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MICROORGANISMS IN URBAN STORMWATER

Municipal Environmental Research Laboratory
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Cincinnati, Ohio 45268

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MICROORGANISMS IN URBAN STORMWATER

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report documents microbiological quantitative assays of Baltimore City urban runoff to show the relationships to several factors such as separate or combined sewer flow, urban characteristics of drainage area, rainfall, and quantity of flow during and between rain storms. In general, there was a consistently high recovery of both pathogenic and indicator microorganisms throughout the study.

ABSTRACT

Microbiological quantitative assays of Baltimore City urban runoff were conducted throughout a 12 month period to show the relationships to several factors such as separate or combined sewer flow, urban characteristics of drainage area, rainfall, and quantity of flow during and between rain storms. In general, there was a consistently high recovery of both pathogenic and indicator organisms throughout the study except for *Shigella* sp. which is believed to have been present but could not be isolated due to interferences during the culture procedure. There appeared to be little relationship between pathogen recovery and season of the year, amount of rainfall, period of the antecedent rainfall, and stream flow. The most concentrated pathogens were *Pseudomonas aeruginosa* and *Staphylococcus aureus* at levels ranging from 10^3 to 10^5 and from 10^0 to 10^3/100ml, respectively. *Salmonella* and enteroviruses, though frequently isolated, were found at levels of only 10^0 to 10^4/10 l of urban runoff. The background samples (sewage, urban streams and reservoirs) between storms gave good positive correlation between indicators and pathogens at a 95 to 99% level of confidence, whereas, the stormwater had no or poor correlation. The ratios of indicators, such as FC/FS, gave some indications of pollution by human sewage, but it was the presence of enteroviruses that definitely showed the mixing of sewage with rain water, whether in a storm sewer or in the combined sewer overflow. The logical solution would point to the removal of sanitary sewage overflows rather than the disinfection of all urban runoff for removing the health hazard and improving the quality of urban runoff.

This report was submitted in fulfillment of grant no. R802709 by the Johns Hopkins University under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 1, 1974 to December 31, 1976 and work was completed as of August 1975.

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INTRODUCTION

Little is known of the early urban sewerage systems in the United States. Often they were constructed by individuals or the small district at their own expense and with little or no engineering or public supervision. The oldest sewers date from 1805 to 1810. It should be noted that these sewers were intended only for the removal of stormwater, and excreta were excluded. However, the runoff from the growing towns and cities containing all kinds of matter washed from unpaved streets, livery stables, dead animals, overflowing cesspools and privy vaults contributed to the rise of the great urban epidemics. These diseases were then known as "pythogenic" (born of putridity) and although scientifically unsound, started the sanitary movement for better town drainage. Col. George E. Waring, Jr. (1) believed in town drainage but promoted the "dry-earth system of sewerage". In a paper on sanitary drainage in 1875 he wrote:

> "I should never recommend water (carriage) sewerage; yet the dry earth in the present states of its development, is so inapplicable to a large majority of cases, or so distasteful to a mass of persons whose necessities demand immediate relief, that, without in any way receding from its advocacy, I freely acknowledge that the practical good which is to come from water sewerage is evident."

Already in Boston in 1833 house connections and cesspool overflows were being made to storm sewers. The quantities of domestic and industrial waste collections were comparatively small to stormwater flow so that the inclusion of sewage did not require an appreciably larger conduit. The practice of introducing sanitary sewage into the nearest storm drain became wide spread with disasterous results. There had been a tendency to employ needlessly large dimensions for stormwater sewers and coupled with flat grade resulted in accumulation of decomposing sludge during dry weather and sluicing of solids into receiving streams during rainstorms. The first application of engineering skill in sewer design was in Brooklyn, New York in 1857 followed in Chicago in 1858. The combined sewer system design with provision for self-cleaning dry weather flow became established and by 1875, of the 67 cities so sewered having a population $\geq$ 100,000 not one was treating its waste but merely discharging to the nearest water course. The increasingly foul runoff into the neighborhood from these sewers was exceedingly disagreeable and a health hazard. In many cities the streams had to be covered to minimize the nuisance and boat docks near polluted waters were often relocated so as not to offend passengers. The solution for the pollution crises was expensive and involved extensive interception of the dry weather flows from hundreds of combined sewer outlets for conveyance or pumping to plants for treatment prior to discharge.

The first system of separate sanitary sewers for the collection of domestic wastes was built in 1880 by no other than Col. Waring in Memphis, Tennessee. Although the system was a comparative failure,

it did much to establish design principles and benefits of the system over the combined sewer. These benefits were apparent in small communities where the receiving streams provided insufficient dilution for combined sewer overflow and the treatment was necessary. Where stormwater was conveyed by naturally occurring open drains, the separate system permitted the best sanitary solution with least cost and delay. Nevertheless, there still remained mistrust regarding the principle of separation and the U.S. Board of Health in 1880 sent an engineer, Rudolph Herring, to Europe to observe the extensive experiences they had with both combined and separate systems. In his report Mr. Herring (2) concluded:

> "The principle of separation, although often ostensively preferred on sanitary grounds, does not necessarily give the system in this respect any decided advantage over the combined, except under certain definite conditions."

Thus, the construction of combined systems was continued and was extended on economic grounds. Most of the major cities in the United States: New York, Boston, Philadelphia, St. Louis, Chicago, Cleveland, Portland, and Washington, D.C., to mention a few, are still largely served with combined sewer systems. Only Baltimore, Maryland at the turn of the century elected to provide the separate system of sewers.

As the cities expanded and became more congested, the sewage and storm flow increased. Combined interceptors could no longer contain even the most modest rain and frequent flooding of streets and basements was common. Interceptor overflows were used to divert the stormwater commingled with sewage to surface waterways away from direct contact with the citizens. Treatment was bypassed and the general sanitary quality of water fronts and urban streams began to deteriorate. As early as 1900 many state regulatory agencies would not permit further construction of combined sewers.

Even where separate systems were built, the problems of urban runoff were not completely resolved. Sewer mains, interceptors, pumping stations and treatment plants did not grow but the demand for sewer service did. The post-World War II boom for sewer service has yet to be satisfied with the extension of sewer lines into fast growing suburban fringe areas, often with high infiltration rates and many illegal rain water connections which overtax the entire system. In order to limit the backing up of raw sewage into basements, hundreds of bleeders are provided which discharge sewage into storm sewers. The net effect is that sewage is not reaching the treatment plant. In a way the problems of the combined and separate systems are becoming more similar. The engineering solution of parallel interceptors and increased pumping and treatment capacities is much more economical for the separate system than for abating the combined sewerage problem.

As in the past, today the problem of urban runoff involves a variety of pollutants as well as the sewage component. Urban stormwater is consistently found to contribute pollutants proportioned to population density, new construction, street and vegetation litter, motor vehicle contaminants, fertilizer, and animal manure as well as intentional and unintentional sewage discharge. Many studies and conferences have

been directed to the urban runoff problem. More research is indicated in several areas including: street materials such as salt, grit, oil and garbage; non-street materials including animal wastes, fertilizers, and pesticides; construction activity; sanitary sewage; airborne particulates; commercial and industrial wastes, and unrecorded and undetected discharges to storm drains. The cost of correcting the problem is apt to be enormous depending upon the degree, and the strategy of abatement is deemed necessary. It has been estimated that the runoff in the urbanized area portion of the Standard Metropolitan Statistical Areas of the United States in 1973 is 85 million m^3/day (22.5 billion gallons/day). The strategy of treatment depending upon the abatement levels required may have a capital cost of $134 to $350 billion for simple screening to advance waste treatment. The operation and maintenance might vary from $93 to $2,700 million/year (3).

The fact that stormwater runoff from urban areas contains large concentrations of microorganisms has been well established. It has been generally supposed that the great occurrence of microorganisms is discharged with the first flush of the combined storm and sanitary sewer which acts as a settling basin during dry weather flow. Also, it has been assumed that the bacterial concentration will be lowered by the dilution of rain water after the entrained pollution within the sewer has been purged. What concentration of microorganisms might be expected in urban runoff from areas with well functioning sewer systems had not been clearly defined. Studies of the bacterial quality of such runoff have been limited to the determination of the densities of indicator microorganisms. The major limitation to the total coliform or fecal coliform index of stormwater quality has been the uncertain correlation to the occurrence of pathogenic bacteria and viruses.

While fragments of such data are available, more is needed on what health hazard potential actually exists keeping in mind the possible priority of modes of pathogen entry. Entry by ingestion has high priority in the case of eating raw shellfish but low in the case of accidental drinking of surface water. Entry by contact may be a major factor in ear, nose and throat infections among those engaged in swimming but a low priority for pathogen penetration of the mucous membrane or through cuts. The latter represents water-borne epidemiological curiosities such as central nervous system amoebiasis caused by *Naegleria gruberi*, or leptospirosis, or *Mycobacterium balnei* skin ulcers.

It is known that rural stormwater runoff from pastures, farms and barnyards have fecal coliform discharges that may be equal to or exceed that of municipal sewage. While the problem of nutrients and BOD of cattle waste exists, the potential health threat of the microorganism remains to be demonstrated. Literature is replete with references to high densities of total coliforms, fecal coliforms, and fecal streptococci in stormwater samples from forested (4, 5), agricultural, and rural (4, 5, 6), urban and suburban (4, 5, 6, 7, 8) drainage areas. Typhoid fever is not an indigenous health problem in the U.S. today. However, with enormous numbers of people travelling abroad and returning to metropolitan areas the health threat from exotic enteric diseases cannot be dismissed. This is especially true in view of the deficiencies

known to exist in the wastewater collection, transmission and disposal systems and the tremendous opportunities for adults and children to contact the waters receiving the urban runoff.

The large urban waterway and its numerous small urban streams (flood ways) are very much in demand for recreational and aesthetic parks serving the city population. Unfortunately, the quality of these waters is greatly impaired even when separate sewers are provided for stormwater and sanitary sewage. Whitman in 1968 (9) surveyed the sources of pollution in the urban streams in Baltimore (separate sewers) and Washington, D.C. (combined sewers) and revealed that the largest cause of poor water quality in both cities was sewer malfunction. Although the contribution of indicator and pathogenic microorganisms from the feces of pets, birds and rodents cannot be ignored, the pollution of urban waterways with untreated sewage presents a greater potential health threat. Many regulatory agencies post signs printed "Danger, Polluted Water, Keep Out!" Obviously, this conflicts with the fullest use and enjoyment of the waterway.

The National Commission on Water Quality study (3) could find no information on any runoff sampling studies conducted specifically for human pathogens. The main objective of this report is to provide the needed information on the presence and concentrations of selected pathogenic bacteria and viruses in the urban runoff from areas served by combined and separate sewers.

CONCLUSIONS

1. High densities of indicator microorganisms were found in the urban streams. Only three samples of 92 were less than the National Technical Advisory Council suggested standard for recreational waters. The mean concentration was 30 times the 200 fecal coliform/100 ml desired. Pathogenic microorganisms were consistently recovered. *P. aeruginosa* were the most numerous, *Staphylococcus aureus* was present at low levels, and *Salmonella* and enteric viruses required concentration for enumeration.

2. High densities of indicator microorganisms were also found in urban storm runoff. Only one sample of 136 was less than the 200 fecal coliform/100 ml standard. Pathogens were consistently recovered at approximately 10-fold higher densities than in the stream samples. The same order of occurrence was observed.

3. There was no marked seasonal variation in the levels of microorganisms in the urban streams. There was a slight elevation of concentration in the density of *P. aeruginosa* in the early fall when rainfall was minimal and water temperature was the highest.

4. The density of fecal coliform was independent of flow and antecedent rainfall in the urban streams.

5. In the routinely examined background samples (sewage, urban streams and reservoirs), there was a strong positive correlation between the levels of total coliform, fecal coliform, fecal streptococci and enterococci and the levels of pathogenic bacteria. Only the levels of total coliform and fecal coliform correlated well with the levels of enteric viruses.

6. In the stormwater samples the densities of indicators and pathogenic bacteria were for the most part independent with no significant positive or negative correlation. The only exceptions were for total coliform to *Salmonella*, and total coliform and fecal coliform to *P. aeruginosa*. No correlation was observed between indicator bacteria and enteric viruses.

7. Although in the examination of samples, the recovery of *Shigella* sp. was negative, there is circumstantial evidence that the genus is present in urban surface water and could present a significant health hazard.

8. Members of the genus *Salmonella* were recovered from all the raw sewage, 91% of the urban stream and 94% of the stormwater samples. The parallel seeding experiments suggested that the levels of *Salmonella* reported in this study and probably in other studies were underestimates of the true densities. Methods for the enumeration of enteric viruses and pathogenic *Staphylococci* also appear to have inherent short comings.

RECOMMENDATIONS

1. Although pathogenic microorganisms were consistently recovered from urban storm runoff in this study, the densities of enteric pathogenic bacteria and viruses were found to be relatively low. It is highly unlikely today that urban populations will consume the large quantities of unattractive storm runoff required to cause overt diseases. In coastal areas, the taking of shellfish from waters in the immediate vicinity of urban storm sewers is forbidden due to unsatisfactory sanitary survey, if not for excessive coliform or fecal coliform densities. It is acknowledged that although commercial harvesting for direct marketing is prohibited in such areas, some recreational taking of shellfish presents a more plausible threat to health since pathogens are concentrated and shellfish are often consumed raw. Urban stormwater contaminants reaching recreational water are further diluted. If beaches are close by, more often than not they are closed because of exceeding of prevailing coliform standards. The threat to those who persist in swimming is small since prodigious swallowing of water would be required to increase enteric disease risk. Pathogenic organisms not requring ingestion, namely, *P. aeruginosa* and *Staphylococcus aureus* are admittedly abundant, yet the evidence is not available that skin, eye, or ear infections arise from the organism in the recreational water. Thus, with the exception of the members of the genus *Shigella*, there is little reason known today for extensive public health concern in recreational waters receiving urban storm runoff. Furthermore, the urban storm runoff and many of the receiving bodies of water are aesthetically unattractive during and immediately following storm events and thereby receive little use, if at all, when the levels of microorganisms are the highest. Given these conditions existing today, there is little justification based on benefit-risk considerations to warrant a program of disinfection of billions of gallons of urban storm runoff. On the other hand, more serious effort should be given to increasing the carrying capacities of sanitary sewers and to maintaining them so as to minimize overflows of raw sewage into urban waterways.

2. The levels of pathogenic microorganisms observed in the intentionally constructed combined sewer in this study (Howard Park, site H) were generally 10-fold higher than the levels in the urban storm runoff. Even at these higher levels, the enteric health hazard is believed to be limited unless there is the likelihood of the direct consumption of combined wastewater or the water in the stream receiving combined wastewater. Combined sewer overflows also place added loads on downstream water treatment works, where they exist. If water contact recreation areas exist downstream, the hazard may be a little more real because of the nature of the escape of the slug of pollution during the storm water flow. In the absence of any cost-effective and practical method of separating storm water from the sanitary

sewage, disinfection of the combined wastewater to reduce the microbial load for subsequent water treatment and to minimize the hazard to downstream users of direct water contact recreational areas may be indicated.

3. Better methods and procedures should be developed for the enumeration of pathogenic microorganisms. Although the techniques for the quantitative determination of *Salmonella* sp. and enteric viruses have improved dramatically in the last ten years, there is considerable room for advancement. Particular attention should be directed toward the improvement of assay methods for these microorganisms for moderately to heavily contaminated samples. Superior media and methods are lacking for the rapid, selective enumeration of *Staph. aureus* in water. Reliable qualitative recovery procedures for *Shigella* sp. are not available.

4. Since there is little danger of direct consumption of urban storm runoff, information on survival of the natural pathogen populations would be useful to better evaluate the impact of the storm runoff on receiving bodies of water. This would be of particular importance for recreational waters and shellfish harvesting waters in the coastal regions.

STUDY SITE

The investigations on microorganisms in urban stormwater were carried out in Baltimore City, Maryland. Baltimore is unique in being the first large city in the United States to construct a comprehensive system of separate sanitary and stormwater sewers. The sanitary sewerage plan was conceived in 1907, completed construction in 1915, including secondary treatment, and 90% of the population of the city was connected by 1920. Today the sewer system extends into the metropolitan areas of Baltimore County. The Baltimore metropolitan area, as shown in Figure 1, is intersected by four separate drainage areas which discharge into the tidal estuary of the Chesapeake Bay. The main arm of the Baltimore harbor is the Patapsco River which drains the area south and west of Baltimore and does not directly effect the drainage of the city. The principal drainage areas are the Gwynns Falls, Jones Falls and Herring Run. These stream valleys at one time had numerous mill dams by virtue of an average stream slope of 0.73% with certain locations through the fall zone with slopes as high as 1.5%. The topography of the area greatly facilitated the drainage scheme. Much of the area is served by sanitary sewers which flow by gravity to the Back River Wastewater Treatment Plant, the largest plant located some 9.26 km (5.75 miles) east of the city. A second but a much smaller plant on the Patapsco River in the south harbor will be enlarged to provide relief for the wastewater from the Gwynns Falls interceptor in the near future. The valleys fan out into wide flatlands along the coastal plain. Here the collected sewage requires considerable pump lift of some 21.3 m (70 feet) to discharge into the main outfall sewer to Back River.

The stormwater drainage was developed separately. In 1902 a provision was made to set aside the stream valleys for floodway parks under public ownership. This action was a forerunner of the modern concept of flood plain management. The railroads ran down the valleys to reach the harbor. This, along with the old water power mills attracted some industry which still exists in the lower Jones and Gwynns Falls reaches. The extent of open areas and valley park is shown for the three drainage areas in Figure 2.

