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COUNTERMEASURES FOR POLLUTION FROM OVERFLOWS
The State Of The Art

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COUNTERMEASURES FOR POLLUTION FROM OVERFLOWS

The State of the Art

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REVIEW NOTICE

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

Essentially every metropolitan area of the United States has a stormwater pollution problem, whether served by a combined sewer or a separate system. This study provides selected results of a comprehensive investigation and assessment of promising methods of treating or controlling such pollution.

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ABSTRACT

Control and/or treatment of stormwater discharges and combined sewage overflows from urban areas are problems of increasing importance in the field of water quality management. Over the past decade much research effort has been expended and a large amount of data has been generated, primarily through the actions and support of the U. S. Environmental Protection Agency's (EPA) Storm and Combined Sewer Research and Development Program. Presented in this text are selected results of a comprehensive investigation and assessment of promising, completed and ongoing projects, representative of the state-of-the-art in abatement theory and technology; a look at recent legislation; and the identification of program needs and emphasis.

Combined sewer overflows are major sources of water pollution problems, but even discharges of stormwater alone can seriously affect water quality. Current approaches involve control of overflows, treatment and combinations of the two. Control may involve maximizing treatment with existing facilities, control of infiltration and extraneous inflows, surface sanitation and management, as well as flow regulation and storage. A number of treatment methods have been evaluated including high rate screening and microstraining, ultra high rate filtration, dissolved air flotation, physical/chemical treatment, and modified biological processes. A swirl flow regulator/solids separator of anular shape construction with no moving parts has been developed. High rate disinfection methods including new disinfectants have been applied.

Promising approaches involve integrated use of controls and treatment. The most disappointing have generally lacked flexibility in their operation and design. Mathematical models have been developed and successfully applied at multiple levels of sophistication and complexity.

CONTENTS

No.		Page
Review Notice		ii
Foreword		iii
Abstract		iv
List of Figures		vi
List of Tables		vii
Acknowledgements		viii
Sections		
I	Conclusions	1
II	Recommendations	2
III	Introduction - Problem Definition	3
IV	Design Constraints	5
V	Management Alternatives	6
VI	Results and Costs	10
VII	Impact of Legislation	15
VIII	R&D Needs and EPA Program Emphasis	18
IX	References	28

FIGURES

No.		Page
1	Representative Strengths of Wastewaters	4
2	Storage - Treatment Example	14
3	Overview of Storm Water Management Model Structure	19
4	Isometric View of Swirl Regulator/Concentrator	25

TABLES

No.		Page
1	Summary of Storage Costs for Various Cities	11
2	Comparison of Treatment Alternatives	12

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SECTION I

CONCLUSIONS

All facts point to a real requirement for treating and controlling stormwater runoff and combined sewer overflows. The multi-billion dollar treatment plant upgrading and expansion program now going on throughout the country will do much to alleviate pollution of our waters. However, means of mitigating the effects of urban runoff must also be found if we hope to abate the pollution in an optimal manner. Wet-weather standards are already being instituted by EPA and some states and localities. Recognizing this, EPA's Storm and Combined Sewer Technology Program will strive to be a prime support for this real-world application.

SECTION II

RECOMMENDATIONS

Before truly effective countermeasures (control or treatment) can be applied to the urban runoff/combined sewer overflow problem a nationwide characterization and evaluation of its impact is needed. New methods for the determination of pathogenic pollution are required in addition to a reevaluation of disinfection requirements. Methods of controlling and treating heavy metals and organics found in runoff must be developed. Detention, both in-line and upstream, needs further development to optimize its effectiveness as a pollution abatement procedure. Improvement of rainfall-runoff models, flow meters, and stormwater reuse concepts would ease the stormflow control problem.

The above-mentioned technology is crucial to abating wet-weather pollution, but equally important is its dissemination and proper use. The various approaches must be evaluated absolutely and compared with each other to determine their cost and actual effectiveness *in situ*. Coverage of these principles and methods in the appropriate schools would distribute the information to those persons who are most in the position to apply it.

SECTION III

INTRODUCTION - PROBLEM DEFINITION

Simply stated the problem is:

When a city takes a bath, what do you do with the dirty water?

Three types of discharge are involved: combined sewer overflows, storm drainage in separate systems, and overflows (bypasses) from infiltrated sanitary sewers. Significantly the storm path and collection system configuration may have a pronounced influence on combined overflow quality, resulting in simultaneous discharge mixtures of sewage and runoff at different points varying from raw to highly diluted as the system adjusts to a particular storm pattern [1]. The problem constituents of general concern are visible matter, infectious bacteria, organics, and solids and in addition may include nutrients, heavy metals and pesticides. Representative comparisons are shown in Figure 1.

Organic loadings in overflows and wet-weather bypasses, while generally averaging (flow weighted means) less than one-half the strength of untreated sanitary sewage, must be considered in terms of their shockloading effect because of their great magnitude. For example, rates of urban runoff from an average storm intensity of 0.10 in./hr (0.25 cm/hr) may be expected to be on the order of 5 to 10 times the dry weather flow contribution from the same area. Likewise, a not uncommon rainfall intensity of 1.0 in./hr (2.5 cm/hr) will produce flow rates of 50 to 100 times the dry weather flow.

Even separate storm wastewaters are significant sources of pollution, "typically" characterized as having (1) solids concentrations equal to or greater than those of untreated sanitary wastewater, and (2) BOD_5 concentrations approximately equal to those of secondary effluent. Bacterial contamination of separate storm wastewaters is typically 2 to 4 orders of magnitude less than that of untreated sanitary wastewaters. Significantly, however, it is 2 to 4 orders of magnitude greater than concentrations considered safe for water contact activities.

