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Rapid-Flow Filter for Sewer Overflows

U.S. DEPARTMENT OF THE INTERIOR • FEDERAL WATER QUALITY ADMINISTRATION

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RAPID-FLOW FILTER

FOR SEWER OVERFLOWS

The Evaluation of Coarse Coal as a

Filter Medium to Remove Large

Solids from Sewer Overflows

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

DEPARTMENT OF THE INTERIOR

by

The Rand Development Corporation
13600 Deise Avenue
Cleveland, Ohio

Contract No. WA 67-2

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ABSTRACT

The concept of a rapid-flow filter able to remove large, visually objectionable solids from the kinds of overflows which result from combined sewer systems, has been shown to be feasible.

In a pilot installation at the terminus of an existing urban overflow location, a filter using lump coal performed this pollution control measure with a minimum of maintenance or difficulty. What difficulty existed centered about obtaining representative samples of overflows containing the large solids the filter was intended to, and did, remove.

A preferred filter uses lump coal as the filter medium, preferably sized to three-fourths by one and one-fourth inches, free of fines, and about eight inches in depth. The overflow is directed onto the filter bed in such a manner that the filter bed is not displaced. When plugged, or upon a routine basis, the filter bed is replaced; the spent bed, composed of coal and solids, is incinerated or landfilled or disposed of by whatever manner is locally in use which does not pollute the atmosphere or surface or underground waters.

The work reported herein indicates that a rapid-flow filter can be used for partial treatment of sewer overflows by removing large solids to the extent of up to sixty-five percent removals. However, the potentially most valuable contribution in the work was the finding that conventional sewage sampling does not provide a representative indication of the nature of large solids content. A recommendation for an improved sampling procedure is made.

This report was submitted in fulfillment of Contract WA 67-2 between the Federal Water Pollution Control Administration and the Rand Development Corporation.

FIGURES

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TABLES

FIGURES

SECTION I

CONCLUSIONS

1. The concept of a rapid-flow filter utilizing inexpensive, disposable, lump media, such as coal, to remove unsightly floating and suspended solids from combined storm and sanitary sewer overflows has been demonstrated to be practical. Cost estimates for utilizing the concept can be based on data obtained during this program.

2. Conventional sewage sampling methods, where composite samples are collected conventionally by the periodic dipping of small portions from the stream, are not adequate for obtaining representative samples of the large solids transported in raw sewage or in sewer overflows. This misrepresentation is then compounded in the laboratory when the small aliquot portions are taken from the composite for actual analysis.

   In sampling, due regard must be given to means by which samples large enough to be truly representative can be drawn. The design of such methods must preclude effects of the sampler itself on the stream flow pattern. These requirements can best be fulfilled by the method described as segment-sampling, wherein a segment of the entire stream, or of a portion of it that is deemed to be representative, is taken periodically and analyzed in its entirety.

3. Optimum particle size of the filter medium for rapid filtration purposes appears to lie in the range of 1/2 by 2-1/2 inches. A standard commercial 3/4 by 1-1/4 inch stoker coal is entirely satisfactory for the removal of gross solids at the design flow rate of twenty gallons per square foot per minute.

   The coal should be reasonably free of dust or fines before it is placed into the filter, in order that the flow rate not be unduly restricted; screening is satisfactory for this purpose. However, washing of the coal is necessary in order to prevent residual dust from being washed into the filtrate.

4. Filter bed depth does not appear to be critical. The degree of solids removal does not materially increase at depths exceeding eight inches.

5. For purposes of design a value of twenty gallons per square foot per minute has been found useful for a bed eight to eighteen inches deep composed of washed 3/4 by 1-1/4 inch coal. Variations in

individual configuration for reasons of topography, convenience, security and similar considerations can be expected. The designed filtering area should of course accommodate the maximum anticipated flow of the overflow structure.

6. Because the concept is based on the use of a disposable filter medium, no backwashing or other processing is required; nor is the attendance of an operator. Replacement of the medium can be pre-scheduled, or determined by periodic inspection or by automatic signalling.

   It appears that replacement approximately six times per year might be expected as an average; actual life expectancy of a given filter bed is more a function of the character and load of the overflow than of the total volume of water passed. It was found in this work that reasonable predictions of the nature of the overflow can be based, in turn, on the season of the year, the nature of the watershed, land use and individual circumstances. Intensity of rainfall is especially influential, and it is important for design purposes that the rainfall data for the microclimate of the individual watershed be used, rather than regional rainfall statistics.

7. The rapid-flow filter is simple in design, and malfunction is limited to overloading or to pluggage of the medium. In such an event the filter itself merely overflows and the net effect is the same as if the filter were not present.

8. Although no conclusive analytical data could be performed on the subject, it is evident that a substantial amount of composting of organic material removed by the filter takes place in the filter, especially during warm weather. Organic material observed on the filter surface immediately following an overflow visibly degrades in size and consistency within a day or two.

9. At no time during this work was an odor of sewage solids or garbage detected in connection with the filter operation as long as unoiled coal was used and the filter was shaded from the sun. The phenomenon appears to be a reproducible characteristic of the process.

10. In other recent work [1] coal has been found to be useful in sewage treatment, partially because of a marked ability of some coals to adsorb dissolved organic matter. Although this characteristic is probably responsible for part of the inhibition of odor, its effect is minimal with respect to sewage treatment in the rapid-flow filter because of the short residence time and small surface area of the large lumps. The rapid-flow filter process is essentially one of physical removal of gross solids.

SECTION 2

RECOMMENDATIONS

1. Sampling techniques for measuring the solids content of waste streams containing gross solids can be improved.

   In the usual technique the increments that make up the sample are too small relative to the size of the solids in the main stream. Furthermore, the sample gathering procedure disrupts the flow pattern of the stream so that representative samples can not be taken. The mere presence of the sampling dipper creates streamlines which divert light solids around it.

   Analytical techniques in general use are valueless for gross solids. The physical size of the increment analyzed is smaller than that of many of the solids in the waste stream; for example, cans and dead rats.

   A decided improvement would be the gathering of a large total segment sample and then filtering it. The filtrate could then be analyzed conventionally. This procedure provides a better representation of what is actually in the waste stream, with regard to both liquids and solids. (See section on Sampling.)

2. The rapid-flow filter concept may be used as a relatively inexpensive measure for removing gross, visually objectionable solids from sewer overflows.

   This system should not be considered as a complete treatment process or as a permanent solution to the problem of overloaded sewers, or of the complete treatment of overflow from them.

3. Automatically cleaned coarse screens with provisions for returning the solids to the main stream of the sewer would probably be better for large - over 10 MGD - overflows. Automatic bypass arrangements would be needed for this type of device so that the overflow would still be operable during power failures.

4. It was found that the 25 square-foot pilot filter failed to duplicate the filtration capacity of the 1.1 square-foot test filter in total gallons filtered for filter area before pluggage. This suggests that filter design modifications are in order for future installa-

tions. The rapid flow (approximately 125 GPM/ft^2) through the test filter kept small materials such as sand, etc. from settling out of the stream and plugging the filter. The flow through a given area of the pilot filter was somewhat dependent upon the storm overflow rate, which varied from 0 to 50 GPM/ft^2. The average maximum pilot filtration rate during each of the 91 natural and simulated events was approximately 15 GPM/ft^2. During the 55 natural events this filtration rate ranged from zero up to the maximum.

Therefore, a better filter would be one that was divided into adjacent sections so that during a low rate event only a few sections would be used and the flow rate through a given section would maintain at a high rate until it became plugged. The unfiltered material would overflow each section onto the next as each succeeding section plugged or for other reasons was not able to accommodate the full overflow.

This can be accomplished by having a series of baskets each fitted with an internal honeycomb arrangement to hold the coal in place against the force of the overflow. The sewer overflow would be distributed from one end onto the first basket. Excess unfiltered waste water would flow out the opposite end down and onto one end of another filter basket. This may be repeated for three to five baskets in series.

Further advantages of this improved design would be that only the minimum number of baskets would be exhausted and need to be changed at any given period while the far end baskets would still be relatively clean and available for use.

SECTION 3

INTRODUCTION

There are over 1,300 U.S. cities served by combined sewers.(2) Approximately one-fourth of the urban population is so serviced, or perhaps 36 million persons. Overflow from sewers, including combined sewers, is an important pollutional source, although its real importance was not widely recognized until the mid-1960's. Not only does the pollutional load contributed by sewer overflows include contaminants easily identified by standard tests for biochemical oxygen demand, suspended solids, pathogens, coliform organisms and the like, but overflows also contribute obvious esthetically objectionable materials to surface waters. The American public is aware of these effects, especially the visual ones, and supports efforts toward their abatement and elimination.

Proposed solutions to the overflow pollution problem are numerous including various screening and filtering means, storage basins, larger sewers and treatment plants, disinfection, sedimentation, etc., any of which will unavoidably add to the costs of protecting surface water quality. Replacing combined sewers with separate conduits for sanitary wastes and storm water could, it is estimated, (2) cost as much as 48 billion dollars. Despite this enormous cost, no treatment whatever of the storm waters would result.

Federal Water Pollution Control Administration Contract No. WA 67-2 with the Rand Development Corporation, Cleveland, Ohio, concerned one of many approaches to solutions to overflow pollution. It was limited to the development and evaluation of a rapid-flow filter device for removal of gross, esthetically objectionable solid objects from combined sewer overflows. The device was intended to accept sudden, large flows while removing relatively large objects such as cans, plastic items, glass objects and the like. Naturally a maximum of removal of pollutants is always sought, but it is obvious that coarse filtration is limited in its ability to effect pollution abatement; nevertheless, the existance of tons of thousands of overflow structures justifies the examination of any approach which may feasibly - and perhaps quickly - begin to alleviate water pollution.

No solution to any pollution is achieved if acceptable ultimate disposal of the pollutants removed is not also achieved. In the rapid-flow filter concept, a combustible filter medium may be used so that the medium with its load of removed pollutants may be properly incinerated for disposal. A non-combustible filter medium may also be used where supervised land-fill operations are used to dispose of solid waste in acceptable fashion.

While coal is the preferred combustible filter medium wherever coal is an item of commerce, the rapid-flow concept is not to be confused with the coal-based sewage treatment process developed by Rand Development Corporation on behalf of the U. S. Department of Interior, Office of Coal Research. (3)

SECTION 4

SITE SELECTION

A number of factors were considered in the selection of the test site.

1. Type of outfall. Only combined storm and sanitary overflow outfalls were considered for the pilot rapid-flow filter.

2. A clearly defined drainage area.

3. Convenience and accessibility. To keep total project costs as low as possible locations which would require little modification and also be relatively close to the contractor's laboratory were given prime consideration.

4. Adaptability to construction. A location at which construction costs could be kept low is always a consideration. This was especially important for this pilot operation because it was necessary to include instrumentation and other accessories not needed for a simple rapid-flow filter structure.

5. Frequency of overflow. Records concerning overflows are limited in the Cleveland area as in virtually all localities. Wherever information was available it was referred to. Local inquiry was also made.

6. Volume of overflow. An overflow conduit in the 18" to 24" diameter size was judged to be a reasonable choice for an initial test facility, able to provide it with at least 1.8×10^6 MGD.

7. Security. The protection of the Federally-owned equipment and the data the instruments would provide.

An engineering report (4) which had recently been made to survey Cleveland's nearby southeast side sewers, suggested consideration of the outfall just west of the blind intersection of Dorver Avenue and East 77th Street. This is a twin outfall (see Figure I) serving single block areas of Beman Avenue (see Figure II) and Dorver Avenue. The overflow structure serving the Beman Avenue combined sewer is of the side spillway construction (see Figure III for a generalized drawing). The Beman Avenue drainage area (see Figure IV) is approximately 1500 feet long and encompasses approximately 8 acres. Approximately

40 percent of the total drainage area is comprised of street, sidewalks, driveways, rooftops and other fast draining areas. The remainder is lawn or natural cover. The drainage area is an established neighborhood of mainly single residences with a population of approximately 300.

From inspection it appeared to meet the criteria imposed. Local information (the only type available) indicated that the flow rate and duration would meet requirements. The headwall was located on the southwestern edge of a 40' x 40' parcel facing East 77th Street and owned by The Cleveland Electric Illuminating Company. Immediately west of the parcel is the right-of-way of the Penn Central Railroad. Property to the south is owned by one Harry Rock. Property to the north is owned by The Cleveland Electric Illuminating Company and on it is located a high tension transmission line tower supporting a 240,000 volt power line. The project site was leased from The Cleveland Electric Illuminating Company. Approvals were obtained from the engineering and sewer departments of the City of Cleveland and from Penn Central Railroad. This particular parcel is zoned "residential" and it was necessary to apply for a variance before any construction work could take place. After a hearing, this variance was granted.