THE SAMPLING SITES

Although separate systems of storm and sanitary sewers have been provided it is still possible to find a few small old subdivision drainage areas which have combined sewers. All have been intercepted and during heavy rain storms discharge into the nearest water course. Figure 3 shows the system of stormwater sewers for Baltimore City and Figure 4 shows the location of background stream and stormwater sampling sites. The stream valleys are an integral part of the storm system. The channels drain a completely urban and suburban city-county population and the water samples from which present an integrated picture of the microbiological quality of runoff from a major metropolitan area. Background samples were taken from each stream throughout the study period as well as samples from storm drains and combined sewers

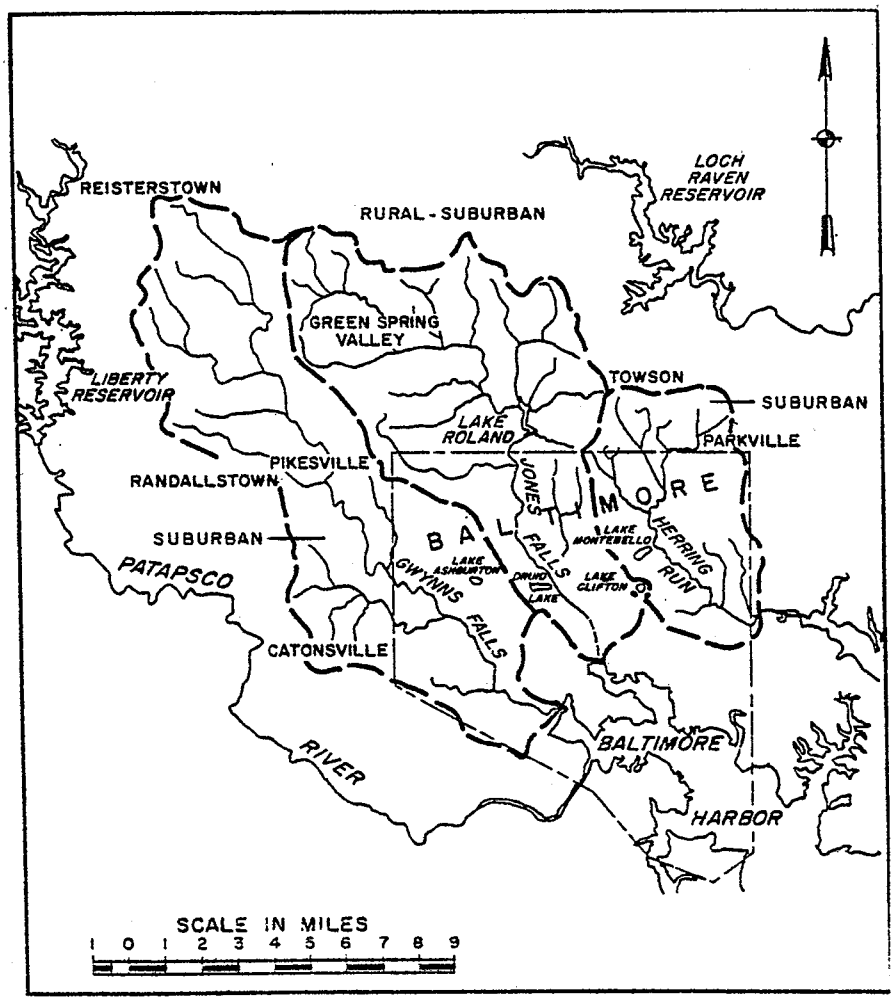


Figure 1. The four major drainage areas of the Baltimore metropolitan area; Patapsco River, Gwynns Falls, Jones Falls and Herring Run.

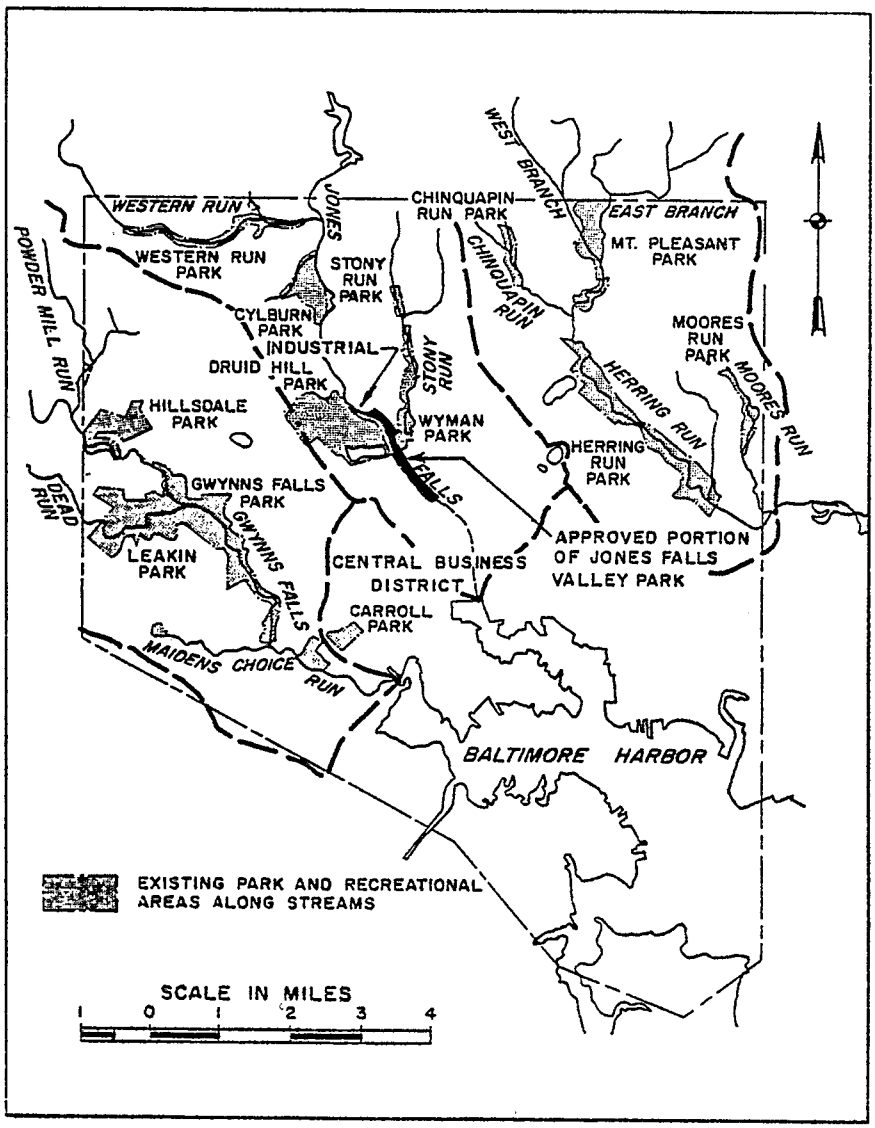


Figure 2. Open areas and stream valley park land in Baltimore City.

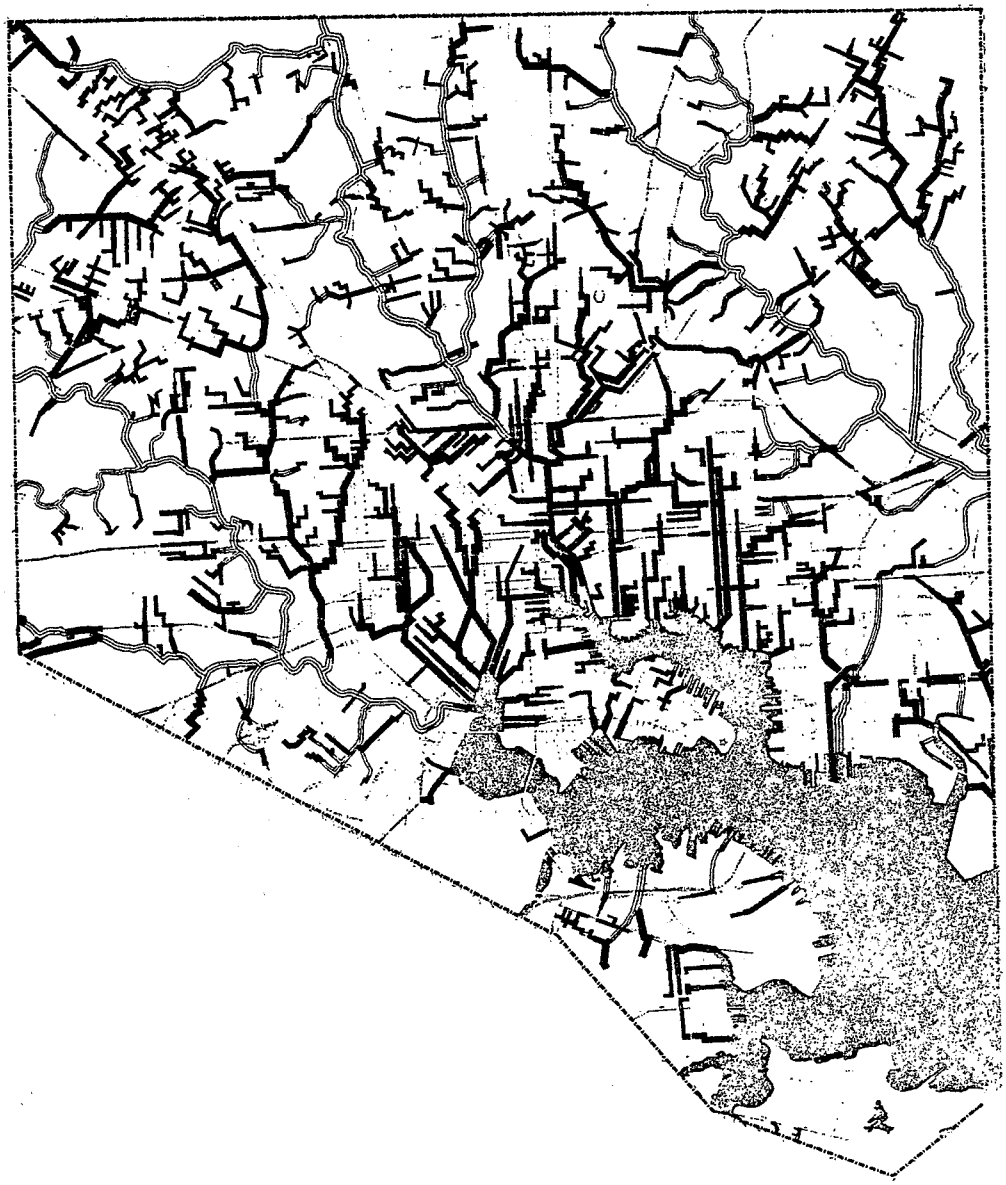


Figure 3. Baltimore City storm sewers. The solid lines represent underground conduits, the thickness of which are proportional to area of cross section. The lightly shaded lines are natural channels.

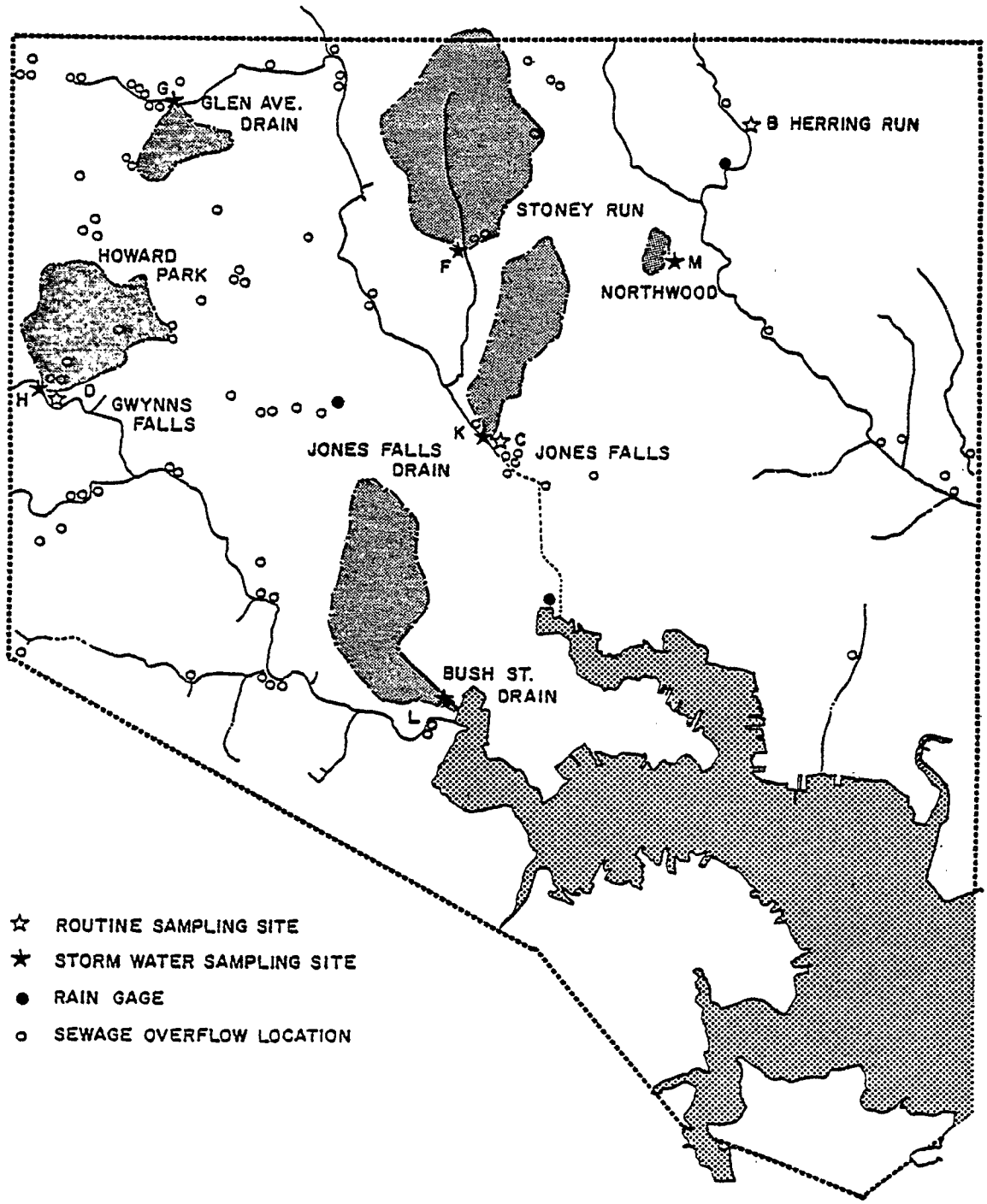


Figure 4. Location of the sampling stations for urban streams and stormwater outfalls studied in Baltimore City. The shaded areas indicate the catchment for the stormwater outfall.

during heavy rains. With the exception of the unsewered country-estate zone indicated as the Green Spring Valley the entire catchment is indistinguishable on either side of the city limits with regard to typical suburban development. It is estimated (1972) that 905,000 people live in the drainage area under study, with 805,000 being within the city. The population density within the city averages 45.7 persons/ha. (18.5/acre) and 37.3/ha. (15.1/acre) in the county.

Background Samples

For the integrated urban surface water background samples, the following waters were collected routinely regardless of the rainfall:

(A) Raw sewage taken at the Back River Wastewater Treatment Plant.
(B) Herring Run at the Mount Pleasant golf course.
(C) The Jones Falls at the Baltimore Street Car Museum.
(D) Gwynns Falls at the Dickeyville Dam.
(E) Loch Raven reservoir (Montebello Filter Plant raw water).

The detail location of these and other samples are shown in Figure 4. A brief description of these drainage areas is given below.

Back River Sewage Treatment Plant--

The Back Rivers Sewage Treatment Plant, started in 1911, is a complete primary plus secondary plant, but its age and lack of maintenance through the years requires a program of reconstruction and modernization now underway. The plant is serving an estimated 1.3 million population in the Baltimore metropolitan region. The average flow in 700,000 m^3/day (185 mgd) but with a peak at 1.2 million m^3/day (350 mgd) during heavy rains indicating the large component of infiltration and inflow into the separate sewer system. The raw sewage, sample A, was taken at the head of the plant and had an average five-day BOD at 20°C of 209 mg/1 and a suspended solids content of 198 mg/1.

Herring Run--

The Herring Run valley is the smallest of the drainage areas under study having an area of 58.8 km^2 (23.5 square miles). The average slope of the streams is 0.74%. As seen in Figures 1 and 3 the tributaries are the Chinquapin, the West Branch, East Branch and Moore's Run. The average flow of Herring Run is 3.67 m^3/min. (2.16 cfs) with a minimum of zero and a normal maximum of 1020 m^3/min. (600 cfs). Hurricane storm runoff flows are, of course, much higher. There are no heavy industrial wastes and the interceptor, since construction, is functioning fairly well. There are about 10 sewage bleeders, particularly in the lower less attractive part of the drainage area where considerable erosion has taken place requiring concrete lining (Figure 5a). The quality of the stormwater taken in the lower reaches was unusually poor before Moore's Run interceptor was completed. Records show a maximum of 3,192 mg/1 of suspended solids, total coliform MPN of 31 million/100 ml, and BOD of 110 mg/1. Today, under normal flow conditions the stream is clear and attractive as seen in Figure 5b. Note the manhole for the sewer interceptor along the stream. The characteristic dwellings are group row homes and apartments (Figure 5c). The routine sample, identified as B, is taken in the park section of the East Branch of

5a. Lower Herring Run open storm water channel.

5b. Attractive natural section of Herring Run (Note manhole of sanitary interceptor).

5c. Typical residential units of Herring Run.

5d. Sample station B, East Branch of Herring Run.

Figure 5. Characteristics of the Herring Run drainage area, sample site B.

Herring Run (Figure 5d). The spillway in the foreground conveniently provided the means for estimating the flow at the time of sampling by use of the Francis formula modified for a flat crested weir.

Jones Falls--

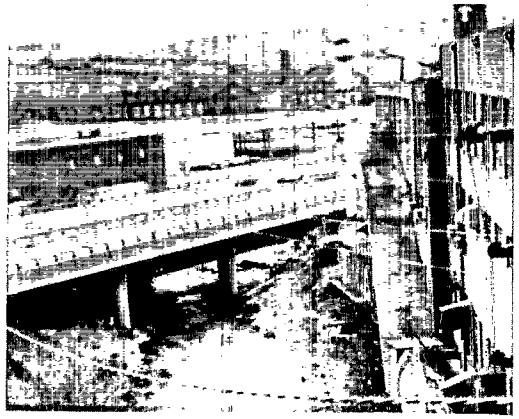
The Jones Falls and its tributaries, Western Run and Stoney Run, encompass some 151 km^2 (58.3 square miles) of drainage area. The stream at one time provided the water supply for the city from the Roland impounding reservoir downstream from the rural Green Spring Valley. The Northern Central (now the Pennsylvania Central) Railroad used the gentle grades of the valley which attracted industries that still exist. The lower reaches of the Jones Falls run through the central business district and are completely covered for 2.4 km (1.5 miles) before discharging into the middle harbor. In the city the natural state of the Jones Falls cannot compete aesthetically with either the Herring Run or Gwynns Falls due to the presence of railroads, expressways, commercial institutions and industries (see Figure 6a). The lower portion of the Jones Falls drains typical Baltimore row housing as shown in Figure 6b. The routine sample site C is located on the edge of the residential and central business district where the stream is not very attractive (Figure 6c).