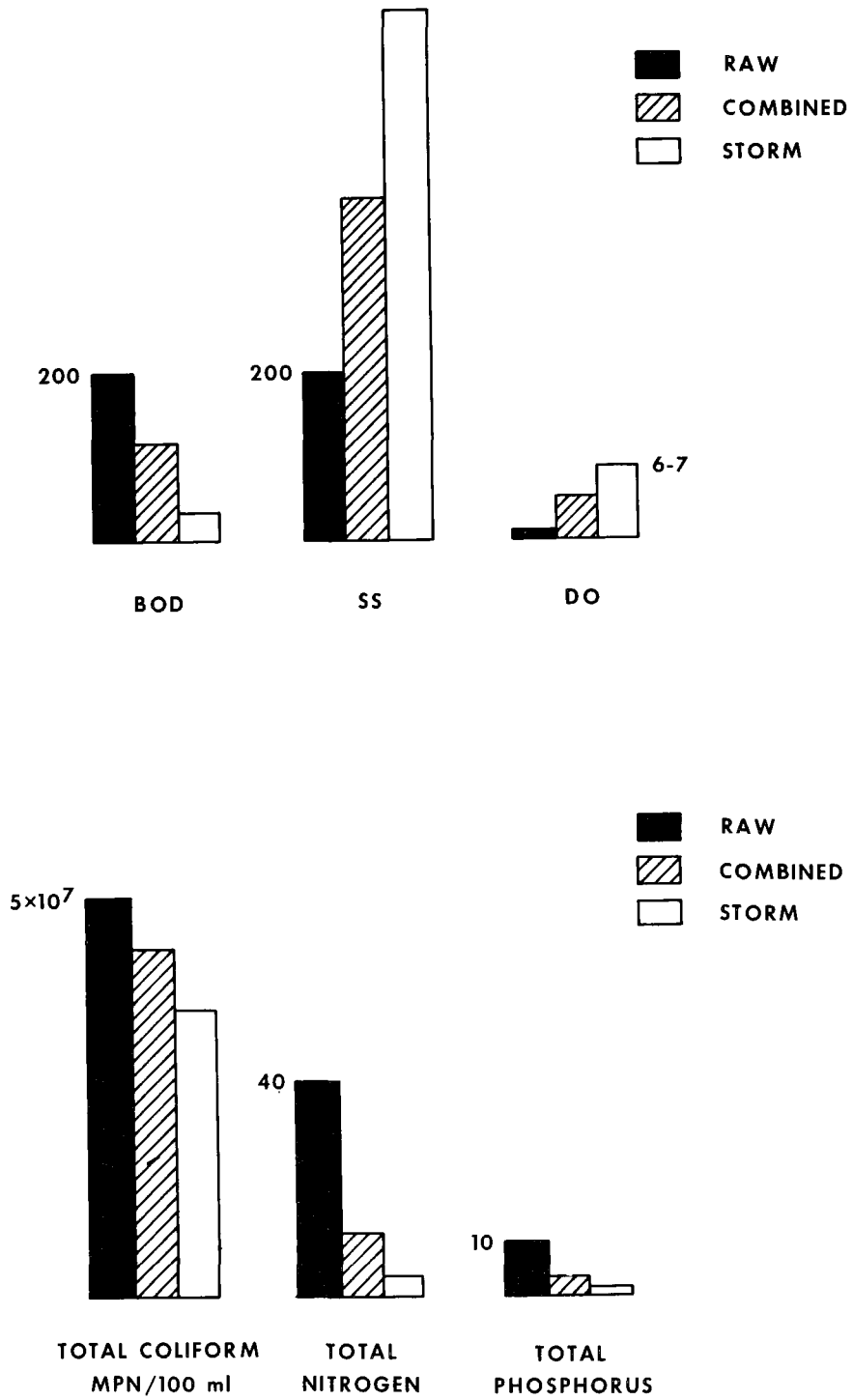


FIGURE 1. Representative Strengths of Wastewaters (flow weighted means expressed in mg/L)

SECTION IV

DESIGN CONSTRAINTS

Precise characterization of the wastewater is virtually impossible because of the variability in the character of storm and/or combined wastewater and because of the many physical difficulties in representative sample collection. Also, because of the intermittency and variability of stormwater runoff and interrelated system flows, there is no such thing as an "average" design condition for stormwater treatment facilities. Therefore, a unit or process that performs only when conditions are right may be too restrictive for practical applications.

In addition, the magnitude, debris content, and brute force of storm flows may be major constraints limiting options for centralization (because of high transmission costs) and rendering sophisticated and complex equipment ineffectual or impossible to maintain.

Finally, in assessing the performance of past projects, the project scale, pretreatment controls, and location with respect to maintenance and supervisory services are critical factors with respect to credibility, applicability, and reliability. Likewise it should be recognized that the sparsity and individuality of real installations make generalizations difficult and hazardous.

SECTION V

MANAGEMENT ALTERNATIVES

What then can be done about the problem? First there is a choice as to where to attack the problem. This may be at the source (e.g. the streets, gutters, and catchment areas), within the collection system, at the terminus or strategic intermediate locations of the system, or combinations of the above including the integrated use of the dry-weather treatment facilities. Second, there is the choice of how much control and/or degree of treatment to introduce. This generates into a cost-effective analysis involving goals, values, and hydrologic-physical system evaluations (generally assisted by mathematical model simulations, pilot-scale trials, and new technology transfer). Thirdly, there is the impact assessment, public exposure, and priority ranking with other needs.

SOURCE CONTROLS

Examples of source controls include flow attenuation, erosion control, restrictions on chemical use (de-icing compounds, pesticides), and improved neighborhood sanitation practices. The theory behind source controls is to limit the supply of contaminants. The benefits are not only reduced water pollution but also cleaner and healthier environments. This point was emphasized in one study [2] which noted:

> Initially, one must consider the temporal condition of the watershed. The general sanitary conditions of the individual parcels influence the environment of the entire drainage basin. Some of the parcel indicators are the housing or establishment condition, the number of uncovered garbage cans, piles of rubbish and rubble, autos and animals maintained, the presence of privies, and the amount of litter in the streets which bound the parcel.

The most sensitive parameter to normal environmental cleanliness, as might be expected, was bacterial contamination with a range approximately two orders of magnitude computed. Construction activity, vacant land, and extent of open channel flow greatly influenced total solids in the runoff.

COLLECTION SYSTEM CONTROLS

Examples of collection system controls include flushing, polymer feed, inflow/infiltration control, improved regulator devices, sewer separation, and remote monitoring/control systems. The emphasis, with the exception of sewer separation, is upon optimal utilization of the existing facilities. To accomplish this an extensive and dependable intelligence system is necessary.

Solids deposition in lines have been a plague to effective maintenance of service since the inception of piped conduits. Considering the significance of such loads (resultant first flush phenomena) surprisingly little research has entered this area, at least until recently [3,4]. Improved regulator devices such as the swirl concentrator [5,18,22] offer the potential for effective solids separation over wide ranges of flow but the ultimate disposal of these solids will be a major problem. Reclamation through some form of decontamination-classification followed by land filling appears to be a logical solution.

System controls utilizing in-line storage represent promising alternatives in combined or partially combined systems in areas where conduits are large and flat (i.e., backwater impoundments become feasible) and interceptor capacity is high. The intent is to assist a dispatcher (supervisor) in routing and storing stormwater flows to make the most effective use of interceptor and line capacities. The necessary components include both sensing (e.g. flow levels, rates, quality, gate positions, and rainfall) and control devices (e.g. gates, valves, inflatable dams, regulators, and pumps) operable from a central facility. As the components become more advanced and operating experience grows, system control offers the key to total integrated system management and optimization.

The concept of constructing new sanitary sewers to replace existing combined sewers largely has been abandoned because of the enormous cost, limited effectiveness, inconvenience to the public, and extended time required for implementation.

STORAGE AND TREATMENT

Storage

Storage facilities possess many of the favorable attributes desired in stormwater treatment: (1) they are capable of providing flow equalization or attenuation and, in the case of tunnels, flow transmission; (2) they are simple to design and operate; (3) they respond without difficulty to intermittent and random storm behavior; (4) they are relatively unaffected by flow and quality changes; and (5) frequently they can be operated in concert with regional dry weather flow treatment plants for benefits during both dry and wet-weather conditions. Disadvantages of storage facilities include their large size, high cost, and dependency on other treatment facilities for dewatering and solids disposal.

Physical Treatment

Physical treatment processes in many ways are well suited to stormwater applications, particularly with respect to solids removal. These processes include sedimentation, dissolved air flotation, screening filtration, and special regulator devices. Handicaps appear to be sensitivities to flows and loadings (although they may be the most tolerant of the treatment alternatives), high maintenance requirements, and absence of effective utilization in the between storm periods.

