WATER QUALITY PLANNING PROGRAM

W/Q Tech Memo No. 83
G. Silverman/M. Stenstrom

DISPERSION AND OUTFALL DEVICES TO MITIGATE EFFECTS

OF OIL AND GREASE IN URBAN STORMWATER

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Introduction

The use of dispersion devices at stormwater outfalls was identified as a potential favorable control measure during the ABAG research on oil and grease in urban stormwater (ABAG 1981a). Since stormwater normally enters the receiving water body along the shoreline, it is the relatively shallow, productive littoral or neritic zones that receive most of the impact of stormwater pollutants. In the San Francisco Bay, much of this shoreline area consists of shellfish beds and important fish habitats. Little has been done to quantify the effects of chronic, low level oil and grease pollution to Bay organisms, although there is evidence that current hydrocarbon levels in the Bay may be sufficient to cause environmental damage (Association of Bay Area Governments 1981b, Di Salvo and Guard; 1975, Di Salvo, et. al. 1976; Jung and Bowes, 1980; Whipple et. al., 1981).

The use of outfalls and dispersant devices is basically a method of removing pollutants from sensitive areas with subsequent deposition in less sensitive areas where rapid dilution will render them innocuous to the environment. No treatment or degradation of the pollutants is anticipated from this method--the total volume of pollution generated from a system remains unchanged. Animosity from environmental concerns is commonly generated toward the dispersion of pollutants, with the fear that dispersion may only mask or translocate the pollutant problem without affecting real environmental benefits. However, much of the concern with outfall diffusers has historically been with industrial and municipal effluents having relatively high levels of pollutants and offering a reasonable capacity for additional treatment at the facility. Stormwater runoff generally has had lower concentrations of pollutants than industrial or municipal effluents. Since pollutant concentrations were relatively low and control of non-point sources relatively difficult, treatment of stormwater runoff has generally been ignored. However, as pollution from industrial and municipal sources has subsided in response to environmental legislation and awareness, the relative proportion of pollution from stormwater has increased. While pollutant concentrations from stormwater runoff remain relatively low, the absolute quantity of pollution may be sufficient to cause significant environmental impact. Removing this pollutant source to deeper water subject to flushing and away from sensitive areas may provide a practical means of introducing these pollutants into the environment at sufficiently dilute concentrations to allow for degradation without promoting environmental harm.

Site Evaluation

It is impractical to offer a specific outfall-diffuser design suitable for a variety of locations. Any site would have very specific requirements depending upon local conditions. However, criteria are identified below which at a minimum should be considered when evaluating specific design characteristics for any given site. Many of these criteria are discussed in great detail in the review of marine outfalls prepared by Grace (1978).

1) Environmental Effects

The purpose of diffuser-outfall systems for stormwater is basically to remove discharge from a sensitive area to an area where the discharge will have little detrimental effect. To accomplish this task, information must be known concerning the effects of the discharge on the existing discharge site and effects that would occur on proposed discharge sites. This type of information is very difficult to obtain and verify, and often is a subject of contention from various interest groups. In the San Francisco Bay, awareness is just beginning to be generated concerning the possibility of significant hydrocarbon pollution from urban runoff, with virtually no work being done to determine critical sites or possible means of removal. Certainly, environmental effects are one of the major concerns that must be satisfied before any outfall-diffusion device is constructed. Major environmental effects are commonly known to occur at municipal and industrial deep water outfall sites, but effects are not known for corresponding systems of stormwater runoff with much more dilute pollutant concentrations. For the Bay, this would entail major research activities in order to better understand Bay ecology from which to base siting and system feasibility decisions.

2) Health Concerns

Care must be taken to protect the environment not only in terms of area ecology, but also in terms of direct human impact. Periodic or sub-critical releases of pollutant material into the environment may not cause local damage, but may be of concern to human consumption of organisms feeding in the outfall area. While outfalls would normally remove discharges away from shellfish beds, deep water discharges may provide contamination of food fishes. Little is known about possible contamination from deepwater stormwater outfalls, but research should be conducted to determine possible adverse effects before outfall construction is promoted.

