9 Pratt C J and Adams JRW, Sediment supply and transmission via roadside gully pots, Sci. Total Environ. Vol 33 pp. 213-224 1984

10 Grottker M, Pollutant removal by gully pots in different catchment areas. Sci. Total Environ. Vol 90 pp. 515-522 1990a

Grottker M, Pollutant removal by catchbasins in West Germany. State of the art-new design Proc. ASCE. Eng. Found. Conf. Urban Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology, Davos, Switzerland, pp 215-244 1990b

11 Butler D, and Karunaratne S H P G, The suspended solids trap efficiency of the roadside gully Pot, Water Research Vol 29, No.2, pp 719-729 1995

12 Karunaratne S H P G, The influence of gully pot performance on the entry of runoff sediment into sewers, Unpublished Ph.D. thesis, South Bank University, London, 1992

13 Hall, M J and Ellis, J B, Water quality problems of urban areas, Geojournal, 11,3, pp. 265-275, 1995

Figures

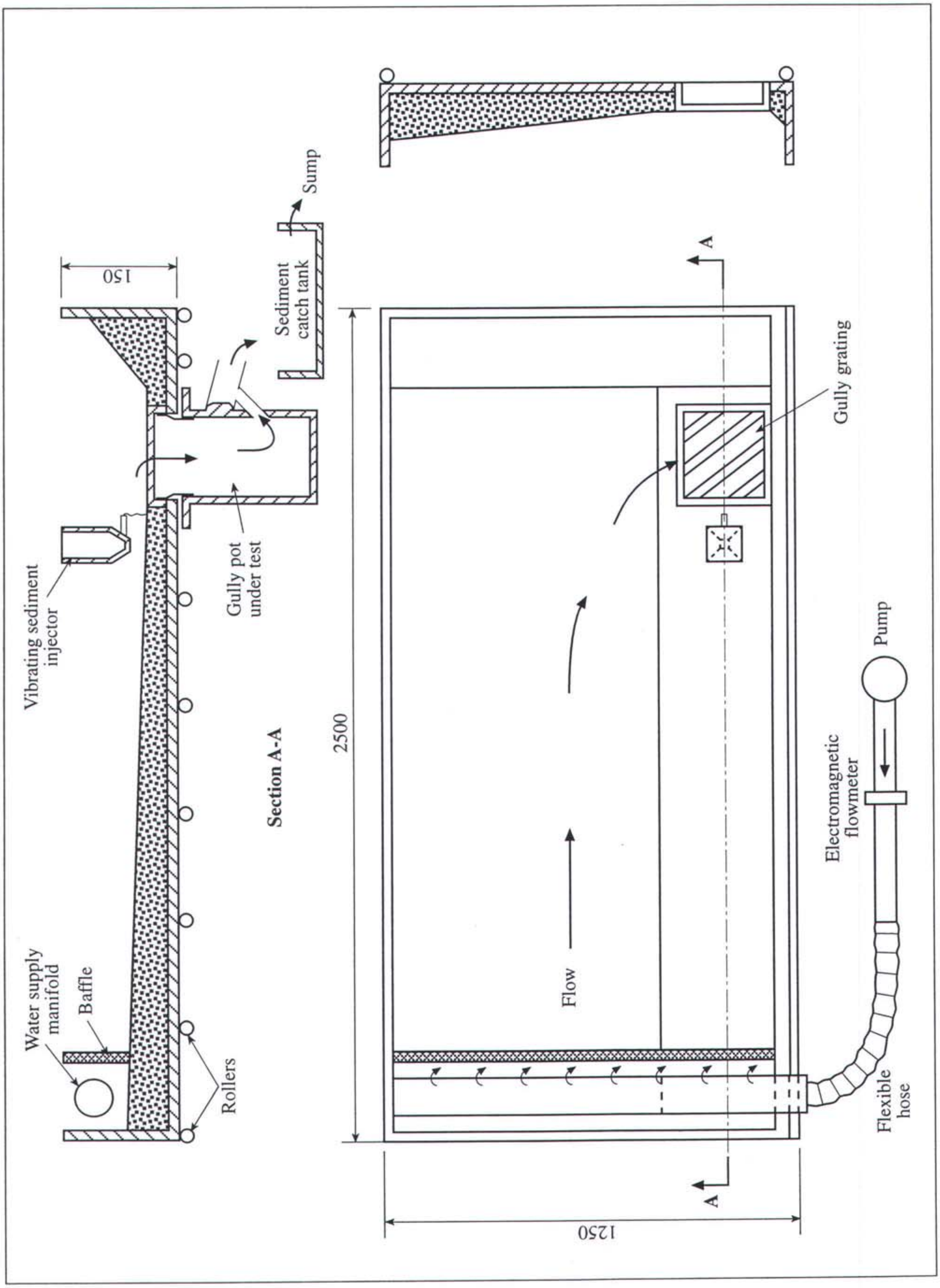


Figure 1 Schematic layout of gully pot test rig

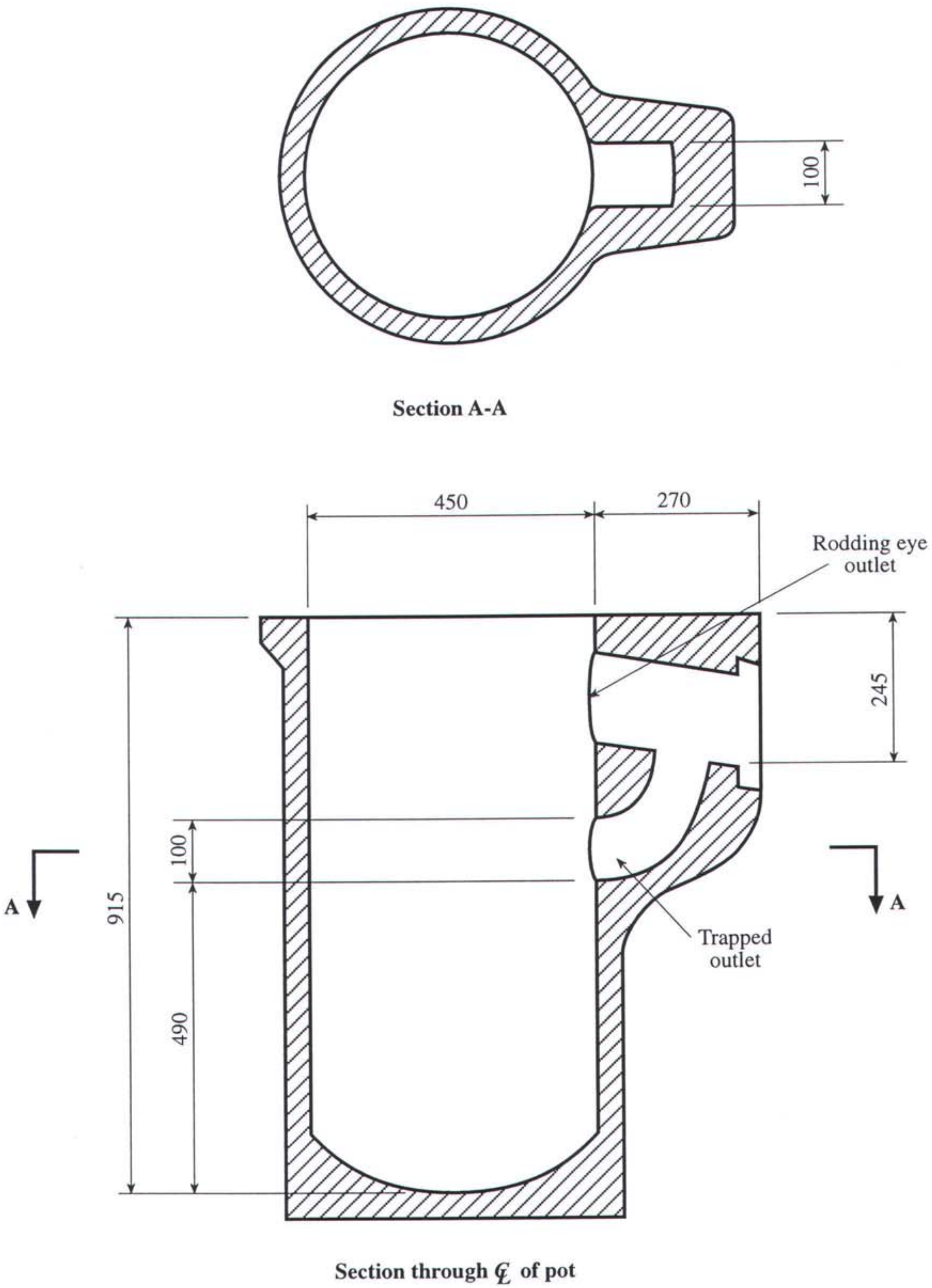


Figure 2 Concrete gully pot

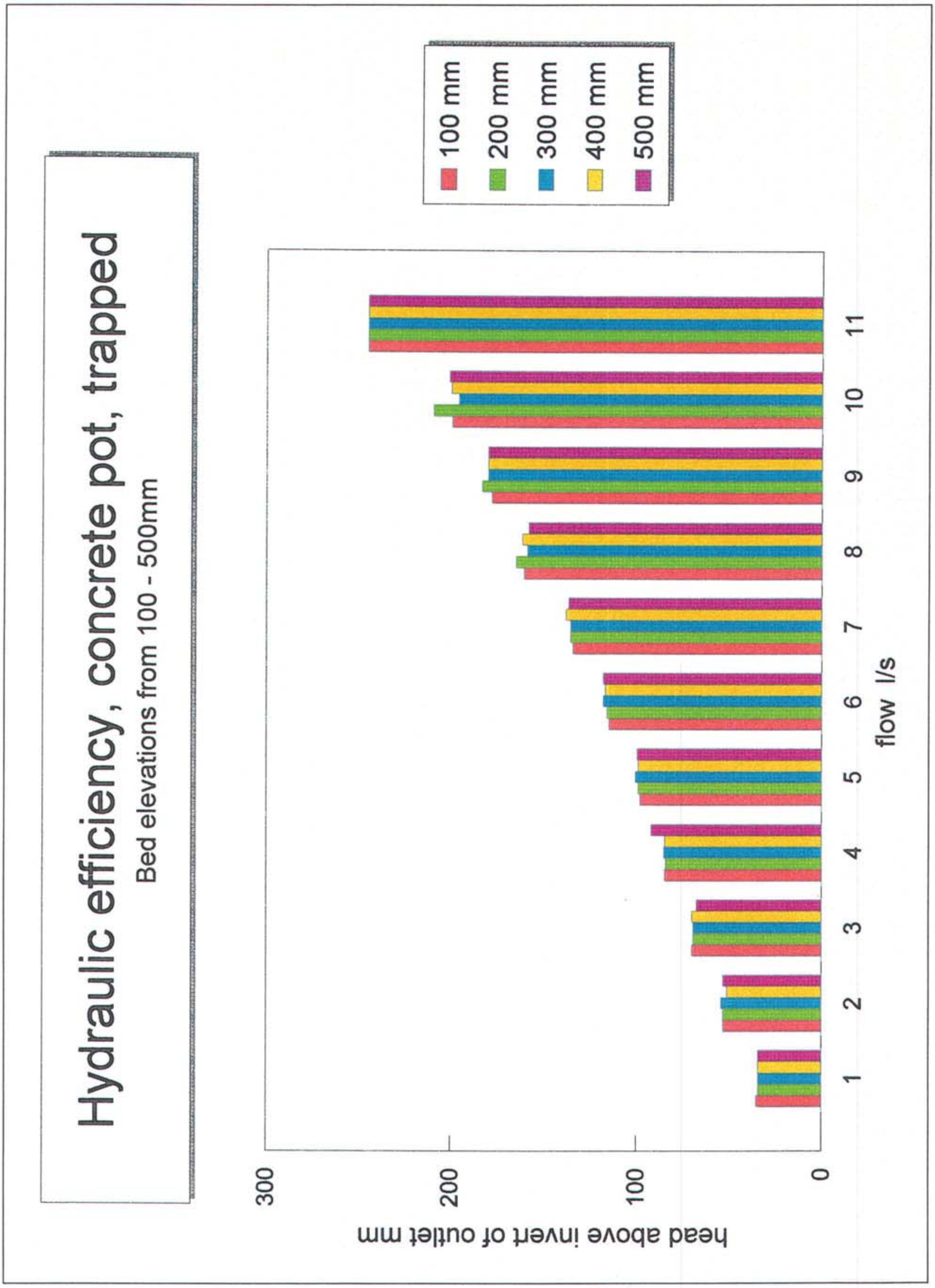


Figure 3 Hydraulic efficiency, concrete pot, trapped

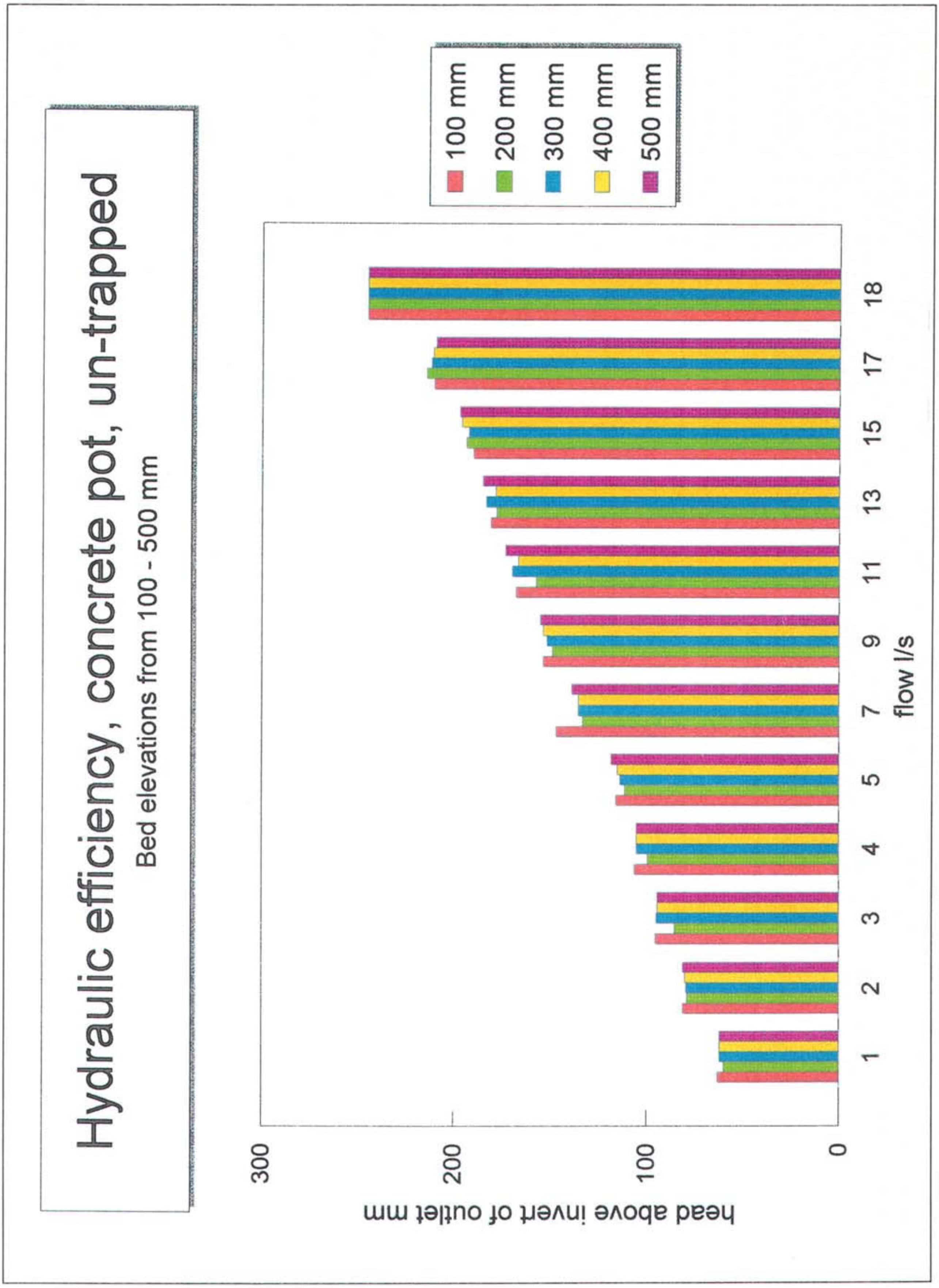


Figure 4 Hydraulic efficiency, concrete pot, un-trapped

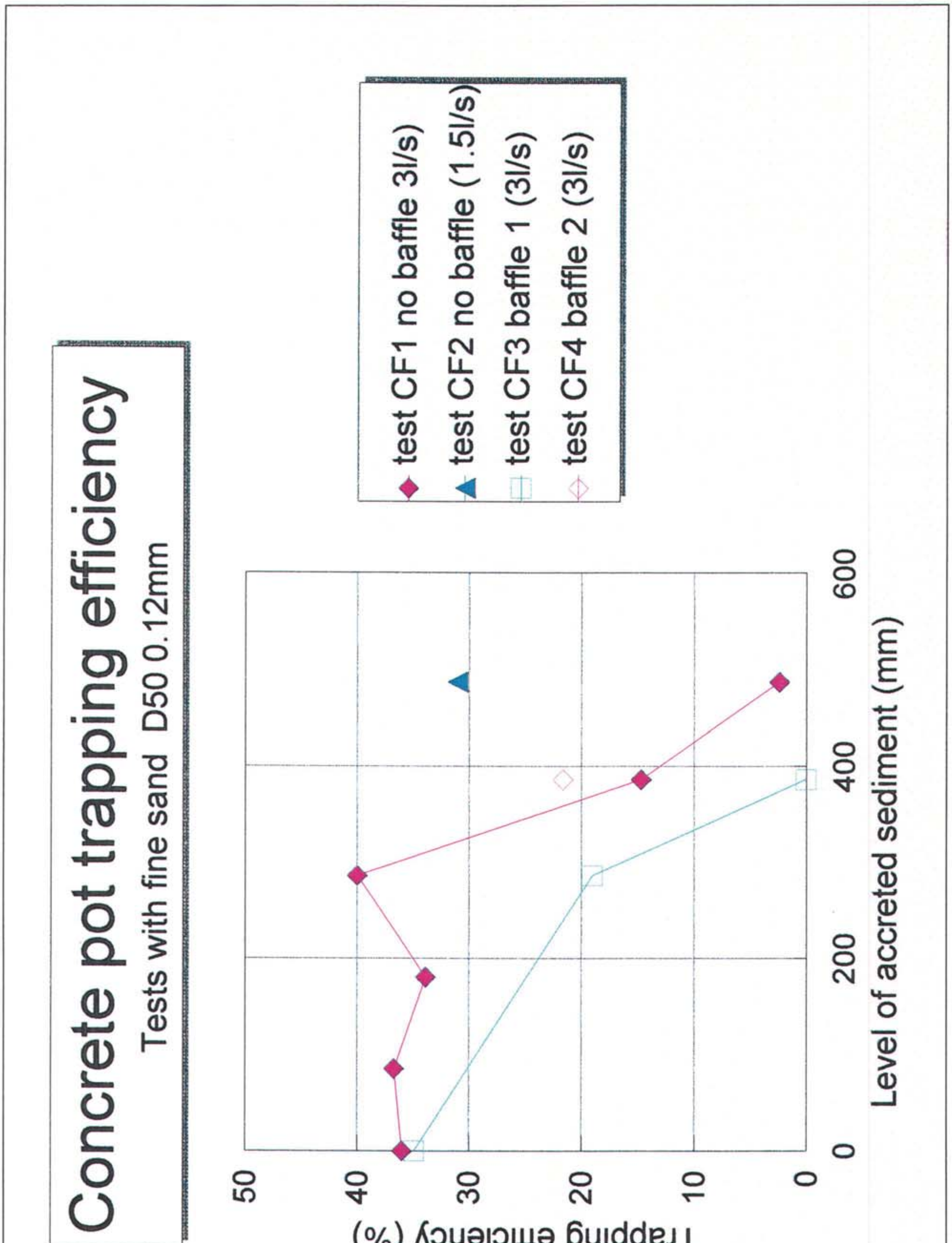


Figure 5 **Concrete pot, trapping efficiency. Tests with fine sand, d_{50} 0.12mm, (natural bed)**

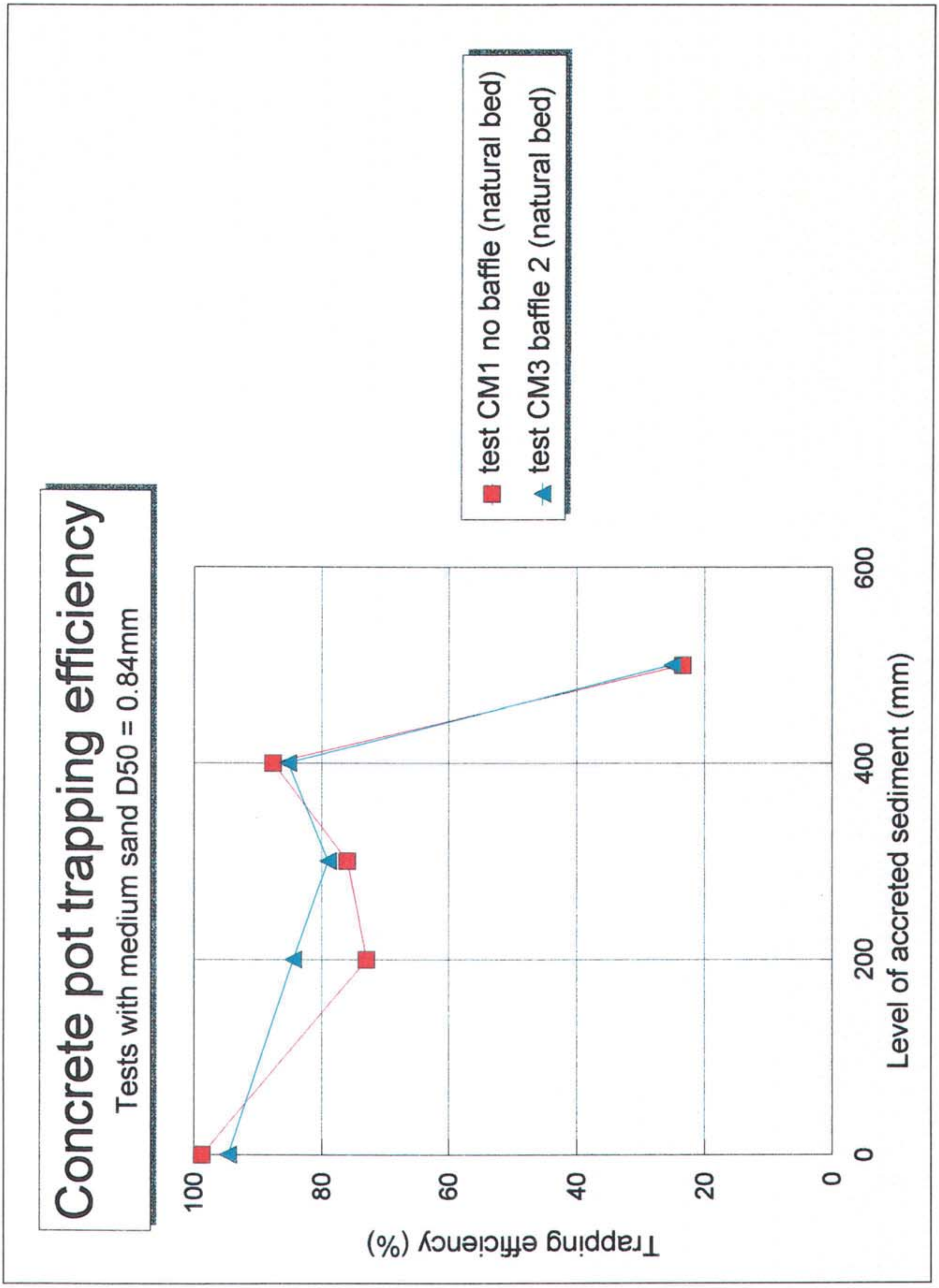


Figure 6 Concrete pot, trapping efficiency. Tests with medium sand d_{50} 0.84mm, (natural bed)

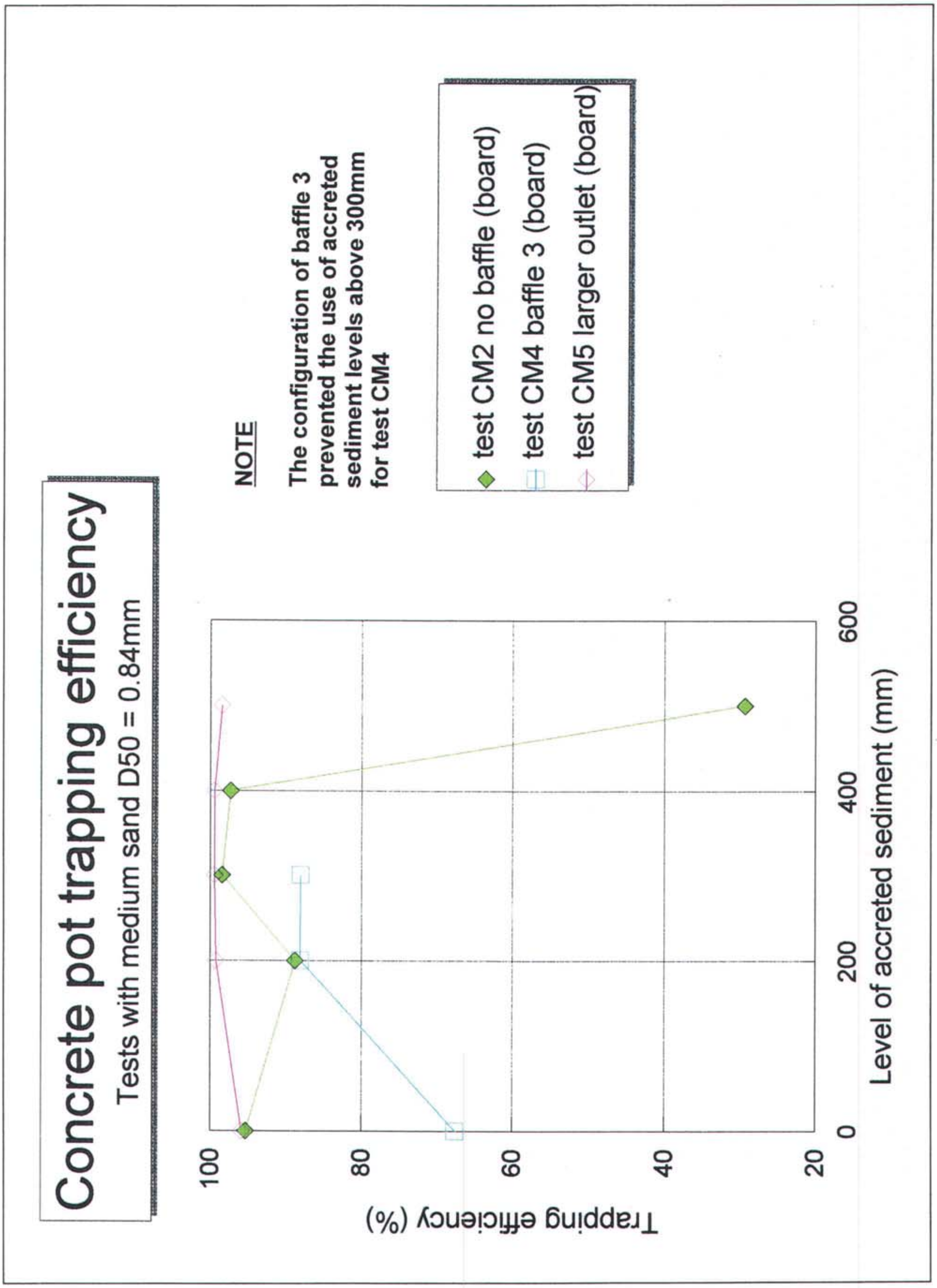


Figure 7 Concrete pot, trapping efficiency. Tests with medium sand d_{50} 0.84, (board)