To reduce capital investments, demonstration projects have been directed towards operations approaching the maximum loading boundaries. Applications include their use for pretreatment or roughing, for the main or sole treatment, and particularly in the case of microstrainers and filters, as effluent polishing devices.

Biological Treatment

Biological treatment of storm wastewaters must overcome some serious drawbacks: (1) the biomass used to assimilate the waste constituents must either be kept alive during times of dry weather or allowed to develop for each storm event; and (2) once developed, the biomass is highly susceptible to washout by hydraulic surges or overload.

Examples of biological treatment applications to stormwater include (1) the contact stabilization modification of activated sludge, (2) high rate trickling filtration, (3) bioadsorption using rotating biological contactors, and (4) oxidation lagoons of various types. The first three are operated conjunctively with dry weather flow plants to supply the biomass and the fourth involves long term storage of the flows. With the exception of lagoons, some form of pre-unit flow equalization and control is essential.

Physical-Chemical Treatment

Physical-chemical processes are of particular importance to stormwater treatment because of their adaptability to automated operation, rapid startup and shutdown characteristics, and very good resistance to shock-loads. Most practical applications, necessarily, will stop far short of the tertiary levels now piloted or in service on sanitary wastewaters. However some projects through repetitive treatment use in non-storm periods may achieve a high degree of beneficial reclamation [6]. Drawbacks to physical-chemical treatment include high initial costs (may be largely offset by reduced land requirements), high chemical requirements, and increased sludge (by dry weight) to be disposed of.

One full-scale plant application on combined sewage has an attractive innovation: the use of waste lime sludge from a nearby water treatment plant as a clarifying aid, is to be tested [7].

Disinfection

The most commonly used disinfectants under the research program are chlorine, sodium or calcium hypochlorite, chlorine dioxide, and ozone. Because the disinfectant and contact demands are great in stormwater applications, current research centers on (1) high rate applications, (2) use of alternative disinfectants, and (3) on-site generation of disinfectants. From the standpoint of safety in storage and transport the use of hypochlorites predominates in current full scale applications.

INTEGRATED (COMPLEX SYSTEMS)

By far the most promising approaches to urban stormwater management involve the integrated use of control and treatment with an areawide, multidisciplinary perspective. Mathematical models have been developed and successfully applied at many levels of sophistication and complexity. These models vary from simple "mass-diagram" balances of runoff, storage, treatment, and overflows to those capable of representing the whole gamut of urban stormwater runoff phenomena (including both quantity and quality).

Integrated approaches are notably demonstrated in programs underway in Chicago, San Francisco, Seattle, Washington, D.C., Rochester, and elsewhere.

SECTION VI

RESULTS AND COSTS

As representative of one facet of source controls, a recent study [8] concluded:

> Current street cleaning practices are essentially for aesthetic purposes and even under well-operated and highly efficient street sweeping programs, their efficiency in the removal of the dust and dirt fraction of street surface contaminants is low.

The removal efficiency of the dust and dirt fraction (contributing most heavily to water pollution effects) averaged 50 percent whereas the pickup of litter and debris ranged from 95 to 100 percent. Improvements to 70 percent removals and possibly as high as 90 percent were considered feasible under the best conditions. Costs were indicated in a range from $2.18 to $8.42 per curb mile ($1.35 to $5.23 per curb Km) swept.

Detroit (4) found the cost of in-system controlled storage to be as low as $0.02 to $0.04 per gallon ($0.005 to $0.01 per liter) of storage based upon the most favorable sites. This range was approximately 1/10 the estimated cost for large off-line facilities. Representative storage costs from other projects adjusted to ENR 2000 are summarized in Table 1. Removals by sedimentation may be estimated by conventional criteria.

A hypothetical comparison of alternate treatment processes based upon an assumed 25 mgd (1.095 cu m/sec) installation is summarized in Table 2. Since the feed to the units varies continuously in both quantity and quality (storms do not repeat themselves), the efficiencies should be regarded as gross indicators only. Similarly the cost estimates are based upon one or at most only a few installations and may not be fully equitable in terms of completeness of facilities and difficulties encountered in construction.

A simplified example will serve to illustrate an advantage of intergrated (complex) approaches. Assume a design composite storm overflow for a combined catchment area is three hours long and the hydrograph is triangular shaped with a maximum value of 25 mgd (1.095 cu m/sec) occurring at the end of the first hour. Total containment in storage would therefore require a capacity of 1.56 million gallons (5.90 Ml) which at a unit cost of $.50 per gallon ($.13 per liter) would cost $780,000 to construct. Similarly a treatment facility designed for the maximum flow rate might cost (25 mgd x $30,000/mgd) $750,000. A 10 mgd (0.44 cu m/sec plant, however, coupled with a

Table 1. SUMMARY OF STORAGE COSTS FOR VARIOUS CITIES[a]

Location	Storage mil.gal.	Capital cost $	Storage cost $/gal.
Seattle, Wash.			
Control and monitoring system	--	3,500,000	--
Automated regulator station	--	3,900,000	--
	32.0	7,400,000	0.23
Minneapolis-St.Paul, Minn.	--	3,000,000	--
Chippewa Falls, Wis.			
Storage	2.8	744,000	0.26
Treatment	--	186,000	--
Jamaica Bay, N.Y., N.Y.			
Basin	10.0	21,200,000	2.12
Basin and sewer	23.0	21,200,000	0.92
Humbolt Ave.,Milwaukee,Wis.	4.0	2,010,000	0.50
Boston, Massachusetts			
Cottage Farm Stormwater Treatment Station	1.3	6,200,000	4.74[b]
Chicago, Illinois			
Storage basins	2,736.0	568,000,000	0.21
Collecting, tunnel and pumping[c]	2,834.0	755,000,000	0.27
	5,570.0	1,323,000,000	0.24

a ENR = 2000.
b Includes pumping station, chlorination facilities, and outfall.
c Includes 193.1 km (120 miles) of tunnels.

NOTE: $/acre x 2.47 = $/hectare, $/gal. x 0.264

= $/liter, mil gal. x 3.785 = Ml

Table 2. COMPARISON OF TREATMENT ALTERNATIVES

Process	Design Loading Rate	Estimated removals or range, %		Capital Cost per mgd[a]
		BOD_5	SS	
Dissolved air flotation[b] (split flow)	3,200 gpd/sq ft	40	60	$35,000
Same w/chem. add'n	25 mg/L	52	78	--
Microstrainer	25 gpm/sq ft	10-50	70	13,000
Ultrafine screen		15	40	7,800
Ultrahigh rate filtration	24 gpm/sq ft	8-36	38-73	63,000[c]
Chemical clarification using waste lime sludge	2,570 gpd/sq ft	60	60	54,000
Contact stabilization modification of secondary plant	108 lb BOD_5/ 1,000 cf	83	92	78,300
High rate trickling filter modification of secondary plant	Plastic media-40 mgad; Rock media-12 mgad	65	65	68,000

a Based on 25 mgd facility.
b Includes ultrafine screens as pretreatment.
c Extrapolated from bench scale data.