The quality of the runoff into the Jones Falls has markedly improved with the completion of the Jones Falls interceptor in 1956 which eliminated the sewage treatment plant at Towson. Metropolitan sewerage service is now provided for the entire drainage area excluding the high-income, low density, country estates of the Green Spring Valley district. The growth of the suburban area in the Towson-Lutherville corridor followed the sewer service. When the Jones Falls interceptor and pumping station were placed into operation in 1956, the capacities provided were considered adequate until 1970. However, the flow dramatically exceeded expectations. By 1962 the flow reached 35,400 m^3/day (9.33 mgd), a flow not anticipated before 1970. Peak flows could no longer be handled and were discharged into the Jones Falls at the pumping station. Today this condition has been remedied through provisions for gravity diversions, additional pump capacities and parallel force mains.

The heavy built-up character of the metropolitan areas results in high flows in the Jones Falls in excess of 10,200 m^3/min (6,000 cfs) resulting in flood problems in the industrial areas. The average flow is 820 l/sec. (29 cfs) and the minimum is 84 l/sec. (3.1 cfs). The water quality in the lower reaches within the city is not good. The maximum suspended solids have reached 404 mg/l. Considerable numbers of industrial waste connections and dozens of sewer bleeders contribute to the poor water quality. The Western Run portion is an early subdivision area which although served by separate sewers has been provided with bleeders. The upper city section of the drainage area is quite a contrast to the lower Jones Falls in terms of parks, housing type and open areas as suggested by the typical homes on the Jones Falls drainage area (Figure 6d).

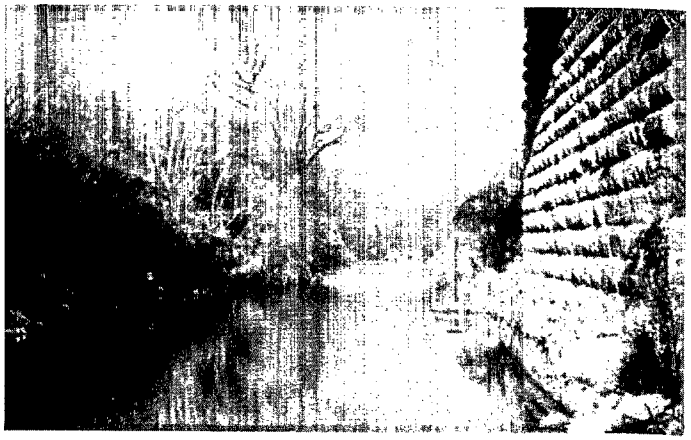
Gwynns Falls--

Of the urban stream drainage basins the Gwynns Falls is the largest having an area of 164.5 km^2 (63.5 square miles). This valley offers



6a. Lower Jones Falls business district

6b. Lower Jones Falls residential area.



6c. Lower Jones Falls sample site C.

6d. Upper Jones Falls residential area.

Figure 6. Characteristics of the Jones Falls drainage area, sample site C.

the greatest recreational potential since it is still in a beautiful natural state seldom found in a modern city. The average stream flow is 850 1/sec. (30.8 cfs) and the minimum is 110 1/sec. (3.6 cfs). Flooding is common with flows up to 140 m^3/sec. (5,000 cfs). Hurricanes have produced much higher discharges with considerable damage to bridges and timber areas. The stream is "flashy" with a rapid rise and fall, is highly turbid, and has much driftwood and floatage. During such periods the BOD_5 reaches a maximum of 46 mg/1; suspended solids, 341 mg/1; and total coliform MPN, 9 million/100 ml. During hot weather and low stream flow there is a sewage odor nuisance in the valley. Fortunately, the numerous rapids quickly reaerate the water so that with normal flow and in winter the stream is very attractive to children and adults who play along the Falls in warm weather and skate on the numerous pools in winter. The upper valley is the fastest growing portion of Baltimore County. The Gwynns Falls and Dead Run sewer interceptors which extend into the new area are reaching design capacities and surcharge into the Gwynns Falls at several points along the sewer in the city and county during heavy rains. Numerous temporary sanitary bleeders have been installed to prevent sewage backing into basements and a State Health Department moratorium has been ordered on new building permits until a parallel interceptor is constructed. Sampling site D is below an old mill dam as seen in Figure 7a. The spillway serves as a flow gauging weir for measurement of the discharge at time of sample collection. The interceptor may be seen along the stream by the manhole structure in Figures 7b and c. Figure 7d shows one of the many pools of Gwynns Falls which attract wild water birds such as herons and ducks and provide fishing for perch, catfish and carp.

Loch Raven Reservoir--

Loch Raven is an impoundment on the Gun Powder River with a 784.8 km^2 (303 sq. miles) of protected catchment area in rural Baltimore County. It delivers to the Montebello Filter Plant 566 to 755 thousand m^3/day (150 to 200 mgd) of good quality raw water. The average daily total coliform MPN/100 ml is 118 with a range from 0 to 2,400. Sample (E) was taken at the raw water sampling tap at Montebello Water Treatment Plant.

Storm Sites

The sites selected for the study of the quality of urban runoff during storm episodes are given in Figure 4 and indicated by the solid star. The drainage areas served by the outfalls are shown in dark shade. The physical characteristics of the stormwater sampling sites are given in Table 1.

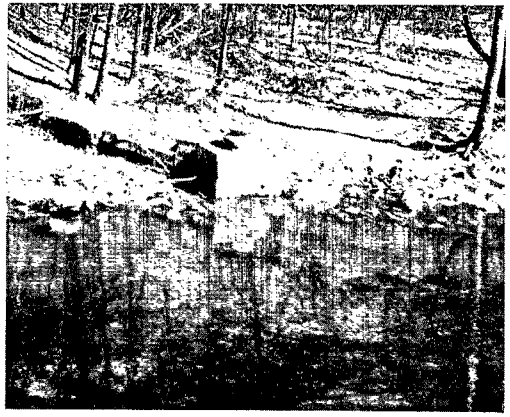
Stoney Run--

The Stoney Run drainage area measures 567 ha. (1,379 acres) in the Jones Falls valley in the north-central section of Baltimore City. The sampling point is identified as site F. The drainage area is primarily residential with a population density of 20.7 people/ha. (8.4/acre).

The dwellings in the area are often large houses on wooded lots as shown in Figure 8a. Although park land occupies only about four

7a. Sample site D below old mill dam.

7b. One of several rapids along the Gwynns Falls.



7c. Manhole of sanitary interceptor along the Falls.

7d. Water fowl using mill dam impoundment.

Figure 7. Characteristics of the Gwynns Fall drainage area, sample site D.

Table 1. CHARACTERISTICS OF URBAN STORMWATER SAMPLING SITES

	Name of station	Drainage area in acres				Population	Density		Remarks
		Residential	Parks	Ind. Comm.	Total		Pop/ac.	Pop/ha.	
F	Stoney Run	1370	4	5	1379	11,600	8.4	20.8	3 sanitary bleeders[a]
G	Glen Ave. drain	195	2	1	198	5,100	26.2	64.6	1 sanitary bleeder[a]
H	Howard Park	606	170	4	780	18,100	29.9	75.0	combined sewer
K	Jones Falls drain	603	1	21	625	27,000	44.8	111.0	1 sanitary bleeder[a]
L	Bush St. drain	853	175	59	1087	78,900	92.5	228.0	storm only
M	Northwood	30	0	20	50	800	26.6	63.3	storm only

[a]Sanitary bleeders - Intentional sanitary sewage overflows from interceptors. The overflows are diverted directly or indirectly into storm drainage system.

8a. Typical residential unit on the Stoney Run.

8b. Example of institutional land use.

8c. Open storm water channel.

8d. Sample site F on the Stoney Run.

Figure 8. Characteristics of the Stoney Run drainage area, sample site F.

acres along the lower open section of Stoney Run, several private schools and religious institutions occupy sizable tracts of land with a park-like nature. Figure 8b shows a view of one of the small private schools in the area. No industry is located in the area and only about five acres are occupied by commercial establishments. The lower section of Stoney Run is lined with concrete (Figure 8c). The sample site was located in this section of the stream and can be seen in Figure 8d. The hash marks shown on the side of the invert in the lower left hand corner were used to determine depth of flow. Note the flow in the drain during dry weather.

The composition of the waters sampled at Stoney Run is believed to be primarily storm runoff from an upper middle class residential community. Three known sanitary sewage bleeders are located within the drainage area. The degree to which these sewage overflows function during storms is not known.

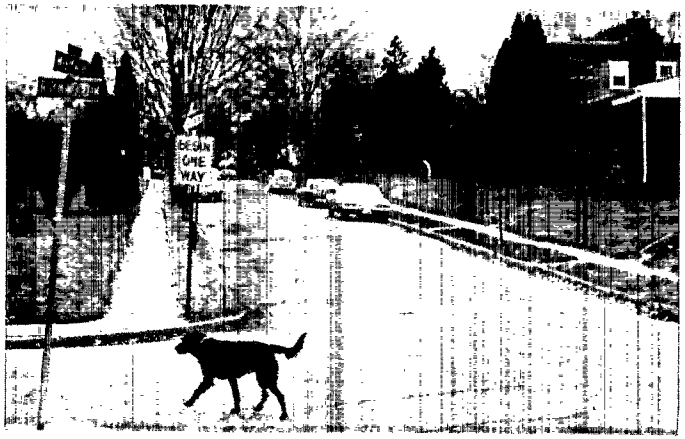
Glen Avenue--

The Glen Avenue storm drain is located on Western Run in the Jones Falls valley in the northwest section of Baltimore City. The sampling point is identified as site G. The drainage area measures 80.3 ha. (198 acres) with a population density of 65 persons/ha. (26.2/acre). The neighborhood consists of cottages and apartment complexes on a rolling timbered terrain. Figures 9a and b show the typical street scenes with the small cottages that comprise the major portion of the drainage area. Figure 9c shows a small wooded park which occupies about two acres in the lower section of the drainage area. No industrial and very little commercial land uses are found in this area. Figure 9d shows the outfall where the runoff samples were taken and an apartment complex in the background. Note the flow in Western Run during dry weather. Western Run represents a major open storm drain in the northwest section of Baltimore. During storms the Glen Avenue outfall is often surcharged.

The composition of the waters from the Glen Avenue drain is believed to be primarily storm runoff from a middle class residential community. One known sanitary sewage bleeder is located in the drainage area. The extent of sewage overflows during storms is not known.

Howard Park--

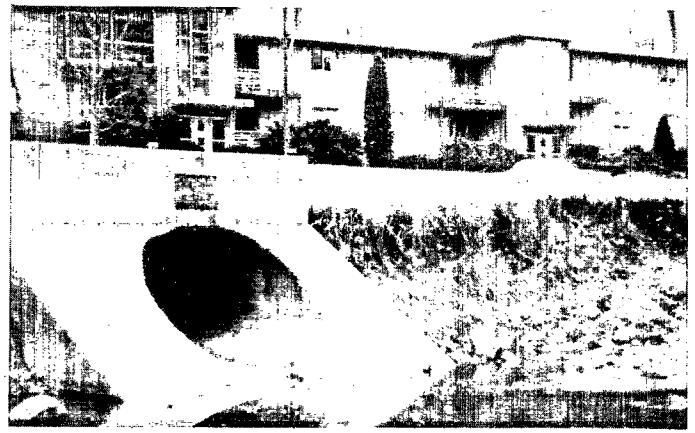
The Howard Park drainage area is located in western Baltimore in the Gwynns Falls drainage basin. The sampling point is identified as site H. The catchment area is 31.6 ha. (780 acres) with a population density of 738 persons/ha. (29.9/acre). A golf course occupies approximately 22% of the drainage area (Figure 10a). The remainder of the area is characterized by small detached dwellings on rolling wooded lots, as shown in Figures 10b and 10c, with some small commercial zones and an apartment complex interspersed. The Howard Park site is unique since it represents one of the few intentional combined sanitary and stormwater sewer systems in Baltimore City. The sanitary sewage is collected and transported to the Gwynns Falls interceptor in a conduit which is also used for stormwater runoff. The Gwynns Falls interceptor runs parallel to the Gwynns Falls and is located under the spillway shown in Figure 10d. During dry weather, the sanitary sewage flows down through a grate located just behind the outfall pictured in Figure



9a. Rolling topography on the Western Run.

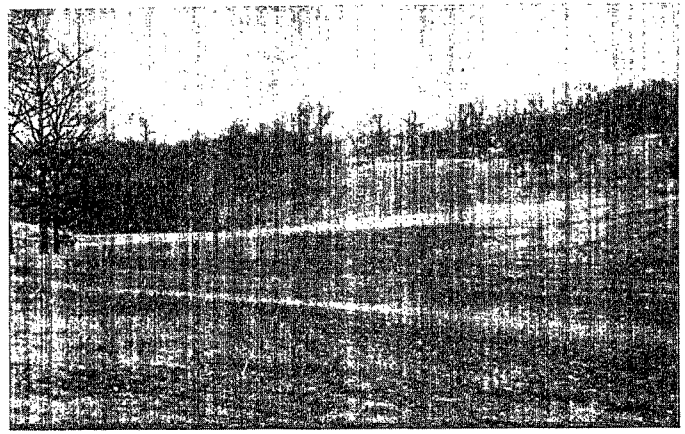
9b. Typical residential area.

9c. Small woodland park in the drainage area.



9d. Glen Avenue storm sewer outfall, site G.

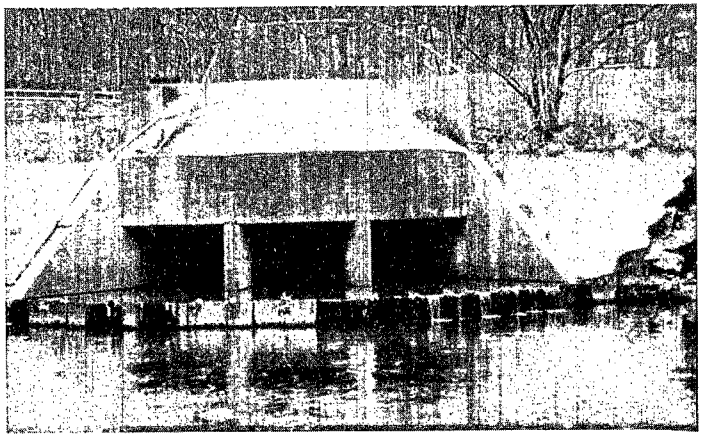
Figure 9. Characteristics of the Glen Avenue drainage area, sample site G.



10a. Golf course in Howard Park drainage.

10b. Typical residential area in Howard Park.

10c. View of the combined sewer drainage area.



10d. Overflow spillway for Howard Park combined sewer at Gwynns Falls interceptor, site H.

Figure 10. Characteristics of the Howard Park combined sewer drainage area, sample site H.

10d into the sanitary sewer. When the grate is clogged with debris or when the interceptor is overloaded, the sanitary sewage from Howard Park or the Gwynns Falls interceptor flows to the spillway and into the Gwynns Falls. The overflow of sanitary sewage into the Gwynns Falls has been a common occurrence at this outfall during dry weather. During periods of rainfall, the runoff and sanitary sewage flow by the grate to the spillway and into the Gwynns Falls. In addition, sanitary sewage from the overloaded Gwynns Falls interceptor mixes with the runoff. Samples were collected at the spillway shown in Figure 10d.

The composition of water collected at Howard Park is believed to represent combined sanitary and storm flow. In addition four sanitary sewer overflows are located in the catchment area.

Jones Falls Storm Drain--

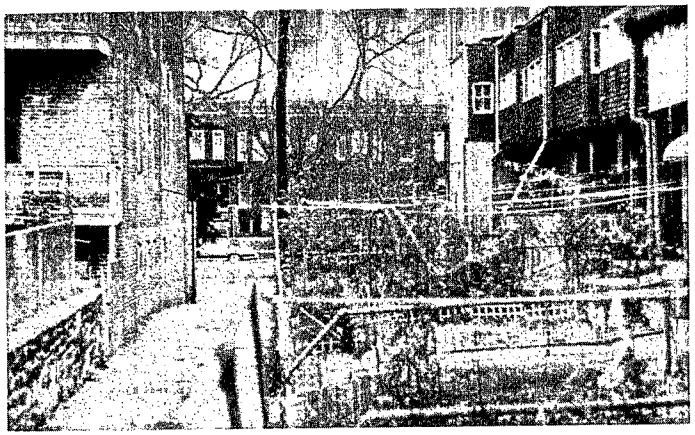
The Jones Falls storm drain is located in the central section of Baltimore City and occupies 253 ha. (625 acres). The sampling point is identified as site K. The population density is approximately 110 persons/ha. (44.8/acre) and is characteristic of a downtown residential-commercial district. The typical dwellings in this area are the row homes pictured in Figure 11a. The characteristic small backyards, generally paved, with a service alley are shown in Figure 11b. A small commercial district with some light industry occupies about 8.5 ha. (21 acres) in the drainage area. Although not intentional, the sanitary sewage from a small area comprising a few square blocks is discharged directly to the storm drain. Figure 11c shows the outfall where the samples were collected. Note the dry weather flow.

The character of the water collected at the Jones Falls storm drain is believed to be representative of combined sanitary sewage and stormwater runoff from an inner city residential-commercial district. No other known sanitary sewage overflows are believed to be located in the drainage area.

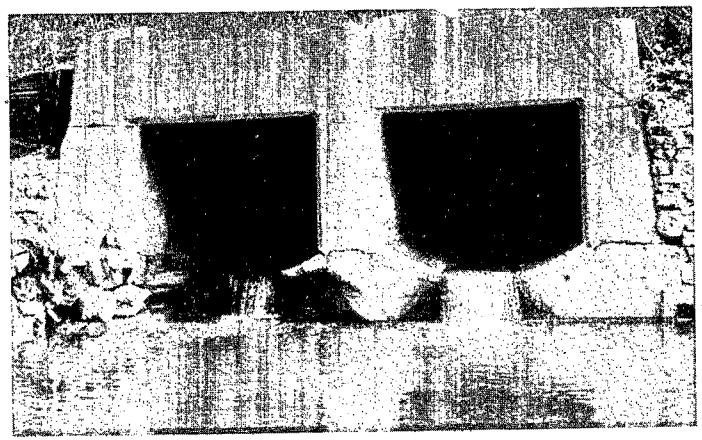
Bush Street--

The Bush Street drainage area has an area of 440 ha. (1,087 acres) in the central section of Baltimore City between the Jones Falls and Gwynns Falls drainage basins. The sampling point is identified as site L. The catchment area is independent of the valley streams and discharges directly into the tidal portion of the Baltimore harbor. The Bush Street drainage area contains a large residential district characterized by row homes with both low and middle income neighborhoods (Figures 12a and 12b) with a population density of 228 persons/ha. (92.5/acre). Typical inner city commercial districts are shown in Figure 12c. The industrial areas are composed of warehouses, truck terminals and miscellaneous light industries as shown in Figure 13a. A large park occupies approximately 16% of the catchment area and is located between the industrial and residential districts (Figure 13b). Samples were collected at the point where the storm drain empties into the Baltimore harbor. The sampling point is shown in Figure 13c. The Bush Street outfall was always surcharged and was influenced by the tides. During storms the flow was always observed in the direction of the harbor.