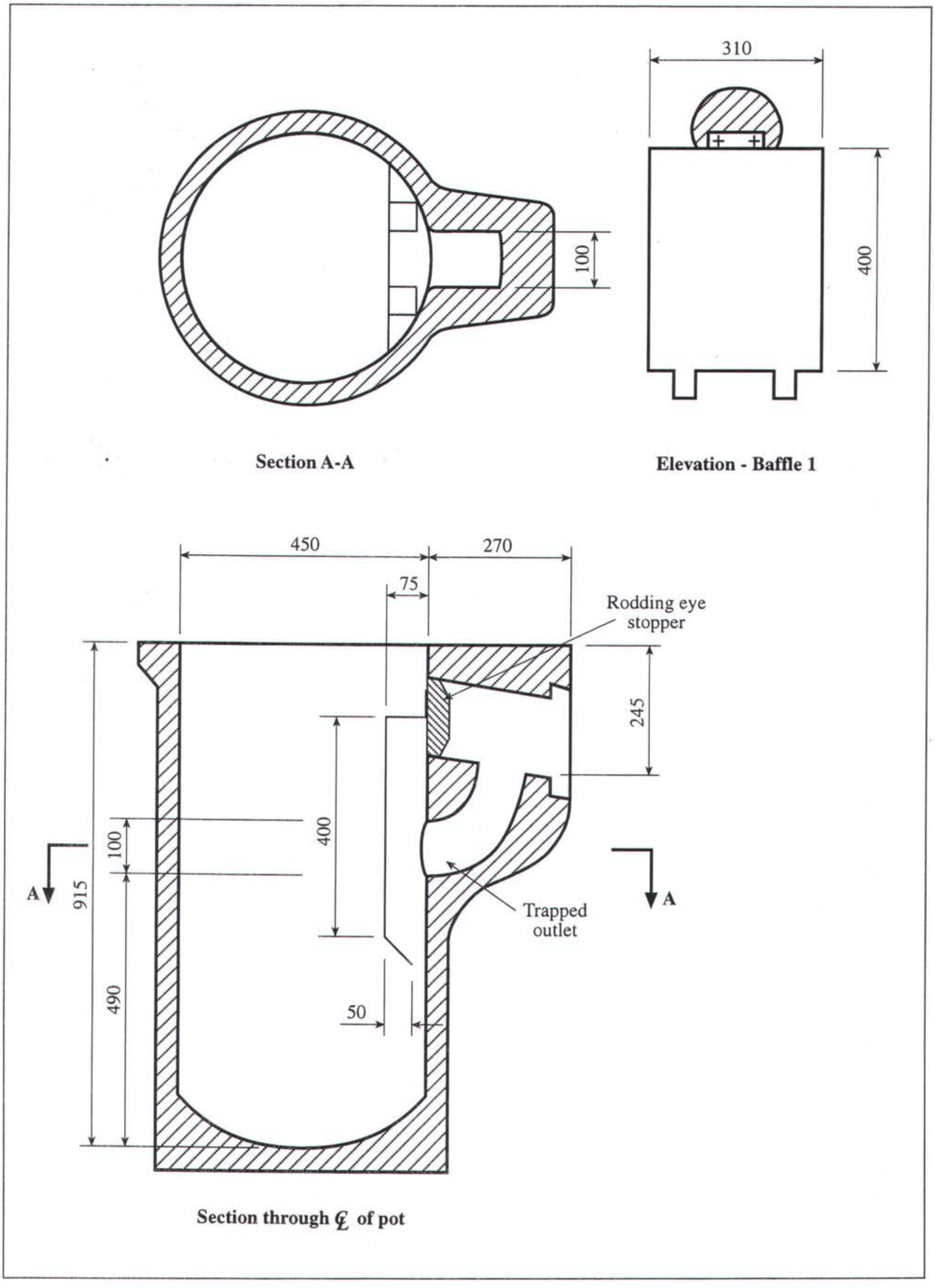


Figure 8 Concrete gully pot with baffle 1

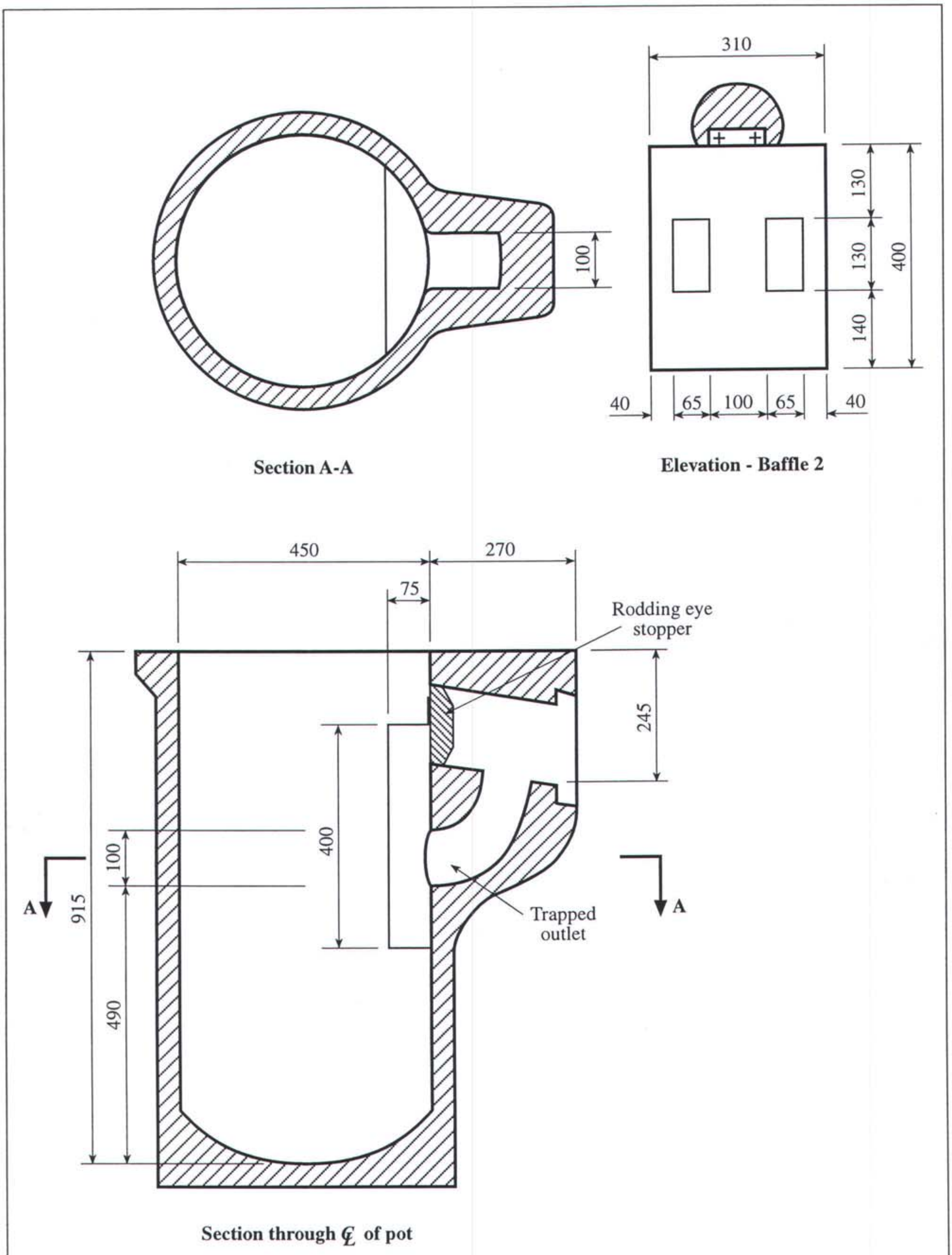


Figure 9 Concrete gully pot with baffle 2

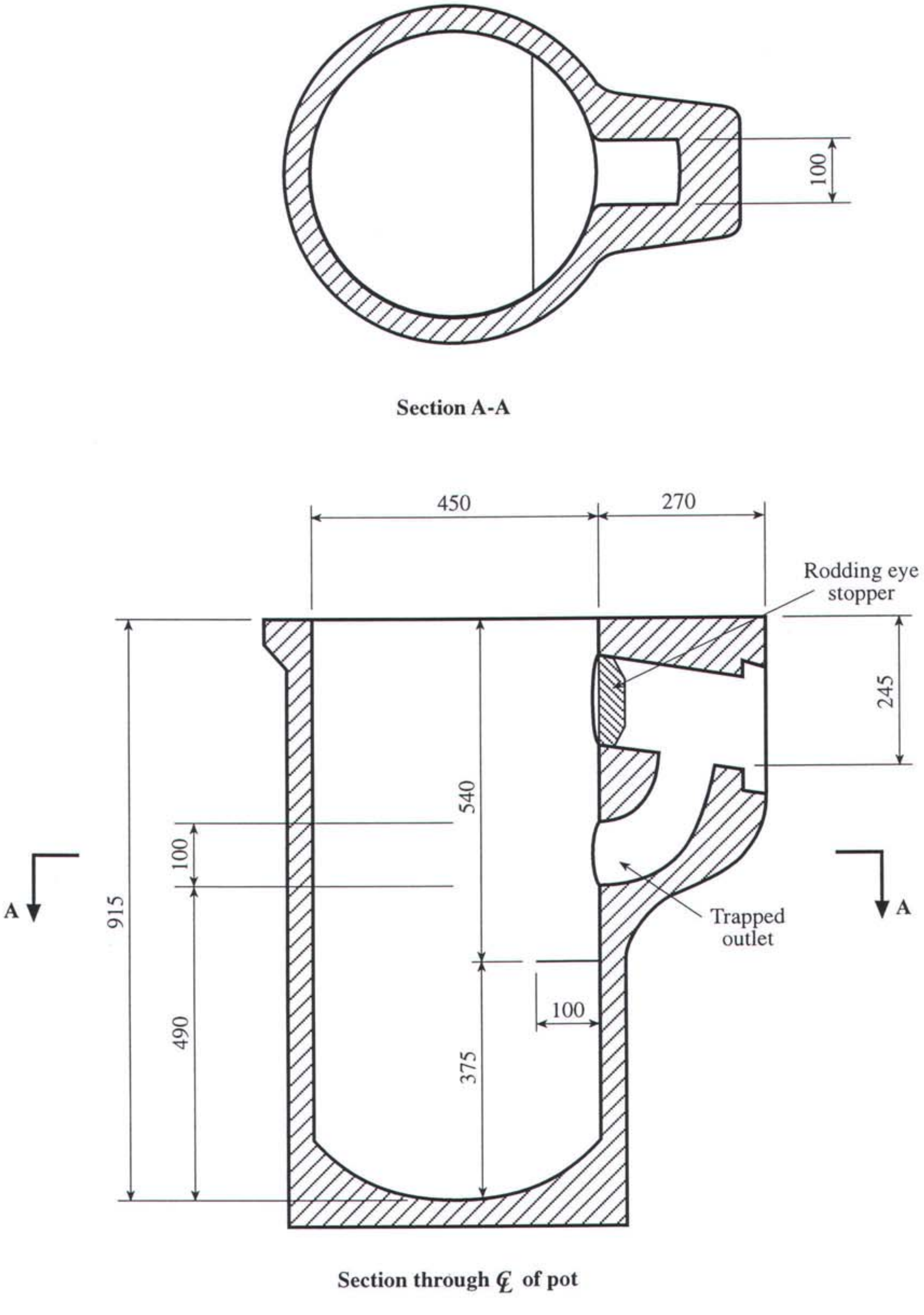


Figure 10 Concrete gully pot with baffle 3

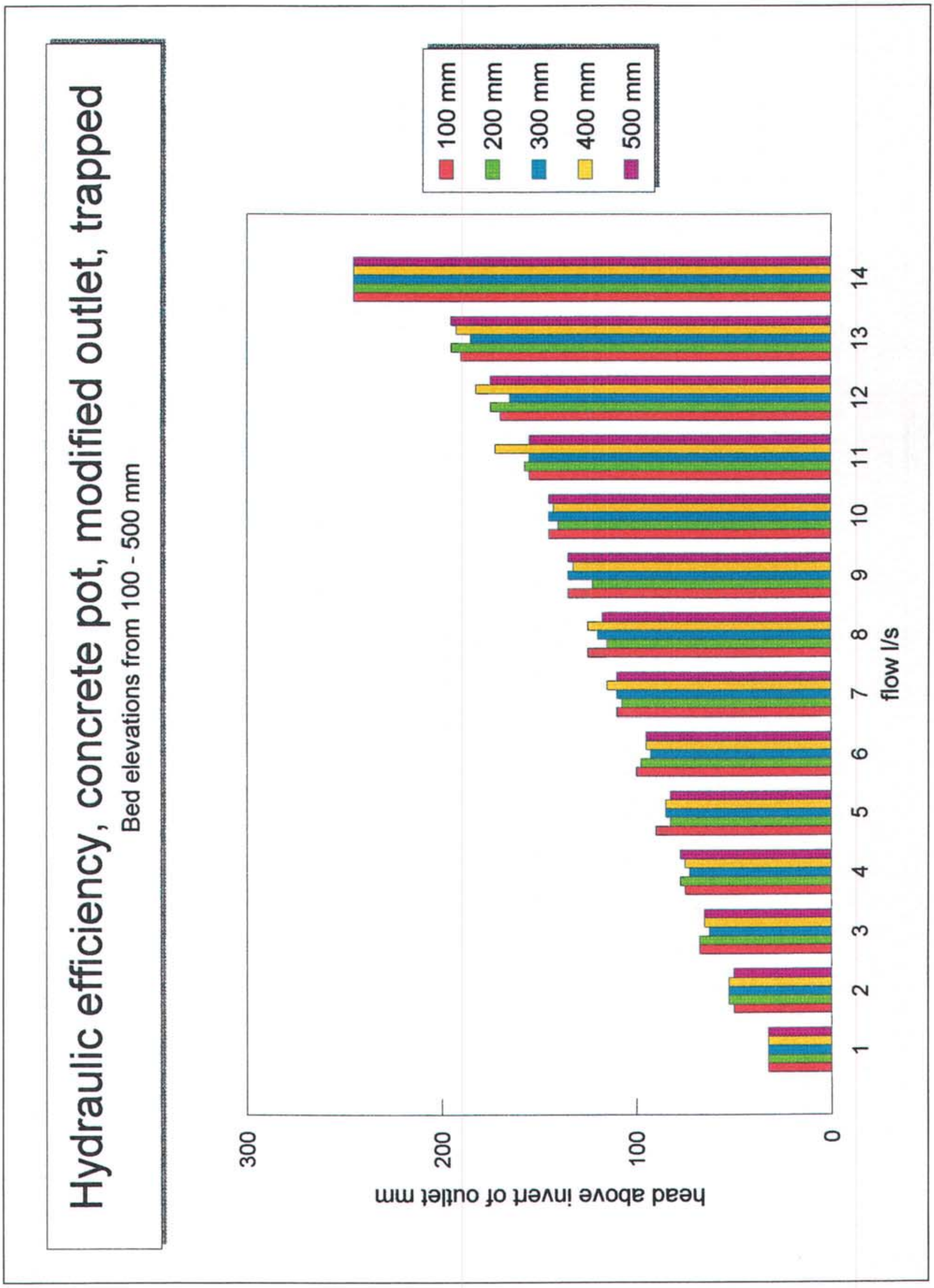