NOTE: gpd/sq ft x 0.283 = cu m/min/ha
gpm/sq ft x 0.679 = l sec/sq m
lb/1,000 cf x 16.077 = g/cu m
mgad x 9.357 = ml/day/ha
mgd x 0.0438 = cu m/sec

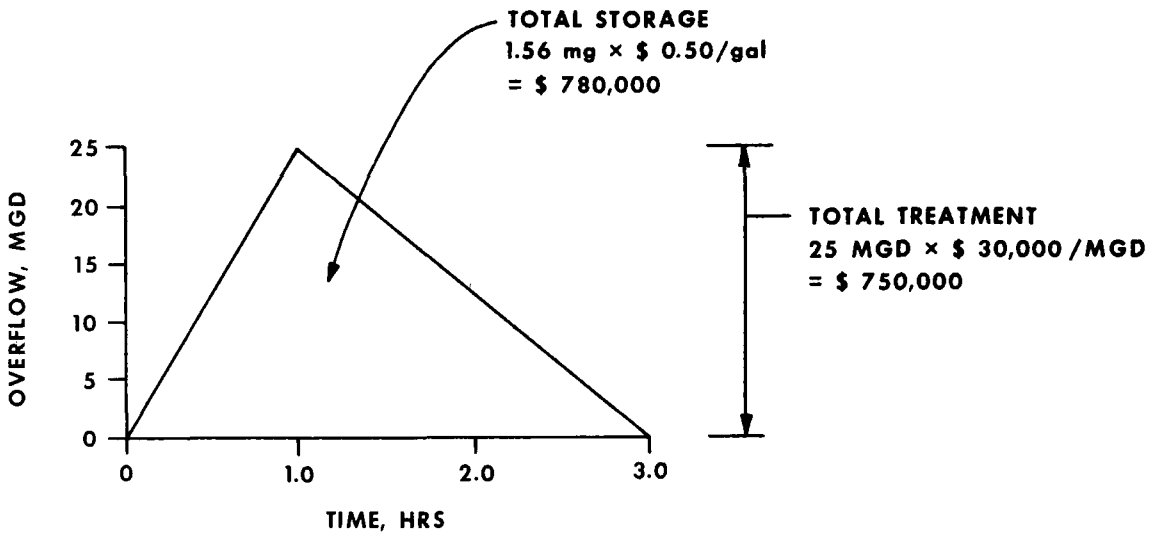
storage capability of .56 million gallons (2.12 Ml), would accomplish the same objectives for $580,000 (see Figure 2). Of particular importance is the opportunity for the treatment plant to operate at its design capacity for a sustained period of time.

While prototype installations in operation today are still relatively few in number some impressive results have been obtained. The in-system storage concepts have proven feasible to operate and maintain with a major curtailment of overflow occurances and durations. Off-line storage and detention-chlorination facilities are proven performers with additional benefits for backing up overloaded treatment works innovated. Stormwater facilities constructed in parallel with conventional dry weather flow treatment plants have introduced dual use functions improving even dry weather performance as well as increasing treatment capacities during storm periods. Direct treatment systems have been slower in coming into use and, in more than a few cases, have been adversely affected by the fickleness of storm misbehavior.

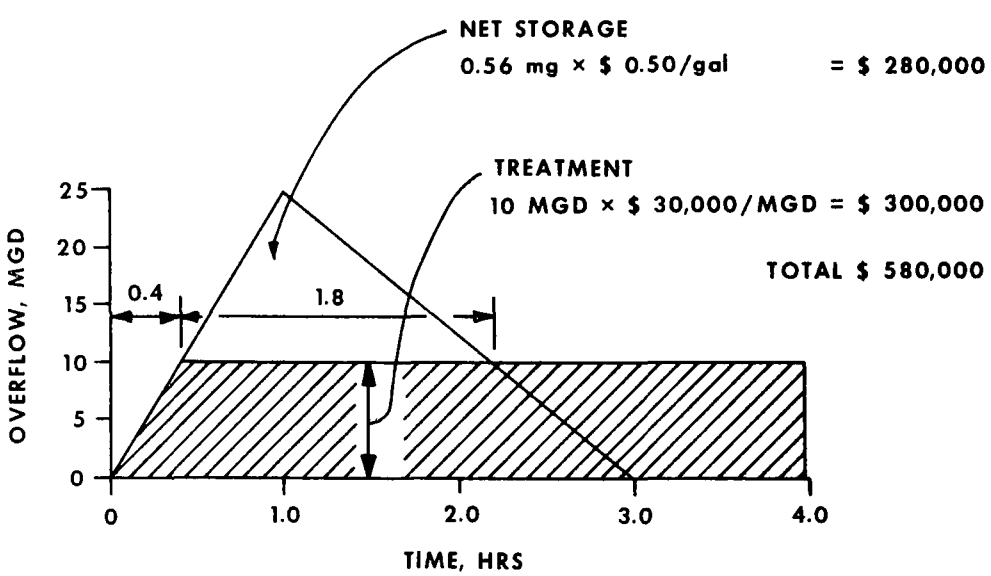
In the authors' opinion, two important points are to be made:

1. Some form of storage (flow equalization) must be considered in any stormwater treatment installation; and

2. Municipal stormwater pollution abatement programs must be scaled and implemented giving full recognition to the limitations in available data and the relative immaturity of the state-of-the-art.



(a) Separate Approach



(b) Integrated Approach

FIGURE 2. Storage-Treatment Example

SECTION VII

IMPACT OF LEGISLATION

The urban runoff problem has received recognition from the Federal government. Since 1965, various acts of legislation have supported the thrust in developing countermeasures against the environmental impacts of urban runoff.

Enough light was borne on the stormwater problem in the early 1960's by the U.S. Environmental Protection Agency's (EPA) predecessor, the U.S. Public Health Service, to create recognition from our legislators. The Federal Water Pollution Control Act (FWPCA) was amended by the Water Quality Act of 1965 (PL 89-234) and the Clean Water Restoration Act of 1966 (PL 89-753) to authorize funds for the development of new and improved methods for controlling pollution caused by combined sewer overflows or stormwater discharges. The 1965 Act created a viable Federal involvement in research, development, and demonstration. Today this EPA program is under the jurisdiction of the Storm & Combined Sewer Section of the National Environmental Research Center-Cincinnati.

The initial Acts authorized funds for demonstration grants for new and improved methods for controlling storm generated pollution to states, municipalities, intermunicipal, or interstate agencies in amounts of up to 75 percent of the estimated project costs. Contracts were also made available to private enterprise for the implementation of worthwhile projects. The more recent FWPCA Amendments of 1972 (PL 92-500) provided continued support of these extramural activities (Sec. 105. (a)(1)).

1972 FWPCA AMENDMENTS PLACE NEW EMPHASIS ON STORMWATER

The 1972 Amendments place new and stronger emphasis on urban runoff as a source of pollution. "An accelerated effort..." is stressed "...to develop, refine, and achieve practical application of waste management methods applicable to nonpoint sources of pollutants to eliminate the discharge of pollutants including, but not limited to, elimination of runoff of pollutants...." (Sec. 105. (d)(1)).