11a. Typical residential area.



11b. Rear view of typical row homes.



11c. Sample site K.

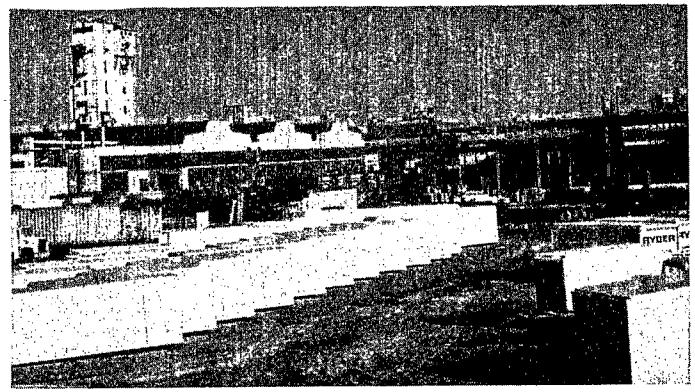
Figure 11. Characteristics of the drainage area of the Jones Fall storm drain, sample site K.

12a. Bush Street residential area.

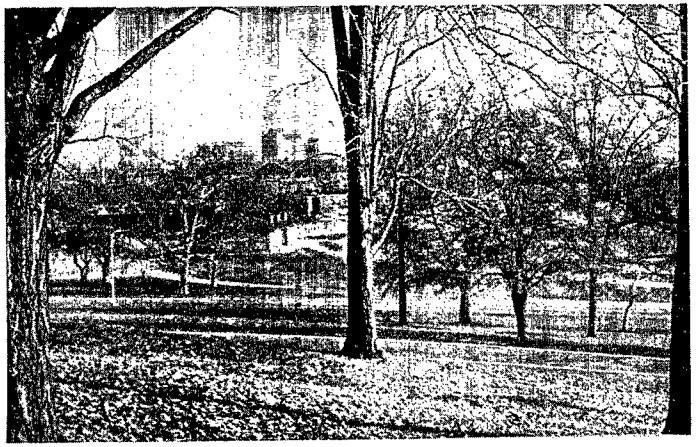
12b. Bush Street residential area.

12c. Bush Street commercial district.

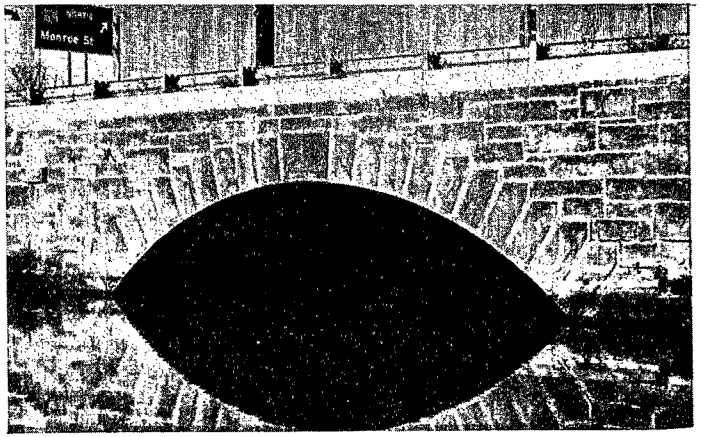
Figure 12. Characteristics of the Bush Street drainage area, sample site L.



13a. Bush Street Industrial district.



13b. Bush Street park area.



13c. Sample site L.

Figure 13. Characteristics of the Bush Street drainage area, sample site L.

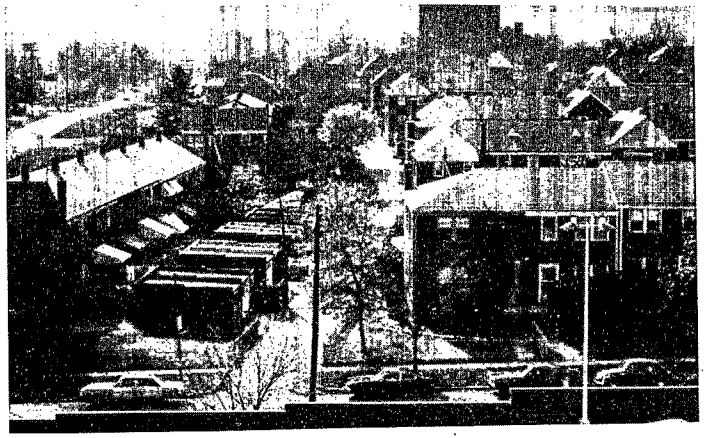
The samples collected at Bush Street are believed to be representative of separate storm runoff from inner city residential, commercial and industrial districts. No known sewage overflows are believed to be located in this drainage area.

Northwood--

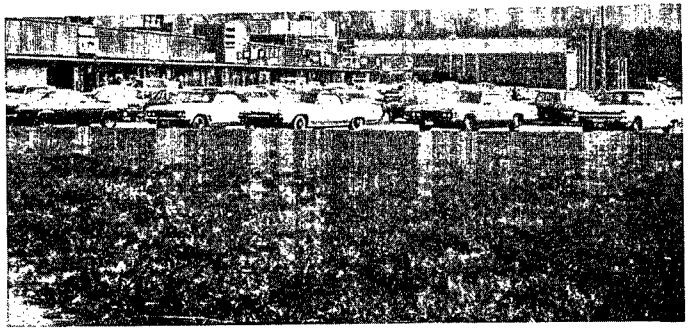
The Northwood drainage area measures 20.2 ha. (50 acres) in the Herring Run drainage basin in the northeast section of Baltimore City. The sampling point is identified as site M. The population density is 65.6 persons/ha. (26.6/acre). About 60% of the catchment area is composed of a residential area. The typical group houses can be seen in Figures 14a and 14b. The remainder of the catchment area (40%) is occupied by a shopping center shown in Figure 14c. The outfall is shown in Figure 14d. A concrete Parshall flume with a 12 foot throat width was located immediately down stream from the outfall and was used to measure the storm flow from the Northwood area. The Parshall flume was constructed in 1963 for a storm drainage research project of the Johns Hopkins University sponsored by Baltimore City, Baltimore County, The State of Maryland and the U.S. Bureau of Public Roads.

The samples collected at Northwood are believed to represent storm runoff only. No sewage overflows are known to be located in the Northwood catchment area.

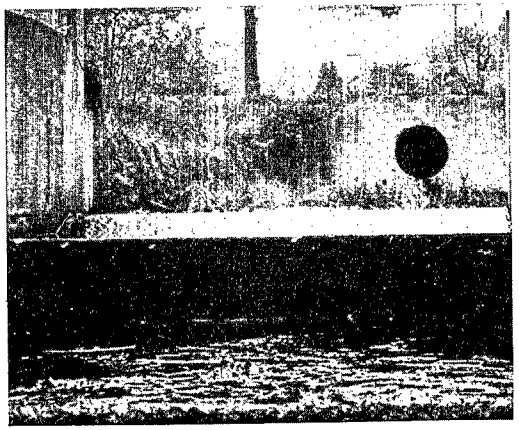
14a. Residential area.



14b. Residential area.



14c. Shopping center.



14d. Sample site M.

Figure 14. Characteristics of the Northwood drainage area, sample site M.

METHODS AND MATERIALS

SAMPLE COLLECTION

All of the water samples in this study were analyzed for microorganisms within four hours after collection. The exceptions were those samples collected for virus assay which were specially handled and prepared for analysis at a later time. The samples were collected in clean, heat sterilized 20 liter (5 gallon) plastic containers.

The volume of water collected was 20 liters for each sample site for both the routine and storm stations. Additional 20 liters were collected for virus samples. Background samples were collected each week from the three urban streams, Herring Run, Jones Falls and Gwynns Falls, from the raw water at the Montebello Water Treatment Plant, and the raw sewage at the Back River Wastewater Treatment Works. After February 1975, background samples were collected biweekly. Virus samples were collected every other week.

The storm sewer discharges and combined sewer overflows were, of course, sampled whenever rain storms occurred. Since automatic sampling of the storms was deleted from the study, a manual "grab" sampling procedure was used. Samples were taken as early in the storm as possible.

Each technician was responsible for the sample collection at outfalls near his residence or conveniently located on his way back to the laboratory. Storm warning forecasts were posted and when the probabilities for rain were high an alert was posted in the laboratory or the supervisor called each technician at home before or after work hours. In this manner a sampling of a representative number of storms was achieved.

ESTIMATION OF FLOWS

The flows in the channel or outfall sewer were estimated by the technicians using relatively simple methods. Three sample sites involved a weir or spillway from which simple measurement of head, H, in feet of water flowing over the lip or crest give the flow estimate, Q, in cubic feet/seconds, (cfs). The sites and appropriate discharge forumlae used were as follows:

B. Herring Run $(Q = 125.5 \times H^{1.5})$
D. Gwynns Falls $(Q = 343 \times H^{1.5})$
H. Howard Park $(Q = 134 \times H^{1.5})$

For the remaining site the estimation of flow required the measurements of the average velocities and the cross sectional areas of the waterways during the time of sampling. The flow velocity meters used were manufactured by the Tsurumi Precision Instrument Company and were of the propellor type identified as 313 TS Flowmeter calibrated to give velocity in meters/seconds. A 100 seconds timed by stop watch made the velocity calculation easy. The flow meter was fixed on the end of six foot staff in order that the traverse across the outfall pipe could be made by the observer on top of the invert without disturbing the flow pattern. For other than pipes the velocity measurements

were made from bridges spanning open channels. The areas of cross sections in the channel were determined for each unit depth of flow at the invert. The flow in m^3/sec. was calculated as the product of the average velocity in m/sec. and the cross sectional area in m^2as measured when samples were collected. The following channels were so estimated:

F. Stoney Run

$Q = (6.36 \times 10^{-2} \times d) + 0.54 \times V$
Q = discharge, m^3/sec.
d = depth of water in channel, cm
V = average velocity, m/sec.

Flow formulae for various shapes of outfalls including an ellipse, a rectangular section with rounded invert, and Parshall flume were derived.

G. Western Run

(for depth in excess of 0.5 ft.)
$Q = (6.18 \times d) - 2.5 \times V$
Q = discharge, cfs
d = depth of flow in ft.
V = average velocity, ft./sec.

K. Jones Falls

$Q = 1.98 + 7 \times (d-1) \times V$
where Q = discharge, cfs
d = depth of water at the invert, ft.
V = average velocity, ft./sec.

L. Bush Street

$Q = 25 \times d \times V$
Q = discharge cfs
d = depth of water at the invert, ft.
V = average velocity, ft./sec.

M. Northwood

Parshall flume available from previous stormwater studies.

$Q = 48.8 \times d$
where Q = discharge is cfs
d = depth of water at entrance section, ft.

The relationship of cross sectional areas and depth of water flow was plotted for each outfall so that the area could be readily obtained for any depth without calculation. All calculations of flow in cfs were converted to metric units as follows: cfs x 2.83×10^{-2} = m^3/sec. or 1000 l/sec.

PHYSICAL MEASUREMENTS

The only physical measurement made in the field was for temperature. However, the collector indicated certain organoleptic values as appropriate with regard to appearance and odor. In the laboratory the pH measurements were made with a Beckman Zeromatic meter. The data for temperature, pH and flow is given in Appendix E.

MICROBIOLOGICAL PROCEDURES

Bacteriological Assays

Differential Biochemical Tests--

The following tests were employed to provide information for the tentative identification of isolates obtained from the microbial assays. A spot inoculation procedure on differential agar plates was employed where possible. Isolates were transferred with sterile toothpicks to a 35 or 50 place grid pattern on 100 mm Petri dishes containing the appropriate agar medium.

Phenylalanine deaminase--Isolates were spotted on phenylalanine agar (Difco) and incubated for 24 hours at 37°C. Phenylalanine deaminase activity was indicated by a green zone around the colony after flooding the plate with a 0.5 M ferric chloride solution (10).

Oxidase--Oxidase production was determined for isolates spotted on tech agar (Baltimore Biological Laboratory) after incubation at 37°C for 18 to 24 hours. The tech agar plate was flooded with a 1% p-amino dimethylaniline monohydrochloride. Oxidase positive colonies turn pink within one minute.

Triple sugar iron agar (TSI)--TSI slants were prepared in 13 x 100 mm culture tubes. Stab-streaks were prepared for each isolate and incubated at 37°C. pH changes in the butt and slant were observed after 18 to 24 hours. Hydrogen sulfide production was observed after 48 hours incubation.

Lysine iron agar (LIA)--LIA slants were prepared as above for TSI and used in conjunction with TSI as recommended by Edwards and Ewing (11).

Malonate utilization--Malonate utilization was determined in malonate broth in 13 x 100 mm culture tubes according to the procedures described in Edwards and Ewing (11). The change in indicator from green to Prussian blue indicated malonate utilization.

Lysine decarboxylase--Lysine decarboxylase activity was determined by the method of Moeller described in Edwards and Ewing (11). Decarboxylase base medium with and without lysine was inoculated from fresh agar slant cultures, overlaid with sterile mineral oil and incubated at 37°C. The cultures were examined daily for four days. Lysine decarboxylase activity was indicated by the change from yellow to violet in the tubes containing lysine. Control tubes without lysine remained yellow.

Urease--Urease activity was determined by the spot inoculation procedure on plated prepared with Christensen's urea agar (11). Urease activity was indicated by the formation of a red zone around the colony after 2 to 6 hours of incubation. Delayed reactions could not be observed by this procedure.

Citrate utilization--Citrate utilization was determined by the spot inoculation procedure on plates containing Simmons citrate agar. Colony formation and color change from green to blue in the medium indicated citrate utilization (11).

Coagulase--The elaboration of coagulase was determined by the plate method described by Esber and Faulconer (12). Isolates were transferred to coagulase agar (Difco) and incubated overnight. *Staphylococcus aureus* stock cultures were included for each fresh batch of media. Coagulase positive and mannitol positive strains yield a yellow opaque zone around the colony. The plate procedure was evaluated by comparing the elaboration of coagulase by the conventional tube procedure for 150 isolates. 100% agreement was observed for the two procedures.

DNase--DNase production was performed by the method of Streitfeld *et al.* (13). Colonies were transferred to DNase test agar (Baltimore Biological Laboratories) and incubated overnight. After incubation the plate was flooded with 0.1% toluidine blue. DNase production is indicated by a rose pink zone around the colonies.

Lipovitellenin-lipase--Lipovitellenin-lipase was determined on lipovitellenin-salt-mannitol agar (LSM) (14). Opaque zones around the colonies indicated lipovitellenin-lipase activity.

Mannitol fermentation--Mannitol fermentation was observed on LSM and coagulase agar. Yellow zones around the colonies were taken as positive mannitol fermentation.

Anaerobic glucose fermentation--Representative isolates that yielded typical *Staph. aureus* reactions were further tested for the ability to ferment glucose anaerobically by the method described by Evans and Kloos (15) to separate any possible soil micrococci. An overnight culture on brain heart infusion (BHI) broth at 37°C was used to inoculate tubes of Brewer's fluid thioglycolate medium (BTM) containing 0.35% agar. Growth throughout the tube after 24 hours was indicative of anaerobic glucose fermentation.

Gram stain--Gram stains were prepared according to the procedures described in *Standard Methods* (16).

Gelatin liquefaction--Gelatin liquefaction was determined on BHI containing 120 g/l of gelatin. Isolates were spot inoculated on plates and incubated at 10°C for five days. Liquid zones around colonies indicated gelatin liquefaction.

Mannitol and arabinose fermentation--Mannitol and arabinose fermentation were determined separately on plates of phenol red carbohydrate fermentation medium containing 10 g/l of each sugar and 2% agar. Plates were incubated at 37°C for 18 hours. Yellow zones around the colonies indicated fermentation.

Growth in bile--Growth in 40% bile and 6.5% NaCl was determined on separate BHI agar plates containing 40 g/l oxgall and 65 g/l NaCl. Colony formation at the point of inoculation after 48 hours incubation at 35°C was considered an indication of growth.

Growth at 45°C and 10°C--Growth at 45°C and 10°C was determined on BHI agar after incubation for 48 hours and five days, respectively. Colony formation at the point of inoculation was considered an indication of growth.

Catalase--Catalase activity was determined for isolates from the fecal streptococci assay by adding a drop of 3% hydrogen peroxide to each colony on the BHI agar replicate control plate after incubation at 37°C for 24 hours. Gas bubbles indicated catalase activity. Catalase activity for *Staphylococci* isolates was determined by transferring a portion of the colony to 3% hydrogen peroxide. Evolution of gas indicated a positive catalase.

Starch hydrolysis--Starch hydrolysis was determined on nutrient agar containing 10 g/1 of soluble starch and 8 g/1 NaCl. After incubation at 37°C for 48 hours each plate was flooded with Gram's iodine. Clear zones around the colony indicated starch hydrolysis.

Casein hydrolysis--Casein hydrolysis was determined on plates of skim milk agar (10 g/1 skim milk and 15 g/1 agar) after incubation for three to five days at 37°C (17). Hydrolysis of casein was indicated by the formation of clear zones around the colony. *Pseudomonas* isolates were observed for fluorescence when exposed to ultra-violet light.

Growth on acetamide--Growth on acetamide was rechecked by spotting isolates on acetamide agar (16) and incubated for 48 hours. Pink to red colonies with blue fluorescence when exposed to ultra-violet light were considered positive.

Growth at 42°C--Acetamide and oxidase positive isolates were transferred to Drake's medium #10 for evaluation of growth at 42°C (18) after 48 hours incubation. Growth was indicated by turbidity with blue-green fluorescence.

Cultural Evaluation and Final Procedures--

The evaluation of methods of detection and enumeration is a fundamental prerequisite for obtaining reliable results. Techniques and procedures employed in the laboratory for a given set of samples may yield poor results in another laboratory for a different sample. The microbial flora can vary significantly in water samples depending on environmental conditions and sources of contamination. The types and levels of interfering microorganisms become important factors and will vary with the procedure employed. Techniques, methods and culture media developed for microbial assays of clinical specimens may yield poor results when applied to water samples where different interfering microorganisms are present. No one method for the detection and enumeration of a particular group of microorganism can be universally employed.

