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Project Summary

Hydro Brake Regulated Storage System for Stormwater Management

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The City of Cleveland, Ohio, and the EPA Great Lakes National Program Office investigated the effectiveness of using a proprietary device to control the release of off-line storage of stormwater. The device, the Hydro Brake,* purportedly permits discharge at a relatively constant rate under varying head conditions. The primary objective of this investigation was to evaluate the ability of the Hydro Brake to effectively regulate specific design flows from storage structures to such an extent that (1) sewers could be protected from surcharging and creating combined sewer overflow into receiving waters and (2) basement and street flooding could be minimized in upstream residential areas.

Three underground storage tanks were constructed using 1.2- to 1.4 m-diameter pipes that were outfitted with Hydro Brakes of different flow rates. The 57- to 283-m^3-capacity tanks were filled with water from nearby fire hydrants, and their rates of discharge were measured to establish discharge curves for the Hydro Brakes. To evaluate these tests, the discharge curves of equivalent-size orifices were compared. Monitored stormwater flows were similarly evaluated. In addition, 1-, 5-, and 10-year return-period storms were identified from storm frequency tables. Stormwater inlet and discharge hydrographs and storage needs were then calculated from the storm runoff data and the observed discharge curves. Homeowners were surveyed to evaluate the effects of the Hydro Brake/storage installations on street and basement flooding.

It was demonstrated that the Hydro Brakes did release storm flows to combined sewers more slowly and at a rate more nearly independent of head than orifices of equivalent size. Also, the use of the Hydro Brake-storage tank system appeared to reduce the incidence of street and basement flooding.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, and the EPA Great Lakes National Program Office, Region V, Chicago, IL, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Combined sewer overflow (CSO) is designed into many urban sewer systems as the primary method of relief when flows exceed the capacity of the systems. Although CSO provides hydraulic relief for receiving sewers and sewage treatment plants, it also carries pollutants to streams and other water bodies. CSO occurrences can be eliminated, or their impacts attenuated, by a variety of acceptable methods. These methods, however, are not always effective in relation to another set of problems often associated with combined sewer systems—basement and roadway flooding. Those CSO control techniques that include flow retardation may actually exacerbate flooding problems.

Investigations have been undertaken to determine cost effective methods to

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

abate CSO without making flooding worse or to abate flooding and surcharging without increasing CSO. Much of this effort has concentrated on methods to retain upstream stormwater without worsening local flooding. One method has been to store upstream stormwater and release it to receiving sewers after downstream stormwater has drained. This approach avoids upstream flooding by not allowing stormwater into sewers until capacity is available, and avoids downstream surcharging and CSO by permitting downstream flow to be conveyed away before upstream flows can arrive.

The City of Cleveland, Ohio, and the EPA Great Lakes Demonstration Program investigated the effectiveness of off-line storage with release controlled by a proprietary device, the Hydro Brake, that purportedly permits discharge at a relatively constant rate under varying head conditions. The primary objective of this investigation was to evaluate the ability of the Hydro Brake to effectively regulate specific design flows from stormwater storage structures so that (1) receiving sewers could be protected from surcharging and creating CSO conditions, and (2) basement and street flooding could be minimized in upstream residential areas.

Description of Hydro Brake-Storage Installations

The Hydro Brake is a proprietary flow regulator device that purportedly acts as an energy dissipator by imparting a vortex pattern to the flow passing through the device. This static device is said to develop control energy from the physical geometry of the head above the unit—as resistance to flow increases with increasing head, the rate of increase of the discharge from the device is reduced. This head-discharge relationship results in a much "flatter" rating curve than does the discharge from unrestricted openings or orifices of the same size. The "horizontal conical" Hydro Brake unit is constructed as a frustum of a cone, having a sealed lower base and an open upper base, which is the discharge side of the device. A schematic diagram of a Hydro Brake regulator is shown in Figure 1. The diameter of the upper base describes the size of the unit. The cone is oriented horizontally such that its axis defines the effective direction of flow. The flow enters through a slot along the face of the cone between the two bases. The orientation of this entry slot and the conical shape combine to produce the spiral flow pattern inherent with the flow regulating capability of the Hydro Brake.