Figure 11 Hydraulic efficiency, concrete pot, modified outlet, trapped

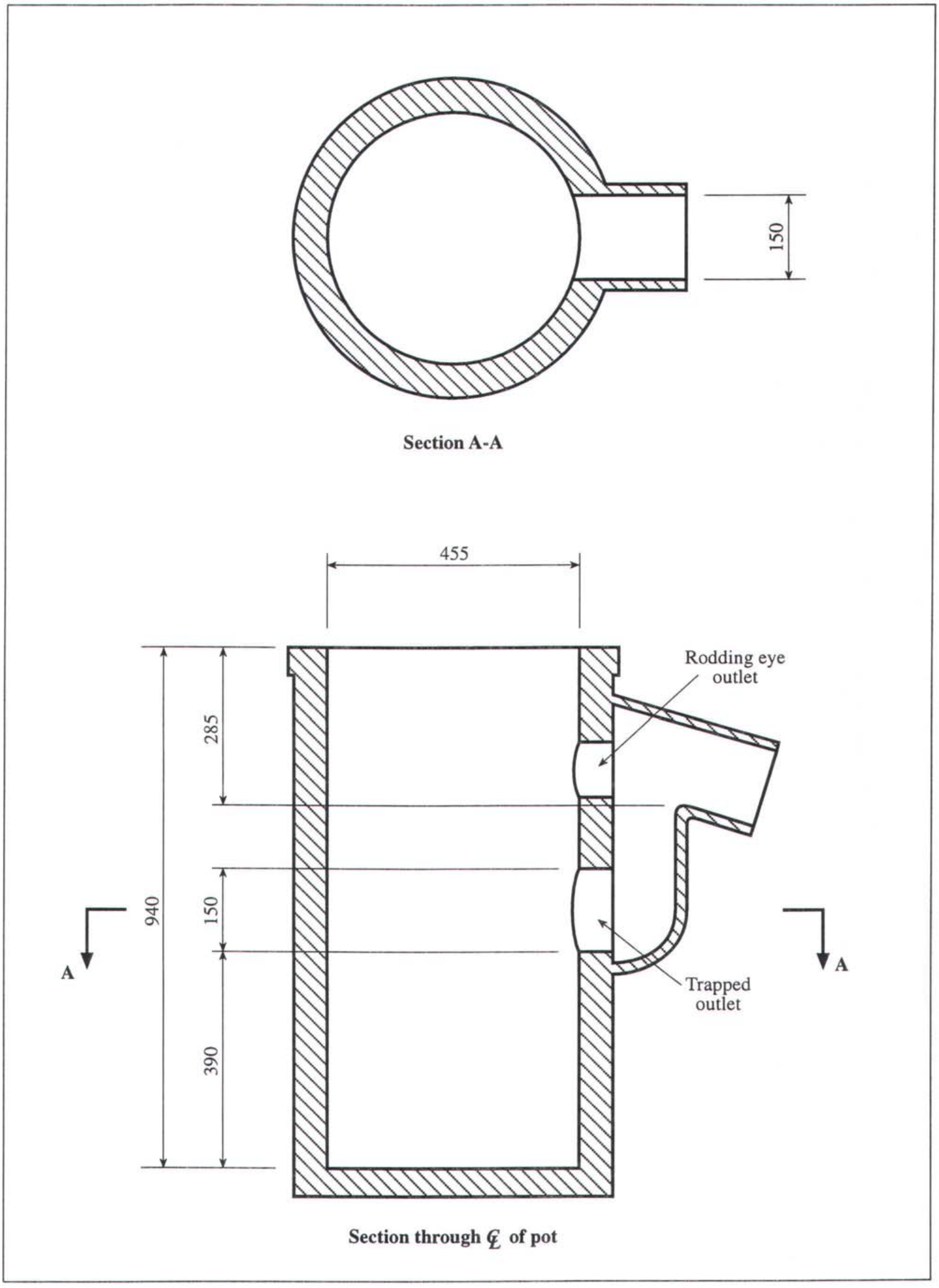


Figure 12 Clay gully pot

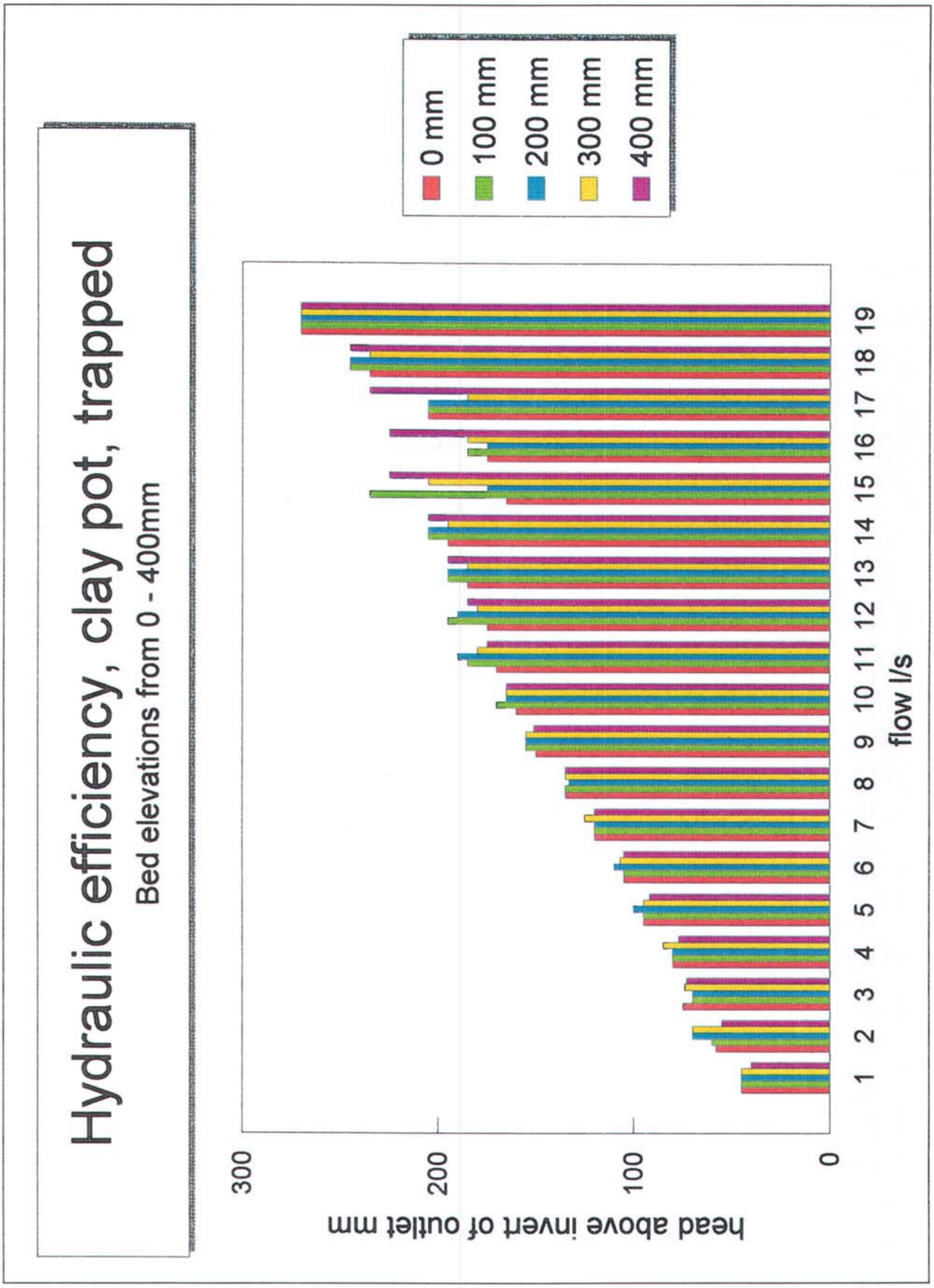


Figure 13 Hydraulic efficiency, clay pot, trapped

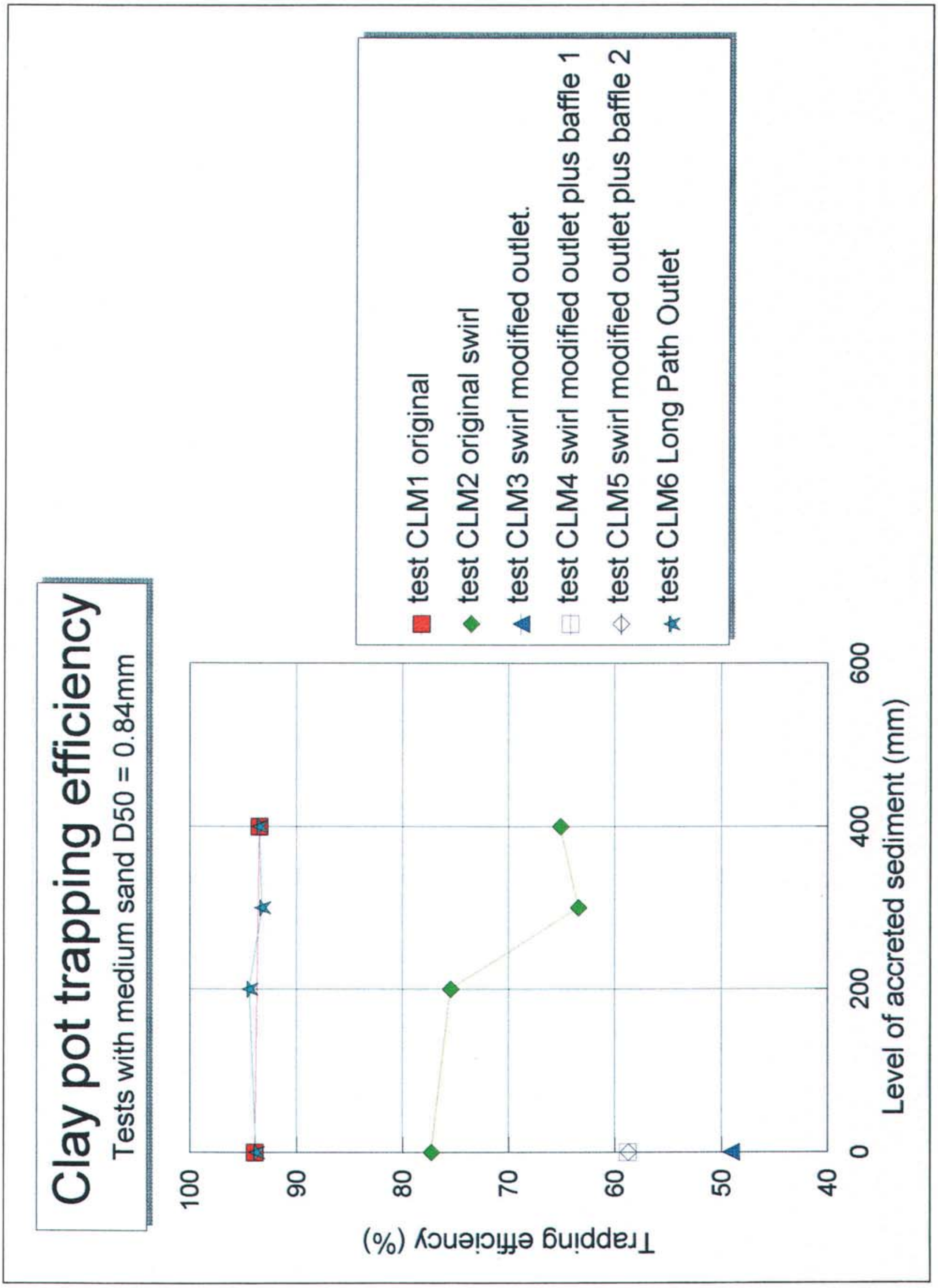
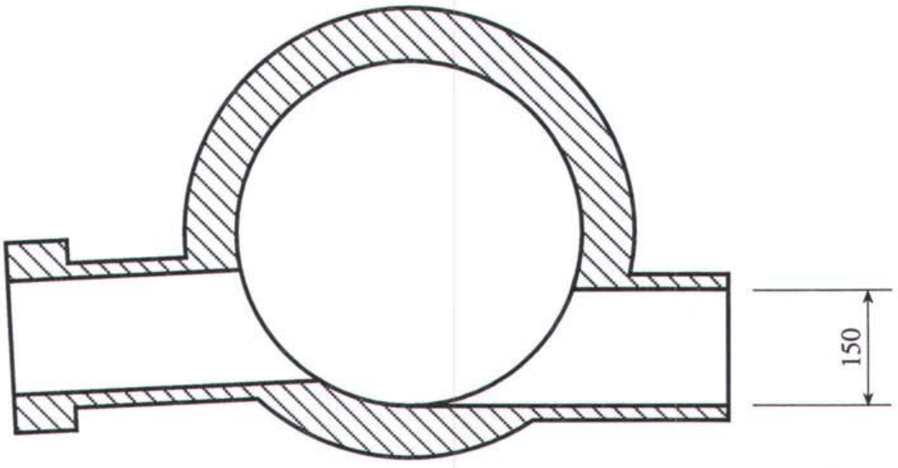
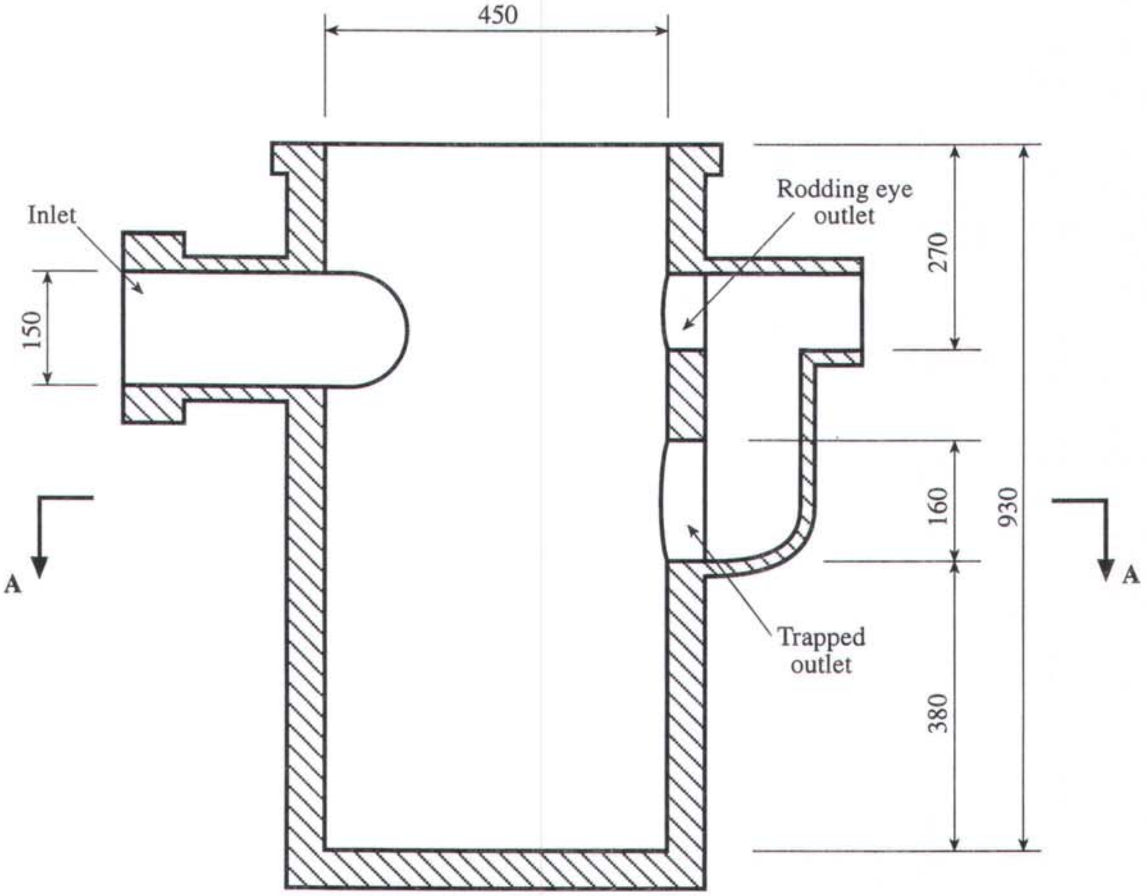