The early phase of the current project involved the evaluation of methods of detection and enumeration of the microorganisms to be assayed. Techniques and culture procedures described in *Standard Methods for the Analysis of Water and Wastewater* (16) and in recent literature were evaluated. Where similar results were obtained, the cultural procedures in *Standard Methods* were chosen. Where the procedures in *Standard Methods* were found lacking, alternative methods were developed. The final selection of techniques, methods and procedures was based on simultaneous analysis of water samples in the laboratory and information in the literature. Multiple tube dilution procedures which permitted a calculation of a most probable number (MPN) were generally favored because of the wide variability in the chemical, microbiological

and physical characteristics (particularly solids) expected in the samples from the urban water courses.

Salmonella sp.--A multiple concentration and enrichment procedure was employed to permit the calculation of a MPN *Salmonella* for each sample. The procedure was similar to that described by Kenner and Clark (19) except that diatomaceous earth was used for concentration. The multiple concentration and enrichment procedure is shown in schematic form in Figure 15. Three replicate tests plus three seeded controls were employed to permit an evaluation of the recovery procedures for each sample. A laboratory strain, *Salmonella typhimurium* SB558, resistant to 1000 µg/ml of streptomycin was used as the seed *Salmonella*. The *Salmonella* seed was prepared from culture stored at -40°C in 23% glycerol. The low temperature glycerol storage provided a readily available test organism at a known density. The three seeded controls evaluated sample toxicity, diatomaceous earth concentration and the overall recovery procedure. A 100-fold dilution of the *Salmonella* seed stock was prepared for each sample to evaluate sample toxicity. The mixture was maintained at room temperature for the duration of the sample processing period and plated on brain heart infusion (BHI) agar containing 1000 µg/ml streptomycin. Samples were considered toxic when more than 90% inactivation was observed. The diatomaceous earth concentration was evaluated by the addition of 5 to 50 *Salmonella* to a replicate of each sample filtered. The diatomaceous earth plug was transferred to enrichment medium containing 1000 g/ml of streptomycin. The recovery of streptomycin-resistant *Salmonella* was considered positive concentration on the diatomaceous earth. The overall concentration and culture procedure was evaluated with an additional replicate of each sample prepared as above. The streptomycin, however, was omitted from the enrichment medium. Isolates obtained from the primary plates were tested for streptomycin resistance. The isolation of streptomycin-resistant *Salmonella* indicated a positive recovery.

During the initial portion of the study various combinations of enrichment media, enrichment temperatures and primary plating media were evaluated using 22 samples prepared with a multiple concentration on diatomaceous earth and multiple enrichment. The results are given in Table 2. The enrichment media and temperatures evaluated were selenite broth at 37°C, selenite broth at 41°C, GN broth at 37°C, tetrathionate broth at 37°C and dulcitol selenite broth at 40°C. The primary plating media employed were bismuth sulfite (BS), brilliant green agar (BGA), *Salmonella Shigella* agar (SS) and xylose lysine desoxycholate agar (XLD). A total of 527 isolates were tested during this phase of the investigation. The elevated temperature enrichments consistently yielded higher numbers of *Salmonella* isolates for primary plating media. The final choice was dulcitol selenite at 40°C coupled with primary plating on XLD similar to the procedure reported by Kenner and Clark (19). Identification of the members of the genus *Salmonella* was performed according to the schematic given in Figure 16. Typical *Salmonella* colonies on XLD (pink colonies with black centers or pink colonies) were screened for phenylalanine deaminase and oxidase activities. Enrichment cultures that did not yield typical *Salmonella* colonies were restreaked at 48 or 72 hours on XLD and subsequent typical colonies were handled as above. Phenylalanine deaminase negative and oxidase negative isolates were streak purified again and transferred to triple

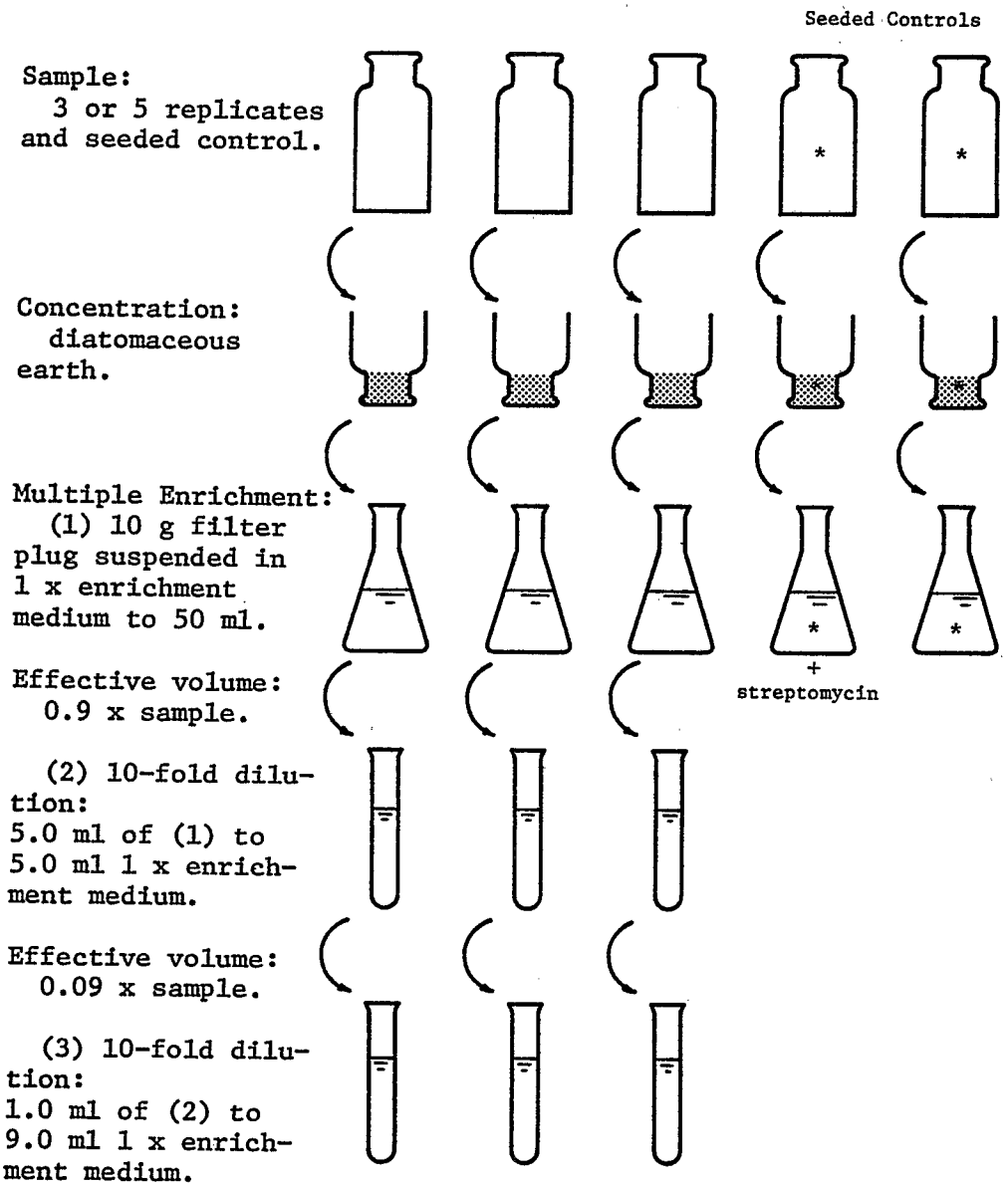


Figure 15. Schematic - Multiple concentration and enrichment for the MPN determination of *Salmonella*.

Table 2. COMPARISON OF ENRICHMENT AND PRIMARY PLATING MEDIA FOR THE ISOLATION OF *SALMONELLA*

Enrichment Temp.	Selenite F 37°C				Selenite 41°C				GN 37°C				Tetrathionate 37°C				Dulcitol-Selenite 40°C				Totals
Primary Plating	BS	BGA	SS	XLD	BS	BGA	SS	XLD	BS	BGA	SS	XLD	BS	BGA	SS	XLD	BS	BGA	SS	XLD	
# Positive	1	0	2	11	-	0	1	37	-	0	0	1	0	0	0	0	-	1	8	28	90
# Isolates	83	16	36	12	-	9	21	67	-	16	59	45	2	14	32	33	-	9	32	41	527
Primary Plate # Positive / # Isolated on Enrichment	$\frac{1}{147}$	$\frac{0}{147}$	$\frac{2}{147}$	$\frac{11}{147}$	-	$\frac{0}{97}$	$\frac{1}{97}$	$\frac{37}{97}$	-	$\frac{0}{120}$	$\frac{0}{120}$	$\frac{1}{120}$	$\frac{0}{81}$	$\frac{0}{81}$	$\frac{0}{81}$	$\frac{0}{81}$	-	$\frac{1}{82}$	$\frac{8}{82}$	$\frac{28}{82}$	
Enrichment # Positive / # Isolated on Enrichment	$\frac{14}{147}$				$\frac{38}{97}$				$\frac{1}{120}$				$\frac{0}{81}$				$\frac{37}{82}$				
# Positive / Total # Positive	$\frac{14}{90}$				$\frac{38}{90}$				$\frac{1}{90}$				$\frac{0}{90}$				$\frac{37}{90}$				

Note (+) Data based on 22 samples (7 raw sewage and 15 urban streams) prepared with a multiple concentration on celite and multiple enrichment

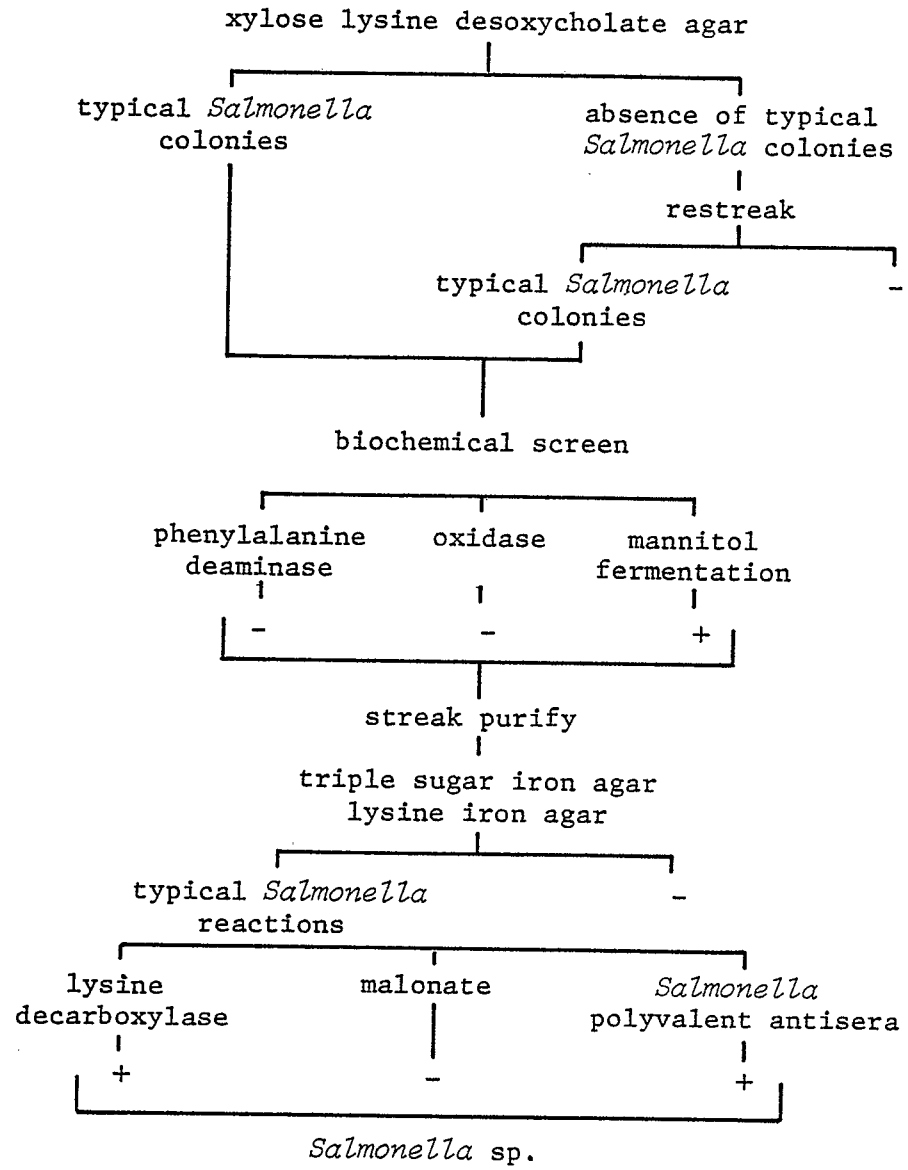


Figure 16. Schematic - Isolation and identification of *Salmonella* sp.

sugar iron agar (TSI) and lysine iron agar (LIA). Typical *Salmonella* was tested for malonate utilization and lysine decarboxylase activity and submitted to a serological examination with polyvalent antisera A-I (including Vi) (11).

Phenylalanine deaminase and oxidase were employed to eliminate the most probable interferences from members of the genus *Proteus*, *Providencia* and *Pseudomonas* and, thereby, minimize the number of isolates submitted to further tests. Table 3 shows a comparison of the phenylalanine deaminase and oxidase screen with the commonly used TSI-LIA screen for suspicious *Salmonella* isolates. Typical *Salmonella* reactions on TSI-LIA were obtained for 92.8% of the isolates from XLD that were phenylalanine deaminase and oxidase negative. The spot inoculation procedure for phenylalanine deaminase and oxidase compares favorably with the TSI-LIA screen for *Salmonella* and provides a rapid, inexpensive and effective method to screen large numbers of suspicious *Salmonella* isolates. Table 3 also indicated the relative efficiency of XLD as a primary plating medium after dulcitol selenite enrichment at 40°C. About 53% of the isolates obtained from XLD yielded typical TSI-LIA reactions. A marked difference, however, can be seen for the two types of colony morphology for suspicious *Salmonella* on XLD. 84.5% of the black centered but only 4.3% of the red colonies were positive through the screening procedure.

Table 4 shows a tentative identification of the genus of microorganisms commonly encountered during the procedure for the detection and enumeration of *Salmonella*. Each of the microorganisms yield suspicious *Salmonella* colonies on XLD. The tentative grouping of isolates into a particular genus was based on a limited number of biochemical tests. The predominant interfering microorganisms were members of the genus *Proteus*, *Providencia* and *Pseudomonas*. *Arizona* sp. and *Citrobacter* sp. were about 3% each of the isolates tested after the phenylalanine deaminase, oxidase and TSI-LIA screens.

Shigella sp.--A multiple concentration and enrichment procedure was used to permit a calculation of a most probable number. Two liters to 3.79 liters were initially filtered through celite for concentration. The entire plug of celite was transferred to GN broth for enrichment. Ten-fold dilutions of the celite suspension were prepared in GN broth. Three replicates were run at 10 to 50 microorganisms to evaluate recovery. The multiple concentration and enrichment procedure for *Shigella* was similar to that given for *Salmonella* in Figure 15 except that *Shigella sonnei* was used for the seed control. After incubation at 37°C each dilution was streaked on xylose lysine deoxycholate agar and suspicious *Shigella* colonies (red) were tested biochemically according to the protocol shown in Figure 17.

Eighteen samples of raw sewage and urban streams were assayed according to the above procedure. It should be noted that each sample represents nine attempts to isolate *Shigella* (3 replicates x 3 dilutions). More than 1,100 suspicious isolates from XLD were submitted to further biochemical tests. *Shigella* was not found in any of the samples tested nor was the seeded *Shigella* ever recovered. Approximately 10% of the isolates were negative in preliminary biochemical screen indicating

Table 3. COMPARISON OF THE PHENYLALANINE DEAMINASE (ϕ) AND OXIDASE (OX) SCREEN WITH TSI AND LIA REACTIONS FOR THE DIFFERENTIATION OF *SALMONELLA*

Number Typical *Salmonella* Reactions (%)

Colony morphology on XLD	Number of isolates	ϕ and OX screen	ϕ and OX followed by TSI-LIA
Black centered colony	6,258	5,286 (84.5)	5,142 (82.2)
Red colony	3,457	288 (8.3)	149 (4.3)
Total	9,715	5,589 (57.5)	5,186 (53.4)

Table 4. GENUS OF MICROORGANISMS COMMONLY ENCOUNTERED DURING THE ISOLATION OF *SALMONELLA* *

	Proteus sp. and *Providencia* sp.	*Pseudomonas* sp.	*Arizona* sp.	*Citrobacter* sp.
Number isolated	1,250	2,809	108	96
Number tested	8,995	8,995	2,967	2,967
%	13.9	31.6	3.6	3.2

* Tentative identification based on a limited number of biochemical tests

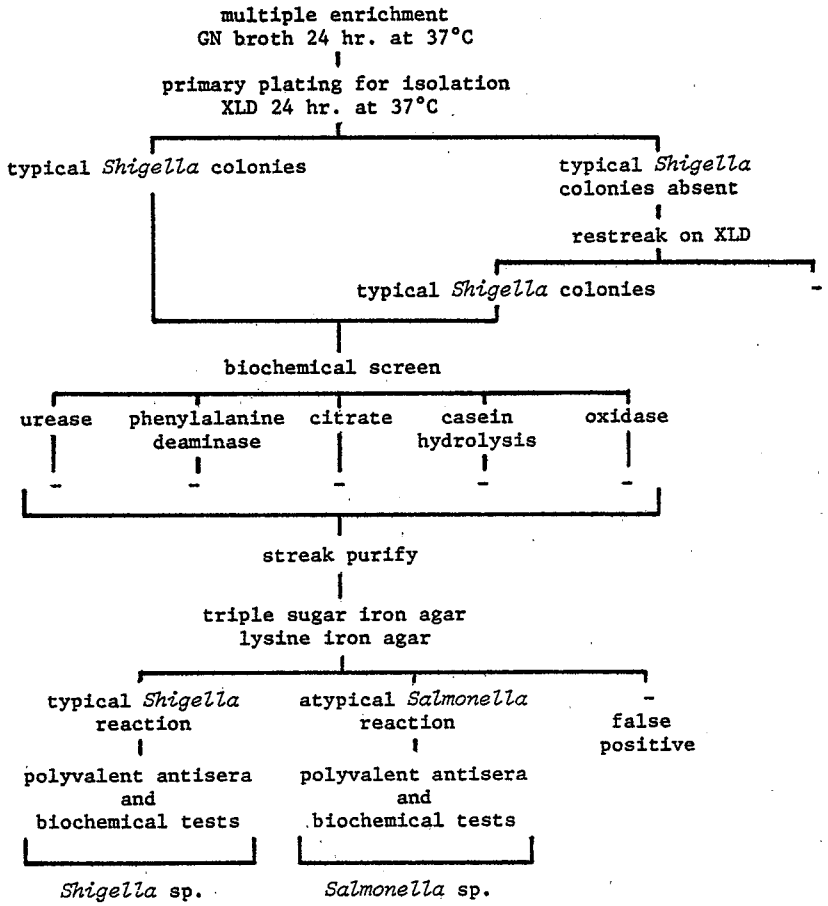


Figure 17. Schematic - Isolation and identification of *Shigella* sp.

possible *Shigella*. One isolate yielded typical reactions for *Shigella* on TSI and LIA but was serotypically negative and hydrolyzed casein. Table 5 is a tentative identification of the major groups of microorganisms isolated. *Pseudomonas* sp., *Providencia* sp. and non-H_2S producing members of the genus *Proteus* yield red colonies on XLD agar indistinguishable from *Shigella*.