At each of the three Hydro Brake installations, a stormwater retention structure is located at the low point of a drainage area and a Hydro Brake regulator device is installed at the effluent end of each structure. Discharge is to the existing combined sewers. Figure 2 depicts the W. 170th Street installation which is typical of all three sites. To direct runoff to these units, there was some minor storm sewer construction and plugging of catch basin leads in the immediate vicinity of the Hydro Brake structures. Catch basins in more remote locations of each drainage area were modified through installation of 0.05 cfs (1.4 L/s) and .25 cfs (7.1 L/s) Hydro Brake devices. When surface runoff rates exceed these values, storm flows bypass the catch basins, flow along the street gutter system, and drain to the retention structures.

The W. 170th Street Hydro Brake control structure consists of one 48-in.-diameter (1.2 m) round corrugated metal pipe, 163 ft (50 m) long, sealed at both ends to form a tank. The storage volume is approximately 2,000 ft^3 (57 m^3), and the tank is buried 7 ft (2.1 m) to the invert.

The Hydro Brake is located at the discharge end of the tank and is inserted in a 12-in. (0.30 m) pipe, which discharges to the 21-in. (0.53 m) combined sewer. Two Hydro Brakes having discharge ratings of 2.0 and 1.25 cfs (57 and 35.4 L/s) were tested at the site.

The W. 177th Street Hydro Brake control structure consists of two 156-ft-long (47.5 m), 87- x 63-in. (2.2 x 1.6 m) cross-section corrugated-metal arch pipes, buried 8 ft (2.4 m) to the invert, with a total volume of 10,000 ft^3 (283 m^3). The two tanks are joined together by a 24-in. (0.61 m) pipe. The Hydro Brake unit is inserted in the 12-in. (0.30 m) effluent line from a connecting manhole and is drained to the 18-in. (0.46 m) combined sewer. Hydro Brakes with ratings of 1.5 and 0.25 cfs (42 and 7.1 L/s) were evaluated at this installation.

The Puritas Avenue Hydro Brake Control structure is a corrugated arch pipe 170 ft (52 m) long with a cross section of 95 x 67 in. (2.4 x 1.7 m). It is buried 10 ft (3 m) to the invert. Total volume is 5,800 ft^3 (164 m^3). At the downstream end of the tank there is an 18-in (0.46 m) spiral corrugated pipe