"In recognition of the serious conditions which exist in Lake Erie..." the Amendments authorize development of "...a demonstration wastewater management program for the rehabilitation and environmental repair of Lake Erie." It is further stipulated that "such a program include measures to control....area sources of pollution, including....urban runoff and rural runoff...." (Sec. 108.(d)(1) & (2)).

Research and investigation for reducing total sewage flow has been stimulated by the FWPCA Amendments (Sec. 104.(o)(1)) "...in order to reduce the requirements for, and the costs of, sewage and waste treatment services." A significant way to reduce sewer flows would be to reduce infiltration and other extraneous stormwater inflows. EPA's Research and Development program has joined hands with their Office of Air and Water Programs to make the required reports to Congress (Sec. 104.(o)(2)) on methods of reducing the total flow of sewage.

Grants for the construction of treatment works will not be approved as of July 1, 1973, "...unless the applicant shows....that each sewer collection system discharging into such treatment works is not subject to excessive infiltration" (Sec. 201.(g)(3)). Authority was given to make grants for the sewer system evaluation studies necessary to carry out this requirement (Sec. 201.(g)(4)). Furthermore, the Office of Research and Development, by these Sections of the Act received impetus to continue their research and development against infiltration and inflows.

Construction grant applications and area wide or basin wastewater treatment management plans are being encouraged to include "...the necessary waste water collection and urban storm water runoff systems.." for the control and treatment of storm generated pollution (Sec. 208. (b)(2)(A) & 212.(2)(B)).

COMPTROLLER GENERAL'S REPORT - MARCH 28, 1973

Because of the seriousness of the combined sewer overflow problem, the Comptroller General of the United States, on March 28, 1973, submitted a report to Congress on the "Need to Control Discharges from Sewers Carrying Both Sewage and Storm Runoff." Findings revealed that combined sewer overflows "...are a major pollution problem and prevent many areas from attaining Federal and State water quality goals." The report recommended that the EPA require states to identify, study, and submit abatement plans for combined sewer overflow pollution and to consider the award of construction grants for these abatement facilities.

Treatment standards mandated by the new Amendments call for secondary treatment by July 1, 1977; best practicable treatment by July 1, 1983; and non-polluting discharge by 1985. Water quality objectives may remain beyond reach so long as attention is not given to the treatment and control of stormwater runoff and combined sewer overflows.

STATE AND LOCAL REQUIREMENTS

On the state and local level, regulations concerning water pollution abatement have been tightened. Illinois [9, 10, 11] and Georgia [12] have promulgated their requirements for overflow control and treatment.

In an effort to curb channel erosion and downstream siltation, the State of Maryland [13, 14, 15] requires the land developer to attenuate runoff so as not to allow flow releases (for up to two year storms) to occur any faster than before site construction.

The City and County of San Francisco, California, has passed a 1970 resolution [16] for a special time schedule to regulate discharges from combined sewers. A recent regulation in Orange County, Florida [17] states that a complete stormwater management system be provided to handle all stormwater runoff in "prime recharge areas." It also states that treatment is required for stormwater in all drainage systems. This regulation is the first to deal so specifically with the control and treatment of urban runoff as opposed to combined storm and sanitary flows.

SECTION VIII

RESEARCH & DEVELOPMENT NEEDS AND EPA PROGRAM EMPHASIS

Looking ahead, the Storm and Combined Sewer Pollution Control Program needs are vast and numerous. Some of the newer approaches being emphasized by the program are discussed below.

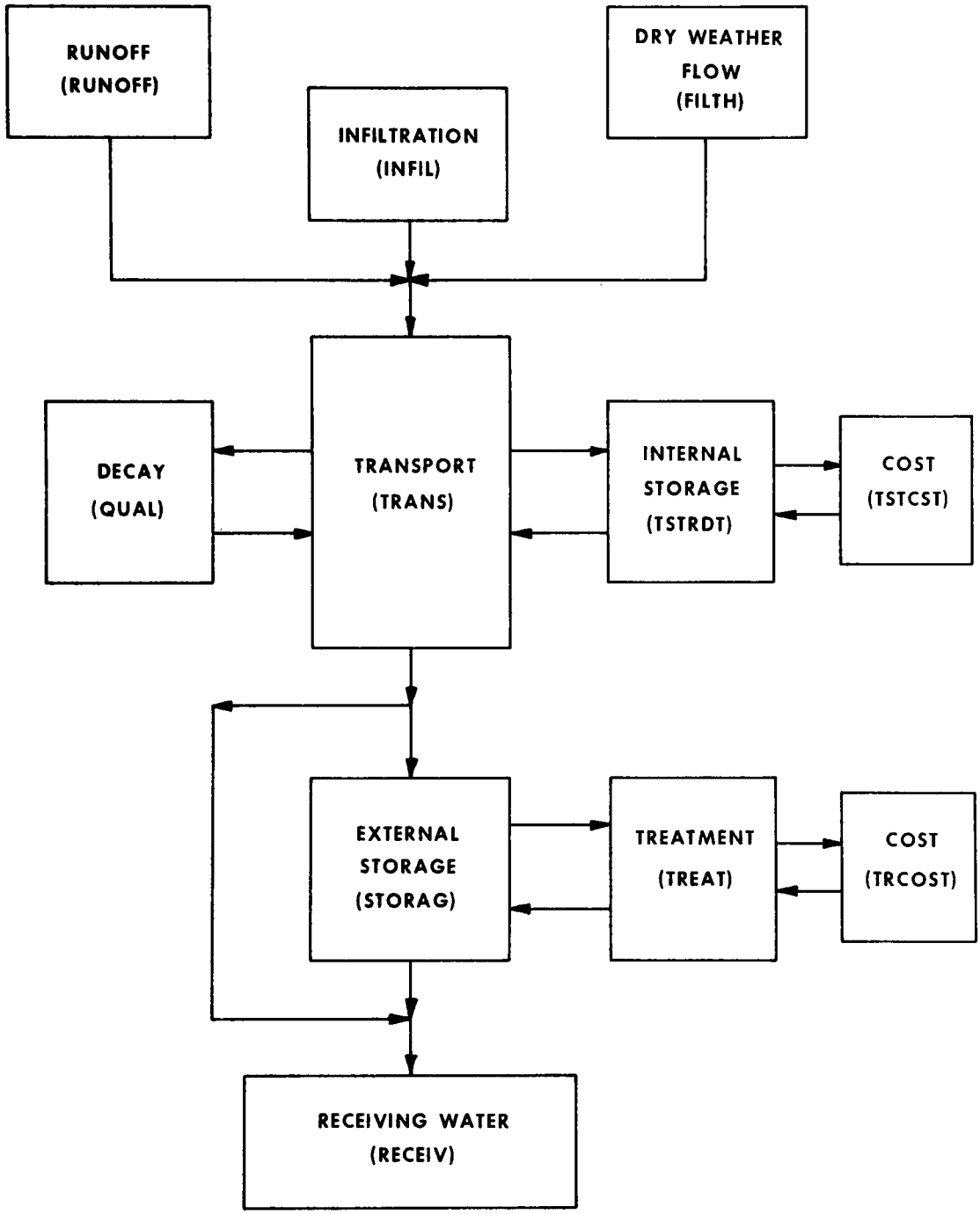
CHARACTERIZATION AND EVALUATION

Simulation Models

The capability to analyze various component flows and pollution loads throughout a sewerage system are the keys to better design of control and treatment systems. Due to complexities of the rainfall-runoff-flow phenomena, past analyses have been less than adequate, resulting in poor estimates of flow and predicted system responses to a storm. EPA now has available a "descriptive" Storm Water Management Model (SWMM) which can overcome former analytical deficiencies. Figure 3 depicts a schematic overview of the model structure. The Program is in the initial phase of demonstrating the application of this method for "decision-making," that is, its ability to analyze a major combined sewer system; to select and to design control and treatment approaches based on cost-effectiveness; and to eventually design a computerized means of overall management of the system during storm flows.