Levels of indicator microorganisms and *Salmonella* for the samples negative for *Shigella* are given in Table 6. One would expect to isolate *Shigella* from the raw sewage and streams containing relatively high levels of total and fecal coliforms, fecal streptococci and *Salmonella* The limitation appears to be the poor methodolody.

The celite concentration procedure employed appears to function reasonably well. Table 7 shows the results of control experiments with low level seeded *Shigella* in phosphate-buffered saline. The recovery of *Shigella* on celite is well within the 95% confidence limits for the MPN procedure. The major difficulty appears to be in the enrichment procedures and methodology. *Shigella* does not appear to compete and survive well in the presence of other actively growing microorganisms. Hentges (20) reported the inhibition of *Shigella* when grown with coliforms and *Klebsiella*. He attributed the inactivation of *Shigella* to organic acids produced by the other microorganism and that a pH below 7 enhanced the effect.

Rather than continue the unproductive *Shigella* assays, the effort was directed at providing some information to explain the inability to isolate *Shigella*. Older literature suggests that *Shigella* is a fragile microorganism in the environment. This assumption of fragility is adequately dispelled by the reports of the ability of laboratory cultures of *Shigella* to survive when added to a variety of polluted and non-polluted waters. The absolute survival times vary markedly from study to study dependent on environmental conditions. Laboratory experiments indicate that at 20°C *Shigella* persisted for 12 days in farm pond water (21). McFeters *et al.* (22) reported half time die-off rates of 22.4 hours, 24.5 hours and 26.8 hours for *Shigella dysenteriae*, *Shigella sonnei* and *Shigella flexneri* at 9.5 to 12.5°C in well water. Bartos *et al.* (23) reported recovery of added dysentery bacilli after 22 days in well water and 40 days in well water with coliforms added. Dolivo-Dobrovol'skii and Rossovaskaia (24) reported *Shigella* survivals from 30 minutes to four days and indicated that aeration markedly reduced survival time. Under conditions of extreme cold (-45°C) *Shigella* persisted 145 days in feces, 135 days in soil and 47 days in frozen river water (25). Although conditions vary, *Shigella* does not appear to be any more fragile than other pathogens. In fact, where comparative studies were reported *Shigella* is significantly more persistent than strains of *Salmonella* and *Vibrio cholerae* (22).

Survival studies conducted in our laboratory also indicated that *Shigella* will persist for reasonable lengths of time in aqueous systems. *Shigella flexneri* was seeded into phosphate-buffered saline (pH 6.8), sterile stormwater, and stream water at a level of 3×10^6 *Shigella*/ml and stored at 40°C. Samples were removed for determination of the levels of *Shigella flexneri*. Figure 18 shows the survival of *Shigella flexneri*. After eight days 37%, 41% and 26% of the seeded organisms

Table 5. GENUS OF MICROORGANISMS FOUND DURING ATTEMPTS TO ISOLATE *SHIGELLA*

Site	*Proteus sp.* #/Total	*Proteus sp.* % Total	*Providencia sp.* #/Total	*Providencia sp.* % Total	*Pseudomonas sp.* #/Total	*Pseudomonas sp.* % Total	Others #/Total	Others % Total
A. Raw Sewage	221/720	31	173/720	24	276/720	38	50/720	7
C. Stream	26/106	24	17/106	16	39/106	37	24/106	23
D. Stream	81/225	36	14/225	6	41/225	18	89/225	40
Total	328/1051	31	204/1051	19	356/1051	34	163/1051	16

Table 6. LEVELS OF INDICATOR MICROORGANISMS AND *SALMONELLA* IN SAMPLES NEGATIVE FOR *SHIGELLA*

Sample Site	Date	TC MPN/100ml	FC MPN/100ml	FS #/100ml	*Salmonella* MPN/10 1
A. Raw Sewage	10/2 (9/30)	2.4×10^7	2.4×10^7	4.1×10^6	$>2.9 \times 10^3$
	10/7	2.4×10^7	4.9×10^6	1.1×10^6	1.2×10^3
	10/14	3.5×10^7	4.6×10^6	1.2×10^6	4.8×10^2
	10/21	2.9×10^6	4.9×10^6	8.3×10^5	5.1×10^3
	10/28	5.4×10^7	1.1×10^7	4.5×10^5	1.7×10^3
	11/4	$<2.6 \times 10^6$	$<2.6 \times 10^6$	2.0×10^4	-
	11/11	3.5×10^7	7.9×10^6	1.1×10^6	2.8×10^2
	11/18	1.7×10^7	7.9×10^6	1.1×10^6	5.1×10^2
	12/2	2.4×10^6	1.3×10^6	3.4×10^5	4.8×10^1
	12/9	7.0×10^6	3.3×10^6	9.7×10^5	1.0×10^2
	12/17	1.6×10^7	4.6×10^5	3.9×10^5	2.6×10^1
C. Stream	12/2	2.4×10^4	2.4×10^4	7.6×10^4	1.3×10^2
	12/17	9.2×10^4	3.5×10^4	4.2×10^4	2.7×10^1
D. Stream	11/4	4.6×10^2	2.3×10^2	1.2×10^2	4.4×10^0
	11/11	2.2×10^3	4.9×10^2	2.1×10^2	1.3×10^1
	11/18	1.7×10^3	3.3×10^2	1.2×10^2	2.2×10^1
	12/2	3.3×10^4	1.3×10^4	1.0×10^5	7.0×10^1
	12/9	3.5×10^4	3.3×10^3	2.4×10^4	7.0×10^1

Table 7. RECOVERY OF *SHIGELLA* ON DIATOMACEOUS EARTH, PHOSPHATE-BUFFERED SALINE, (pH 7.2, TEMPERATURE 20-25°C)

	S. sonnei		*S. flexneri*		*S. flexneri**	
	#/1	% Recovery	#/1	% Recovery	#/1	% Recovery
Shigella seeded	9	-	13	-	10	-
MPN Recovered on Celite	13	144	7	54	7	70
95% Confidence Limit for MPN	2-70	22-777	1-38	2-292	1-38	2-292

* *S. flexneri* 3 strain 3-5 Op, resistant to 500 µg/ml streptomycin

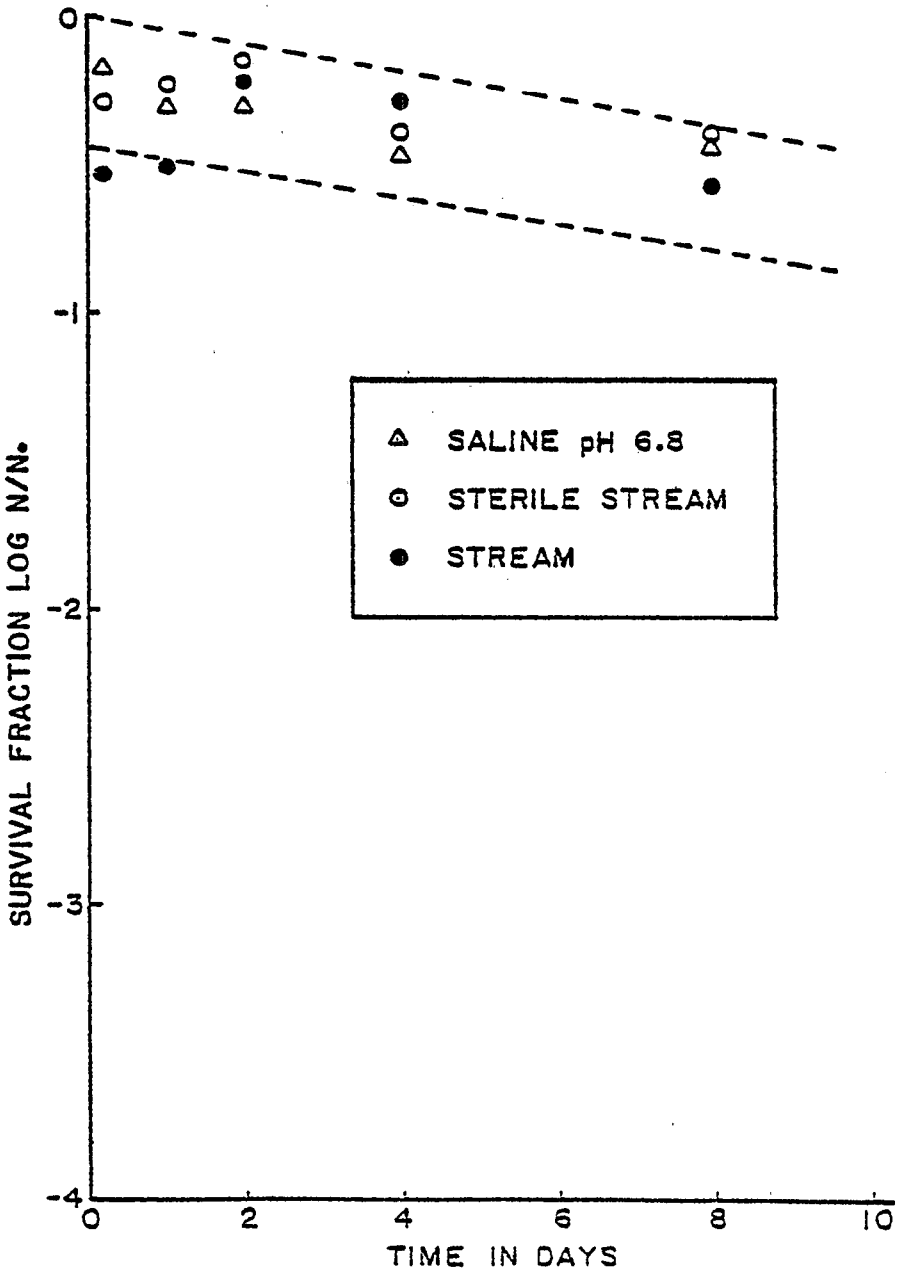


Figure 18. Survival of *Shigella flexneri* at 4°C.

remained in the saline, sterile stream water, and stream water, respectively. The stream water contained 7 x 10^2 total coliforms, 7 x 10^2 fecal coliforms, 5.1 x 10^3 fecal streptococci, 3.3 x 10^2 *Pseudomonas aeruginosa* and less than 1.8 *Staphlococcus aureus* per 100 ml and 2.7 x 10^1 *Salmonella*/10 l. The stream water pH was 7.5.

The major difficulty at present appears to be the enrichment step. Enrichment is necessary because of the low levels of *Shigella* present in the aquatic environment. The antagonism between the normal intestinal flora and enteric pathogens has received attention for quite some time. Hentges (20) recently reported the ability of 22 strains of microorganisms to suppress the growth of *Shigella* in the mouse intestine. All strains of *Escherichia coli* and *Enterobacter aerogenes* and most strains of *Proteus vulgaris* tested were antagonistic to *Shigella*. The bacteriostatic and bactericidal effects of the coliform organisms were attributed to volatile acids produced as metabolic end products. The effects were enhanced at lower pH values.

The application of the findings of Hentges (20) to the development of a suitable enrichment procedure has yielded some success. Enrichment conditions were set up to minimize the production and effect of volatile acids. Nutrient broth, a complex medium which contains low levels of carbohydrates, was adjusted to pH 8.0 and inoculated with 59 *Shigella sonnei* and *Shigella flexneri*. One ml of stream water or 1 ml of raw sewage was added as a source of interfering microorganisms. Comparable cultures were set up with GN broth. Replicate cultures were incubated under aerated and stationary conditions. *Shigella sonnei* was recovered from the flasks seeded with stream water with an initial pH of 8.0. The predominant interference was members of the genus *Pseudomonas*. One subsequent attempt to recover low levels of *Shigella* (14 *S. sonnei*, 28 *S. flexneri* and 9 *S. flexneri*) did not produce any *Shigella* isolates. Of 148 suspicious colonies, 129 were tentatively identified as *Pseudomonas*. The minimal content of carbohydrate in the medium and the aerated conditions favored the growth of the *Pseudomonas*. Experiments conducted in the laboratory indicate that the growth of laboratory cultures of *Pseudomonas aeruginosa* was not antagonistic to *Shigella* and the results are in agreement with the reports of Hentges (20). *Pseudomonas* apparently masks the presence of *Shigella*.

Staphylococcus aureus--Serious difficulties were encountered with the determination of levels of *Staph. aureus*. Membrane filter procedures using m-staphylococcus broth and Vogel-Johnson medium (V-J) and plate counts on tellurite glycine agar were evaluated with samples of sewage and urban streams. Each medium yielded many suspicious *Staph. aureus* colonies with typical morphology. However, those colonies failed to yield typical biochemical reactions. Gram stains and microscopic morphology. Table 8 shows the recovery of confirmed *Staph. aureus* for 1,249 isolates in four procedures for 66 samples of raw sewage and urban streams. High levels of interfering microorganisms were found with m-staphylococcus broth, tellurite glycine and V-J medium. The predominant interference on tellurite glycine was Gram positive cocci that were catalase negative, DNase negative and yielded pink to red colonies of KF streptococcus agar. The typical colony morphology expected for *Staph. aureus* on V-J medium is a black colony surrounded

Table 8. RECOVERY OF *STAPH. AUREUS*

Medium	Procedure	Number of samples	Number of typical isolates	Number of confirmed *Staph. aureus*	% confirmed *Staph. aureus*
Tellurite-glycine	plate count	19	265	7	2.6
Vogel-Johnson	membrane filter	13	109	1	0.9
M-staphylococcus broth	membrane filter	16	344	30	8.7
M-staphylococcus broth + 0.75mM azide enrichment and LSM primary plate	MPN	18	531	507	95.4
Totals		66	1,249	-	-

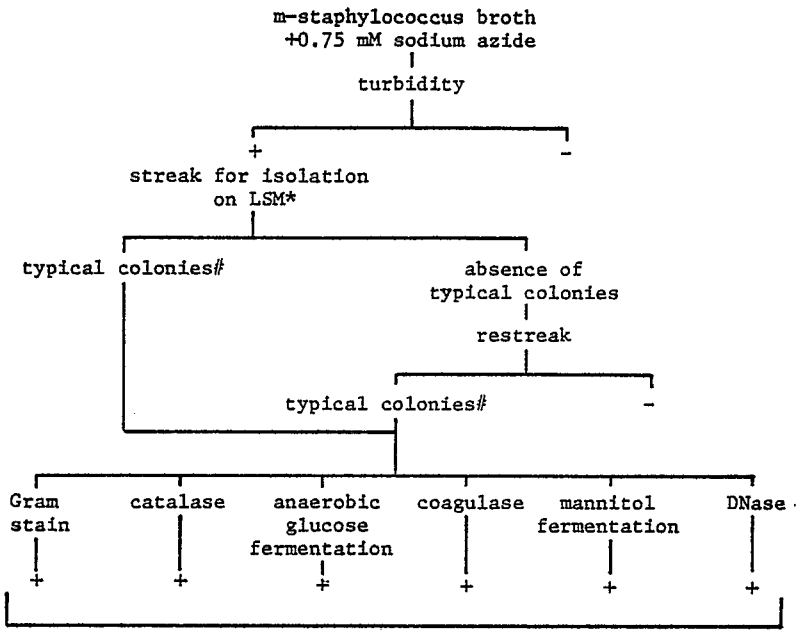
by a yellow halo which indicates mannitol fermentation. Stock *Staph. aureus* on V-J medium is a black colony surrounded by a yellow halo which indicates mannitol fermentation. Stock *Staph. aureus* cultures when collected on membrane filters and grown on V-J medium did yield black colonies but the yellow halo was obscured by the membrane filter and difficult to detect. The isolates obtained from the membrane filters incubated on m-staphylococcus broth were predominantly Gram positive and Gram nagative, rod-shaped bacteria. In each case the presence of *Staph. aureus* was heavily masked by interfering microorganisms that gave typical colony morphology. Simple enumeration of suspicious colonies would yield a gross overestimate of the levels of *Staph. aureus* for each sample.

Smuckler and Appleman (26) reported similar difficulties with staphylococcus medium 110 when attempting to enumerate *Staph. aureus* in meat pot pies. Staphylococcus medium 110 was the medium from which m-staphylococcus broth was developed for use with membrane filters. The former was prepared as a solid medium with agar and contains gelatin. The latter is a broth without gelatin. Similar to these observations with m-staphylococcus broth, Smuckler and Appleman (26) observed high levels of interfering rod-shaped bacteria that yield typical colonies on staphylococcus medium 110. After testing several inhibitors they recommended the addition of 0.75 mM sodium azide to the staphylococcus medium 110 to inhibit the growth of the rod-shaped bacteria.

Sodium azide was added to m-staphylococcus broth at a concentration of 0.75 mM and the modified medium was employed as an enrichment broth for *Staph. aureus*. A multiple tube dilution procedure was utilized to permit the calculation of a MPN. Lipovitellenin-salt-mannitol agar (LSM) was employed as a primary isolation medium from the modified m-staphylococcus broth. Gunn *et al.* (14) used LSM to isolate and identify *Staph. aureus*. The production of opaque yellow zones around the colonies was considered positive evidence for lipovitellenin-lipase activity (opaque) and mannitol fermentation (yellow). Lipovitellenin-lipase activity was found to correlate with coagulase production for 94.7% of the isolates tested by Gunn *et al.* (14). Table 8 shows the recovery of *Staph. aureus* for typical colonies on LSM after enrichment in the modified m-staphylococcus broth with 0.75 mM sodium azide. 507 of 531 or 95.4% of the typical isolates after enrichment and plating on LSM were confirmed *Staph. aureus*.