Figure 14 Clay pot trapping efficiency



Section A-A



Section through ℄ of pot

Figure 15 Clay gully pot swirl design

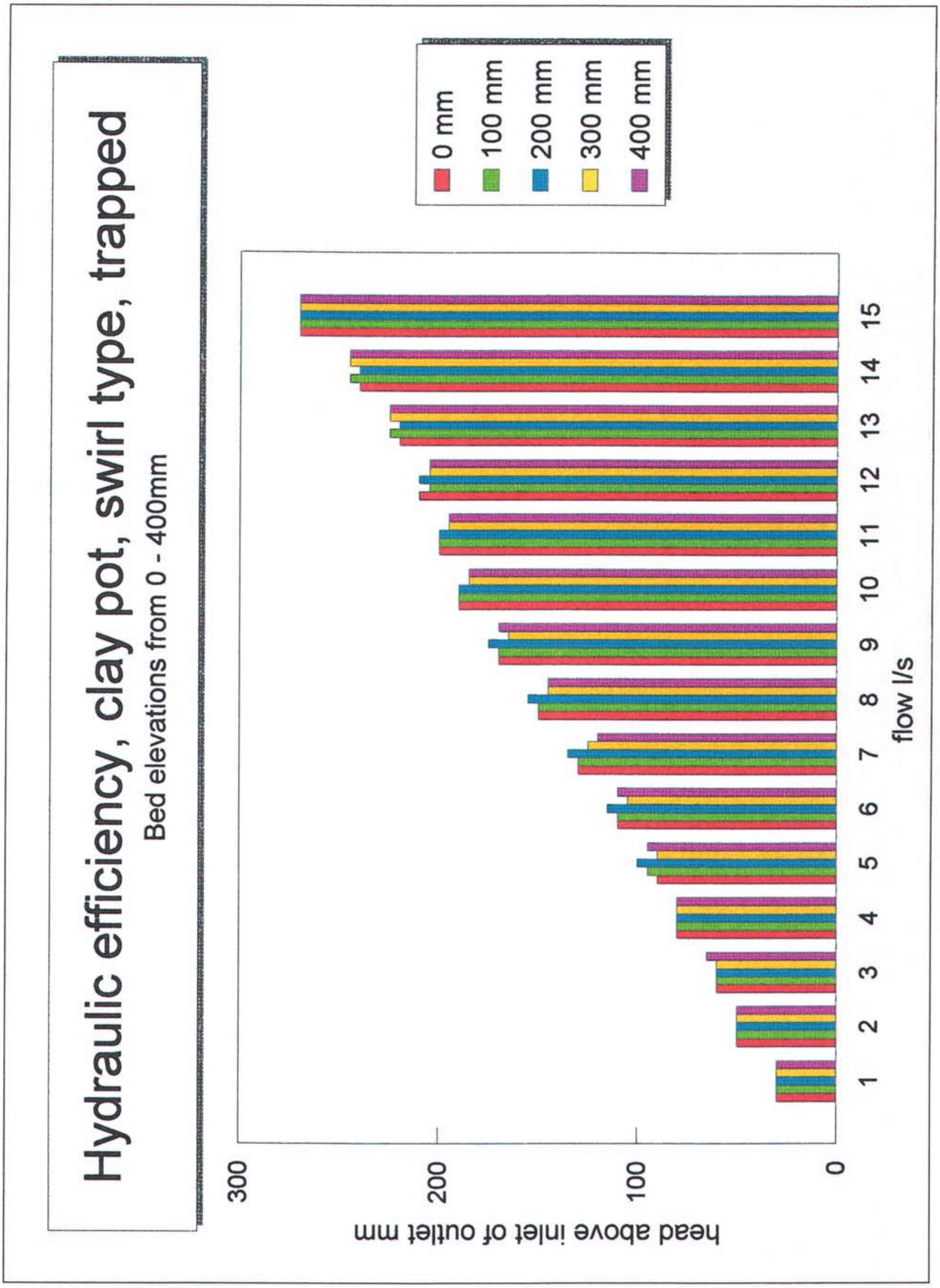


Figure 16 Hydraulic efficiency, clay pot, swirl type, trapped

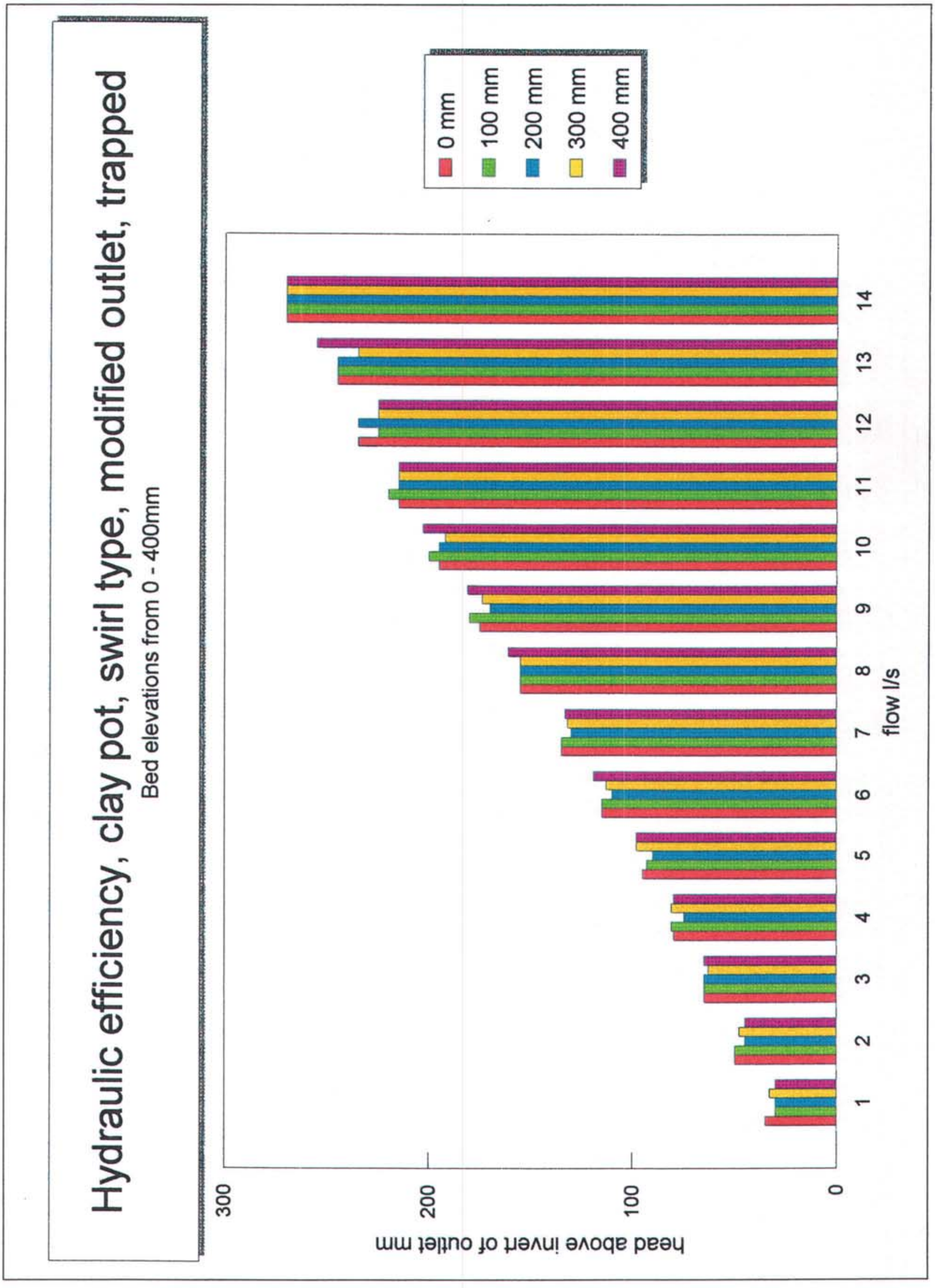


Figure 17 Hydraulic efficiency, clay pot, swirl type, modified outlet, trapped

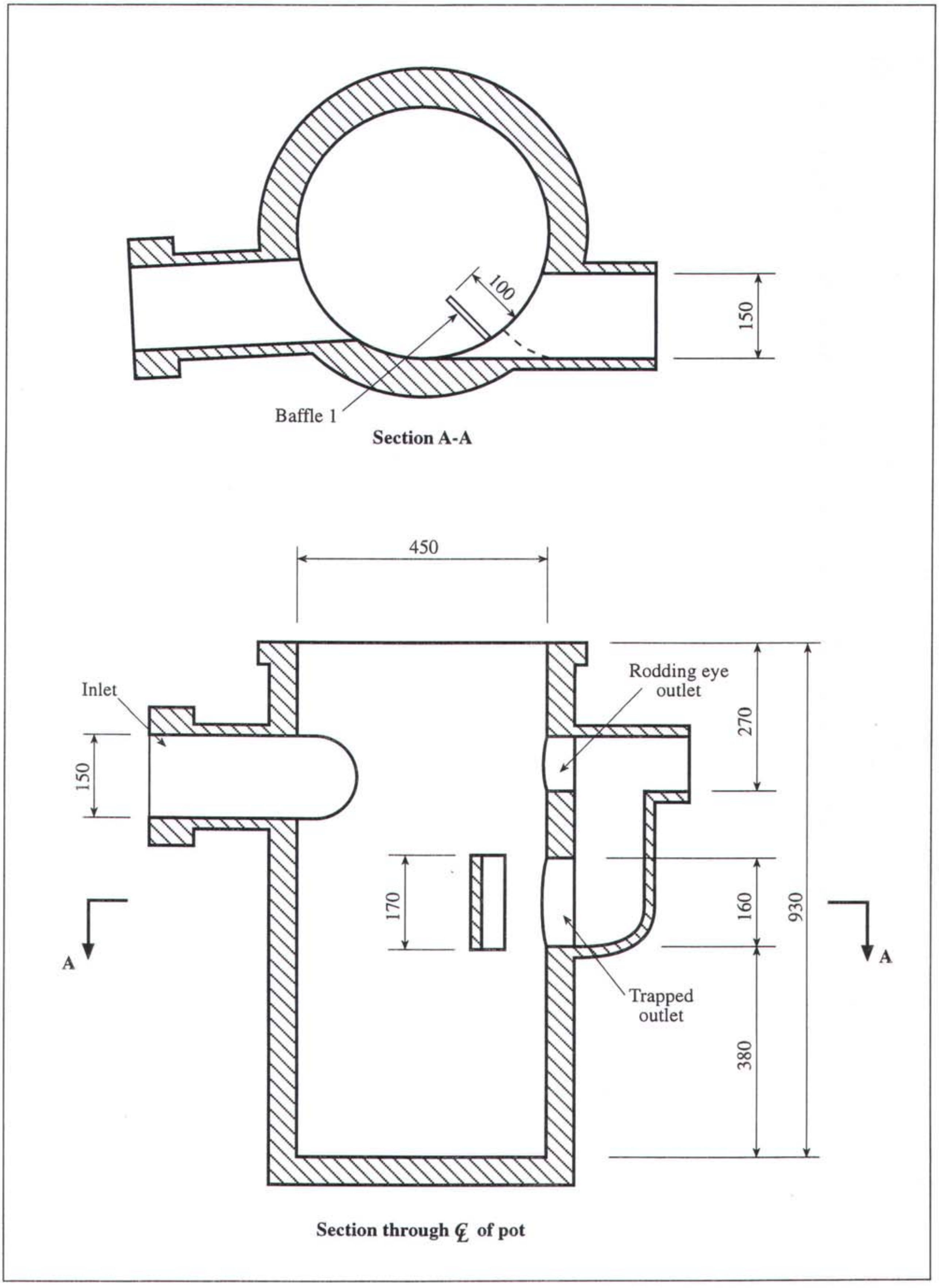


Figure 18 Clay gully pot swirl design with baffle 1