SECTION 5

FILTER DESIGN

The concept of a rapid-flow, high capacity filter for sewer overflows is based upon the well-known practice and art of removal of suspended and floating material from fluid streams by causing the fluid to pass through a bed of particulate matter sized and graded so that the filter medium presents only a nominal flow restriction while retaining the solids on and within the filter medium. Since sewer overflows contain suspended and floating matter in quantity, removal constitutes a water pollution abatement measure.

The following design criteria were used:

1. The device was to be capable of removing visually objectionable floating or suspended solids, such as cans, bottles, rubber or plastic articles and the like. (Figure V and VI)

2. The rapid-flow filter was to be capable of sustaining a flow rate of 20 gallons per square foot per minute, and accepting a flow whose rate might increase from zero to 20 gallons per square foot per minute within 15 seconds. Flows exceeding approximately 75,000 GPH were to be diverted to the existing overflow.

   The literature reports a variety of filter bed configurations to accommodate water containing relatively finely divided solids. These filters are capable of flow rates of two to five gallons per square foot per minute. These are generally graded sand, sand and coal, or sand and gravel filter beds up to several feet of thickness with the particle size of the media generally in the 14-60 U.S. Standard Mesh range. Prior Rand Development Corporation experience with filter beds comprised of materials in the 18 to 80 mesh range indicated sanitary sewage flow rate for this finer range of media to be in the 0.5 to 1 gallon per square foot per minute range at a pressure drop of approximately twelve feet.

   Using the available literature data, prior experience and a limited number of exploratory trial runs, extrapolation indicated that a filter bed comprised of 3/4 inch lumps, and larger, could accept a flow rate up to twenty times that of a conventional water treatment bed, and still remove reasonably small objects from sewer overflows. Items as small as the filter-tip of a cigarette could be expected to be removed.

3. Provision was to be made for by-passing and measuring flow in excess of rated filter capacity. This requirement was imposed in order that the amount of overflow reaching the filter could be determined. This is not an engineering requirement for an operating rapid-flow filter, but was considered desirable for this one particular pilot unit. (See No. 4)

4. Provision was to be made for an overflow from the filter itself, if the filter could not accommodate the rated flow because of plugging or of characteristics of the test media or procedures, provision was to be made to permit any flow the filter could not pass simply to discharge over or around the filter device and thence to the existing overflow outfall. In any such case the sewer overflow would operate ultimately as originally constructed and remove little if any of the solids from the overflow until maintenance could be provided.

5. Means were to be provided for measuring the volume of flow to, through, and by-passed around the rapid-flow filter, via Parshall flumes. This was a design factor used in this installation solely for the purpose of experimentation. It is not required in a working situation except as information might be desired in specific cases.

6. Provision was to be included for at least one demonstrable method for easy maintenance of the overflow device.

   Ultimately, rapid-flow filters will presumably be maintained on some kind of regular service basis, similar to the manner in which solid waste pick-ups are made. One simple method of loading and unloading an overflow filter-used in this program - is to use a winch mounted on a vehicle, which vehicle can also transport "spent" filters to disposal as well as place "fresh" filters into the overflow. Any of a variety of methods could of course be used; local option will no doubt be taken.

7. The design was to be flexible in regard to experimental usage. The following were considered:

a. The filter device was to be capable of accepting filter media from 3/4" nominal diameter upwards to perhaps 4" nominal diameter.

b. The filter device was to be capable of accommodating a maximum filter medium bed depth of four feet.

c. Sheet metal construction was to be used to permit changes, especially in the filter inlet, where dissipation of considerable kinetic energy during major overflows was expected to be required. It was indeed found necessary to make these modifications to the initial design.

8. Specific design requirements of the site were also to be met, in consideration of topography, sewer line locations and elevations. These included:

a. Restriction of the height of any metal structure to nine feet, a requirement imposed in this location by the proximity of the 240,000 volt power line.

b. Strict electrical grounding of all structures, again because of proximity to the power line.

c. Restriction of the device and all appurtenances to the forty foot square plot.

d. Inclusion of safety items wherever indicated.

9. Two intangible design factors relating solely to an experimental demonstration unit were also to be considered:

a. Public relations.

A degree of activity not normally associated with sewers was expected to accompany the operation of the overflow demonstration. Special care was indicated to protect what would undoubtedly become an object of local curiosity, as well as to insure that the installation would present a workmanlike appearance.

One aspect of the installation which could not be avoided as a result of the need for flow measurement and sampling was that of apparent large installation size in comparison with the headwall runoff structure.

The rapid-flow filter occupied an area of only about fifty square feet while the flumes and equipment shed to house the instruments nearly filled the 1,600 square foot site.

b. Public safety

As a measure of protection to residents of the area - especially children - the installation was to be fenced and designated by sign to be a Federally sponsored site. The fence was later found to be of equal value in protecting the site from the children. A working unit would probably need only normal provision for safety such as those made in overflow locations in conventional practice and those used in solid waste handling.

These criteria were then incorporated into a set of specifications, which was approved by FWPCA. The Cleveland engineering firm of Trygve Hoff and Associates was selected to complete the engineering according to the specifications, with the selection approved by FWPCA in September, 1966.

Final approval of the plans and construction drawings by FWPCA was given in January, 1967, and construction was begun in February, 1967. The test facility went on stream on schedule, May 8, 1967.

Figure VII is a flow diagram of the device.

The main portions of the pilot rapid-flow filter as installed consisted of:

1. Main flume to receive the total sewer overflow.

2. Filter inlet flume off the main flume and headed by an adjustable gate to limit flow to filter to about 1200 GPM and further designed to conduct the sewage to the middle of the filter through a section that can be swung away so that the filter can be removed.

3. Bypass flume off the main flume to receive the excess flow.

4. Twenty-five square foot filter; a four foot high sheet metal hopper with an expanded metal false bottom for supporting the filter medium or shallow baskets. A hinged sunshade was fitted

over the filter to eliminate fetid odors found to be produced by the sun's action on the sewage solids.

5. Filter baskets; expanded metal containers to contain the coal (see Figure V).

6. Filter pit used to hold the filter hopper.

7. Filter outlet flume used to conduct the filtrate to the receiving waters.

8. Flow rate indicator and recorders to monitor the flows in the main, bypass, and filter outlet flumes.

9. Conventional dipper type samplers to sample the main and filter outlet flumes. These were activated by a moisture sensor located in the filter outlet flume.

SECTION 6

OPERATION AND MAINTENANCE

A rapid-flow sewage overflow filter is simple to operate and maintain. The device simply rests at the terminus of an overflow conduit, requiring attention only for replacement of filter elements and for routine inspection.

However, the pilot rapid-flow filter was instrumented to provide information; moreover, efforts were made in its operation to have personnel present during natural overflow events so that visual observations could supplement recorded data. When it became apparent that naturally occurring overflow events were so infrequent during the test period available to provide a large amount of data, simulated overflow events were conducted. In these, sanitary sewage was pumped from a reservoir formed by sandbagging the sanitary sewer serving the drainage area and sometimes supplemented by hydrant water.

A moisture sensor located in the main flume terminus initiated and stopped the sampler devices, one of which was located in the inlet Parshall flume and the other of which was located in the Parshall flume metering the effluent of the filter baskets. Liquid samples were composited in five gallon containers and taken to the analytical laboratory as quickly as practicable after any event, usually within three hours. In those runs in which segment samples were taken, fifty-five gallon rubber storage containers were used to obtain the samples; these containers were then transported to the analytical laboratory in toto.

Flow recorders located in the influent flume, its overflow flume, and the filter effluent flume recorded flows continuously upon activation of calibrated float arms. A recording rain gauge located at the pilot plant site also operated continuously.

Operation of the pilot filter included sample collection, interpretation, analyses of samples, and evaluation of filter medium size. A standard flat-bed truck equipped with a conventional hydraulic hoist was used to transport empty filter baskets to nearby coal yards, carry the filled baskets to the pilot site, and lower the baskets into place. The truck also was used to deliver the spent coal to a local incinerator for disposal. All of the pilot operations were easily handled by one operator; no special skills were required.

In actual rapid-flow filter operations, routine inspection would of course be important, as it is with any sewer collection system device. Replacement of the filter elements may be made on the basis of such inspection, or on a predetermined schedule.

SECTION 7

COSTS

The rapid-flow filter concept is quite simple, comparable in many respects to industrial solid refuse pick-up operations in which full trash-bins are automatically hoisted by means of self-propelled mobile mechanisms and dumped into a vehicular carrier for removal to a suitable disposal operation. The emptied, or a replacement, bin is left for reuse.

In the case of a rapid-flow filter for sewers, a similar operation is entirely feasible. For example, a vehicle carrying replacement filter elements (containers pre-loaded with the filter medium) and equipped with a hoist arrives at an overflow location. Its arrival is either pre-scheduled, or triggered by the occurence of showers, or by an electrical signal. On arrival, the filter element is inspected. If replacement seems warranted or is scheduled, the used element is removed and a fresh one installed. The single vehicle deals with both delivery of fresh, and with removal for disposal of spent filter baskets for devices.

Any estimate of filter construction and installation cost must of necessity be generalized and so considered. Overflow structures vary with respect to size and capacity, location and accessability, special topographical consideration, and so on. Some uncertainty always exists when operating costs are estimated. In this case, the frequency of replacement of filter elements, local labor costs, materials costs, disposal costs, and the like all can be expected to vary from city to city. A contingency of 25 percent is recommended for consideration in the following estimates which include construction cost, frequency of replacement of filter element, and labor costs including disposal; the estimates cover filters handling overflow sewers up to twenty-four inch diameter. For the purpose of this estimate, overflow rates up to 10 MGD discharge are considered. High rate overflows can probably best be handled by automatically cleaned bar screens: an estimate of the point where bar screens would be more practical is approximately 10 MGD.

Basis of Estimate

1. Apparatus to be capable of accommodating twenty gallons per minute per square foot of filter surface.

2. Apparatus to consist only of filter element with a simple apparatus to direct overflows to it. That is, no analytical instrumentation or special equipment other than sun shade and elements of safety.

3. Filter element replacement to average six times yearly.

4. Disposal costs to be equivalent to solid refuse incineration disposal costs per load, or $5.00/truck load.

5. Spent filter pickup and exchange cost to be $35.00 per station pickup for the first basket plus $5.00 for each additional basket.

6. Filter basket loading costs to be $5.00 per basket.

Filter baskets 6 feet wide by 8-1/2 feet long and 2 feet deep weighing approximately 2,500 pounds loaded would be a practical size to handle using standard trash bin handling trucks. This size filter basket could handle 1,000 to 2,500 GPM. The sewer overflow discharge would be diverted to the filter baskets through simple distribution channels that would distribute the flow over the baskets. This was the method used in the pilot project.

An improved distribution method might have the overflow water distribution along one end of a basket which would handle 1,000 to 2,500 GPM. Excess flow would cascade off the opposite end of the filter basket. Additional filter baskets could be used in series or paralleled. Approximately six baskets would be needed for a 10 MGD flow rate.

The baskets would be of a straight sided steel plate fabrication with an expanded metal bottom. Internal baffles would minimize displacement of the filter medium due to hydraulic action.