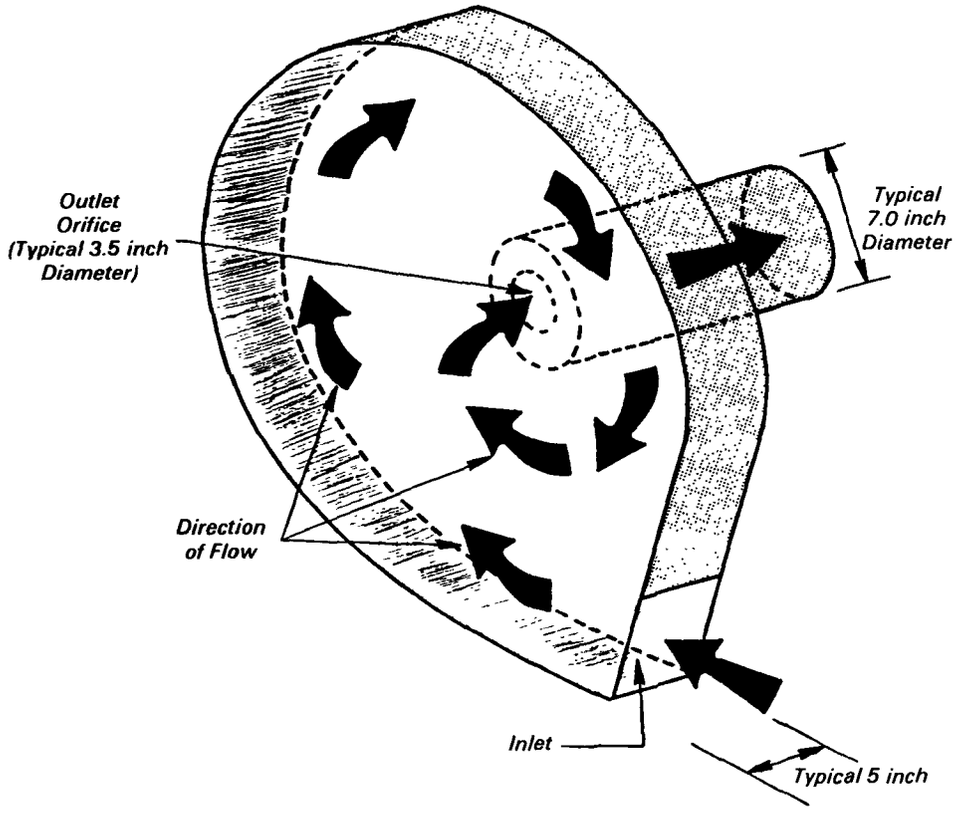

Figure 1. *Schematic of hydro-brake regulator.*

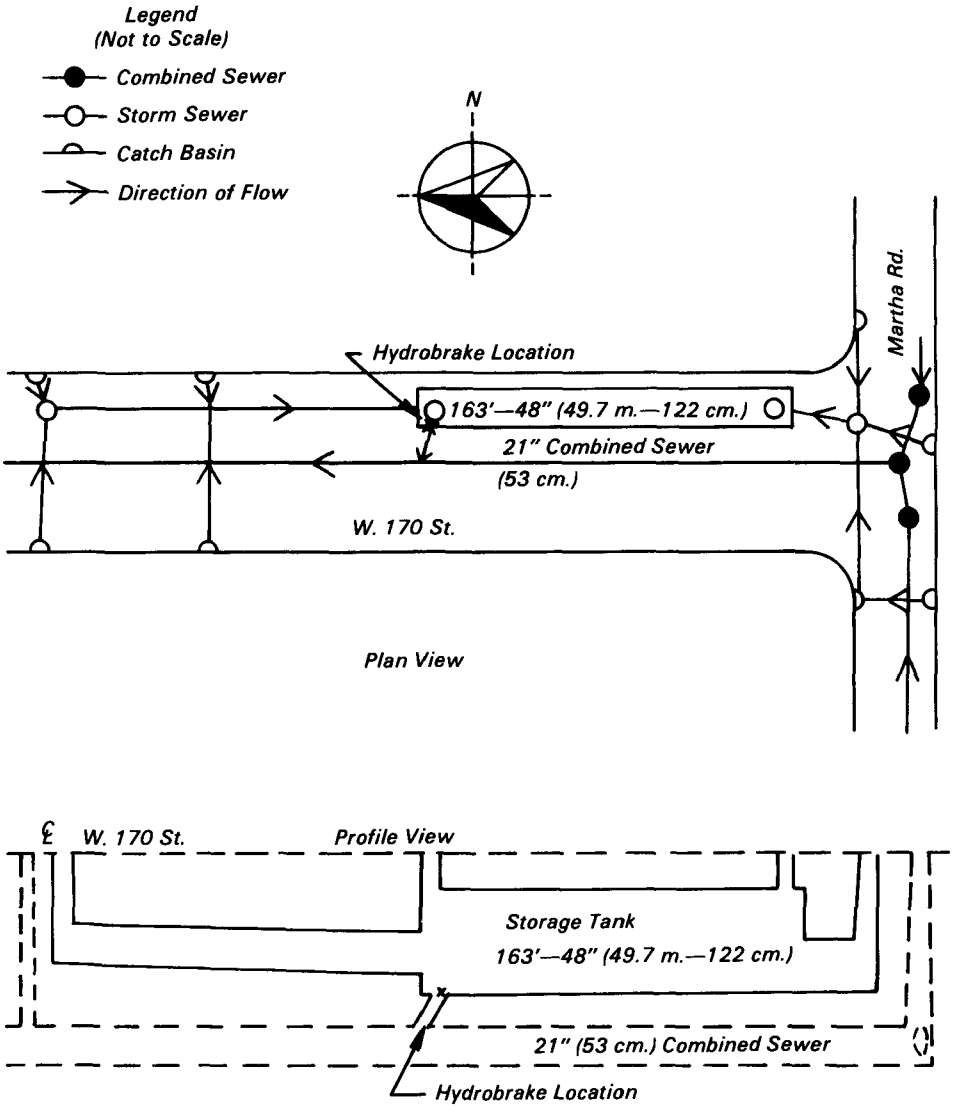

Figure 2. W. 170 St. installation.

leading to a manhole containing the Hydro Brake unit. This manhole has an invert approximately 3.3 ft (1 m) below the invert of the tank. An 18-in. (0.46 m) effluent line from the Hydro Brake manhole discharges to the 42-in. (1.1 m) brick combined sewer. The original installation consisted of a 7.0 cfs (197 L/s) rated Hydro Brake. A new unit rated at 1.0 cfs (28 L/s) was installed later in the project.