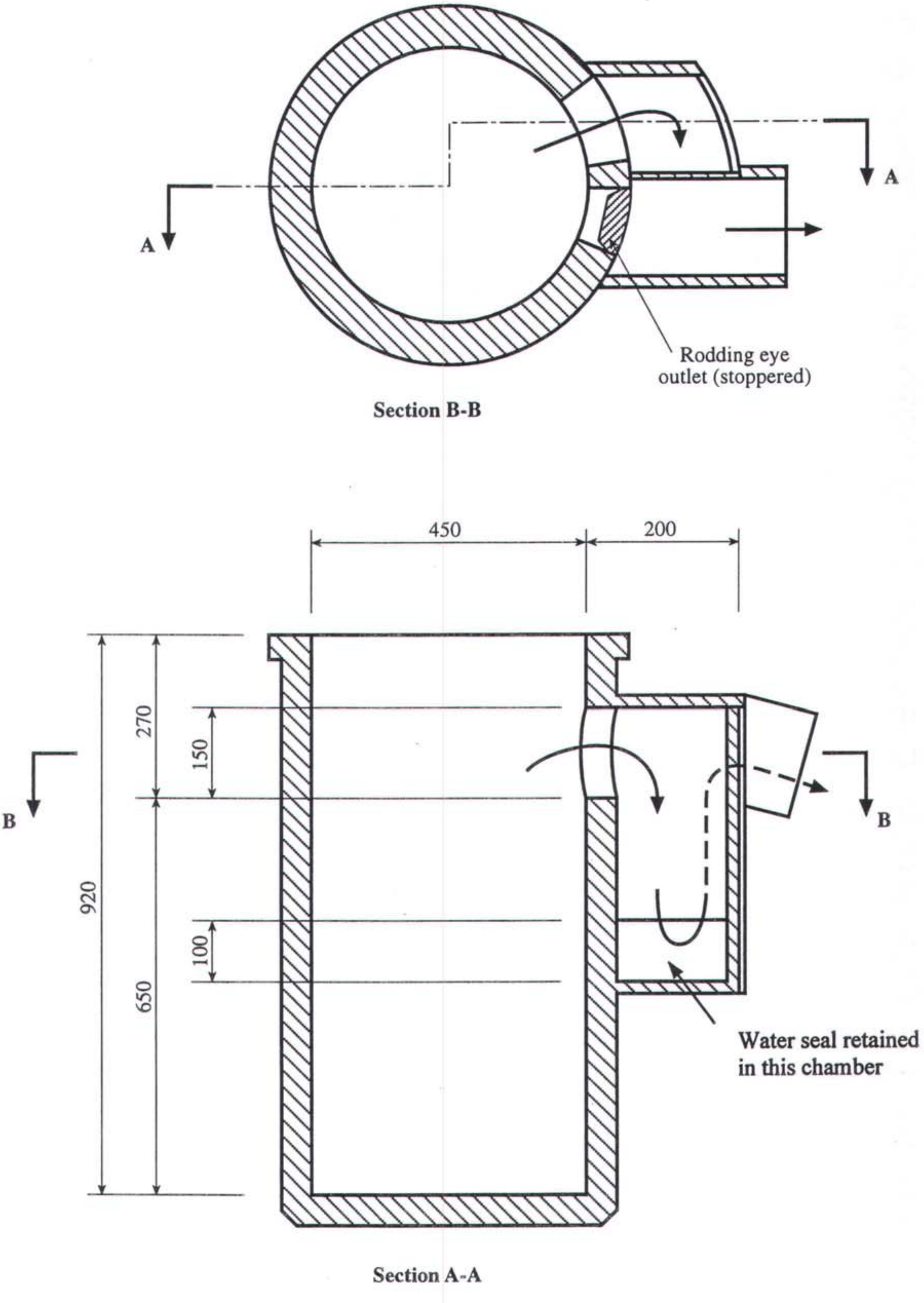


Figure 19 Clay gully pot long path outlet

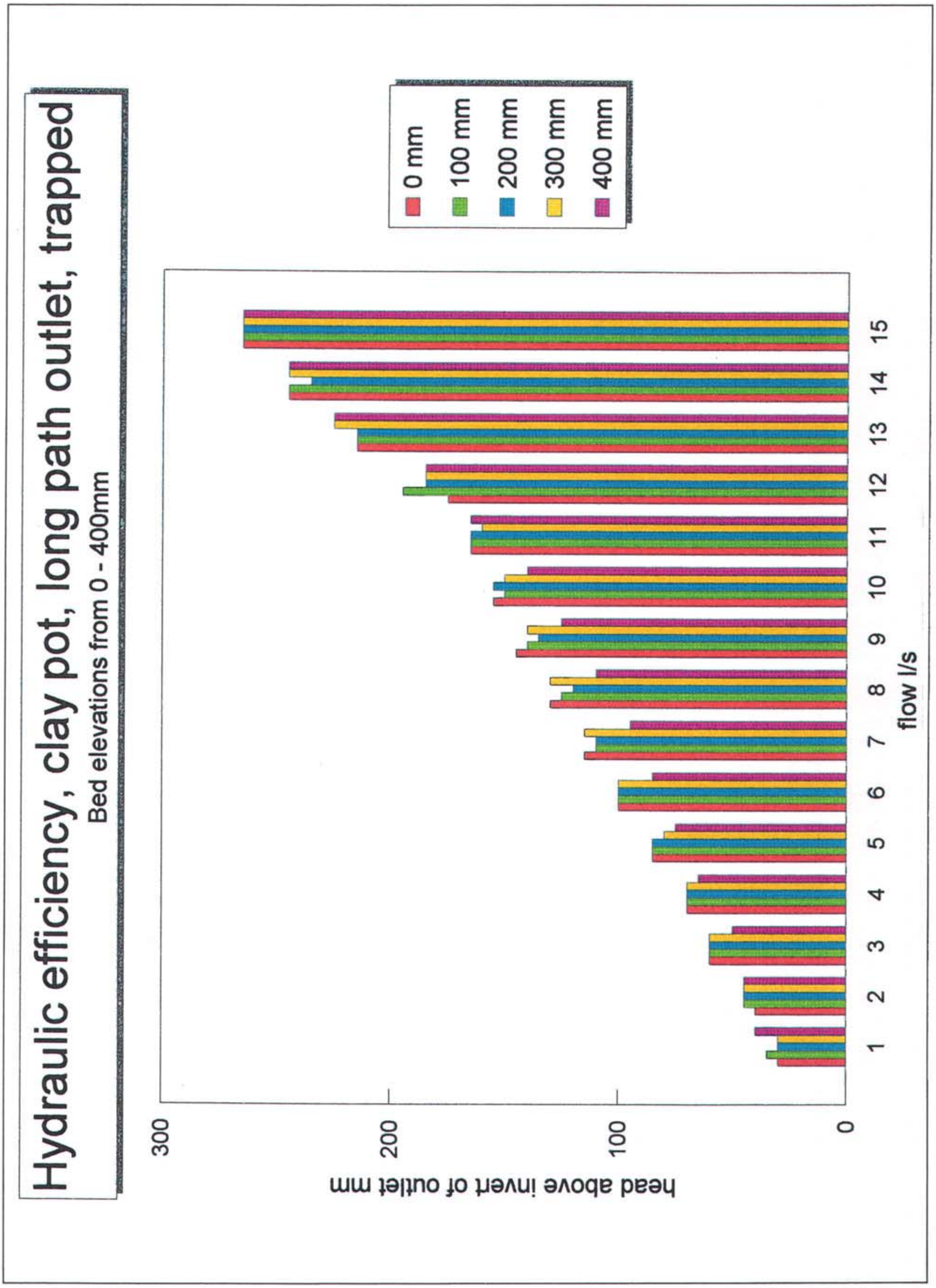


Figure 20 Hydraulic efficiency, clay pot, long path outlet, trapped

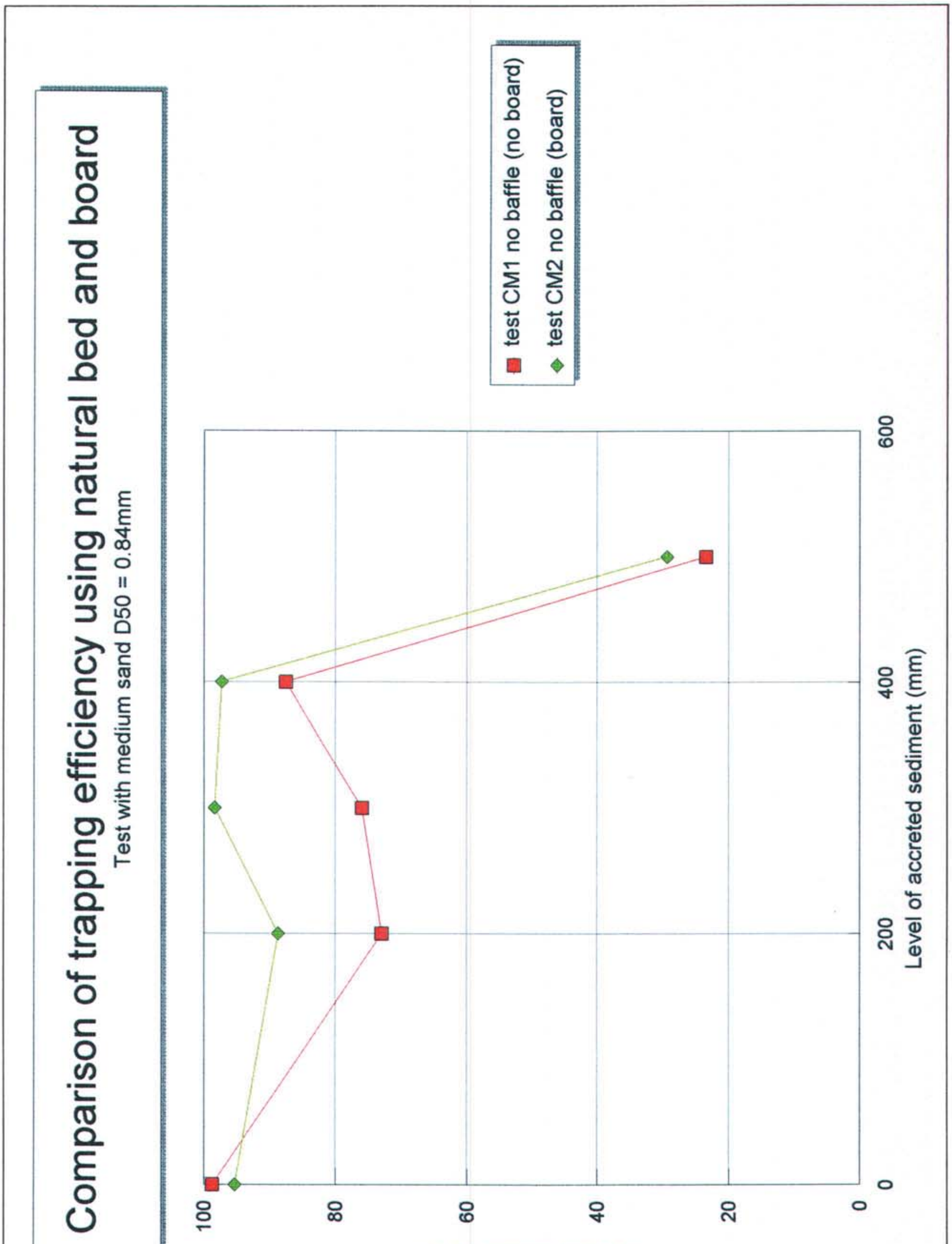


Figure 21 Comparison of trapping efficiency using natural bed and board

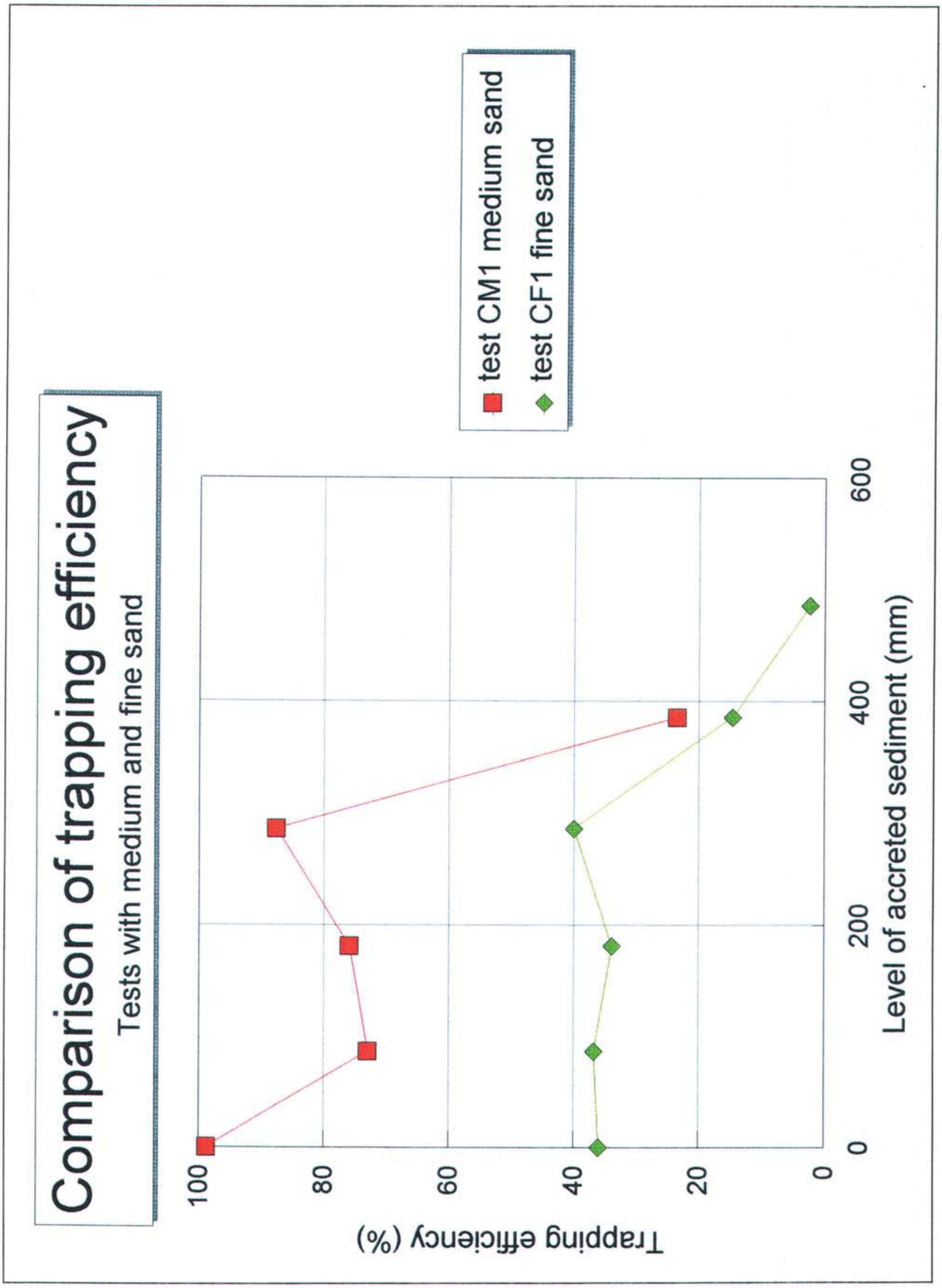


Figure 22 Comparison of trapping efficiency using medium and fine sand