EPA is presently seeking a municipal location where a development and operational demonstration can be made of totally automated "real-time" or "feed-forward" control of a sewerage system during storm flow conditions. This system would be based on in-line routing and storage in a sewer network for control and subsequent treatment.

Simplified models requiring simple inputs need to be developed for early stage planning. Extensions to the SWMM will enable total basin planning by interfacing it with dry weather municipal flow and beneficial potable and sub-potable water supply and resource features. The eventual goal is to demonstrate a "total urban intelligence system," whereby a regional system which employs runoff impoundment and recharge for aesthetic, recreational, and supply purposes; and integrated wet and dry weather wastewater routing and treatment could be planned, designed, and operated real-time by a mathematical Urban Water Resource Management Model.



Note: Subroutine names are shown in parentheses.

FIGURE 3. Overview of SWMM Model Structure

Nationwide Assessment of Urban Runoff Impacts

A project has been sponsored by EPA to characterize, evaluate the impacts, and determine costs for the control of urban stormwater runoff (not combined sewage) pollution on a nationwide basis--a consideration which has been stressed by the 1972 Amendments to the FWPC Act, and which is needed to set enforcement guides and appropriate financial backing. Such information would be extremely useful in planning and implementing the best available and most cost-effective means of control and treatment of urban stormwater discharges.

Combined Sewage Sludge

Due to priorities of the problem at hand, the sludge handling aspects of combined sewer overflow treatment processes have just now been given due consideration and investigation. A recently authorized effort will characterize sludges and solids resulting from overflow treatment and make recommendations for the most appropriate systems for their handling and disposal. Recommendations will consider on-site disposal at the wet weather plant and pump back to the municipal treatment works; and will result in a handy reference for designers of future complete combined sewer overflow treatment and control systems.

Uniform Procedures For Analysis And Evaluation of Storm Flow Characteristics And Treatability

Since the quantitative and qualitative nature of the wet weather flow problem is such that the application of conventional dry weather flow field procedures and analytical determinations are not adequate for stormwater and combined sewage characterization and treatability evaluations, a set of standardized procedures specific to this problem is being formulated under EPA contract. Such a set of procedures would not only help in the deduction, comparison and statistical interpretation of data collected to date, but also in formulating evaluations of future projects. In this way, data comparison and performance evaluations will be more meaningful and more adaptable to planning and design.

Flow Measurement

The quantitative and qualitative measurement of storm overflows is essential for process design, control, evaluation, and enforcement. "Urban intelligence systems" require real-time data from rapid, remote sensors in order to achieve remote control of a sewerage network. Sampling devices do not provide representative aliquots; and in-line measurement of suspended solids and organics is needed. Conventional rate-of-flow meters have been developed mainly for relatively steady-state irrigational, streams, and sanitary flows and not for the highly varying surges encountered in storm and combined sewers. In these sewers, a measuring device may be subjected to very low flow rates, submergence, reverse flow and surcharge, all during a single rainstorm. These severe flow conditions rule out the reliable and accurate application of conventional devices, such as weirs and flumes, at many

locations. Consequently, the Storm and Combined Sewer Technology program is deeply involved in the development and demonstration of sophisticated and new flow-measuring equipment. Two efforts are being initiated to develop reliable obstructionless means of measuring both gravity and pressurized flow at one gaging point utilizing the principles of electromagnetics and passive sound, respectively. Passive sound instruments offer the additional benefit of an extremely low power requirement; thus rendering them amenable to installation at remote overflow locations (where power may not exist) and for integration into citywide, in-sewer, sensing and control systems.

The program has contributed to the development of a prototype monitor capable of instantaneous, in situ measurement of suspended solids based on the optical principle of suspended solids depolarizing polarized light. This device is now being demonstrated. Two other projects are in the process of developing a sampler that will gather flow representative samples [20], and an automatic, rapid, on-line monitoring device for concentrations of organics, respectively.

Consideration of Trace Pollutants

Characterization studies revealed a significant amount of trace pollutants in the runoff which included heavy metals (lead, zinc, cadmium, mercury, copper, chromium) pesticides and PCB's, nutrients, chemical deicers, and non-biodegradable and refractory organics. Street cleaning and chemical use limitations are ways to reduce these pollutants, but specific stormwater treatment methods are also needed.

Pathogen Detection

High coliform counts in surface runoff or combined sewage could lead to unnecessary stormwater disinfection requirements and overdesigned facilities. Parameters for pathogenic contamination have been taken almost blindly from municipal pollution control practice and applied to stormwater and combined sewer flows when in fact, high concentrations of fecal and total coliform can come entirely from animal and soil sources. EPA is attempting to define more realistic methods to determine pathogenic pollution (either directly or indirectly) and associated disinfection requirements.

CONTROL METHODOLOGY

New Sewer Design

A demonstration is being sought for the development of a master plan for a community-wide sewer collection system based on an advanced method. Basically the new method is the old combined sewer concept which incorporates in-line storage for wet-weather flow along with flow conveyance. The method will include up-to-date hydrologic and hydraulic theory which employs the complete momentum equation for unsteady storm flow and adequate low-flow velocities to prevent solids buildup.

Comparisons will be made with conventional combined and separate sewer designs which do not consider in-line control and employ older concepts such as the Rational Method and the Kutter or Manning equations. These methods have been the subject of much criticism. Comparisons will be based on cost-effectiveness for stormwater pollution control and an analysis of collection system inadequacies arising from inexact concepts.

A task is being implemented to develop a combined sewer design for adequate carrying velocity at low flow dry-weather conditions to avoid the first flush phenomena. Present design criteria is based on carrying velocities (2 to 3 fps) occurring at maximum, one half, or full-pipe flow rates. This stems from the antiquated philosophy: less pumping means optimum design (with dependence on periodic storm flows for the higher flow rates to maintain the sewers by flushing deposited solids). The philosophy of employing low velocities during dry-weather and high during wet-weather has backfired. Today we recognize that combined sewer purging by storm flow creates our overflow first flush pollution. Combinations of steeper sewer slopes and different sewer cross sectional shapes (with less cross sectional area at the bottom) are ways to maintain adequate solids carrying velocities at all flow rates. For a correct economic evaluation added costs for sewer and pumping station installation and power should be compared to capital and operational costs for conveyance, storage, and treatment of the first flush which would otherwise result.