Study Approach

The Hydro Brakes were calibrated by filling the storage tanks with water from nearby fire hydrants and measuring head and flow to develop discharge curves. Five storm events were monitored for inflow, hydraulic head on the Hydro Brakes, and discharge. Discrete and composite water quality samples were taken from the storage tanks and analyzed for biochemical oxygen demand (BOD_5), volatile suspended solids, and total suspended solids. Composite samples were analyzed for total organic carbon, chemical oxygen demand, chlorides, sulfates, copper, cadmium, chromium, lead, and zinc. Sedimentation in the storage tanks was observed, and discharge curves were developed and analyzed for each of the Hydro Brakes. In addition to the hydraulic monitoring and water quality analysis, observations of the operating characteristics of the device were made, homeowner interviews were undertaken, performance of the devices were evaluated using storm simulation techniques, and similar installations in other communities were comparatively analyzed using data from published reports. With this information, an analysis of the efficacy and cost effectiveness of the off-line storage/Hydro Brake system as a CSO attuentuation and flooding relief approach was prepared.

Findings

This study examined the performance and design concept of the Hydro Brake method of flow control for regulating peak runoff rates from the temporary storm-flow storage. This application was evaluated in relation to its ability to reduce combined sewer surcharge and to minimize flooding problems. Study findings include:

1. The Hydro Brake device does regulate flow rates at relatively constant levels once an effective operating head has been developed. Below the effective range of heads, however, the device behaves as an orifice. Hydro Brake flow rates above the effective operating head are substantially lower than those for an orifice or other clear opening of the same size. The head-discharge curves for the W. 170th Street Hydro Brake and an equivalent size orifice are shown in Figure 3.
2. The flow regulating capability of the Hydro Brake combined with a storage system reduces CSO peak rates and total volumes by reducing the stormwater inflow rate to the sewers upstream of the control point and by delaying the drainage of storm runoff. The data presented in Figure 4 shows the potential effectiveness of the W. 170th Street installation.
3. By reducing the peak flow in the sewer system, combined overflow pollutant loadings are reduced because the first flush effect is dampened.
4. Hydro-Brake-regulated storage tanks are effective in alleviating sewer surcharge and basement flooding problems.
5. Reduction in peak flow by the Hydro-Brake-regulated detention system depends on the percentage of total runoff that can be inter-