Plates

Plate 1 Concrete pot, trapped, accreted sediment at bed elevation of 400mm

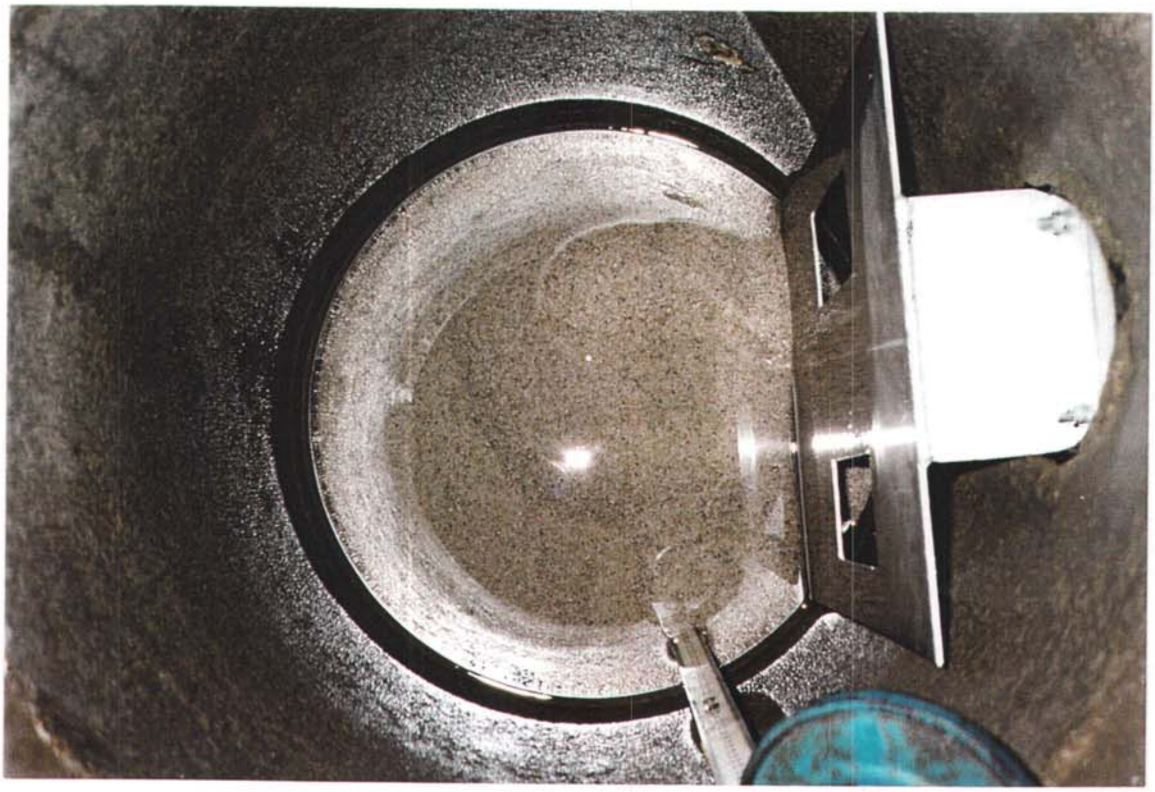


Plate 2 Concrete pot with baffle 2, trapped

Plate 3 Concrete pot with baffle 3, trapped

Plate 4 Concrete pot with larger outlet

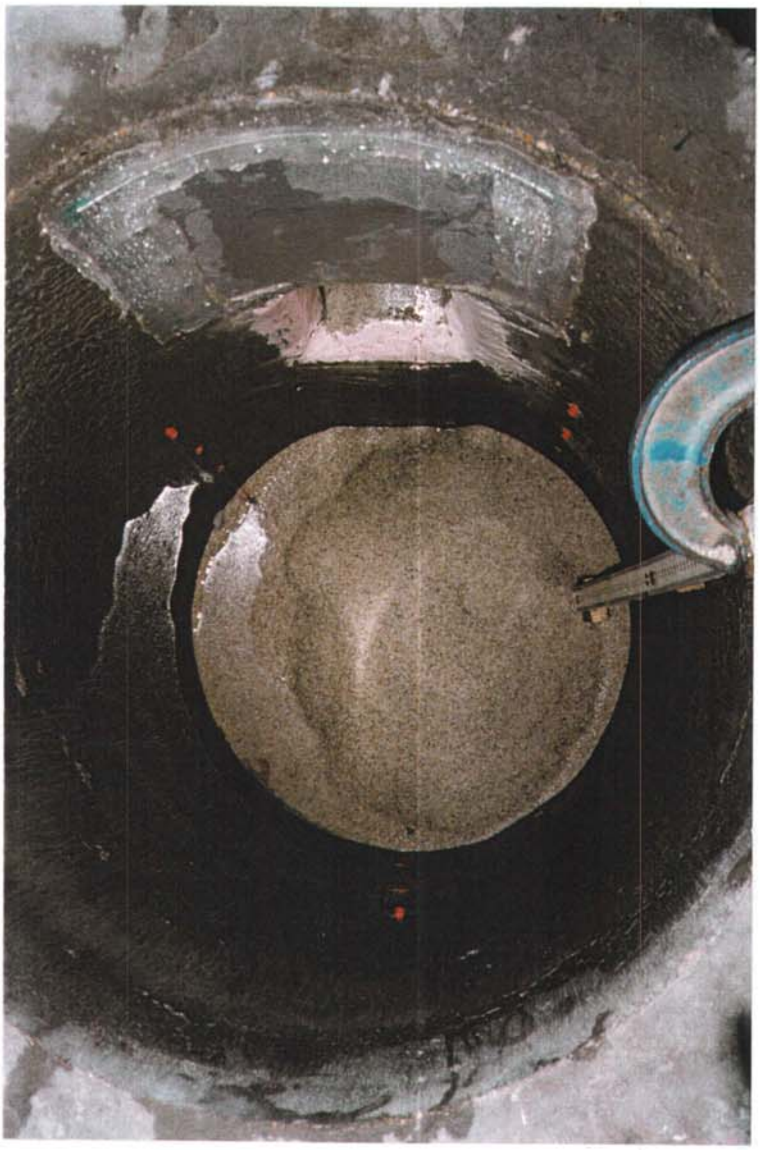


Plate 5 **Concrete pot with larger outlet, accreted sediment at bed elevation of 200mm**