The rapid flow filter structure would consist of:

1. Filter baskets to contain the coarse filter medium.

2. Distribution channels or weirs, etc. to conduct the overflow from the overflow sewer to the surface of the baskets.

3. Pit or excavation and walled area to contain the filter.

4. Security fencing.

5. Access roadway for servicing the filter.

Following are estimated costs for components of a representative rapid-flow filter installation assuming the construction of several:

1.	Filter baskets, each	$ 350.00

2.	Distribution channel, per basket	$ 500.00
3.	Pit (excavation and concrete work), per cubic yard.	$ 250.00
4.	Security fencing, per foot.	$ 5.00
5.	Roadway	Variable
6.	Survey and engineering	$ 1,500.00
7.	Contingency	25%

The estimated costs for a minimum sized filter (1.5 MGD)would be:

1.	Filter baskets - 1-1/2 needed	$ 500.00
2.	Distribution channel, one needed	500.00
3.	Pit, 12 cubic yards	3,000.00
4.	Fencing, 100 feet	500.00
5.	Roadway, average	2,000.00
6.	Engineering	1,500.00
	Sub-Total	$ 8,000.00
7.	Contingency	2,000.00
	Total	$10,000.00

The estimated costs for a 10 MGD filter would be:

1.	Filter baskets, 9 needed	$ 3,150.00
2.	Distribution channel, 2 needed	1,000.00
3.	Pit, 56 cubic yards	14,000.00
4.	Fencing, 150 feet	750.00
5.	Roadway, average	2,600.00
	Sub-Total	$21,500.00

			$21,500.00
6.	Engineering		1,500.00
		Sub-Total	$23,000.00
7.	Contingency		6,000.00
		Total	$29,000.00

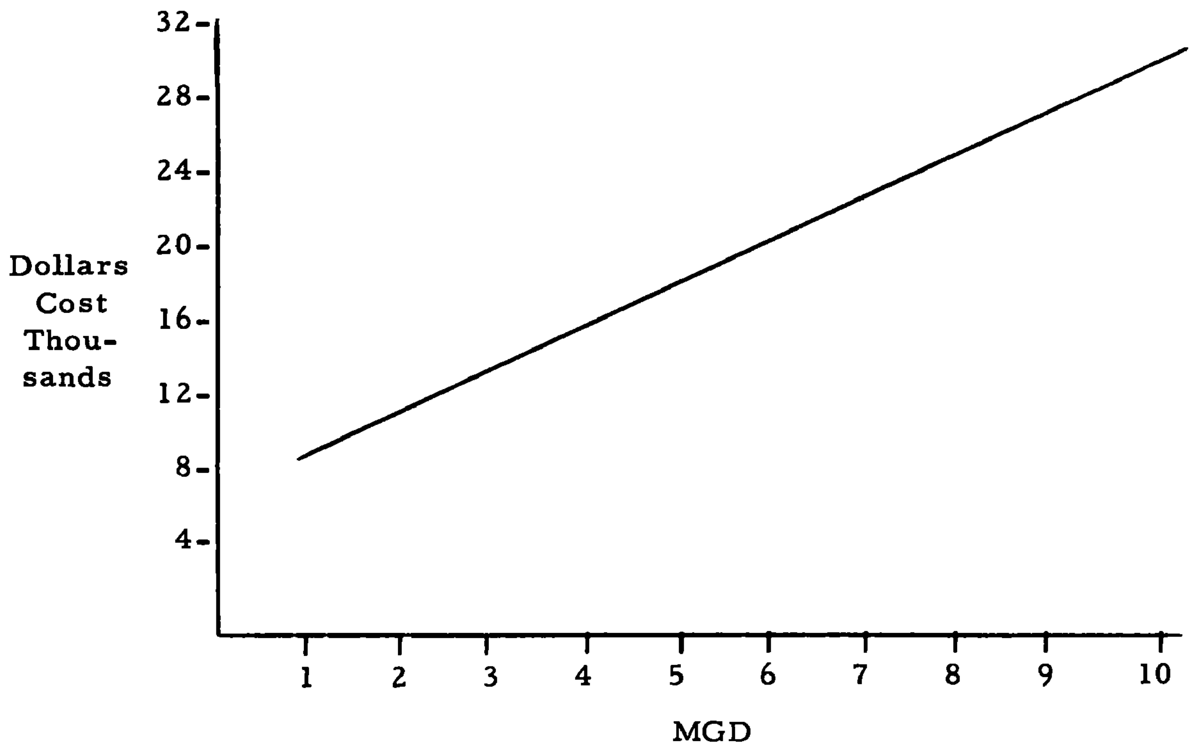


Figure VIII. Construction Cost, Estimated

Annual operational costs for the minimum sized filter if the filter medium is incinerated:

1.	Pickup		$ 210.00
2.	Coal		75.00
		Sub-Total	$ 285.00

		$	285.00
3.	Loading		30.00
4.	Incineration disposal		5.00
	Total	$	320.00

Annual operational costs for the 10 MGD filter would be:

1.	Pickup	$	360.00
2.	Coal		450.00
3.	Loading		200.00
4.	Incineration disposal		30.00
	Total	$	1,050.00

The above costs would be lower if the spent coal were burnt in a conventional stoker being used for steam generation. This would probably be satisfactory if oversized items were removed. Taking a credit for the coal and estimating the disposal costs above would give operating cost of $240. 00 and $570. 00 respectively.

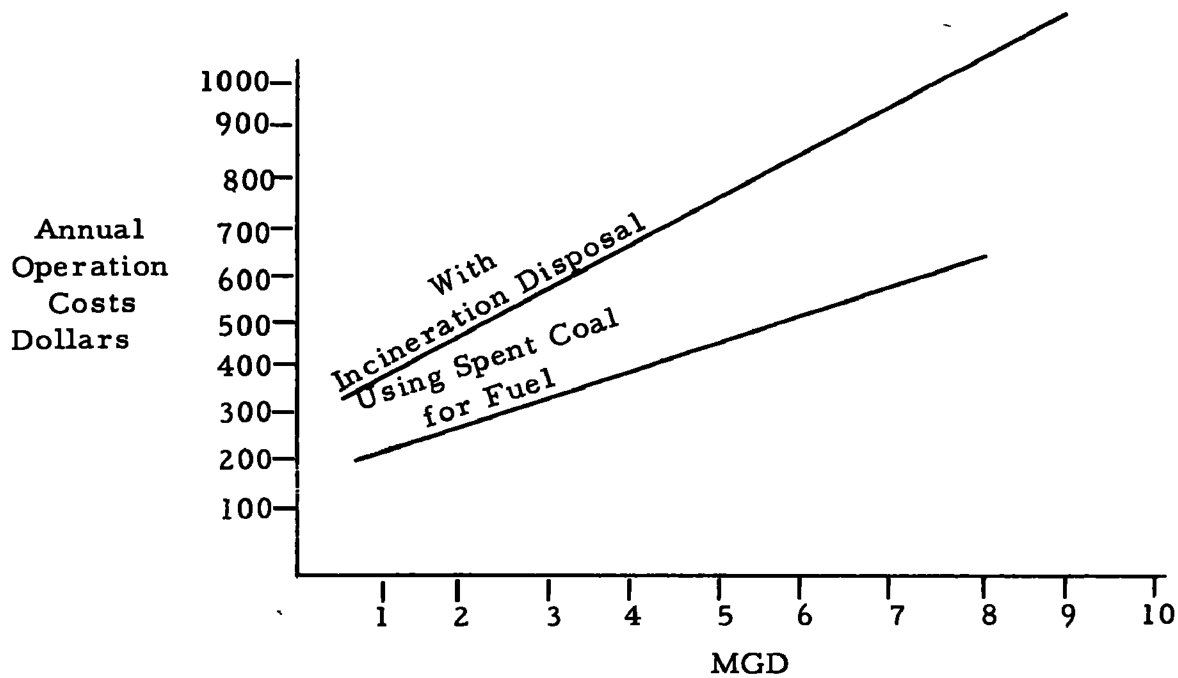


Figure IX. Yearly Operating Costs, Estimated

SECTION 8

RESULTS AND DISCUSSION OF RESULTS

Table I is a complete tabulation of analytical and rainfall data with filter characteristics, representing 55 natural and 36 simulated overflow events. The data in Tables II through VIII are abstracted from Table I. These latter tables group similar events and sampling techniques for clarity in analyzing the results. Mixed events and incomplete sample events have been excluded from these latter tables.

Description of Natural Events

Table II summarizes pertinent recorded data obtained during those storm events which caused overflows to the pilot filter during the investigative period.

Accumulative rainfall was recorded on a seven-day time chart while flow rates were automatically recorded on 24 hour time charts. Total overflows were calculated by integration from the flow rate-time records. Attempts to correlate total recorded rainfall and rainfall intensity with overflow rates or overflow totals were unsuccessful.

There were far fewer storms of sufficient duration or intensity to cause overflows at the pilot plant site than were expected on the basis of normal rainfall expectations for the region. Visual observations made during many of the storms which did occur revealed that during the first ten to twenty minutes of storm overflow gross solids are numerous and identifiable as material being scoured from the combined sewer itself as well as solids being transported as an immediate result of the rain. Subsequent to this period, the overflow contains few solids and in general lost its characteristic sewage coloration.

As a point of interest, there was a delay of almost precisely 12 minutes from the start of a sharp shower or storm and the corresponding overflow at this particular overflow installation.

Conventional Sampling

Tables III and V list the percent reductions of suspended solids and settleable solids in the natural and simulated events as indicated by conventional sampling and analytical techniques. In general the results indicate either no reduction, or an apparent increase. This behavior would not be reasonable unless the filter was adding solids to the filtrate.

The unexpected lack of apparent solids reduction in runs monitored by conventional sampling techniques can have several logical explanations, including:

1. Fines from the filter medium being washed out of the bed into the effluent. Experience has indicated that this can happen during the initial use of a bed unless it has been hydraulically dedusted. Except during the shakedown portion of the project, filter bed washing was practiced. The effect of no or incomplete washing would be most pronounced during the initial use of a bed, but Table VIII indicates that the results from initial events on a given filter bed were not significantly different from succeeding ones.

2. Filter medium spalling. Visual and microscopic examination of the solids in the samples did not reveal coal fines in the effluent from washed filter beds.

3. Reslurrying of collected solids. Once the solids have been removed from the overflow stream and collected on and within the filter bed it is possible that they could be returned to the filtrate if the filter medium were disturbed and displaced by the force of the stream, or if the collected solids were degraded so that they broke down into pieces small enough to wash through the medium. After the initial shakedown period, when it was found necessary to install a baffle plate to break the force of the inlet stream, observation of the filter medium failed to indicate sufficient disturbance of the bed to cause wash-through.

   Degradation of the collected solids with time was an observed fact, although no quantitative measure could be made. Organic materials - leaves, paper, fecal matter, etc. - were observed to diminish greatly in volume, or disappear completely within a few days. This probably was caused by composting, a natural biological decomposition which occurs under moist aerobic conditions. Possibly some chemicals from the coal helped but this effect is speculative. At no time was an appreciable odor from the entrapped and shaded solids ever detected except during the one instance that oiled coal was used. The oil may have isolated the coal surface from the sewage solids, and thus diminished the known ability of coals to adsorb odor.[1]

The actual mechanisms involved in the reduction of the collected solids could not be investigated, but the fact that the solids did tend to "disappear" was incontrovertibly observed. It is reasonable to assume that some of the degradation products would have appeared in the effluent. Initial runs through a new coal bed did not demonstrate a significantly greater solids reduction, however, which fact diminishes the strength of this argument.

4. Faulty analytical technique. Procedures given in "Standard Methods for the Examination of Water and Wastewater" were used by experienced analytical personnel, and this argument has no validity, at least as it relates to the correct performance of conventional analytical techniques.

5. Non-representative sampling. It was evident merely from visual inspection of the operation test filter, performance was not being accurately characterized by the analytical samples. The influent and effluent scoop type samplers were of a standard type used in waste-treatment systems, and were similar except that the former was larger and operated less frequently than the latter. The influent and effluent channels differed in geometry, with differing stream velocities, turbulence, etc. The influent channel was necessarily large to handle the peak overflows, so that the normal influent overflow stream was relatively shallow. A well was therefore required for the sampler; however, the well tended, in service, to act also as a settling basin. This fact, plus the tendency of the automatic sensor to keep the sampler operating for some time after cessation of the overflow, resulted in an influent sample containing proportionately fewer solids than the stream being sampled. It was also visually apparent that classification by density was taking place in the flumes, with heavy solids moving along the bottom beneath the reach of the scoops, so that an additional error was introduced into the technique.

Grab Sampling

Some of the data pertaining to natural and simulated events monitored by grab samples are tabulated in Tables IV and VI. In general these grab samples were taken by compositing four one-quart dipper-fulls taken from different points across a section of the stream. Grab sampling is subject to lack of consistency in technique, but it does permit larger sample increments to be taken and also permits the use of judgement by the operator. The grab samples taken in this work were therefore considered to be more representative of the solid portion of the stream. The inaccuracy of the scoop sampler, the well in the flume and the segregation of heavy materials were not factors with the grab sampling technique.

Based on the analysis of grab samples taken in seven of the nine natural events, the expected reduction of suspended and settleable solids did take place. For Events No. 53 and 63, in which the greatest flow rates were measured, an addition of solids to the effluent was indicated. On the other hand, the data for Events No. 15 and 80, in which low flow rates were measured, abnormally high suspended solids removals were attained. Evidently a high-flow turbulent filtration can wash out fine solids which accumulate during less turbulent - or nonturbulent - filtration of low rate overflows. The rapid-flow filter concept was not designed for the removal of fine solids, but it was observed that dirt, sand and fine organic solids did sometimes accumulate in the filter.

Grab sampling, and also the standard analytical procedures, still suffer from a basic problem of being unable reliably to sample and measure gross solids.