3) Physical Feasibility

There are multiple physical criteria that must be satisfied before an outflow-diffuser system can be considered practical. The bottom topography and surface material must be such as to allow placement of the pipeline while providing sufficient depth at the terminus with a reasonable length pipe in a relatively uniform direction. Winds, currents and tides must be taken into account to ensure that the discharge is not washed into sensitive areas. Hydraulics must be studied to determine the dispersion of the discharge, particularly with regard to differences in salinity and temperature, as well as currents, tides and winds. Surface wave action must also be considered, particularly in shallow areas where wave forces may impose severe stress on pipelines.

4. Legal Constraints

The legal requirements involved in constructing an outfall-diffuser system are quite complex and hampered by the fact that this type of system is not usually constructed for stormwater; there is no precedent from which to base legal restraints. If such a system were constructed in the Bay Area, it would probably require permits from: Army Corps of Engineers, Bay Conservation and Development Commission, State Water Quality Control Board, city and/or county governments and perhaps the U.S. Coast Guard. Substantial public review would be required, where many of the environmental and health concerns mentioned above would be brought forth by the public. Legal constraints appear to be another major obstacle to the construction of a outfall-diffuser system.

5) Conflict With Other Uses

Care must be taken to account for pre-existing or potential uses of an area that could conflict with the construction and use of an outfall-diffuser system. A major concern is that the system does not interfere with ship traffic, both in terms of hindering traffic and in terms of pipeline damage from anchors or other gear. Other concerns include possible interference with fishing, reduction in aesthetic quality and deterioration of recreational qualities through physical changes and/or psychological concerns.

6) Economic Capability

Unlike the other oil and grease control measures recommended by the Association of Bay Area Governments (1981), outfall-diffuser system structures require a substantial capital investment. Even if the cost/benefit ratio is favorable, a municipality may lack the financial ability to construct a system. A commitment must be made to construct the complete system; it cannot be done incrementally with benefits accruing in proportion to the amount of effort expended.

7) Construction

While the above considerations extend through the life of the project, special consideration needs to be given to impacts generated through the construction of an outfall-diffuser system. Even if the system would not be harmful to the environment while in operation, construction might cause irreversible damage to the ecosystem. Construction can result in the direct destruction of bottom fauna as well as destruction of habitat through excessive siltation. Similarly, thought must be given to the disruption of recreational, wildlife and aesthetic values during project construction.

Preliminary System Design

While specific design of a diffuser-outfall system is impractical, a preliminary analysis of a system for the Richmond watershed used in the ABAG oil and grease study (ABAG, 1981) has been performed to demonstrate the applicability of the system. Much of this preliminary design has been reported by ABAG (1981a). In designing the diffuser one must first select the maximum rainstorm size. It is not possible or economical to diffuse all stormwaters since the maximum storm magnitude can never be known. A simple approach to determine a reasonable diffuser size is to select a maximum probability storm event, and design to diffuse this storm. To determine the maximum probability storm it is useful to use a cumulative log-normal probability plot, as shown in Figure 1.

Figure 1 shows the measurable rainfall events for the year of the experimental phase of the ABAG study, March 1980 to March 1981. During this year there were 47 measurable rainfall events, ranging from 0.025 in/day to 2.0 in/day. The maximum probability rainfall event can be selected in either a deterministic basis or economical basis, but for this example a probability of 90% was chosen which is approximately 0.9 inches/day.

The total runoff flow at the mouth of the watershed can be estimated from the experimental data from this study. The total flow rate (integral of the hydrograph) can be correlated to the total rainfall. For this study, the following correlation was developed:

$$TF = 34.77 * TRAIN - 3.82$$

where

TF = estimate of the total runoff (10^6 gal/day)

TRAIN = total rainfall (in/day)