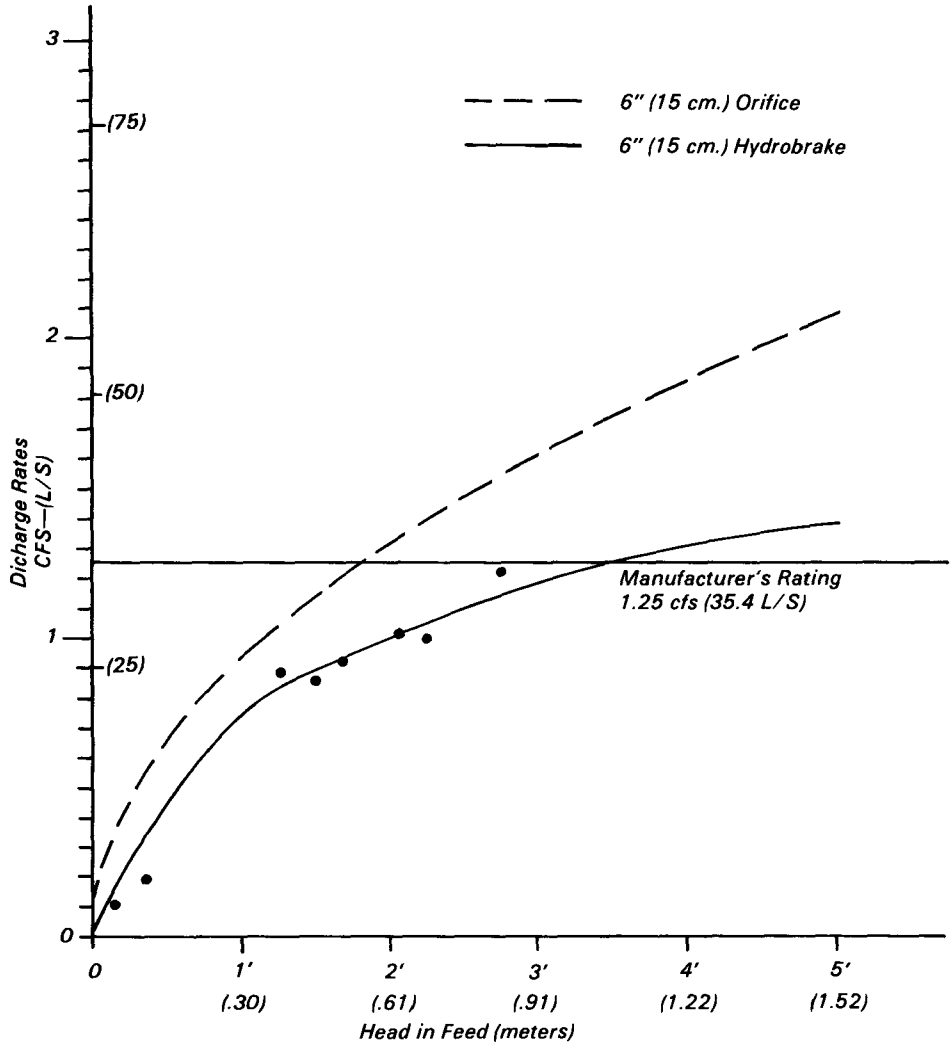

Figure 3. W. 170 St. head-discharge curves:redesign.

cepted, as well as the level of control and discharge rate desired. Using discharge rates that are less than the available excess capacity in receiving sewers may depend on the availability of surface storage or the feasibility and expense of additional below grade storage, or both.

6. To regulate stormwater flow rate, orifices can be used to control the inlet, but the orifice size must be smaller than that of the Hydro Brake needed for the discharge rate desired. The use of an orifice results in a larger range of discharge rates and a higher peak discharge rate over a given range of heads when compared with a Hydro Brake of the same size as the orifice.
7. For effective application of the Hydro-Brake-regulated technology, the design approach must include accurate characterization of drainage areas and sewer hydraulics to properly identify site-specific release rate requirements. The level of control desired determines the required storage volume, and the characteristics of the site determine whether to employ above-grade or below-grade storage, or a combination thereof.
8. Where surface ponding is an acceptable form of stormwater storage, the application of Hydro Brakes alone is more cost-effective than Hydro Brakes used in conjunction with off-line, below-grade storage structures. Both applications, however, appear to be more cost-effective than the other evaluated alternatives where both surcharging and overflows are the prevailing problems.
9. The design and construction of surface inlet control-storage systems and below grade storage structures with their related appurtenances, are the major cost elements in the application of these systems. The cost of the Hydro Brakes is a small portion of the total project cost.
10. Because the Hydro Brake is a specialty item, sufficient lead time must be allowed for manufacturing and delivery delays. Installation of the device is relatively simple where the proper clearances have been provided in control structures.
11. During the first 18 months of operation, the Hydro Brake control/detention structures exhibited minimal maintenance requirements. Solids deposition in the storage tanks was negligible and did not increase significantly with time.
12. The minimum practical size of Hydro Brake devices appears to be approximately 2 in. (5 cm), provided that inlet structures are trapped or otherwise constructed to capture debris this size and larger. Two-inch (5 cm) units were used in catch basins in Cleveland without any reported incidents of plugging. Smaller sizes of Hydro Brakes are possible where stormwater flows are relatively clean, as has been suggested for downspout control on rooftop storage systems.
13. Hydro Brake regulated catch basins in depressed areas may cause surface flooding or exacerbate existing problems.

Comparison with Other Installations

Hydro Brake flow regulator devices have been used and evaluated in Rochester, New York; Napean Township, Ottawa, Canada; Borough of York, Ontario , Canada; Euclid, Ohio; and in Cleveland, Ohio, the site of the study reported here. Applications varied, as did the sizes of drainage areas and the control systems configurations. Although differences in monitoring and calculation methodologies among the studies make quantitative comparisons difficult, it is apparent that in Rochester, Napean Township, and Cleveland the Hydro Brakes, in combination with storage (surface or underground) did reduce peak flows, thereby delaying entry of stormwater into the sewer system. Therefore, in all three cases, additional