Initial Filter Bed Tests

Results of all runs are listed in the tables; however, careful discrimination is required in the interpretation of numerical data obtained during the early tests. These runs included, to various degrees, shakedown of the test equipment and analytical procedures, and of means of communicating the existence of an overflow event from the test site to the office. For the preparation of this report personal judgement has been used where conclusions are drawn from the early runs.

Stratified Filter Media Experiments

The usefulness, in sewage overflow filtration, of filters composed of layers of media of progressively smaller size ranges was examined. The purpose of this group of experiments, reported in Table VII, was to see if the additional cost of layered filter beds was justifiable in terms of solids removals.

Tests were run in a 9 square foot filter set in the place of the filter baskets in the pilot installation. The flow used was all sanitary sewage.

The media consisted, top to bottom, of approximately 4 inches of 1-1/2" x 2", 4 inches of 3/4" x 1-1/2", and 4 inches of 1/4" x 3/4", washed coal except for Event No. 76 which did not use the smaller sized coal layer.

The average suspended solids reduction using the stratified beds was 11 percent while the settleable solids reduction averaged 31 percent, found using conventional analytical means. Similar runs using single medium filter beds in the larger filter baskets gave average suspended solids reduction of 11 percent and an average settleable solids reduction of 30 percent. (see Table VI) Therefore, it was concluded that there is no discernable advantage found within the limits of this experimentation to justify the added expense of preparing a stratified or graded filter bed for the purpose of removing gross solids.

Experimental Filter Screen Sampling

During three separate simulated overflows wire mesh screens (Figure X) were inserted into the influent and effluent streams for given times, varying from one to four minutes depending upon the screen size used, in such a manner that the total flow had to pass through the screen. The screens were then air dried to constant weight and the increase in weight noted. See Table IX for the results of the experiments with this sampling technique.

The general approach indicated an improvement over conventional sampling but suffered from two obstacles. The deposition of solids upon the screens impeded the flow so that the total flow screened was somewhat variable as a consequence. The screens were also unable to retain large solids, such as rocks, cans, etc., that would not embed in the screen and so be sampled.

Small scale filter media evaluation tests using raw sanitary sewage were run to determine the ability of coal to remove solids. Nylon tulle net bags with 1/16" holes were used to filter 1,000 gallons each of the full influent and effluent streams. The collected solids were dried and weighed (Table XII).

This procedure did collect all of the gross solids but relatively few of the fine solids.

Total Segment Sampling Experiments

Large samples were taken of simulated overflow runs by diverting the entire influent stream into a 55-gallon drum and then diverting the entire effluent stream into a second drum for the period of time required to fill the drums. The samples were then filtered through a series of screens, U.S. Standard Mesh Sizes 16, 30, and 35. The solids were then air dried to a constant weight. A consistent reduction was noted (Table X).

This approach is believed to represent the beginning of an improved sampling procedure.

Filter Capacity

Tests were conducted to determine the probable life expectancy of a filter medium. These runs were made using a 1.1 square-foot filter with an 18-inch depth of coal filter medium. In most cases the bench tests were run at the very high throughput of 125 GPM/ft^2 of filter area, using raw sanitary sewage. The criterion for calling a filter bed plugged was when the bed pressure drop reached one foot of water (Table XI).

For coal size consists ranging from three-fourths to two inches in diameter the bench scale filter capacity per square foot ranged from 16,300 to 49,000 gallons before pluggage was attained.

Capacities of the pilot filters ranged from 2,200 to 8,100 gallons per square foot. The pilot filters were changed whenever sufficient back pressure to have caused the filter to overflow at rated capacity was noted. A more economical arrangement would be to permit approximately one foot or more of pressure drop before considering the filter to be exhausted.

Filter Media Effectiveness Experiments

In any filter design a compromise between effectiveness (in this instance, removal of gross solids) and flow rate must be made. Capability of sustaining a high flow rate is of considerable importance in the concept of a filter for sewer overflows. Cost is always a primary variable.

The effectiveness of filter media comprised of various coal consists in removing solids were directly evaluated, and filter life and anticipated costs were judged in a series of experiments summarized in Table XII. A 1.1 ft^2 filter was used in these experiments. Coal particulate sizes were varied from 3/4" minimum to 4" maximum. It was found that solids removals in the order of 50 percent might be expected from coal consists in which the minimum size was 3/4" and it was judged that a satisfactory flow rate could be sustained. Coal sized between 3/4" and 1-1/4" is commercially available and except for having to be washed is directly useful in a rapid-flow filter. This size range was most commonly used in the pilot runs to accommodate the requirements of cost, effectiveness, and flow capacity.

SECTION 9

DISCUSSION

The rapid-flow filter concept was evaluated at one location in Cleveland, Ohio. Sections of this report describe the pilot design assumptions, the site selected, data obtained, and problems encountered with conventional sampling methods. A recommendation for improved sewage sampling is included. Costs of construction and operation are estimated for overflows to 10 MGD.

The most important overall findings, however, can be quite simply stated and are supported more by observation than by the data returned via conventional sampling. A rapid-flow filter for combined sewer overflows will remove gross objects from large volume overflows. It will operate on demand, without any need for labor except as occasional or routine maintenance. If the removed sewage solids are protected from direct sun, and if the filter medium is coarse coal, no objectionable odor is associated with the operation. No flies congregate, no nuisance factors are observed. From visual observation, it is believed that aerobic digestion of organic materials occurs; if this be so, decomposable organics would be reduced in their ultimate demand for oxygen in surface waters when the residues reach those waters.

The filter performance was not affected adversely by any extremes of weather, including severe cold. If, on occasion, the filter bed does become plugged or is otherwise unable to pass the entire overflow (or is not in place) the situation merely reverts to current overflow practice. While such diversion of overflows directly to surface receiving waters would be unfortunate in that no solids would be removed during such period, it would be a temporary return to conventional practice.

A filter bed of 3/4" x 1-1/4" nominal diameter media has been shown to have an extended life, extending for many months. In many situations, replacement every several months would be entirely adequate.

Naturally, any filter bed life is a function of flow and solids contained therein, if any of the solids are captured. It is visualized that rapid-flow overflow filters can be maintained either on some routine basis or upon visual inspection. Inspection readily reveals whether a filter bed is plugged with non-decomposable solids, i.e. cans, bottles, plastic items, and should be replaced. Evidence that the filter device itself had overflowed would suggest replacement; this information could be telemetered if desired.

There appear to be two substantive limitations to the rapid-flow filter concept for removing gross solids from combined sewer overflows. One consideration is that large diameter overflow situations will require so large a filter bed area as to become prohibitive in terms of available land, cost of construction or of servicing. The second consideration is that the data obtained in this work are not conclusive in showing numerically that pollution abatement is served by filtering combined sewer overflows. Conventional sewage sampling techniques were not adequate to make the numerical evidence available. However, visual observation and experimental sample gathering and analytical techniques did make it unequivocal that significant and useful quantities of solid materials are actually removed from overflows. A recommendation for an improved sewage sampling procedure is given in this report. The problem of sampling liquid streams containing solids of a variety of sizes and densities has been resolved in certain other fields of endeavor, and the recommendation draws upon that experience.

It should be noted that if one wished to remove gross solids from overflows, such existing equipment as bar screens may be employed. They are dependable and relatively compact, and in a sense competitive to filters. It should be remembered, however, that operations of conventional bar screens would require some positive and constant means of dealing with the decomposable solids removed from the overflow streams to prevent unpleasant odors and insect infestations. In the coal filter, odor and insect problems did not arise. Further, in the case of mechanically cleaned screens auxillary electric power should be provided in the event of power failure during a storm, which is precisely when the unit will be expected to operate. A design engineer will wish to consider all aspects of the several choices open to him.

SECTION 10

SAMPLING

"Standard Methods for the Examination of Water and Wastewater" is the accepted authority in the waste water field with regard to the physical and chemical examination of natural and treated waters. In this text emphasis is placed on the analytical procedures, rather than on sampling methods.

WPCF Manual of Practice No. 11 "Operation of Wastewater Treatment Plants" points out the importance of obtaining representative samples, and indicates further that in dealing with sewage this is a difficult task. This manual also states: "Nearly everyone agrees that laboratory analyses have little value or meaning if the material analyzed is not fairly representative of the conditions or quality which actually prevails."

Difficulty in obtaining representative samples is increased when one is especially concerned with raw sewage solids, and still further when one is concerned with gross solids. The WPCF Manual on Operations recommends that raw sewage samples "should be collected preferably after the waste has passed through screening and grit removing facilities."

As a result there does not now exist recommended sample collecting equipment or procedures for sampling sewage flows containing gross solids.

That sampling difficulties exist for sewage overflows was recognized by the contractor, his engineering consultants, and the sponsoring Administration. A number of approaches to the sampling problem other than conventional means were carefully considered in the original pilot design. Finally, however, conventional dipper-type sewage samplers and conventional analytical methods were selected. This decision was based on a strong recommendation by FWPCA that unless conventional equipment and procedures were used, the results derived might not be acceptable to the sanitary engineering field.

The present work encountered the expected difficulties frequently experienced in obtaining representative raw sewage or combined overflow samples. Conventional samplers were found not to provide representative samples of grossly polluted raw sewage overflow streams. Although it was not anticipated in the contract objective, one of the most meaningful conclusions that can be drawn from this program is the fact that sampling techniques for sewages can be improved with respect to flows contaminated with gross solids. Representative samples of such complex flows can be taken, and it is believed that use of improved sampling techniques would be of considerable benefit both to waste water treatment operators and also to investigators and researchers in the sanitary engineering field.

The tables of analytical results contained in the appendix of this report summarize the laboratory results obtained in this work and clearly point up the unsuitability of using conventional sewage sampling devices and analytical procedures for sewage overflows. Both are unsuitable for providing meaningful analyses of streams containing such contaminates as bottles, leaves, cans, fecal matter, contraceptives, toilet tissue, sanitary napkins, plastic articles, and the like that are found in quantity in such streams. Therefore, it must be emphasized that analyses of influent samples taken during this work have little validity except in those few instances in which segments of the total flow were taken. Moreover, standard analytical procedures fall short of numerically identifying these gross contaminants; if they are to be identified, new procedures must be defined. By observation, gross solids were invariably filtered from the overflow, yet conventional sewage sampling and analysis consistently failed to reveal that fact accurately.

An improved procedure for taking samples of liquid flows containing gross solids is to take the entire flow of the stream part of the time. If the flow rate is too great to permit this, the stream can be split in such a way that a side stream is formed which is representative of the entire stream. All of that side stream can then be taken part of the time as the sample. Periodic sampling by this method to accumulate a composite can also be practiced, where its use is indicated. In sampling combined or storm sewer overflows, where the composition varies rapidly - especially during the first portion of overflow - frequent samples would be necessary to provide a valid representation of the contents of the stream.

The proposed general sample collecting and analytical procedure is cumbersome. Sample volumes become large in order for the analyses to be accurate, but they must be large because of the large and varying sizes of the particles to be analyzed for. Also the design of the side-stream piping must be considered carefully so that the side-stream is representative of the main stream. Nevertheless, a generalized sewage or overflow sampling technique can be recommended which, it is believed, will represent an improvement over conventional sampling methods.

Sample taking and analytical procedures for determining gross solids in liquid streams:

1. Take all of the flow, part of the time. When the flow rate is large, exceeding 1000 GPM, split the stream so that the side sampling stream is about 1000 GPM and representative of the main stream. Divert the flow to a corrosion resistant deep-coned sample tank for a preselected interval between 15-60 seconds. The diversion gate must be quick acting and positive.

2. Filter the sample promptly through a filter screen after noting the volume. Retain the solids. A 60 mesh stainless steel screen is tentatively recommended.

3. Sample the filtrate conventionally as it is released at a steady flow rate from the sample tank.

4. Repeat the above three steps periodically to obtain a representation composite of the total flow.

   Dry and weigh the solids and calculate the ppm of the gross solids in the stream. Identify the solids if desired.

5. Analyze the filtrate for suspended solids and other contaminants conventionally.

The above must be considered as simply a preliminary suggestion. Improvements undoubtedly will suggest themselves in practice.