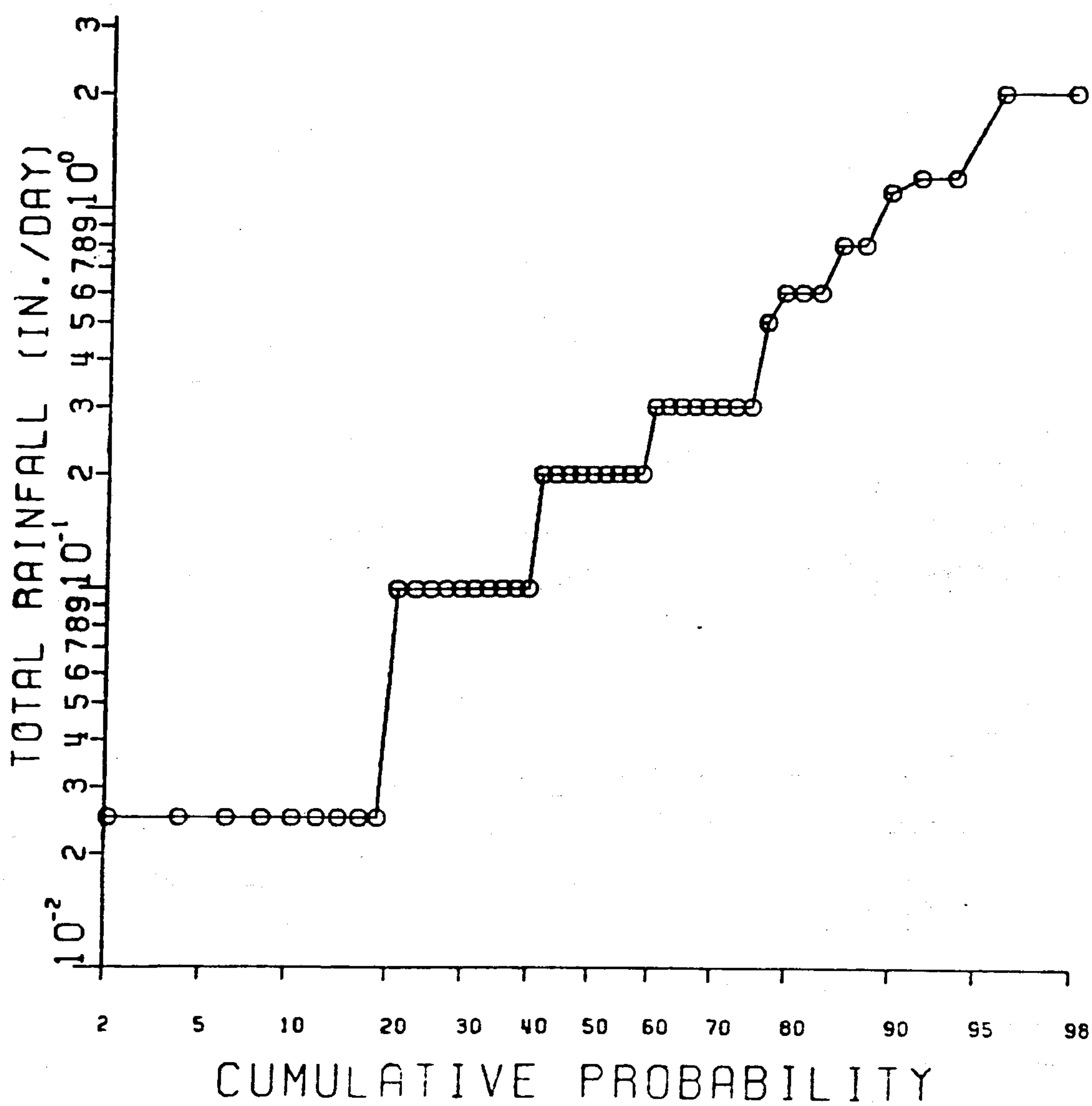


Figure 1. Cumulative log - normal probability plot of rainfall events March 1980 - March 1981.