The correlation of biochemical characteristics with pathogenicity of staphylococcus isolates has been the subject of numerous reports. Unfortunately, no one criterion is adequate for the identification of *Staph. aureus*. Even coagulase production, which has traditionally been used to differentiate *Staph. aureus* from *Staph. epidermis* (formerly *Staph. albus*) is not absolute (27). The enumeration must be based on several biochemical characteristics that will enable a differentiation from not only *Staph. epidermis* but other genera of microorganisms not normally encountered at high levels in clinical samples.

Enrichment tubes in the multiple dilutions procedure were considered positive when isolates were recovered that were catalase negative, coagulase positive, DNase positive, fermented mannitol, fermented glucose anaerobically, yielded typical microscopic morphology and Gram positive. A schematic of the culture procedure is given in Figure 19.



Staphylococcus aureus

* LSM - lipovitellenin salt mannitol agar

\# typical colonies - colonies surrounded by opaque and/or yellow zones

Figure 19. Schematic - Isolation and identification of *Staphylococcus aureus*.

Pseudomonas aeruginosa--Culture media for the enumeration of *Pseudomonas aeruginosa* were evaluated with samples of raw sewage and urban streams. MPN procedures using L-asparagine broth and confirmation on acetamide broth according to *Standard Methods* (16), Drake's asparagine broth #10 (28) confirmed on acetamide broth and membrane filter procedures using MacConkey agar according to Nixon and Brodsky (29) were tested. Table 9 shows the results of the initial culture evaluation for 16 samples of raw sewage and urban streams. L-asparagine broth according to *Standard Methods* yielded consistently higher levels of confirmed *Pseudomonas aeruginosa* than either of the other methods tested and was employed in the remainder of the study. Spot inoculation on acetamide agar (acetamide broth + 1.5% agar) was compared to acetamide broth for a confirmatory procedure to permit the use of acetamide agar as a one step isolation and confirmatory procedure and as confirmatory screening procedure before streak isolation. Table 10 shows the comparative levels of *P. aeruginosa* calculated from confirmation on acetamide broth and acetamide agar. The contents of each presumptive positive dilution tube were transferred for confirmation to acetamide broth and spotted or streaked on acetamide agar. The levels of *P. aeruginosa* were similar for each confirmatory method except for one stream sample.

The final procedure for the enumeration and identification of *P. aeruginosa* is given in schematic form in Figure 20. Asparagine tubes showing growth with fluorescence after incubation at 37°C for 48 hours were streaked on acetamide agar or spotted on acetamide agar and subsequently streaked on PAP agar for isolation. Isolates were submitted to the tests indicated for verification of *P. aeruginosa*. Calculation of the MPN *P. aeruginosa* was based on the recovery of isolates that were acetamide and oxidase positive and grew at 42°C. Casein hydrolysis with fluorescence (30) was employed as a secondary characteristic.

Coliform group--Total coliforms were determined by the multiple tube dilution procedure with lactose broth as the presumptive medium according to *Standard Methods* (16). Positive tubes were confirmed on brilliant green lactose broth with 2% bile at 35°C.

Fecal coliforms were determined by confirmation of positive lactose broth presumptive tubes on EC medium incubated at 44.5°C for 24 hours (16).

The effect of homogenization on the levels of microorganisms was evaluated. Stream samples were blended at room temperature for varying time periods and the levels of total and fecal coliforms determined. The results for five trials are shown in Figure 21. No consistent trends and little significant differences were observed for the levels of total coliforms after blending for time periods up to 180 seconds. Two trials showed an increase in levels of fecal coliform while three trials showed little significant differences with blending time. Again no consistent trends were observed and no blending time necessary for optimum levels of coliforms could be predicted. As a result, a preparative blending step for each sample before the microbial assays would be of questionable value.

Table 9. EVALUATION OF PRESUMPTIVE MEDIA FOR THE ENUMERATION OF *PSEUDOMONAS AERUGINOSA*

	L-Asparagine broth a MPN/100ml	Drakes #10 broth a MPN/100ml	MacConkey agar - mf a b #/100ml
Raw Sewage	9.2×10^5	3.5×10^5	4.5×10^5
	3.5×10^5	2.3×10^5	ND
	2.3×10^6	9.2×10^5	4.5×10^6
	1.7×10^6	4.6×10^5	1.0×10^6
Stream	1.7×10^2	1.1×10^2	1.4×10^2
	1.7×10^3	1.4×10^2	4.0×10^3
	1.6×10^5	1.6×10^5	2.0×10^4
	2.2×10^3	1.1×10^2	ND
	2.3×10^4	2.2×10^4	1.1×10^3
	2.4×10^4	1.7×10^3	3.0×10^4
	3.5×10^5	1.9×10^4	2.0×10^4
	1.1×10^3	3.1×10^2	4.0×10^3
	1.7×10^5	3.3×10^4	1.5×10^4
	2.8×10^4	4.9×10^3	1.5×10^4
	7.0×10^4	3.3×10^3	1.0×10^4
	5.4×10^3	7.9×10^2	1.5×10^3

a Confirmed in acetamide broth

ND No data

b Brodsky and Nixon (29)

Table 10. LEVELS OF *PSEUDOMONAS AERUGINOSA* CONFIRMED ON ACETAMIDE BROTH AND ACETAMIDE AGAR

Sample	*Pseudomonas aeruginosa* MPN/100ml Acetamide confirmation	
	Broth	Agar
Raw Sewage	2.3×10^6	2.3×10^6
	1.7×10^6	2.8×10^6
	9.2×10^5	1.6×10^6
	4.6×10^5	1.7×10^5
Stream	1.6×10^5	2.2×10^4
	2.4×10^4	2.4×10^4
	2.8×10^4	7.0×10^4
	2.2×10^3	3.5×10^3
	3.5×10^5	1.6×10^5
	1.6×10^5	1.6×10^5
	1.7×10^3	1.3×10^3
	4.9×10^3	1.3×10^4
	1.7×10^4	1.8×10^3
	3.3×10^3	3.5×10^3

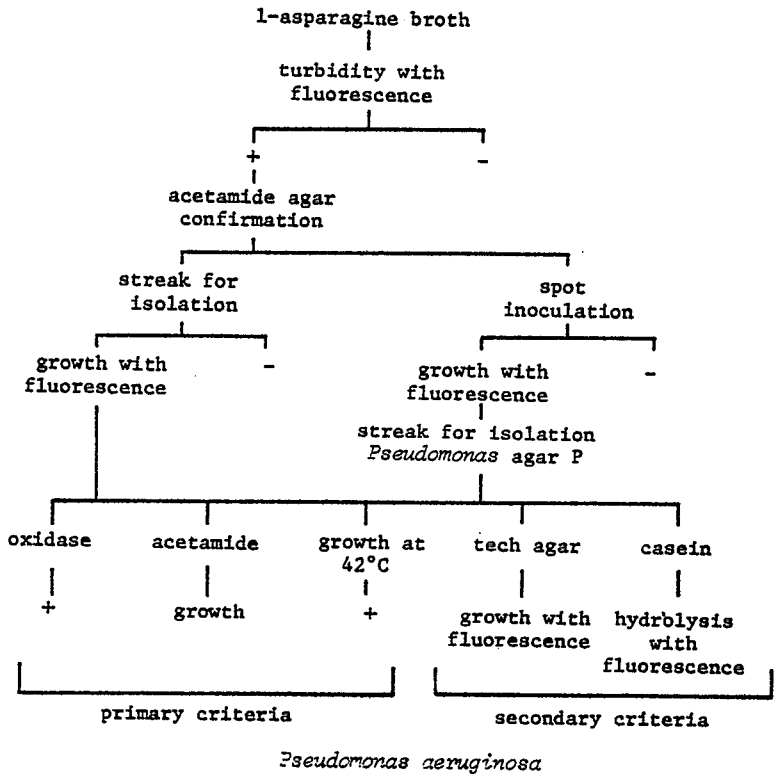


Figure 20. Schematic - Identification of *Pseudomonas aeruginosa*.

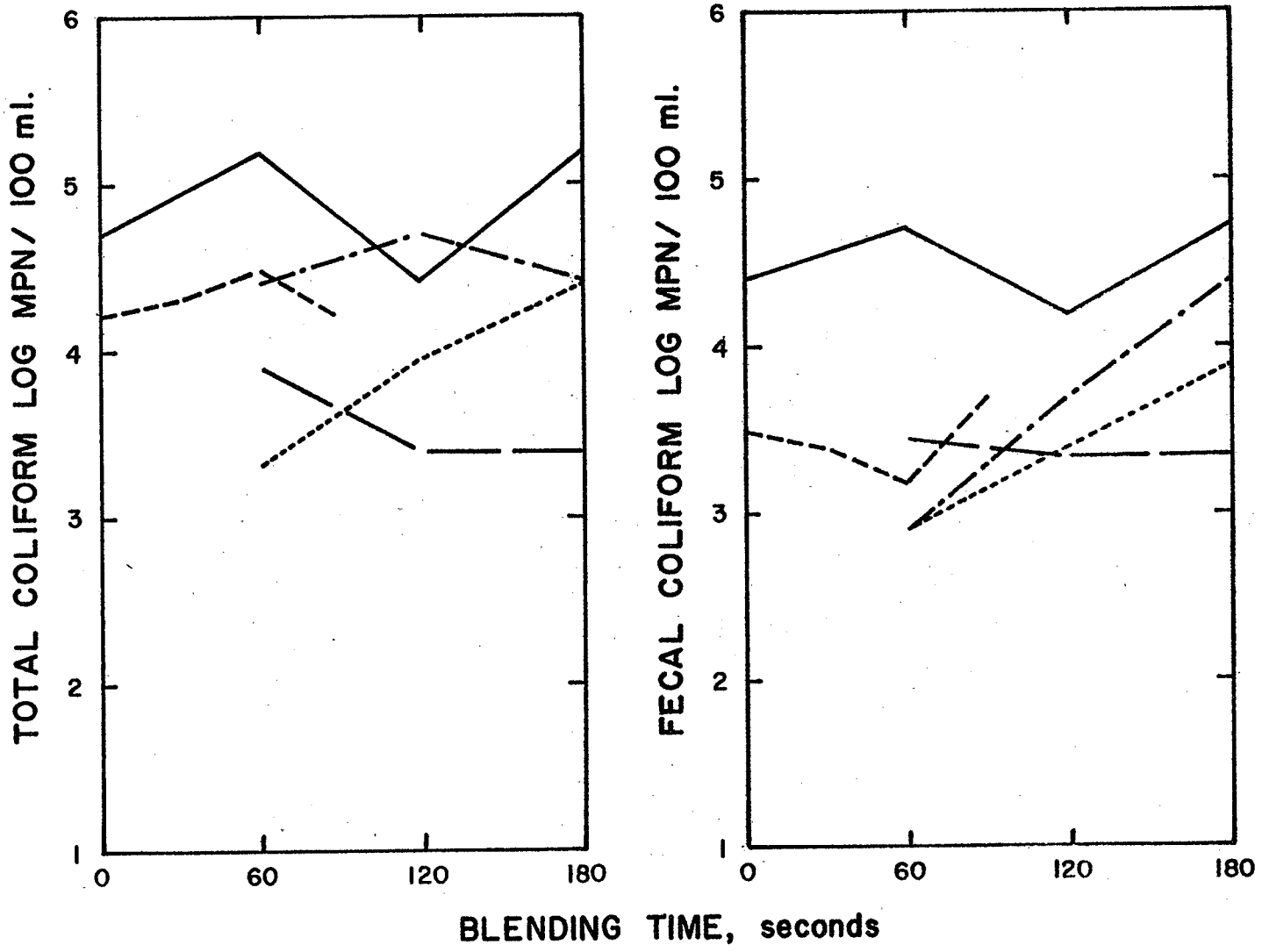


Figure 21. Effect of homogenization on the levels of total and fecal coliforms.

Fecal streptococcal group--There has been an increasing usage of fecal streptococci for evaluating the microbial quality of surface waters. However, there is some controversy concerning the sanitary significance of the microorganisms that comprise this indicator group. *Standard Methods* (16) defines the fecal streptococcal group to contain the following species: *S. faecalis, S. faecalis* var. *liquifaciens, S. faecalis* var. *zymogenes, S. durans, S. faecium, S. bovis* and *S. equinus* and is considered synonymous with "Lancefield's Group D. Streptococcus". The more restrictive term "enterococcus" excludes *S. bovis* and *S. equinus*. Geldreich (31) assigns limited sanitary significance to the *S. faecalis* strain capable of starch hydrolysis (designated atypical) and *S. faecalis* var. *liquifaciens* and provides evidence to suggest that the subgroup of *S. bovis* and *S. equinus* may be indicative of non-human animal pollution. The latter two streptococcal species were found in significant levels of animal feces but not recovered from human feces.

An initial effort in this study was directed toward evaluation of media for the enumeration of the fecal streptococcal group. Multiple tube dilution technique with azide dextrose broth confirmed on ethyl violet azide (EVA) and/or enterococci confirmatory agar, M-enterococcus plate counts and KF streptococcus plate counts were evaluated with samples of raw sewage and water from urban streams. KF streptococcus plate counts consistently yielded the highest recovery of fecal streptococci. M-enterococcus agar consistently yielded low recovery. Subsequent evaluation of the more recent selective enterococcus medium (Pfizer Diagnostics) (PSE) yielded results similar to KF streptococcus agar with the advantage of a shorter incubation period. Based on the results of the preliminary culture evaluations and the similar findings of Pavlova *et al.* (32), Hartman *et al.* (33), and Kenner *et al.* (34), KF streptococcus agar was employed for the enumeration of the fecal streptococcal group.

Isolates obtained from KF plates were differentiated according to the scheme given in Figure 22. Generally, 35 to 50 isolates were randomly picked from the countable plates for further differentiation. This represents a minimum of 5.7% to 58% of the available isolates on duplicate plates containing 30 to 300 colonies. All colonies were picked when the number of colonies were below 30 at the lower sensitivity limit of the assay. Two types of replicate plate procedures were employed to enable the differentiation of a large number of isolates. Colonies were transferred with sterile toothpicks to a grid pattern on a master plate and incubated. The master plate was then used to inoculate a velveteen pad and transferred in the grid pattern to the appropriate differential agars. The second procedure employed the preparation of a master plate as above, but a multiple point inoculation device utilizing toothpicks was used. Each isolate was picked from the master plate with a sterile toothpick and transferred to a plexiglass toothpick holder in a similar grid pattern. The charged toothpicks were then used to inoculate the appropriate differential agars. The last plate in each replication series was a BHI agar control to evaluate the transfer. Isolates not replicated through the final control plate were not considered. Each procedure would easily transfer microorganisms through 15 plates.

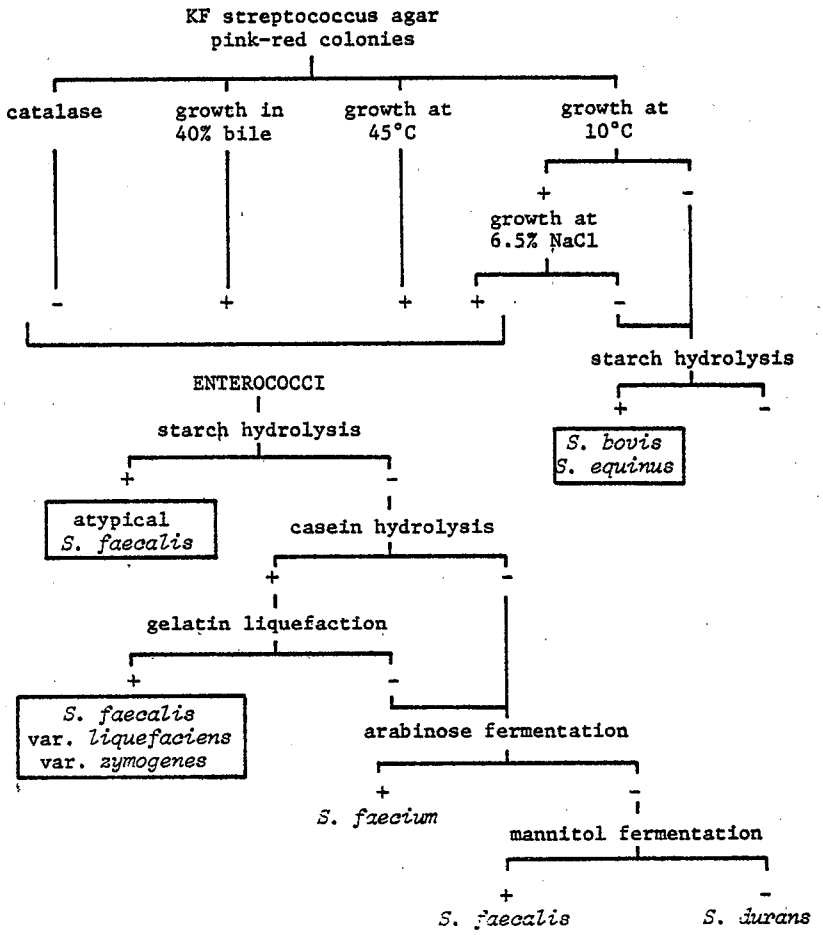


Figure 22. Schematic - Identification of the fecal streptococci.

The velveteen and toothpick replicator were evaluated by comparing results obtained in simultaneous determinations with conventional tube methods. The results for 250 trials of isolates obtained from KF streptococcus agar is given in Table 11. With the exception of arabinose fermentation 94.4% agreement or better was observed between the replication procedures and standard tube methods. The relatively poor agreement on arabinose fermentation appears to be a function of the initial pH of the medium. If the initial pH of the medium was too low the fermentation reaction was difficult to read. Subsequent comparison with 50 isolates where the pH was adjusted to 7.4 before autoclaving yielded 98% agreement. The overall agreement on species identification by the replication procedures and the tube methods was 93.0% for the velveteen technique and 94.5% for the toothpick method. Many of the isolates that did not agree with the tube procedures for arabinose fermentation did not require arabinose fermentation for the determination of species. With respect to the group identification of enterococcus, *S. bovis* and *equinus*, the *liquefaciens* and *zymogenes* variations of *S. faecalis*, atypical *S. faecalis* and false positives, the percent agreement overall was 97.0% for both procedures.

Both replication procedures were rapid, inexpensive and reasonably accurate. The toothpick replicator yielded a more positive (small noticeable holes in the agar at the time of replication) inoculation of the agar and was less sensitive to plate moisture than the velveteen replication technique. The major portion of the assays was conducted with the toothpick replicator.