Upstream Impoundment

Upstream storage or other control processes to decrease the stormwater runoff effect on lower portions of the system require further development and demonstration. Aside from the main objective of controlling stormwater pollution (while offering greater flexibility for control and treatment), upstream control can: (1) preclude the need for additional sewer line capacity and associated construction requirements; (2) alleviate shock loadings due to storm flow scouring velocities; (3) relieve the often occurring expense of constructing facilities downstream near watercourses in unstable soil with high water table. Examples are the temporary storage or attenuation of stormwater at the building or immediate area through the use of holding tanks; seepage pits, possibly for recharge; roof tops; parks, playground, greenbelts and other open spaces; backyard detention facilities; porous pavement; or neighborhood, decentralized stormwater collection sumps including storage facilities under streets. Upstream control systems should automatically regulate discharge from storage to the groundwater, a watercourse, or sewer system. Plans for reuse of stored water for irrigation, street cleaning, sewer flushing, aesthetic and recreational ponds, potable and sub-potable supply, and other purposes are also encouraged.

Catch Basins -- Good or Bad?

The so-called control practice being studied by EPA's program is the conventional employment of catch basins. Despite the purported reduced need for catch basins, they are still used regularly. For the most part, the various catch basin configurations are inefficient for their

intended purpose -- solids removal. Answers will be sought to such questions as:

1. What is their actual need as used today?

2. Can new types be developed, or existing ones be improved by recommending cost-effective cleaning procedures and schedules or other physical alterations?

Runoff Attenuation By Porous Pavement

A method for attenuating flows that has exhibited pilot-scale feasibility [19] is the installation of porous pavement. If used for highways, streets, and parking lots, it would have the potential for reducing capacities and associated costs for both sewer and wet-weather flow treatment systems and groundwater recharge, features attributable to the porous pavement's ability to equalize flows entering or divert flows away from the sewerage system. Even more important are the safety features which could be realized, that is, an increased coefficient of friction to prevent wet skidding or hydroplaning accidents, and enhanced visibility of pavement markings due to more rapid removal of rainwater and rougher surfaces. A full-sized demonstration project has been initiated in the Woodlands -- a new town community near Houston, Texas -- to demonstrate the benefits of porous pavement. In addition, the efficiency of street vacuum cleaning to reduce pollution load from streets will be demonstrated.

Dual Use Facilities

Wet-weather overflow control and treatment facilities built in conjunction with new or existing sewerage works is emphasized as a first consideration.

Surge facilities (or existing combined sewers) at the municipal plant could serve a dual function in equalizing not only wet-weather flows but dry-weather flows as well. In this way, a single future treatment system can readily be designed for storm and sanitary flow conditions. This could also assist presently overloaded sanitary plants in obtaining more uniform operation. Short-term storage would even out the daily cycle of dry-weather flows, allowing more efficient use of the treatment process over the entire 24 hours. Equalization also permits reduced treatment process design capacity.

Wet-weather treatment systems integrated with the sanitary plant can demonstrate their synergistic benefit by being utilized to take over during repairs, polishing secondary effluents, or increasing dry-weather treatment capacity during the vast majority of the time, when it is not raining.

At present, officials are considering the award of demonstration grants to state and local governments for the evaluation of physical-chemical processes applying the dual treatment concept, such as screening coupled with deep-bed, dual-media, ultra-high-rate filtration; and activated carbon adsorption. Both treatment schemes would be aided by chemical additions.

Swirl and Helical Separators

The EPA program has refined and is demonstrating the swirl flow regulator/solids-liquid separator [5,18,22]. The device, of simple annular shape construction, requires no moving parts. It provides a dual function, regulating flow by a central circular weir while simultaneously treating combined wastewater by a "swirl" action which imparts liquid-solids separation. The low-flow concentrate is diverted via a bottom orifice to the sanitary sewerage system for subsequent treatment at the municipal works, and the relatively clear liquid overflows the weir into a central downshaft and receives further treatment or is discharged to the stream. Figure 4 shows an isometric view of the swirl regulator/concentrator. The device is capable of functioning efficiently over a wide range of combined sewer overflow rates, and can effectively separate suspended matter at a small fraction of the detention time required for conventional sedimentation or flotation. For these reasons, projects are underway to perfect swirl units to take the place of grit chambers [23] and primary sedimentation units.

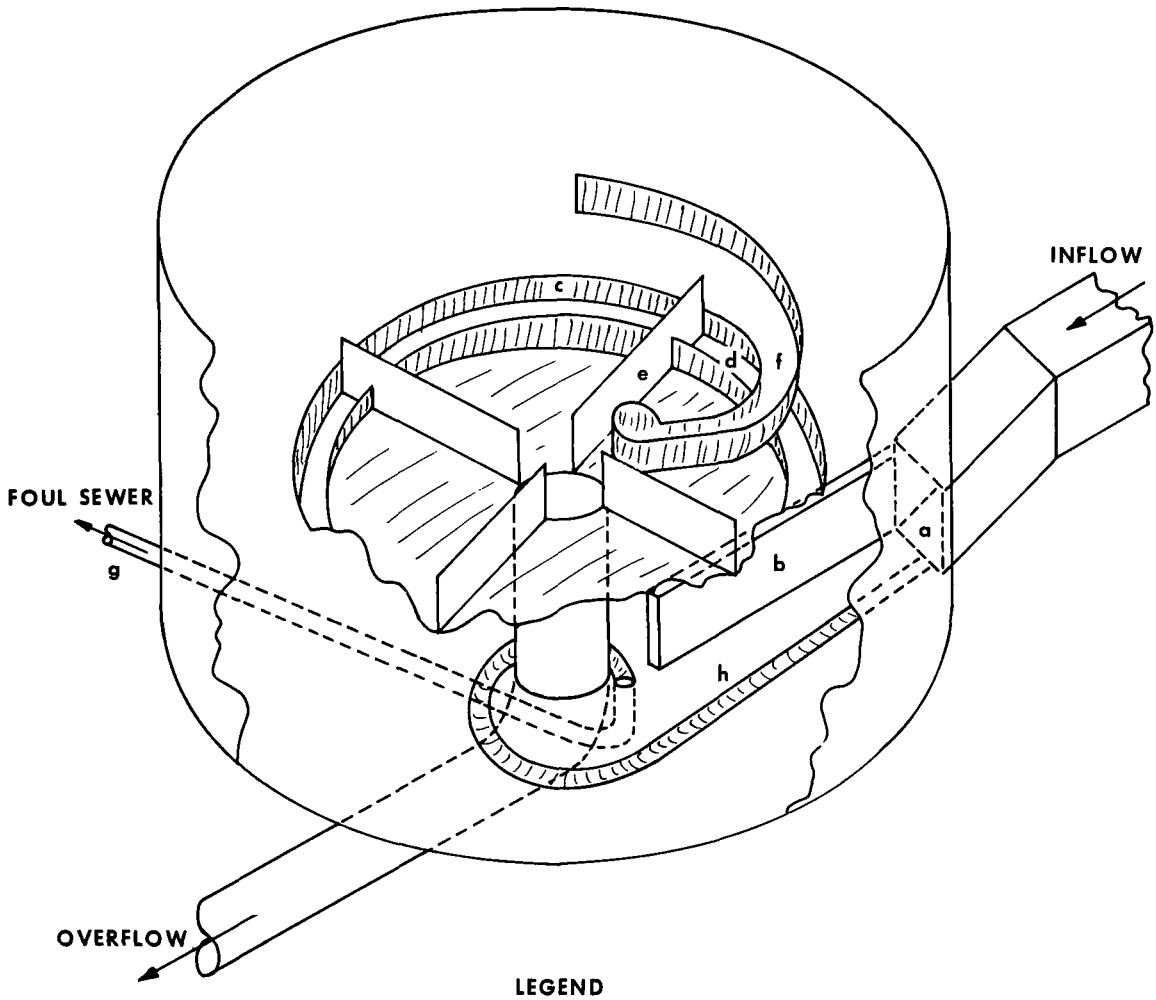
Development is proceeding on a helical or spiral-type regulator/separator based on principles similar to those of the swirl device. This device is beneficial as its solids separation action is created by only a bend in the sewer line.