TABLE I

Rapid Flow Filter Combined Sewer Overflow Treatment Conditions and Results

Chronological Tabulation of Natural and Simulated Events

Event Number	Date	Description of Event: Natural	Description of Event: Simulated	Description of Event: Rainfall Inches	Description of Event: Rainfall Time Hour	Filter Used	Size of Coal Filter Medium	Total Filtered This Event	Maximum Overflow Rate GPM	Accumulative Total This Bed	Type of Sample	Suspended Solids In	Suspended Solids Out	Suspended Solids % Reduction	Volatile Suspended Solids In	Volatile Suspended Solids Out	Total Solids In	Total Solids Out	Volatile Total Solids In	Volatile Total Solids Out	Settleable Material In	Settleable Material Out	Settleable Material % Reduction	Total Phosphate In	Total Phosphate Out	Nitrogen In	Nitrogen Out	BOD In	BOD Out	pH In	pH Out	Color Filtrate In	Color Filtrate Out	MPN In	MPN Out	Comments
1	6-16-67		x			Hopper	1" x 2"	1,450	890	1,450	Grab-1 gal	26 0	20 0	23	8 0	15.0	768	624	226.0	136.0						2.90	1.80			6.0	6 0					New filter medium
2	6-21-67 1600 hrs	x		0 15	0.25	"	"	1,300	290	2,750	Grab-1 qt.	462 0	406 0	12	251 0	181.0	757	242	506.0	61.0				0 84	0.84	9.60	0.00			6.4	6 4					
3	6-21-67 1745 hrs	x		0 30	0.25	"	"	7,500	1,000	10,250	Grab-1 qt.	482 0	226 0	53			669	278						0 24	0.48	0.00	0.00			6.4	6 4					Total of 7,500 gallons filtered during both events
4	6-21-67 2200 hrs	x		0 33	0.25	"	"				Grab-1 qt	448 0	222 0	50			815	287						0 54	0.66	0.00	0.00			6.4	6 4					
5	7- 9-67	x		0 10	N/A	"	"	1,200	270	11,450	N/A																									
6	7-23-67	x		0 25	0.25	"	"	3,000	660	14,450	N/A																									
7	7-25-67		x			Hopper	3/4" x 1-1/4"	47,000	280	47,000	N/A																									New filter medium
8	7-28-67	x		0 25	1 00	"	"	400	110	47,400	N/A																									
9	8- 2-67	x		0 20	0 25	"	"	1,100	310	48,500	N/A																									
10	8- 9-67	x		0 30	1 00	"	"	3,400	300	51,900	N/A																									
11	8-29-67	All San	x			"	"	2,000	200	53,900	Grab	186 0	140 0	25	112 0	74.0	696	760	252 0	237.0				55 60	71 20	20.40	22.40	380.0	382.0	6.5	6 8	50	50			
12	8-30-67	Natural plus Sanitary		0 25	1 50	Baskets	3/4" x 1-1/4"	2,400	310	2,400	Inf -Auto Eff -Grab	124 0	104 0	16	42 0	30 0	326	296	160 0	140.0	1.90	1 10	42	2.10	2.40	5.30	6.80	385.0	360.0	5.7	5 0	15	15			New filter medium
13	9- 7-67		x			"	"	39,000	340	41,400	N/A																									
14	9- 9-67	x		0 65	14 00	"	"	500	80	41,900	Auto	102.0	43.0	58	50 0	28 0	261	368	124.0	135.0	0.60	0 55	8	4 50	11.50	5.20	2.40	149.0	113.0	7.1	7 2	20	10	7 3	1 2	
15	9-21-67	x (2)		0 60	9 50	"	"	1,400	110	43,300	Grab	278.0	59 0	79	108 0	7 0	256	204	108.0	85.0	1.25	0 20	84	7 00	3.30	1.30	1.30	62.0	42.0	6.1	6 6	20	20			
16	9-26-67		x			"	"	23,400	480	66,700	Auto	56 0	59 0	(5)	43 0	42 0	262	380	141 0	145 0																
17	10- 3-67		x			"	"	36,800	430	103,500	Auto	69 0	50 0	28	61 0	46 0	324	318	108 0	111 0																
18	10- 6-67		x			"	"	37,700	530	141,200	Auto	94 0	76 0	19	80 0	69 0	340	375	109 0	113 0																
19	10 -8-67	x (2)		0 55	2 30	"	"	4,900	690	146,100	Inf -Auto Eff -N/A	138 0			100 0		241		152 0		0 45			3 04		6 30				6 0						
20	10-13-67		x			Baskets	2" x 4'	30,700	550	30,700	Auto	114 0	130 0	(14)	94 0	77.0	389	396	185 0	163.0																New filter medium
21	10-16-67	x		0 25	0 25	"	"	3,200	280	33,900	Auto	24 0	84 0	(250)	6 0	36 0	122	170	74 0	17.0	0 03			<0 10	<0.10	0.80	0.40	53 0	67.0	6 0	6 4					
22	10-17-67	x		0 45	2 00	"	"	1,100	180	35,000	Auto (Inf Only)	39 0			23 0		132		82.0					0 10		0.60		54.0		7.4						
23	10-25-67		x			"	"	19,200	540	54,200	Auto	72 0	101 0	(40)	68.0	98 0	372	364	201.0	134.0				19 60	19.60					6.6	6.9					
24	11- 1-67		x			Baskets	2" x 4"	15,200	520	69,400	Auto	191 0	222 0	(16)	144 0	167 0	394	460	223 0	254 0				9 40	12 80					6 0	6 4					
25	11-21-67	x		0.18	1.50	"	"	80	15	69,480	Auto	116 0	180 0	(55)	44 0	88 0	310	260	261 0	180 0				2 00	3 60					6 2	6 3					
26	11-30-67		x			"	"	37,200	550	106,680	Auto	85 0	75 0	12	57 0	46 0	792	845	207 0	142 0	1 25	0.75	40	11 00	8 00					6 4	6 5					
27	12- 5-67		x			"	"	35,400	530	142,080	Auto	57 0	70 0	(23)	30 0	50 0	332	365	122 0	115 0	1 10	1.00	9	17 60	18.40					6 2	6 3					
28	12-12-67		x			Baskets	1" x 2"	24,500	540	24,500	Grab	38 0	39 0	(3)	34 0	36 0	380	335	120 0	110 0	1 50	1.50	0	23 00	20 80					6 3	6 4					New filter medium
29	12-18-67		x			"	"	31,800	530	56,300	Grab	35 0	39 0	(11)	29 0	36 0	382	377	162 0	162 0	1.50	1.50	0	21 00	21 40					6 3	6 6					
30	12-19-67		x			"	"	13,200	520	69,500	Grab	46 0	33 0	28	36 0	28 0	412	340	165 0	110 0	1 40	0.80	43	9 20	6 00					6 8	6 6					
31	12-22-67	x		0 50	11 00	"	"	90	25	69,590	Auto	89 0	143 0	(61)	16 0	59 0	186	218	96 0	122 0	0 30	0.60	(100)	3 25	4 10	1.70	2 20	85 0	85 0	6 4	6 4					
32	1-28-68	x		0 80	10 00	"	"	2,600	30	72,190	N/A																									
33	1-29-68	x		0 50	11 00	"	"	1,000	40	73,190	Auto (Eff Only)		71 0			27 0		478		142 0		2 50			2 40						6 2					

TABLE I (Cont'd)

Rapid Flow Filter Combined Sewer Overflow Treatment Conditions and Results

Chronological Tabulation of Natural and Simulated Events

Event Number	Date	Description of Event: Natural	Description of Event: Simulated	Rainfall Inches	Rainfall Time Hour	Filter Used	Size of Coal Filter Medium	Total Filtered This Event	Maximum Overflow Rate GPM	Accumulative Total This Bed	Type of Sample	Suspended Solids In	Suspended Solids Out	Suspended Solids % Reduction	Volatile Suspended Solids In	Volatile Suspended Solids Out	Total Solids In	Total Solids Out	Volatile Total Solids In	Volatile Total Solids Out	Settleable Material In	Settleable Material Out	Settleable Material % Reduction	Total Phosphate In	Total Phosphate Out	Nitrogen In	Nitrogen Out	BOD In	BOD Out	pH In	pH Out	Color Filtrate In	Color Filtrate Out	MPN In	MPN Out	Comments
34	2- 5-68		x			"	"	16,[illegible]	490	87,690	Auto	250 0	1[illegible].0	56	54 0	40 0	350	415	64 0	52 0	2 00	1 75	12	33 00	30 40					6 1	6 3					
35	2- 6-68		x			"	"	37,[illegible]	530	125,590	Auto	150 0	1[illegible].0	(20)	34 0	27 0	356	370	42 0	37 0	2 50	2 25	10	22 50	22 50					6 0	6 0					
36	3- 8-68		x			"	"	16,[illegible]	500	140,490	Auto	145 0	1[illegible].0	(21)	18.5	22 5	357	390	46 5	61 0	1 40	2 00	(43)	14 00	19 [illegible]					6 3	6 3					
37	3- 9-68	x		0 15	0.50	"	"	[illegible]70	35	140,660	N/A																									
38	3-15-68		x			"	"	32,[illegible]	540	173,060	Auto	67 5	1[illegible]	(52)	23 0	29 5	398	415	37 0	47 5	0 30	1.10	(267)	10 10	16.[illegible]					6 3	6 2					
39	3-28-68		x All Sun	-		Baskets	1/4" x 1-3/4"	[illegible]0	20	50	Spec	155 0	1[illegible]	(16)	22 0	20 0	507	485	28 6	25 3				9 20	9.[illegible]	17.10	12 60	48 0	36 0	6 2	6 5					COD.In-159,Out-117 New filter medium
40	4- 3-68		x All Sun			1 ft.² filter	1/4" x 1-3/4"	2,[illegible]	15	2,250	Grab	460 0	3[illegible]	25	262 0	212 0	1,240	1,225	470 8	435 0	16 00	10.00	38	46 00	44.[illegible]					7 1	7 0					COD:In-765 Out-725 New filter medium
41	4- 4-68	x		0 85	3 00	Baskets	1/4" x 1-3/4"	14,[illegible]	1,100	14,150	Auto	718 0	3,7[illegible]	([illegible]21)	192 0	470 0					2 60	6.50	(160)	Tr	Tr	[illegible].20	13 00	52 0	78 0	6 5	6 5					
42	4-14-68	x		0 50	1 25	"	1" x 2"	6,[illegible]	680	6,400	Auto	332 0	9[illegible]	([illegible]86)	142 0	290 0	650	1,625	435 0	550 0	9 00	6.00	33	5 40	9.[illegible]	[illegible].50	12 60	68 0	96 0	6 7	6.6					New filter medium Coal was oiled
43	4-23-68	x		0 50	0 25	"	"	11,[illegible]	1,300	16,200	Auto	360 0	3[illegible]	7	156 0	84 0	515	392	215 0	125.0	1 80	0.50	72	4 80	2.[illegible]	[illegible].60	3 70	26 0	18 0	6 6	6 8					
44	5-15-68	x (2)		N/A	N/A	Baskets	3/4" x 1-1/4"	6,[illegible]	100	6,400	Auto	110 0	2[illegible]	(94)	72 0	131 0	300	330	90 0	100 0	0 35	0.50	(43)	2 80	2.[illegible]	[illegible].70	4 40	10 0	23 0	6 8	6 8	Grey				New filter medium
45	5-19-68	x (3)		0 35	19 00	"	"	[illegible]	20	4,720	Auto	43 0	[illegible]	(4)	18 0	15 0					Negligible	Negligible		2 80	[illegible]			8 4	6 0	6 8	6 6	Cloudy				
46	5-26 - 5-27-68	x (4)		1 40	24 00	"	"	2,[illegible]	230	7,320	Auto	47 0	[illegible]	20	16 5	17 0		-		-										6 0	6.7			25,000	4,500	
47	6-11-68	x		0 35	1.75	Baskets	3/4" x 1-1/4"	1,[illegible]	290	8,820	N/A																									Coal was dumped and recharged before event
48	6-25-68	x (2)		0 65	7.00	"	"	3,[illegible]	320	12,420	Auto-Inf only	137 5			[illegible]9.0		252		120.0					3 20						6 6						
49	6-26-68	x		0 50	3.00	"	"	3,[illegible]	250	16,020	Auto	28 5	39 0	(37)	13 0	8.5								2.00	2.[illegible]					6 6	6 6					
50	7- 1-68		x			9 ft.² filter	1/4" x 3/4" 3/4" x 1-1/2" 1-1/2" x 2"	16,[illegible]	510	16,300	Grab	87 0	90 0	(3)	[illegible].0	26 0	316	360	136.0	232.0				42 00	42.[illegible]					[illegible].2	6 7					New filter medium in graded layers.
51	7- 5-68	x		0.30	2.00	Baskets	3/4" x 1-1/4"	3,[illegible]	250	3,[illegible]	Auto	129 0	76 0	41	[illegible].0	31 0	260	370	126.0	172.0										[illegible].2	6 5					New filter medium
52	7- 8-68		x			9 ft.² filter	1/4" x 3/4" 3/4" x 1-1/2" 1-1/2" x 2"	17,[illegible]	520	17,200	Grab	93 8	76 0	18	[illegible]2.0	50.0	500	458	232.0	182.0				44 00	42.[illegible]					[illegible].9	6 9					New filter medium in graded layers.
53	7-16-68	x		0.75	1.50	Baskets	3/4" x 1-1/4"	9,[illegible]	960	12,200	Grab	745.0	1,040 0	(40)	[illegible].0	380.0	1,120	1,428	475.0	574.0				34 00	34.[illegible]	[illegible].80	28.30	>150 0	>150.[illegible]	[illegible]	5 8			660,000	660,000	
54	7-17-68	x		3 60	3.75	"	"	155,[illegible]	[illegible],700	168,100	Auto	66 5	24 5	63	[illegible].5	3.0	316	176	118.0	70.0	0 22	0.10	55	2 00	0.[illegible]	[illegible]	1 68	20 0	9.[illegible]	[illegible].2	6 3			7,400	4,900	
55	7-23 - 7-24-68	x (6)		0.55	19 00	"	"	2,[illegible]	370	170,200	Grab	95 0	42 0	56	[illegible].0	5.0	196	168	72 0	68.0	1 20	0 10	92	2 00	1.[illegible]	[illegible].00	2 25	22 0	15 0	[illegible]	6 3					
56	7-26-68	x		0 15	0 25	"	"	1,[illegible]	380	171,[illegible]	N/A																									
57	7-31-68	x		0 25	0.25	"	"	3,[illegible]	560	174,[illegible]	Auto	66 0	240 0	(264)	[illegible]	[illegible]	196	420	[illegible]	136.0				1 00	3.[illegible]					[illegible]	6 4					
58	8- 7-68	x (2)		0 70	0 50	-	"	6,[illegible]	510	181,600	Auto	78 0	170 0	(118)	[illegible]	[illegible]	168	222	72.0	72.0				2 38	2.[illegible]			43.5	98 [illegible]	[illegible]	6 2					
59	8- 8-68	x		0 30	0.75	"	"	[illegible]	100	184,100	N/A																									
60	8-14-68		x			9 ft.² filter	(See Comment)	6,[illegible]	490	22,100	Grab	233.0	123 0	47	[illegible]	81.0	420	434	160.0	178.0	2 40	1.60	33	23 00	23 [illegible]					[illegible]	6 8					Same filter media as Event No. [illegible]
61	8-15-68	x		0 30	3.00	Baskets	[illegible]	9,[illegible]	890	193,800	Auto-Inf only	44 0			[illegible]		228		44.0					11 30						[illegible]						
62	8-17-68	x		0 75	3.00	"	"	7,[illegible]	530	201,700	Auto	75 0	42 0	44	[illegible]	9.0	152	184	72.0	74.0	0 80	0 27	66	2 40	2.[illegible]					[illegible]	6.5					
63	8-27-68		x			9 ft.² filter	1/4" x 3/4" 3/4" x 1-1/2" 1-1/2" x 2"	21,[illegible]	518	21,600	Grab	156 0	132 0	15	[illegible]	[illegible]	424	468	136.0	164 0	1 50	1 10	27	28.40	27 [illegible]					[illegible]	6.8					New filter medium