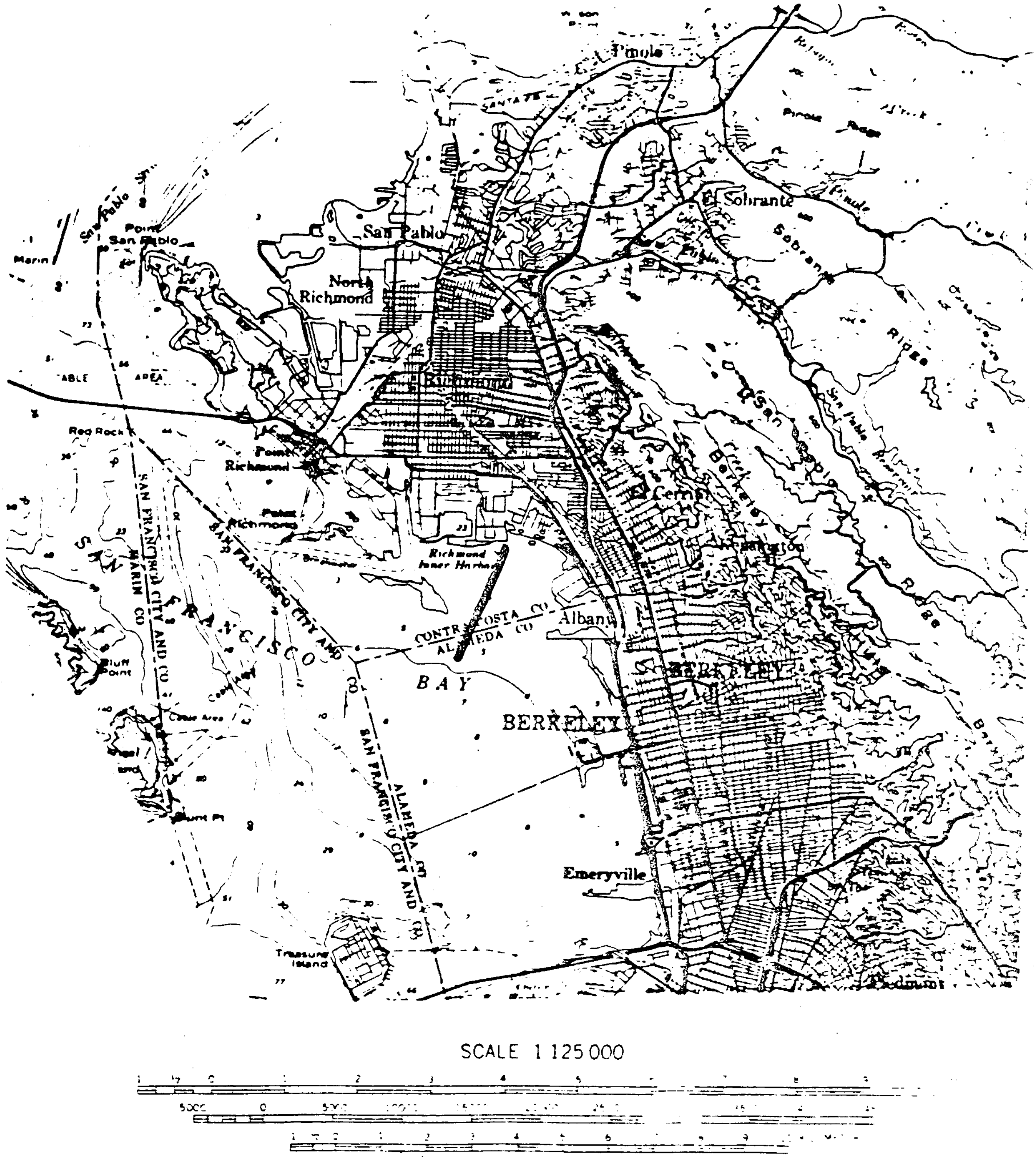
The correlation coefficient for this regression (r^2) is 0.97. The negative intercept results because there is no measurable runoff in very low rainfall. Obviously this correlation is only valid when it predicts positive values of total runoff. For a 0.9 in/day rainfall, the regression predicts 27.5 million gallons of stormwater.

Alternatively, other storms could be selected for system design. Following Rantz (1971), the 12 hour, 10 year storm in Richmond would deposit 2.42 inches of rain. Using the correlation discussed above, the regression predicts that the 10 year storm would result in 80.3 million gallons of rainwater. The choice of design storm would to a large extent be an economic/political decision.