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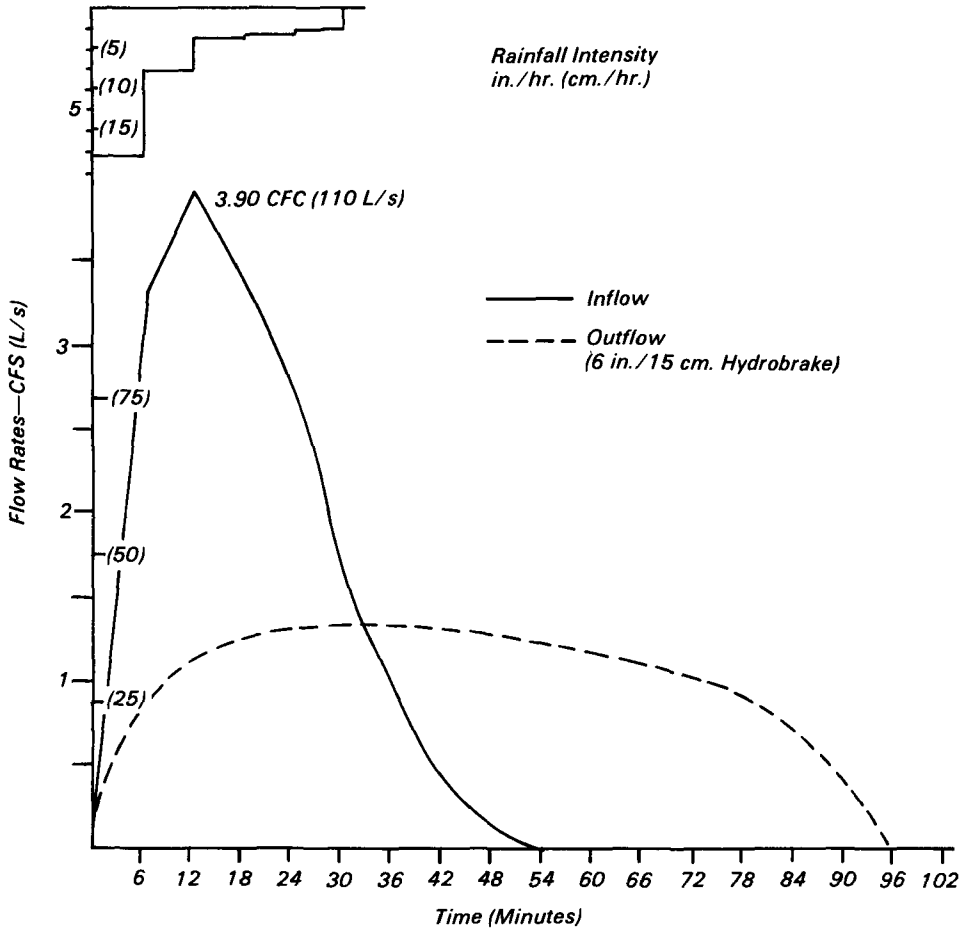

Figure 4. *W. 170 St. design storm hydrographs 10 yr. return—1/2 hr. duration (1.37 in.-3.48 cm.).*

sewer capacity was made available during the monitored storm events. Comparative flow rate analyses of ordinary orifices, similar in size to the Hydro Brake devices, strongly suggest that the Hydro Brakes were able to control flow using larger outlets than would have been possible with a standard orifice.

In addition, the Cleveland study indicates that by making additional sewer capacity available, basement flooding and street flooding were reduced. The City of Euclid reports similar results. With the use of Hydro Brakes in catch basins and street storage, the City of Euclid was able to reduce catch basin surcharging and, consequently, basement flooding caused by back-up flows from those catch basins.

The method of storage appears to be relatively unimportant. As suggested in the study prepared for the Borough of York, the uses and needs of the project area should determine the type of storage —street, roof, and parking lot or buried off-line tank. Then the Hydro Brake is designed to best serve the discharge rate and chosen storage method.

Hydro Brakes, by retarding flow while permitting a larger outlet, appear less likely to become fouled by refuse than would a smaller orifice of comparable discharge rate. As demonstrated in Cleveland, however, Hydro Brakes may themselves become fouled in some instances. In the W. 177th Street installation (Cleveland), a styrofoam cup wholly blocked the flow of stormwater. In the Standard 5-B-7 installation (Rochester), a piece of lath apparently interrupted the vortex within the unit, and thereby permitted stormwater flow to occur at a rate equal to a 3.5-in. (8.9 cm) orifice. Generally speaking, maintenance was not a problem at most of the sites, although the Napean Township catch basin installations were subject to solids depositions and regular clean-out was necessary because of odors.

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The complete report, entitled "Hydro Brake Regulated Storage System for Stormwater Management," (Order No. PB 84-110 378; Cost: $19.00, subject to change) will be available only from:
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