TABLE I (Cont'd)

Rapid Flow Filter Combined Sewer Overflow Treatment Conditions and Results

Chronological Tabulation of Natural and Simulated Events

Event Number	Date	Description of Event: Natural	Description of Event: Simulated	Description of Event: Rainfall Inches	Description of Event: Rainfall Time Hour	Filter Used	Size of Coal Filter Medium	Total Filtered This Event	Maximum Overflow Rate GPM	Accumulative Total This Bed	Type of Sample	Suspended Solids In	Suspended Solids Out	Suspended Solids % Reduction	Volatile Suspended Solids In	Volatile Suspended Solids Out	Total Solids In	Total Solids Out	Volatile Total Solids In	Volatile Total Solids Out	Settleable Material In	Settleable Material Out	Settleable Material % Reduction	Total Phosphate In	Total Phosphate Out	Nitrogen In	Nitrogen Out	BOD In	BOD Out	pH In	pH Out	Color Filtrate In	Color Filtrate Out	MPN In	MPN Out	Comments
64	9-[illegible]	x		0.25	0.25	Baskets	3/4 x 1-1/4"	2,900	360	2,900	Auto-Inf only	87.0			25.0		168		64.0		0.46			1.30				10.0		6.0						New filter medium
65	9- 5-68	x		0.50	0.75	"	"	6,200	870	9,100	Auto	176.0	400.0	(127)	53.0	134.0		432		224.0				2.80	5.00			12.0	43.0	6.4	6.5					
66	9-10-68	x		0.30	0.25	"	"	3,600	550	12,700	Auto	69.0	126.0	(83)	17.0	47.0	144	216	42.0	60.0	0.40	0.75	(87)	4.80	5.10			13.0	23.0	6.5	6.7					
67	9-11-68	x (2)		0.60	1.00	"	"	12,300	1,300	25,000	Grab	76.0	321.0	(244)	19.0	48.0	234	384	72.0	112.0	0.30	0.60	(100)	1.20	1.60			8.0	14.0	6.5	6.5					
68	9-22-68	x		3.60	N/A	Baskets	3/4" x 1-1/4"	35,000 Approx	N/A	60,000	Auto-Inf only	65.0			6.0		314		130.0		0.10			1.20				8.0		6.0	-					
69	9-24-68	x (2)		0.08	0.15	"	3/4" x 1-1/4"	600	150	600	N/A																									New filter medium
70	10- 3-68	x		0.15	0.25	"	"	1,200	100	1,800	Auto	128.0	184.0	(44)	80.0	70.0	286	350	128.0	168.0	2.20	1.80	18	8.00	13.00			49.0	84.0	6.8	6.5					
71	10- 3 - 10- 4-68	x (2)		0.70	5.25	"	"	22,600	270	24,400	Auto	51.0	89.0	(75)	25.0	35.0	276	276	134.0	118.0	1.50	0.70	53	5.00	4.00			18.0	15.0	6.4	6.8					
72	10- 6-68	x		0.10	3.50	"	"	360	20	24,760	Auto	49.0	87.0	(78)	32.0	56.0	310	358	108.0	190.0	0.50	0.50	0	19.00	23.00			49.0	52.0	6.8	6.8					
73	10- 7-68		x			9 ft² filter	1/4" x 3/4" 3/4" x 1-1/2" 1-1/2" x 2"	7,400	470	7,400	N/A																									New filter media in graded layers.
74	10-14-68		x			Baskets	3/4" x 1-1/4"	24,200	500	48,960	1/4" wire screen																									
75	10-18-68	x		0.20	1.00	"	"	600	30	49,560	Auto	83.0	96.0	(16)	39.0	26.0	198	200	66.0	60.0	0.70	0.70	0	3.00	5.00			22.0	25.0	6.5	6.5					
76	10-23-68		x			9 ft² filter	3/4" x 1-1/2" 1-1/2" x 2"	26,300	515	26,300	Grab Grab	84.0 70.0	79.0 80.0	6 (14)	61.0 84.0	63.0 59.0	368 400	360 408	144.0 142.0	152.0 166.0	2.50 4.00	1.80 3.00	28 25	24.00	25.00					6.6	6.6					New filter media in graded layers
77	10-25-68	x		0.50	5.75	Baskets	3/4" x 1-1/4"	4,100	320	53,660	Grab Auto	100.0 166.0	43.0 172.0	57 (4)	63.0 85.0	12.0 116.0	114 188	104 232	94.0 86.0	80.0 108.0	0.93 0.93	0.71 0.71	24 24	5.00 5.00	5.00 5.00			12.0 24.0	9.0 28.0	6.3 6.3	6.4 6.4					
78	10-30-68		x			"	"	N/A	N/A	N/A	55-gal	-	-	-	-	-	-	-	-	-	-	-		-												
79	11-28-68	x (2)		0.75	4.50	"	"	1,800	220	55,460	Auto	102.0	100.0	2	40.0	36.0	260	284	110.0	140.0	0.60	1.00	(67)	3.50	5.80			13.2	14.4	6.8	6.8					
80	12- 3-68		x	0.75	4.50	"	"	4,100	245	59,560	Grab	174.0	106.0	39	152.0	101.0	866	754	591.0	506.0	5.20	2.70	48	44.00	42.00			>100.0	>100.0	6.8	6.8					
81	12-27-68	x		1.75	19.25	"	"	2,500	40	62,060	Grab	890.0	140.0	84	420.0	58.0	1,000	290	600.0	144.0	25.00	0.70	97	36.00	7.00			>110.0	23.0	6.4	6.4					
82	1-31-69	x		0.25	4.00	"	"	600	60	63,660	Auto	74.0	115.0	(56)	24.0	29.0	352	380	116.0	142.0	0.40	0.20	50	3.10	3.30			18.0	20.0	6.3	6.3					
83	2-20-69		x			"	"	5,300	255	67,960	Grab&55 gal	190.0	188.0	1	137.0	137.0	866	840	398.0	374.0	6.00	5.50	8	63.00	61.00			>110.0	>110.0	7.0	7.0					
84	3-18-69		x			"	"	3,600	260	71,560	Grab&55 gal.	278.0	234.0	16	186.0	170.0	980	844	452.0	360.0	9.20	6.60	28	80.00	77.00			192.0	186.0	6.8	6.9					
85	3-18-69		x			"	"	2,800	250	74,360	Grab	186.0	186.0	0	146.0	136.0	836	824	328.0	308.0	7.50	5.50	37	85.00	84.00			162.0	147.0	7.0	7.1					
86	4- 4-69		x			"	"	8,000	250	82,360	Grab	134.0	141.0	(5)	183.0	180.0	678	706	410.0	284.0	5.10	3.20	37	51.00	58.00			125.0	134.0	6.4	6.4					
87	4- 5-69	x (2)		0.35	3.25	"	"	17,000	440	99,360	Auto	238.0	548.0	(130)	109.0	177.0	432	814	190.0	284.0	1.00	2.50	(150)	9.00	17.00			21.0	66.0	6.0	6.0					
88	4-10-69	x		0.50	3.50	"	"	1,000	270	100,360	Auto	288.0	372.0	(29)	79.0	128.0	336	498	114.0	160.0	1.20	2.00	(67)	2.50	3.00			41.0	69.0	6.1	6.1					
89	4-16-69		x			Baskets	3/4" x 1-1/4"	3,700	250	3,700	Grab&55 gal	87.0	97.0	(11)	69.0	75.0	624	668	258.0	250.0	4.00	2.50	37	40.00	41 [illegible]			95.0	93.0	6.8	6.8					New filter medium
90	4-18-69	x (2)		0.25	5.25	Baskets	3/4" x 1-1/4"	500	20	4,200	Auto	74.0	133.0	(80)	32.0	60.0	222	314	70.0	128.0	0.50	1.30	(160)	8.00	5.00			20.0	39.0	5.7	5.6					
91	4-18-69	x		0.20	0.50	"	"	5,600	550	9,800	Auto	260.0	481.0	(85)	81.0	133.0	420	642	142.0	174.0	1.10	1.50	(36)	5.00	5.00			21.0	30.0	6.2	6.2					