Plate 6 Clay pot, trapped, accreted sediment at bed elevation of 400mm

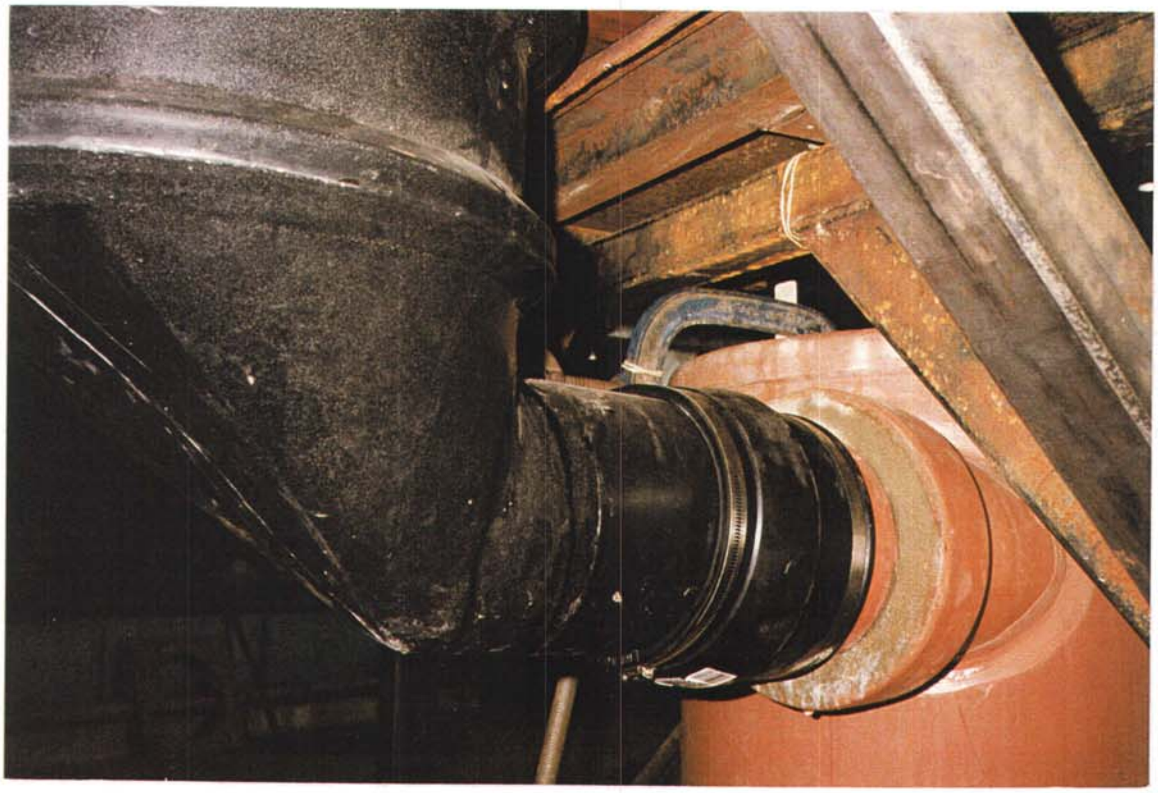


Plate 7 Clay pot, swirl design showing gully chute and short inlet tube

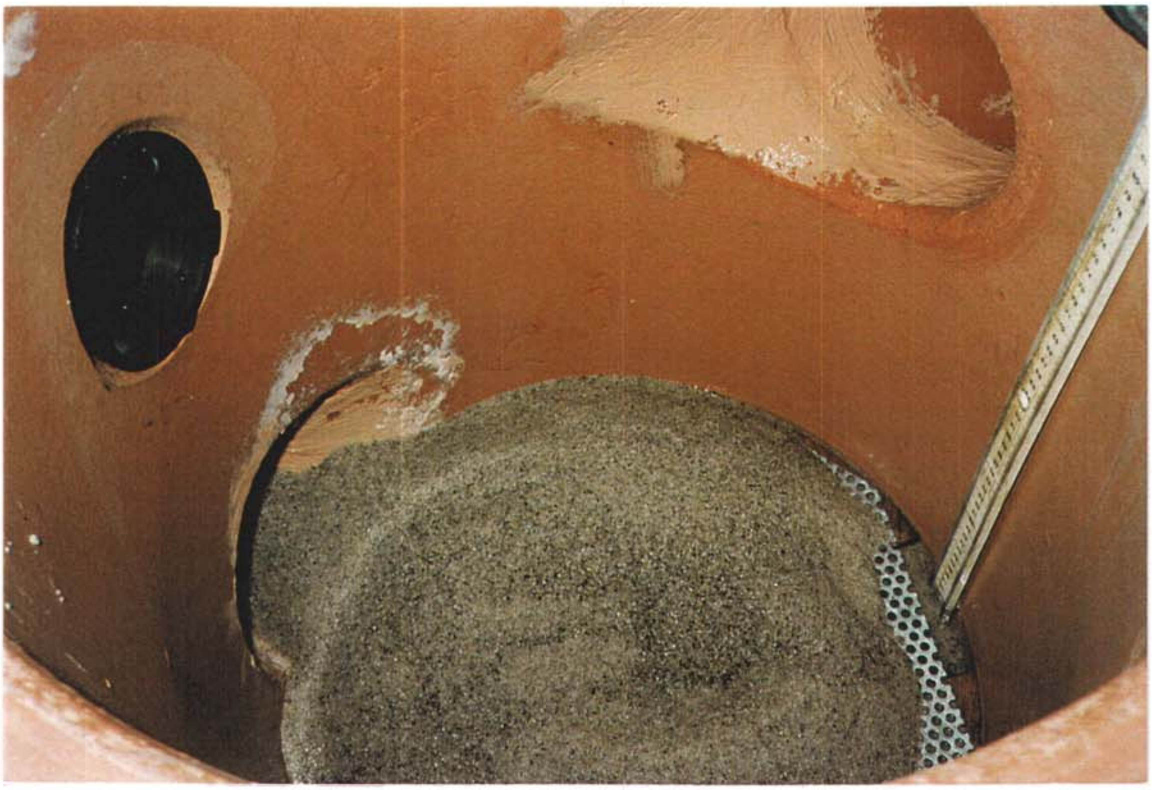


Plate 8 **Clay pot, swirl design, trapped, accreted sediment at bed elevation of 400mm**

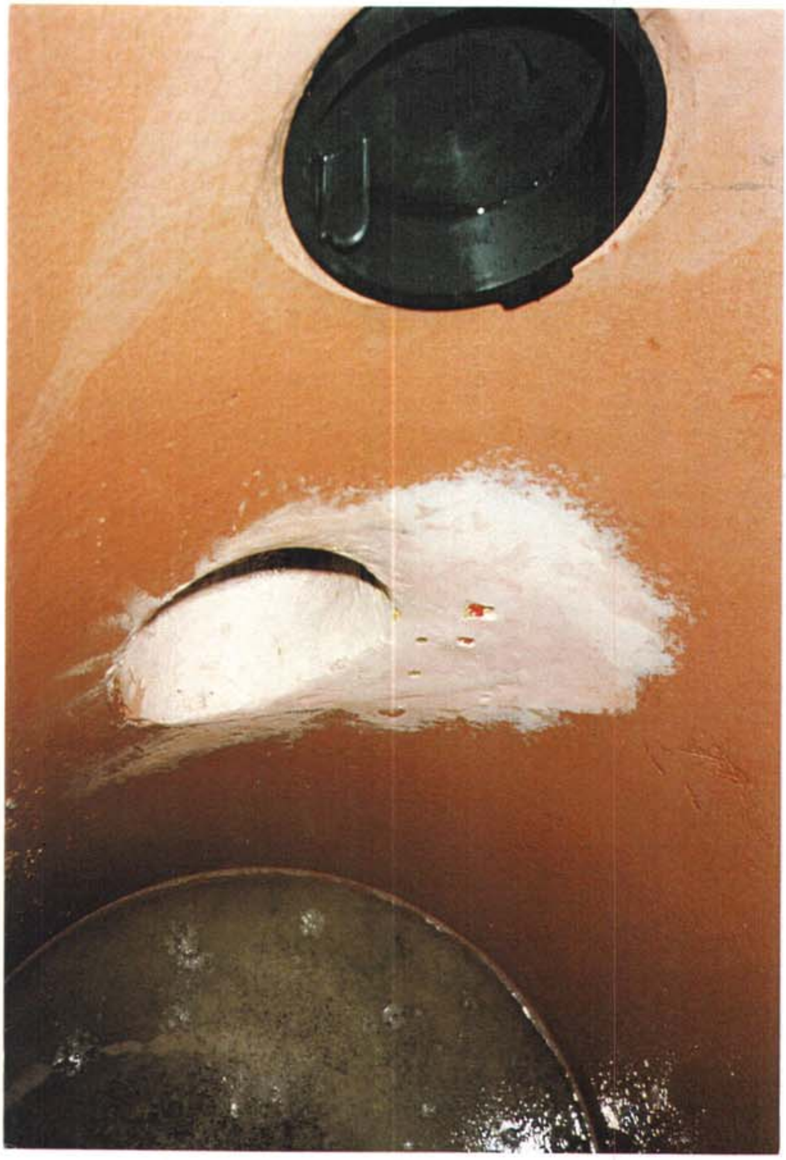


Plate 9 Clay pot, swirl design with modified outlet, trapped

Plate 10 Clay pot, swirl design with modified outlet and baffle 1, trapped

Plate 11 Clay pot, long path outlet, trapped, accreted sediment at bed elevation of 0mm

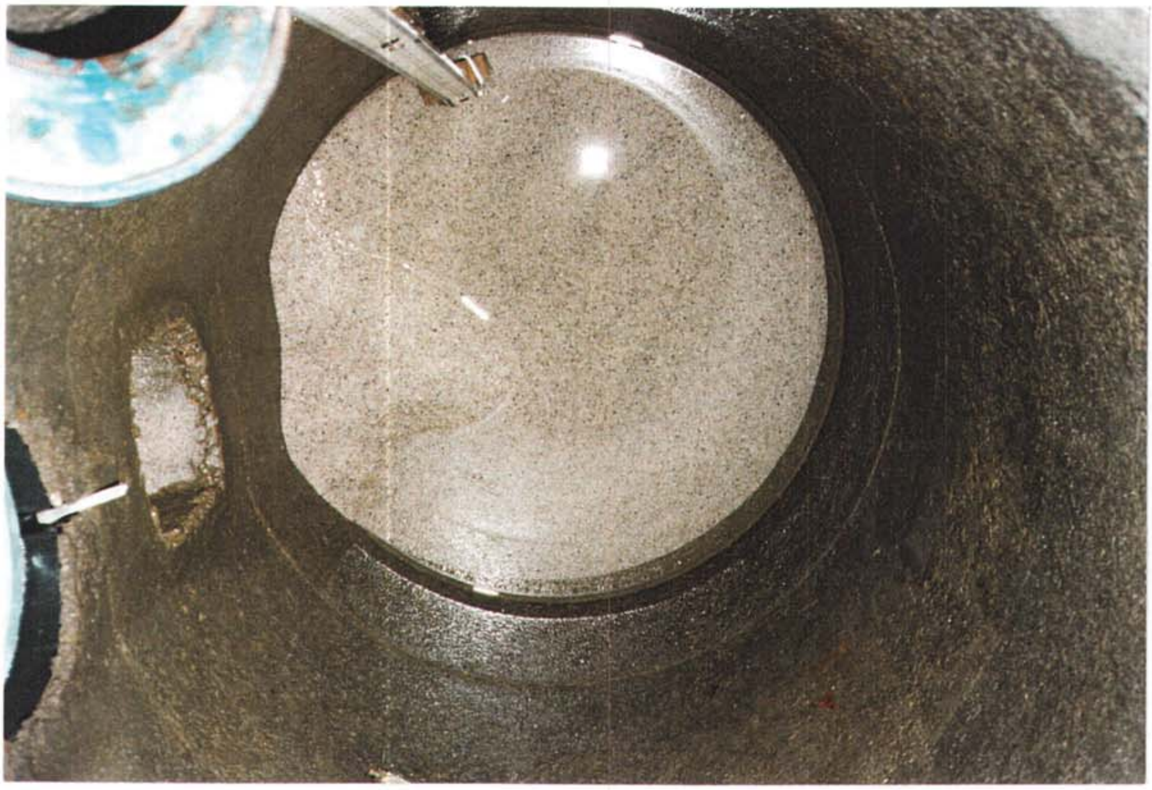


Plate 12 Concrete pot, trapped, accreted sediment at bed elevation of 200mm (natural bed)

Plate 13 Concrete pot, trapped, accreted sediment at bed elevation of 200mm (board)

Plate 14 Concrete pot, trapped, accreted sediment at bed elevation of 500mm (natural bed)

Plate 15 Concrete pot, trapped, accreted sediment at bed elevation of 500mm (board)