Comparisons of Screening Devices

Screening is adaptable to the intermittent and variable hydraulic and solids characteristics of storm caused flows, and accordingly fine mesh screening devices and microstrainers have been developed for the program. To enhance previous work and allow better selection and design in the future, EPA has awarded two grants to Fort Wayne, Indiana, and to Onondaga County (Syracuse), New York. Multiple screening options are being tested at these locations to directly gain this needed comparative data.

Hydrologic-Hydraulic Design Rationale

Urban hydrology is a field which is almost devoid of modern research investment. As a consequence, too little is known about the rainfall-runoff process and still less about rainfall-runoff quality, particularly for sewered catchments. More research is needed to develop a more complete understanding of the entire urban runoff pollution problem.



LEGEND

- a Inlet Ramp
- b Flow Deflector
- c Scum Ring
- d Overflow Weir and Weir Plate
- e Spoilers
- f Floatables Trap
- g Foul Sewer Outlet
- h Floor Gutters

FIGURE 4. Isometric View of Swirl Regulator/Concentrator

A project was implemented to study the methods currently in use to describe and predict rainfall intensity duration relationships as they relate to storm and combined sewer flow, and to non-sewered urban runoff. This study will evaluate the relative merits of particularly those which involve empiricisms and statistics or rainfall prediction based on limited historical data. A document will be developed to aid engineers and planners in assessment, design, and control. The aim will be to provide recommended methods for determining cumulative runoff volumes and flow rates for design and operation of combined sewer overflow and stormwater runoff control and treatment facilities.

Beneficial Use of Stormwater

A previous project evaluated the reuse of stormwater runoff for aesthetic, recreational, and sub-potable and potable water supply purposes in the new Columbia, Maryland Development [21].

In Mount Clemens, Michigan, a series of three "lakelets" have been incorporated into a park development. Treatment is being provided so that these lakes are aesthetically pleasing and to allow their waters to be used for recreation and reused for irrigation. The Mount Clemens design has won the ASCE Conceptor award in the state. Other projects have shown the feasibility of reclaiming stormwater [6].

Because of their value in urban planning, more demonstrations are needed. A new EPA project is part of a planned community being developed near Houston. Entitled "Maximum Utilization of Water Resources in a Planned Community," the study will focus on how a "natural drainage system" can be integrated into a reuse scheme for recreation and aesthetic purposes. Runoff will flow through low vegetated swales and into a network of wet-weather ponds, strategically located in areas of porous soils, as well as into variable volume lakes. This attenuation process will allow some of the runoff to seep into the ground and retard the flow of water downstream, thus preventing floods caused by development. A twelve acre man-made lake, used as a pilot, will be the main focal point. Concentrations of various biocides, nutrients, and disinfectant residuals in runoff and their effect in the receiving lake system will be measured. Evaluation of a multi-process and flexible stormwater pilot plant which will treat runoff before it enters the lake will also be part of this program. The pilot system evaluations will result in control recommendations for a larger 400 acre lake to be built in the future.

Considering urban runoff as a benefit as opposed to a wastewater, along with the concept of new community development which blends into and enhances its environment rather than upsetting it, will be employed and thoroughly evaluated for the first time. Hopefully, it will be shown that man and the natural environment can coexist.

EDUCATION

Storm generated pollution ranks high along with domestic and industrial sources and yet remains unstressed in the schools. With wet-weather control requirements evident, now is the time to encourage universities to cover the concepts of stormwater runoff and combined sewer overflow pollution in proper perspective in their graduate and undergraduate school water pollution control curriculum.

EPA has sponsored the development of a course manual which will eventually be distributed to colleges throughout the country for easy and direct incorporation into their respective curriculums. This project is extremely valuable since it will give today's students an initial background in a newly developed technology which is receiving national emphasis.

A thorough mathematical modelling seminar has been presented at the University of Massachusetts on August 19-23, 1974. Presentation of the second seminar is anticipated during the summer of 1975. This program is needed as rational solutions to urban hydrologic problems by simulation models have been slow in reaching consulting engineers. Modelling requires detailed understanding and instruction. To enhance its effect, the seminar will start at an elementary level before continuing with model development and user instruction.

CONCEPT RECRUITMENT

Many more ideas and concepts could be added -- some may be more significant than those discussed. Submission of ideas, project proposals, or grant applications to the EPA is strongly encouraged.

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16. ABSTRACT

Control and/or treatment of stormwater discharges and combined sewage overflows from urban areas are problems of increasing importance in the field of water quality management. Over the past decade much research effort has been expended and a large amount of data has been generated, primarily through the actions and support of the U.S. Environmental Protection Agency's (EPA) Storm and Combined Sewer Research and Development Program. Presented in this text are selected results of a comprehensive investigation and assessment of promising, completed and ongoing projects, representative of the state-of-the-art in abatement theory and technology; a look at recent legislation; and the identification of program needs and emphasis. Combined sewer overflows are major sources of water pollution problems, but even discharges of stormwater alone can seriously affect water quality. Current approaches involve control of overflows, treatment and combinations of the two. Control may involve maximizing treatment with existing facilities, control of infiltration and extraneous inflows, surface sanitation and management, as well as flow regulation and storage. A number of treatment methods have been evaluated including high rate screening and microstraining, ultra high rate filtration, dissolved air flotation, physical/chemical treatment, and modified biological processes. A swirl flow regulator/solids separator of annular shape construction with no moving parts has been developed. High rate disinfection methods including new disinfectants have been applied. Promising approaches involve integrated use of controls and treatment. The most disappointing have generally lacked flexibility in their operation and design. Mathematical models have been developed and successfully applied at multiple levels of sophistication and complexity.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Disinfection, Drainage, *Water pollution, *Waste treatment, *Sewage treatment, *Surface water runoff, *Runoff, *Waste water, *Sewage, Contaminants, *Water quality, *Cost effectiveness, *Storage tanks, *Storm sewers, *Overflows-sewers, *Combined sewers, *Hydrology, *Mathematical models, Hydraulics	Drainage systems, Water pollution control, pollution abatement, *Storm runoff, *Water pollution sources, *Water pollution effects, *Wastewater treatment, *Urban hydrology, *Combined sewer overflows	13B

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