TABLE II

Beman Avenue Combined Sewer Overflow

Description of Natural Events

Event No.	Rainfall Amount Inches	Rainfall Durat-ion Hour	Rainfall Intensity Inches per Hour	Total Overflow Filtered	Maximum Overflow Rate GPM	Filter Medium Coal Size Inches
2	0.15	0.25	0.6	1,300	290	1 x 2
3	0.30	0.25	1.2			1 x 2
4	0.33	0.25	1.3			1 x 2
5	0.10	-		1,200	270	1 x 2
6	0.25	0.25	1.0	3,000	660	1 x 2
8	0.25	1.00	0.3	400	110	3/4 x 1-1/4*
9	0.20	0.25	0.8	1,100	310	3/4 x 1-1/4
10	0.30	1.00	0.3	3,400	300	3/4 x 1-1/4
14	0.65	14.00	0.0	500	80	3/4 x 1-1/4*
15	0.60	9.50	0.0	1,400	110	3/4 x 1-1/4
19	0.55	2.30	0.2	4,900	690	3/4 x 1-1/4
21	0.25	0.25	1.0	3,200	280	2 x 4*
22	0.45	2.00	0.2	1,100	180	2 x 4
25				80	15	2 x 4
31	0.50	11.00	0.0	90	25	1 x 2*
32	0.80	10.00	0.0	2,600	30	1 x 2
33	0.50	11.00	0.0	1,000	40	1 x 2
37	0.15	0.50	0.3	170	35	1 x 2
41	0.85	3.00	0.3	14,100	1,100	1/4 x 1-3/4*
42	0.50	1.25	0.4	4,400	680	1 x 2*
43	0.50	0.25	2.0	11,800	1,300	1 x 2
44				4,400	100	3/4 x 1-1/4*
45	0.35	19.00	0.0	320	20	3/4 x 1-1/4
46	1.40	24.00	0.0	2,600	230	3/4 x 1-1/4
47	0.35	1.75	0.2	1,500	290	3/4 x 1-1/4
48	0.65	7.00	0.0	3,600	320	3/4 x 1-1/4
49	0.50	3.00	0.2	3,600	250	3/4 x 1-1/4
51	0.30	2.00	0.2	3,000	250	3/4 x 1-1/4*
53	0.75	1.50	0.5	9,200	960	3/4 x 1-1/4
54	3.60	3.75	1.0	155,900	1,700	3/4 x 1-1/4
55	0.55	19.00	0.0	2,100	270	3/4 x 1-1/4
56	0.15	0.25	0.6	1,600	380	3/4 x 1-1/4
57	0.25	0.25	1.0	3,100	560	3/4 x 1-1/4
58	0.70	0.50	1.4	8,700	510	3/4 x 1-1/4

TABLE II (Cont'd)

Beman Avenue Combined Sewer Overflow

Description of Natural Events

	Rainfall					
Event No.	Amount Inches	Durat-ion Hour	Intensity Inches per Hour	Total Overflow Filtered	Maximum Overflow Rate GPM	Filter Medium Coal Size Inches
59	0.30	0.75	0.4	500	100	3/4 x 1-1/4
61	0.80	3.00	0.3	9,700	890	3/4 x 1-1/4
62	0.75	3.00	0.3	7,900	530	3/4 x 1-1/4
64	0.25	0.25	1.0	2,900	360	3/4 x 1-1/4*
65	0.50	0.75	0.7	6,200	870	3/4 x 1-1/4
66	0.30	0.25	1.2	3,600	550	3/4 x 1-1/4
67	0.60	1.00	0.6	12,300	1,200	3/4 x 1-1/4
68	3.60			35,000		3/4 x 1-1/4
69	0.08	0.15	0.5	600	150	3/4 x 1-1/4*
70	0.15	0.25	0.6	1,200	100	3/4 x 1-1/4
71	0.70	5.25	0.1	22,600	270	3/4 x 1-1/4
72	0.10	3.50	0.0	360	20	3/4 x 1-1/4
75	0.20	1.00	0.2	600	30	3/4 x 1-1/4
77	0.50	5.75	0.1	4,100	320	3/4 x 1-1/4
79	0.75	4.50	0.2	1,800	220	3/4 x 1-1/4
81	1.75	19.25	0.1	2,500	40	3/4 x 1-1/4
82	0.25	4.00	0.1	600	60	3/4 x 1-1/4
87	0.35	3.25	0.1	17,000	440	3/4 x 1-1/4
88	0.50	3.50	0.1	1,000	270	3/4 x 1-1/4
90	0.25	5.25	0.0	500	20	3/4 x 1-1/4*
91	0.20	0.50	0.4	5,600	550	3/4 x 1-1/4

* Filter changed with fresh coal.

TABLE III

Rapid Flow Filter Combined Sewer Overflow
Treatment Results

Natural Events - Conventional Automatic Samples

Event No.	% Reduction: Suspended Solids	% Reduction: Settleable Solids	% Volatile: Susp. Solids In.	% Volatile: Susp. Solids Eff.	% Volatile: Total Solids In.	% Volatile: Total Solids Eff.	Character of Overflows
14	58		49	65	48	37	Low Flow
21	(250)		25	43	60	34	
25	(55)		38	49	84	69	Low Flow
31	(61)	(100)	18	41	52	56	Low Flow
41	(421)	(160)	27	13			High Flow
42	(186)	33	43	31	70	18	
43	7	72	43	25	42	32	High Flow
44	(94)	(43)	66	62	30	30	
45	(4)		42	34			Low Flow
46	20		35	45			
49	(37)		46	22			
51	41		38	41	48	46	
54	63	55	25	12	37	40	High Flow
57	(264)		21	33	35	32	
58	(118)				43	35	High Flow
62	44	66			47	48	High Flow
65	(127)					52	High Flow
66	(83)	(87)	25	37	39	28	
70	(44)	18	39	38	45	48	
71	(75)	53	49	39	49	43	
72	(78)	0			35	53	Low Flow
75	(16)	0	47	27	33	30	
77	(4)	24	51	67	46	47	
79	2	(67)			42	49	
82	(56)	50	32	25	33	37	
87	(130)	(150)	46	32	44	35	
88	(29)	(67)	27	34	34	32	
90	(80)	(160)	43	45	32	41	Low Flow
91	(85)	(36)	31	28	34	27	High Flow

TABLE IV

Rapid Flow Filter Combined Sewer Overflow
Treatment Results

Natural Events - Grab Samples

Event No.	% Reduction: Suspended Solids	% Reduction: Settleable Solids	% Volatile: Suspended Solids In.	% Volatile: Suspended Solids Eff.	% Volatile: Total Solids In.	% Volatile: Total Solids Eff.	Comments
2	12		54	45	67	25	
3	53		-	-	-	-	
4	50		-	-	-	-	
15	79		39	12	42	42	
53	(40)		43	37	42	40	High Flow
55	56	92	27	12	37	46	
67	(244)	(100)	25	22	31	29	High Flow
77	57	24	63	28	83	77	
81	84	97	47	41	60	50	Low Flow

TABLE V

Rapid Flow Filter Combined Sewer Overflow
Treatment Results

Simulated Events (Diluted Sanitary Sewage) - Conventional Automatic Samples

Event No.	% Reduction		% Volatile				Comments
	Suspended Solids	Settleable Solids	Suspended Solids		Total Solids		
			In.	Eff.	In.	Eff.	
16	(5)		77	71	54	38	
17	28		89	92	33	35	
18	19		85	91	32	30	
20	(14)		83	59			
23	(40)		94	97	54	37	
24	(16)		75	75	57	55	
26	14	40	66	61	26	17	
27	(23)	9	53	71	37	32	
34	56	8	22	36	18	13	
35	(20)	0	23	15	12	10	
36	(21)	(36)	13	19	13	16	
38	(52)	(11)	34	39	9	11	

TABLE VI

Rapid Flow Filter Combined Sewer Overflow Treatment Results

Simulated Events (Diluted Sanitary Sewage) - Grab Samples

Event No.	% Reduction: Suspended Solids	% Reduction: Settleable Solids	% Volatile: Suspended Solids In.	% Volatile: Suspended Solids Eff.	% Volatile: Total Solids In.	% Volatile: Total Solids Eff.	Comments
1	23		31	75	29	22	
11	25				26	31	No dilution
28	(3)	0	89	92	32	33	
29	(11)	0	83	92	42	43	
30	28	43	78	85	40	32	
40	25	38	57	62	38	36	1 ft.^{2} filter No dilution
50	(3)		25	29	43	65	9 ft.^{2} filter
52	18		72	67	46	40	9 ft.^{2} filter
60	47	33	40	66	38	41	9 ft.^{2} filter
63	12	37	41	45	46	35	9 ft.^{2} filter
76	6	28	73	80	39	42	Sample from early part of run. 9 ft.^{2} filter
	(14)	25	77	74	36	41	Sample from latter part of run.
80	39	48	87	95	68	67	
85	0	37	79	73	39	37	
86	(5)	37	77	71	61	40	
89	(11)	37	79	77	41	37	

TABLE VII

Rapid Flow Filter Combined Sewer Overflow
Treatment Results

Simulated Events - Grab Samples

Filter Media: Stratified Bed using 1/4 x 3/4; 3/4 x 1-1/2; and 1-1/2 x 2 Coal

	% Reduction		% Volatile				
			Suspended Solids		Total Solids		
Event No.	Suspended Solids	Settleable Solids	In.	Eff.	In.	Eff.	Comments
50	(3)		25	29	43	65	
52	18		72	67	46	40	
60	47	33	40	66	38	41	Same filter medium as for Event No. 52
63	12	37	41	45	46	35	
76	6	28	73	80	39	42	Sample from early part of run.
	(14)	25	77	74	36	41	Sample from latter part of run.

Note: The filter bed for Event No. 76 did not contain the 1/4 x 3/4 coal layer

TABLE VIII

Rapid Flow Filter Combined Sewer Overflow

Treatment Results

Results of Initial Runs through a Filter Bed

Event No.	Descr. of Event	Type of Sample	% Reduction Sus. Sol.	% Reduction Sett. Sol.	% Volatile Sus. Sol. In	% Volatile Sus. Sol. Eff	% Volatile Total Solids In.	% Volatile Total Solids Eff.	Filter Medium Coal Size, Inches	Comments
1	Sim.	Grab	23	-	31	75	29	22	1 x 2	
7	Sim.	N.A.							3/4 x 1-3/4	
12	Sim. & Nat.	Grab	16	-	34	29	49	47	3/4 x 1-1/2	
20	Sim.	Auto	(14)	-	83	59	-	-	2 x 4	
28	Sim.	Grab	(3)	0	89	92	32	33	1 x 2	
40	Sim.	Grab	25	38	57	62	38	36	1/4 x 1-3/4	
41	Nat.	Auto	(421)	(160)	27	13	-	-	1/4 x 1-3/4	First significant run with this filter
42	Nat.	Auto.	(186)	33	43	31	70	18	1 x 2	
44	Nat.	Auto.	(94)	(43)	66	62	30	30	3/4 x 1-1/4	
50	Sim.	Grab	(3)	-	25	29	43	65	1/4 x 2	Coal in 3 graded layers
51	Nat.	Auto	41	-	38	41	48	46	3/4 x 1-1/4	
52	Sim.	Grab	18	-	72	67	46	40	3/4 x 2	Coal in 3 graded layers
63	Sim.	Grab	12	37	41	45	46	35	3/4 x 2	Coal in 3 graded layers
64	Nat.	Mixed	-	-	-	-	-	-	3/4 x 1-1/4	Sample results not comparable
69	Nat.	N.A.	-	-	-	-	-	-	3/4 x 1-1/4	
73	Sim.	N.A.	-	-	-	-	-	-	1/4 x 2	Coal in 3 graded layers
76	Sim.	Grab	6, (14)	28, 25	73, 77	80, 74	39, 36	42, 41	3/4 x 2	Coal in 2 graded layers
89	Sim.	Grab	(11)	37	79	77	41	37	3/4 x 1-1/4	

TABLE IX

Rapid Flow Filter Combined Sewer Overflow
Treatment Results

Simulated Events - Experimental Filter Screen Sampling Technique

Event No.	Mesh Size in Screen	% Reduction Filterable Solids	% Reduction Suspended Solids	% Reduction Settleable Solids	Comments
74	4	57.7			
76	2	36.8	6	28	Grab Samples
89	8	38.0	(11)	37	Grab Samples

TABLE X

Rapid Flow Filter Combined Sewer Overflow
Treatment Results

Simulated Events - Total Segment Sampling Technique

	Weight of Dried Solids		% Reduction			
Event No.	Influent	Effluent	Filterable Solids	Suspended Solids	Settleable Solids	Comments
78	23.2	13.0	43.9			
80	29.7	17.1	42.5	39	48	Grab Sample
84	49.1	31.0	36.9	16	28	Grab Sample
89	47.2	25.1	46.9	(11)	37	Grab Sample

TABLE XI

Rapid Flow Filter Flow Rate Tests

Raw Sanitary Sewage — 1.1 ft^2 Coal Packed Filter

Flow Rate Test No.	Filtration Rate-GPM	Coal Size inches	Total Flow before pluggage gal.	Comments
1.	100	3/4 x 1-1/4	1,500	Sewage was comminuted
2.	140	3/8 x 6	> 20,000	
3.	140	3/8 x 1-3/8	2,380	
4.	140	1-3/8 x 2	48,000	
5.	140	4 x 6	>230,000	
6.	140	3 x 4	> 80,000	
7.	140	3 x 4	> 50,000	
8.	140	2 x 3	> 50,000	
9.	140	1-3/8 x 2	48,000	
10.	140	1-3/8 x 2	36,000	
11.	140	1 x 1-3/8	48,000	
12.	140	1 x 1-1/2	36,000	
13.	140	3/4 x 1-3/8	46,000	
14.	140	3/4 x 1-3/8	36,000	
15.	140	3/4 x 1	37,500	
16.	140	3/4 x 1	26,000	
17.	140	3/4 x 1	18,000	
18.	140	3/4 x 1 and 1 x 1-3/8	28,000	2 layers of coal
19.	140	3/4 x 1 and 1 x 1-3/8	19,000	2 layers of coal
20.	140	1 x 1-3/8 and 1-3/8 x 2	48,000	2 layers of coal
21.	140	1 x 1-3/8 and 1-3/8 x 2	43,000	2 layers of coal
22.	140	1-3/8 x 2 and 2 x 2-3/4	50,000	2 layers of coal