The rate of flow of storm water is more difficult to predict. Detailed hydrographs of the study area would be required. Furthermore, flow rate would depend on the length and intensity of the rainfall. For the purpose of this example it is sufficient to select an average flow rate of 5 MGD. In reality the flow rate during the storm would initially be much less than the average flow, but would quickly exceed average flow and then gradually decline to less than average flow. To mitigate the effects of changing flow rate and to increase diffuser efficiency storage can be provided. Storage will allow a greater percentage of the total runoff to be diffused.

The problem of designing ocean diffusers is very complicated and requires solution of the continuity and momentum equations. Fortunately a number of preliminary design techniques using nomographs have recently been published by Wallis (1977), Chai and Campuzano (1972), Chao (1975) and Schan (1978). To determine the dilutions produced by the diffuser it is necessary to know the water depth and length of diffuser. Water depth usually cannot be controlled, except through diffuser location with diffuser length a design variable.

Figure 2 shows the depths of the Bay near the Richmond watershed. From this figure it is easy to observe that water is generally quite shallow with a depth of only four or five feet for distances extending outward to two miles. Therefore, the Richmond location is not optimal for a diffuser; however, a diffuser could still be provided and could provide dilutions of approximately 10 to 1 in the 4 to 5 foot depth range. The resulting 2 mile pipe, if sized for 5 MGD flow rate, and assuming a velocity of 2.5 feet/sec could use a 24" diameter pipe. If a greater flow design was indicated, the pipe diameter could be increased appropriately (e.g. a flow rate of 15 million gallons/day using the same water velocity of 2.5 feet/second would require approximately a 42 inch diameter pipe). Thus, the design storm is a critical consideration in sizing the outfall pipe which is a major cost factor.



CONTOUR INTERVAL 200 FEET
DOTTED LINES REPRESENT 40-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Figure 2. Depths of San Francisco Bay near Richmond. Heavy bar shows 4-5 foot depth near study watershed.

The head loss in the two mile pipe can be calculated using the Darcy - Weisbach equation (Brater and King, 1976). Assuming a discharge coefficient of 140, the 2 foot diameter outfall pipe would have a friction loss of approximately .06 feet /100 feet, or approximately 6.5 feet of dynamic head loss for the 2 mile length. If the larger, 42 inch diameter, pipe were used, the dynamic head loss would be approximately 4 feet for the two mile length.

It would be relatively simple to build a small storage system inland from the present outfall that would provide the elevation required to account for the head loss. Alternatively, a smaller diffuser diameter could be used and a pumping station provided. The best economical choice of diffuser size would depend on site specific information. The capital cost of such a facility would be several hundred thousand dollars depending upon the size of the diffuser used (USEPA, 1979). The operating cost would be small. Only infrequent cleaning of debris would be required. To pump an additional 10MGD of stormwater through the diffuser, approximately 250 horsepower of pumping capacity would be needed assuming 75% pump efficiency. The cost of this pumping, if needed for a total of five 24-hour days per year, would be approximately $1600 at $0.07 per kilowat.

Conclusions

Outfall-diffuser systems offer the potential of a practical means of diverting stormwater runoff from sensitive areas with subsequent release and disposal without resulting in detrimental effects. However, many barriers need to be overcome before any such system could be employed. Individual sites would have to be carefully examined with consideration given to local conditions. General area ecology and hydraulics would also have to be well understood in order to ensure that diffuser location would not result in a general spreading of environmental harm. Legal and economic difficulties would have to be overcome, and the views of an interested public would have to be considered. Compounding these problems is the lack of direct precedent, with the best available analogy being deep water industrial and municipal effluent disposal systems which have a mixed record of effectiveness.

In the San Francisco Bay Area, there is generally insufficient knowledge from which to examine the feasibility of outfall-diffuser systems. However, with increasing knowledge of shoreline biotas and indications of significant pollutant potential from stormwater runoff, future work should consider the option of removing outfalls from sensitive areas. The stigma of associating outfalls with municipal and industrial effluents would have to be overcome before general public acceptance could be obtained of the stormwater outfall-dispersion system. Before an system could be recommended for any specific site in the Bay Area, more information would be needed on general Bay ecology and hydraulics, as well as specific site information concerning runoff water quality, local hydraulics and area ecology.

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