TABLE XI (Cont'd)

Rapid Flow Filter Flow Rate Tests

Raw Sanitary Sewage — 1.1 $ft.^2$ Coal Packed Filter

Flow Rate Test No.	Filtration Rate-GPM	Coal Size inches	Total Flow before pluggage gal.	Comments
23.	140	1-3/8 x 2 and 2 x 2-3/4	38,000	2 layers of coal
24.	140	2 x 2-3/4 and 2-3/4 x 4	50,000	2 layers of coal
25.	140	2 x 2-3/4 4 x 6	>50,000	2 layers of coal
26.	140	3/4 x 1	46,800	
27.	140	1 x 1-3/8	49,800	
28.	140	1-3/8 x 2	54,000	
29.	140	3/4 x 1 and 1 x 1-3/8	28,000	2 layers of coal

TABLE XII

Rapid Flow Filter Solids Removal Tests

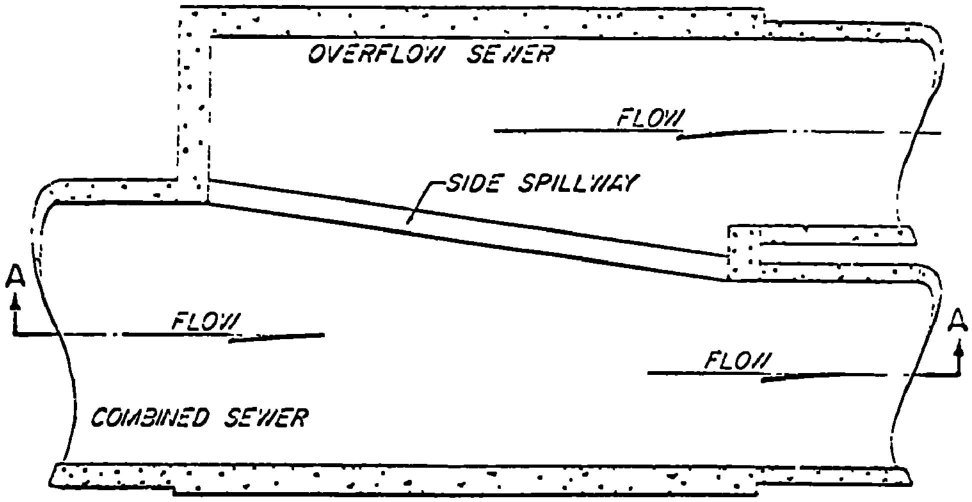
Raw Sanitary Sewage — 1.1 ft^2 Coal Packed Filter

Solids Removal Test No.	Filtration Rate-GPM	Coal Size Inches	% Solids Reduction*	Comments
1.	140	3/4 x 1	66	
2.	140	1 x 1-3/8	40	
3.	140	1-3/8 x 2	27	
4.	140	2 x 3	23	
5.	140	3 x 4	18	
6.	140	3/4 x 1 and 1 x 1-3/8	68	2 layers of coal
7.	140	1 x 1-3/8 and 1-3/8 x 2	53	2 layers of coal
8.	140	1-3/8 x 2 and 2 x 3	40	2 layers of coal

* The amount of solids in the influent and effluent streams was measured by filtering 1,000 gal through a nylon tulle net bag containing 1/16" holes and then weighing the dried solids.

Figure I. Twin outfall near Dorver Avenue and East 77th Street in Cleveland, Ohio

Figure II. View of typical houses on Beman Avenue



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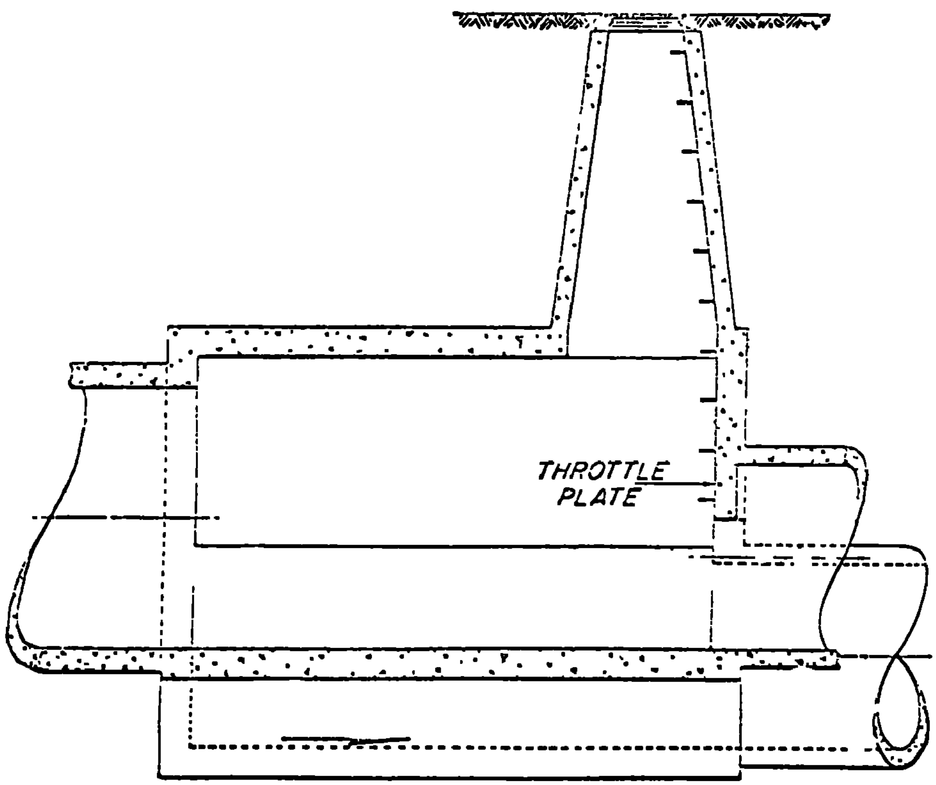

SECTION A-A

Figure III. Side spillway type Overflow Structure

Figure IV. Topographical representation of Beman Avenue drainage area. Pilot filter site is 30 feet from west end of Dorver Avenue, 1"=170'

Figure V. Appearance of filter basket with filtered solids.

Figure VI. Some of the larger solids removed from a combined sewer overflow by the Rapid-Flow Filter.

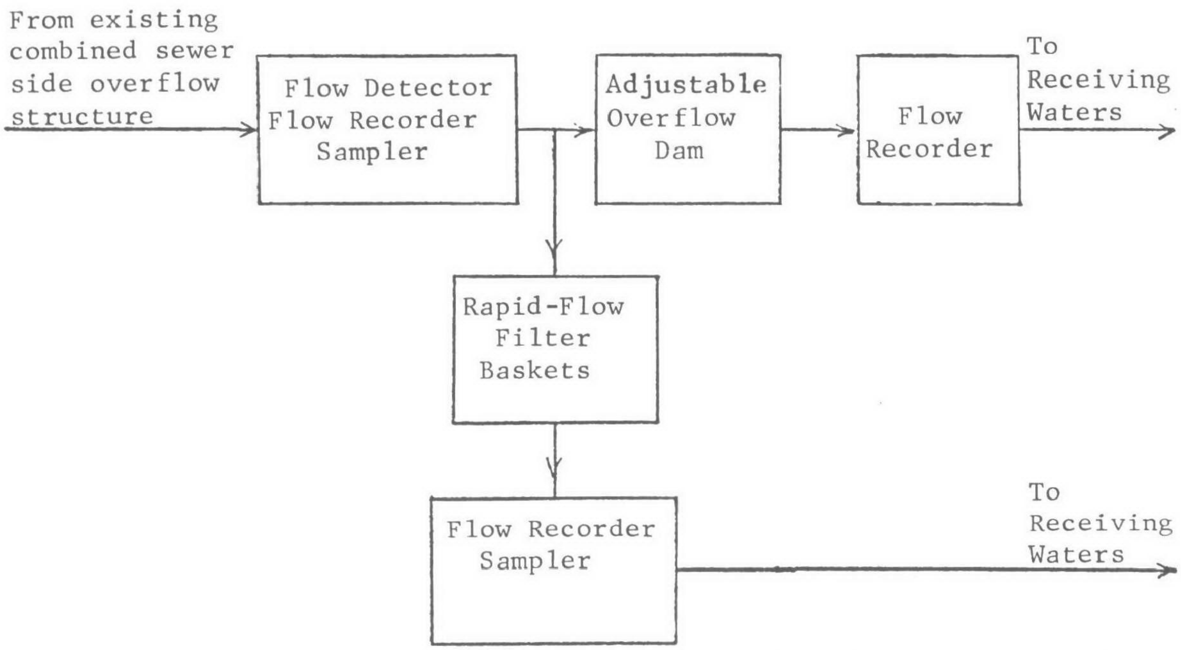

Figure VII. Rapid-Flow Filter Pilot Plant Flow Sheet

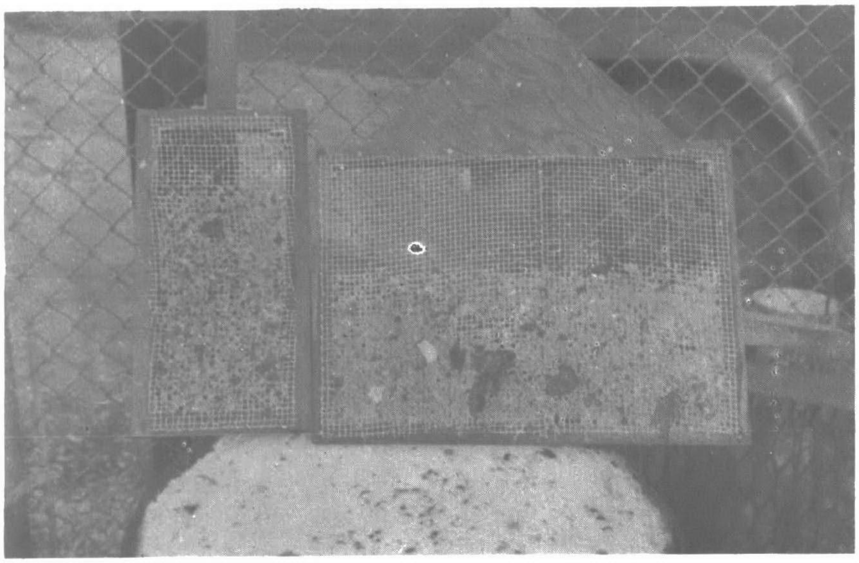

Figure X. View of the solids sampling screens before air drying. Effluent sample on left, influent on right.

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APPENDIX I

Sample Handling and Analysis

Samples were gathered automatically and collected in plastic five gallon cans. Each five gallon can was then stirred and a two gallon bottle was filled from it. The two gallon bottles were then stored in a refrigerator (5° C) until analyzed during the next weekday day shift. The samples were stored at ambient temperatures at the collection site for varying lengths of time if a natural overflow event had occurred. They were refrigerated within two hours if a simulated event was sampled.

Simulated runs were all made during the day shift so that the amount of time that these samples were not refrigerated before being analyzed was fairly uniform. This type of handling was also characteristic of all the grab samples from the natural events.

In the laboratory the samples were transferred to a two gallon polyethylene vessel equipped with a 500 RPM mixer. Sample increments for the various analyses were taken from this agitated vessel through a 1/2 inch I.D. spigot.

The 12th Edition of Standard Methods for the Examination of Water and Wastewater was used for all analyses with minor modifications:

1. Suspended Solids

   Eight-micron porous plastic (Millipore) filters were used in all cases. A sample volume was selected that would pass the filter in less than five minutes. Duplicates were run in all cases.

2. Total Solids

   Twenty-five milliliter samples were dried in tared crucibles at 105° C overnight. Duplicates were run.

3. pH

   A Corning Model 7 pH meter with a glass electrode was used. A pH 7.05 phosphate buffer was used for calibration before each use.

4. Volatile Solids

Samples in tared crucibles were heated for twenty minutes at 600° C. Duplicates were run.

5. PO_4

Phosphates were run by the amino naphthol sulfonic acid method as outlined in Standard Methods.