Animal Virus Assays

Animal virus assays were conducted by Dr. James E. Smith at the Syracuse University Biological Research Laboratories in Syracuse, New York.

Tissue Cultures--

BGM cells were grown in a 1:1 mixture of MEM medium (Hanks basal salts) and L-15 medium (Leibovitz) using 10% fetal calf serum and 1% of a 7.5% $NaHCO_3$ stock (35). Human HEp-2 cells were grown in H-MEM above plus 5% fetal calf serum. Human fetal embryonic lung (HEL) cells were obtained from Flow Laboratories (as Flow 4000) and grown for 4 to 8 passages in E-MEM (Earles basal salts) plus 10% fetal calf serum. Addition of gentamicin (5 µg/ml) to the growth media for BGM and HEL cells markedly improved the growth and plaquing capabilities of these cell lines.

Plaque Formation--

BGM and Hep-2 cells were used for plaque assays as described by Dahling *et al.* (36) using an agar overlay containing per 100 ml: H-MEM, L-glutamine, MEM nonessential amino acids, 2% fetal calf serum, 3.0 ml 7.5% $NaHCO_3$, 1.0 ml 1% $MgCl_2 \cdot H_2O$ solution, 1.5 ml 0.1% neutral red solution, 200 units penicillin, 100 µg streptomycin and 50 µg mycostatin. HEL cells were overlaid with E-MEM, 5% fetal bovine serum, pH 7.4. All agar overlays contained either 0.8% ion agar No. 2 (Oxoid) or 0.8-1.0% Noble agar (Bacto). Plaque formation was observed in 60 mm polystyrene plates and in Multiwell (Falcon) plates (37, 38).

Table 11. COMPARISON OF VELVETEEN AND TOOTHPICK REPLICATION PROCEDURES TO CONVENTIONAL TUBE METHODS FOR THE DIFFERENTIATION OF FECAL STREPTOCOCCI

Test	# of tests	Velveteen # agree	Velveteen % agreement	Toothpick # agree	Toothpick % agreement
Growth in 40% bile	250	250	100	250	100
Growth in 6.5% NaCl	250	237	94.8	236	94.4
Growth at 45°C	250	242	96.8	243	97.2
Growth at 10°C	250	242	96.8	240	96.0
Starch hydrolysis	250	-	-	-	-
Gelatin liquafaction	150	150	100	150	100
Casein hydrolysis [a]	250	250	100	250	100
Arabinose fermentation	200	166	83.0	184	92.0
Mannitol fermentation	250	240	96.0	243	97.2
Species identification [b]	-	-	93.0	-	94.5
Group identification	-	-	97.0	-	97.0

[a] Casein hydrolysis was compared to peptonization of litmus milk

[b] *S. durans* classified as a variation of *S. faecium*

Microtiter $TCID_{50}$ Endpoint Assays and CPE--

Techniques described by Conrath (39) were used for viral neutralization and metabolic inhibition tests of virus concentrates eluted from sewage solids. Microtest II plates were employed and the cell monolayers were stained with Giemsa reagent according to the following schedule (40). After 2 to 10 days the Microtest II culture plates were washed by immersion in PBS and fixed by immersion in methanol 5 minutes. The monolayers were washed 15 minutes in dilute Giemsa solution (stock Giemsa diluted 1:15) and rinsed 20-40 seconds in tap water and distilled water. The plates were inverted and air-dryed. (Stock Giemsa: 1g Giemsa powder was dissolved in 66 ml glycerol, 55 C, 1 hr. and 66 ml methanol was added.)

Methods of Identification--

A two-step scheme was employed to make quantitative estimates of the number of viruses in each of five groups: polio-, Coxsackie B-, echo-, adeno- and reoviruses. A presumptive test of the virus concentrates was made first in Microtest II plates to determine which groups were represented in the sample and what was their approximate $TCID_{50}$ titer. The dilution sequences, the challenge with eight neutralizing units of antipoliovirus IgG (rabbit) and the cell sensitivity spectrum are illustrated in Figure 23. The interpretation of the patterns obtained by this procedure are shown in Table 12. Generally it was possible to differentiate the virus groups even when they occurred in mixtures by suppressing one or two groups with antiserum or a nonpermissive host. In those samples where a fourth or an unrecognized component was present the samples were plated and the individual plaques were picked with sterile toothpicks and a confirmed test was applied. For this test the unknown plaques were subcultured in microtiter wells, the resulting virus was passed back through the screen (Figure 23) and/or the cytopathology of the infected cells was examined by staining with May-Grunwald Giemsa stains. If adeno- or reoviruses were suspected, the plaques were grown in 16-chamber Lab-Tek well slides and stained with acridine orange as well as MGG (41).

Virus Concentration--

Five gallon stormwater samples were decanted and viruses in the supernatant were isolated by selective adsorption to membrane filters. The Aquella Virus Concentrator (Carborundum Co.) was used to remove the remaining solids and to adsorb the viruses to "sandwich" of three cellulose acetate membrane filters - 5 µm and 0.47 µm porosities. Orlon (10 and 1 µm porosities) and cellulose acetate (0.8 µm) wound textile filters ("Fulflo") were used ahead of the membrane filters to remove suspended solids which would clog the membrane filters (42, 43). Virus samples were adjusted to pH 4.5 with HCl and $MgCl_2$ (0.05 M) was added after the prefiltration step. The adsorbed viruses were eluted from the membrane with 0.05 M glycine, pH 11.5 or 3% beef extract, pH 9.5. Eluates were collected in cold buffer, pH 7.2 to prevent damage to the virions (individual virus particles) and sterilized with chloroform. Two percent fetal calf serum and 1% $MgCl_2$ were added to the preparations which were then frozen and stored at -40°C.

Sampling and Shipping--

Twenty liter samples were collected in polystyrene containers and shipped by express bus from Baltimore to Syracuse, N.Y. During shipment

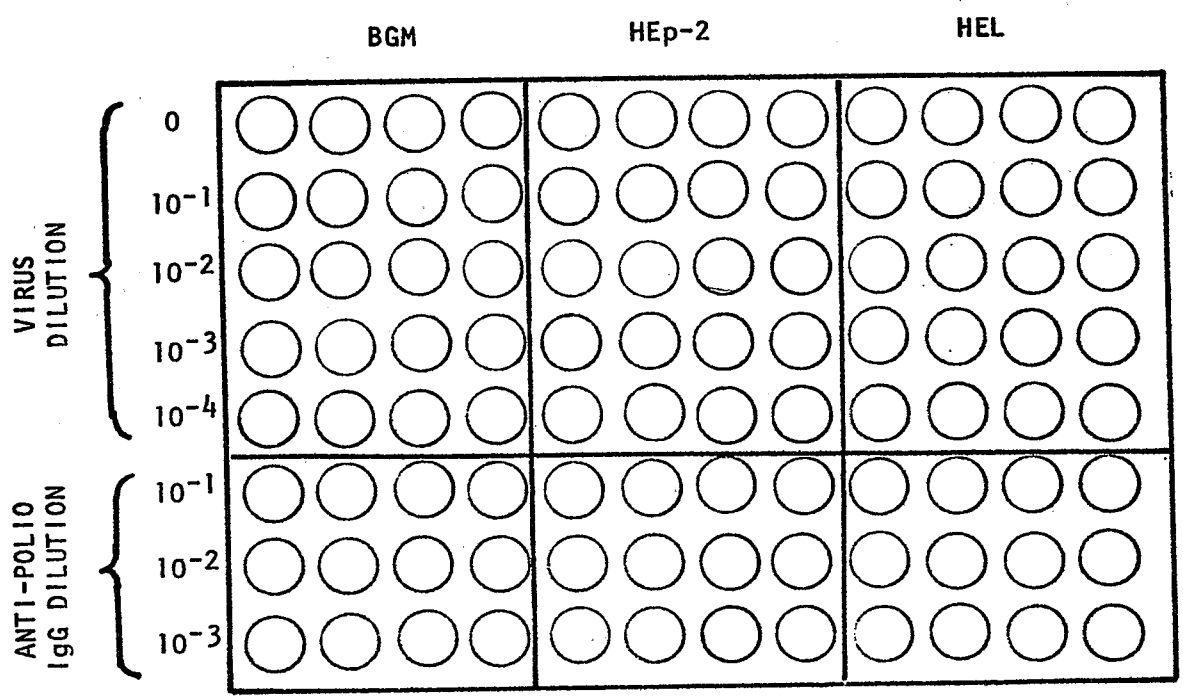


Figure 23. Presumptive assay for virus concentrates (Micro Test 11 plate).

Table 12. DIAGNOSTIC PATTERN FOR PRESUMPTIVE IDENTIFICATION OF ENTEROVIRUSES IN TISSUE CULTURE

Virus Group	Treatment with anti-polio IgG[1]	Cytopathic effect on: BGM	HEp-2	HEL
Polioviruses	No	+	+	±
	Yes	-	-	-
Coxsackie B viruses	No	+	+	-or±
	Yes	+	+	-or±
Echoviruses	No	+or-	-	+
	Yes	+or-	-	+

[1] Rabbit sera fractionated by precipitation with ammonium sulfate and cross-absorbed with packed cells of the three indicator cultures.

the samples were maintained at ambient temperatures for 9 to 12 hours; on arrival they were refrigerated overnight at 4°C. Thermal controls were included in each grab sample. One ml aliquots of commercial poliovirus vaccine which had been diluted 1:25 in tryptose phosphate broth (TPB) were mixed with 9 ml of each water sample in tightly capped tubes. These tubes plus one with virus in sterile TPB were placed in the water containers during shipment. Upon receipt they were sterilized by chloroform extraction, aerated to remove the chloroform and frozen, -40°C, after the addition of 2% calf serum and $MgCl_2$ to 0.05 M. The plaque titers of the surviving viruses were compared to reference stocks of the original vaccine maintained at -65°C.

Shipment of waste water samples by bus was found to be an adequate procedure for the holding time involved in these experiments - eight hours at ambient temperatures. When temperatures of newly arrived samples were measured, they were not more than one or two degrees °C above external temperatures, suggesting that the cargo holds remained cool throughout the trip. Trivalent oral polio vaccine was chosen for the thermal control since there are some differences in temperature sensitivity among the polio serotypes.

Average recoveries of PFU are shown in Table 13, ranging from 84 to 94% of the expected values. The average values for recoveries of virus diluted in water samples were consistently lower than the values for viruses diluted in TPB. Although those differences were not significant enough to affect the method of handling samples, it did suggest that the viruses may be osmotically shocked when diluted in stream water or that TPB may protect them against thermal damage in some way.

An earlier progress report appeared to show marked losses and irregular recoveries of enteroviruses when their plaque recoveries were measured. However, this problem was corrected later when it was demonstrated that the chloroform-preserved thermal control samples were not being adequately aerated. Traces of chloroform in some samples reduced the plating efficiency and the apparent recovery of virus.

Table 13. CONTROL SAMPLES FOR LOSSES DUE TO SHIPPING

Sample no.	Percent survival compared to frozen polio vaccine				
	Sampling site				
	A	B	C	D	TPB
36	88	91	90	76	104
38	79	61	80	95	120
39	103	100	101	91	99
46	90	79	99	78	91
48	87	100	112	87	111
52	96	89	82	80	86
55	85	93	87	67	ND
57	91	105	114	93	99
60	88	ND	96	92	ND
61	73	86	90	ND	88
63	81	97	78	99	100
Average	87.4	90.1	93.5	83.7	99.7
σ	12.2	12.1	11.4	10.0	10.6

ND - No Data

RESULTS

Samples were collected for microbial analysis from August 1974 through September 1975. The samples collected in August and September of 1974 were used to evaluate culture methods and set logistical procedures for the routine microbial assays of subsequent background and storm samples. The data presented cover 13 months, from September 1, 1974 through September 30, 1975. During this period, 35 sets of background samples and samples from 24 storm events were collected and assayed. This represents a total of 298 samples, 154 background and 144 storm samples. Table 14 gives some idea of the magnitude of effort to obtain information on the levels of pathogenic and indicator microorganisms. A total of 34,511 isolates were tested. Each isolate was processed through a series of biochemical tests to enable a tentative identification of pathogenic and indicator microorganisms.

RAINFALL

Rainfall data were obtained at three rainfall gauges in Baltimore City. The three locations are indicated on Figure 4 by filled circles. The Customs House station was operated by the U.S. Weather Bureau and located close to the downtown business district. The Woodborne and Ashburton gauges were operated by the City of Baltimore and located in the northeastern and northwestern sections of the city. Rainfall data during gauge malfunction at Woodborne and Ashburton were estimated from the measurements taken at the Customs House. The monthly precipitation data from September 1974 to August 1975 at the three gauging stations in Baltimore City are given in Table 15. The 50 year normal precipitation data are given in the column on the right for comparison. The Customs House station in downtown Baltimore recorded considerably more rainfall than the 50 year normal in September and December in 1974 and March, May and July in 1975. The annual rainfall at the Customs House exceeded the 50 year normal by more than 40 cm. The Woodborne gauge recorded higher rainfalls in September and December 1974 and March, May, June and July 1975. The annual total at this station was more than 17 cm higher than the 50 year normal. The Ashburton gauge in the northwestern section recorded almost 8 cm more rain than the 50 year normal. The amount of precipitation measured at three different locations in Baltimore City varied considerably. The daily rainfall at each gauging station can be seen in Appendix A.

OCCURRENCE AND LEVELS OF MICROORGANISMS

The raw data for the levels of bacteria and animal viruses for each sample are given in Appendix B and Appendix C, respectively. The data are presented for each sample station. The levels of indicator microorganisms, *P. aeruginosa* and *Staph. aureus* are reported as MPN or number/100 ml. The *Salmonella* sp. and animal virus are reported as MPN/10 1 and PFU/10 1, respectively. It is important to recognize that the denominator for the *Salmonella* and animal virus data is 100 fold greater than the denominator for the indicator and other micro-

Table 14. NUMBER OF BACTERIAL ISOLATES TESTED DURING THE PROJECT PERIOD

Bacterial Assay	Number of Isolates
Salmonella sp.	10,242
Shigella sp.	1,051
Pseudomonas aeruginosa	7,389
Staph. aureus	7,587
Fecal streptococci	8,242
Total	34,511

Table 15. MONTHLY PRECIPITATION IN cm (INCHES) DURING THE STORMWATER STUDY PERIOD AT THREE GAUGING STATIONS OF BALTIMORE CITY

Period	Woodborne		Ashburton		Custom House		50 year normal	
1974								
September	13.59	(5.35)	10.67	(4.20)	15.27	(6.01)	9.22	(3.63)
October	2.79	(1.10)	2.41	(0.95)	3.40	(1.34)	10.24	(2.82)
November	4.70	(1.85)	4.32	(1.70)	4.50	(1.77)	9.84	(2.71)
December	15.37	(6.05)	15.62	(6.15)[a]	20.47	(8.06)	11.80	(3.25)
1975								
January	8.76	(3.45)	4.95	(1.95)	9.14	(3.60)	12.09	(3.33)
February	5.72	(2.25)	3.18	(1.25)	6.35	(2.50)	12.09	(3.33)
March	12.07	(4.75)	10.67	(4.20)	15.01	(5.91)	13.58	(3.74)
April	5.21	(2.05)	6.73	(2.65)	7.72	(3.04)	12.20	(3.36
May	11.94	(4.70)[a]	10.29	(4.05)	20.52	(8.08)	12.52	(3.45)
June	11.05	(4.35)[a]	8.51	(3.35)[a]	9.40	(3.70)	14.05	(3.87)
July	27.94	(11.00)[a]	27.94	(11.00)[a]	29.67	(11.68)	16.92	(4.66)
August	6.60	(2.60)	10.92	(4.30)	9.50	(3.74)	16.49	(4.53)
12 month total	125.73	(49.50)[a]	116.21	(45.75)[a]	150.95	(59.43)	108.41	(42.68)

a - estimated

organisms. The levels of viruses are reported as $TCID_{50}$/10 1 for the presumptive test and PFU/10 1. All calculations involving enteric viruses were made using the PFU/10 1 data.

Background Samples

The occurrence of selected pathogenic bacteria is summarized in Table 16 for the background samples (sewage, urban streams and reservoirs). *Salmonella* sp. were recovered from all the raw sewage samples, 84% of the samples from Herring Run, 94% of the samples from the Jones Falls and 100% of the samples from Gwynns Falls. Only 7% (1 of 14) of the samples from Loch Raven reservoir were found to contain *Salmonella*. *P. aeruginosa*, the most abundant pathogen, was found in all the samples of raw sewage, Herring Run, and Jones Falls, and 97% of the samples from Gwynns Falls. *P. aeruginosa* was isolated in 62% of the Loch Raven reservoir samples. *Staph. aureus* was found in 93%, 57%, 93% and 59% of the raw sewage, Herring Run, Jones Falls, and Gwynns Falls samples, respectively. No *Staph. aureus* was recovered from Loch Raven reservoir. It should be noted that the lower sensitivity limit for the *Staph. aureus* assay was an MPN of 2/100 ml.

The occurrence of viruses in the background samples is shown in Table 17. The percent occurrence was based on the presumptive test of the virus concentrates with neutralizing antisera and cell sensitivity spectrum for five virus groups; poliovirus, Coxsackie B virus, echovirus, adenovirus and reovirus. Animal viruses were isolated in 93%, 82%, 75% and 79% of the raw sewage, Herring Run, Jones Falls, and Gwynns Falls samples, respectively. A surprisingly high 71% (5 of 7 samples) of the samples from Loch Raven reservoir contained viruses. Poliovirus was the predominant virus recovered in Gwynns Falls and Loch Raven reservoir. Similar frequencies of recovery of poliovirus and Coxsackie B virus were observed for faw sewage and Herring Run. Coxsackie B virus was the predominant group found in the Jones Falls. Echovirus was recovered from 8% to 29% of the background samples. Adenovirus was recovered from raw sewage and Gwynns Falls, and reovirus was found in Jones Falls and Gwynns Falls.

The fecal streptococcal group contains several species and strains that have limited sanitary significance. Table 18 shows the distribution of fecal streptococci in the background samples. The occurrence is presented as the average percent of the isolates and the percent samples positive for each subgroup of fecal streptococci. The average percentage of enterococci isolates varied from 50.5% to 56.5% for the raw sewage and urban streams with typical *S. faecalis* and *S. faecium* representing 43.4% to 48.4%. *S. faecalis* var. *liquefaciens* and *S. faecalis* var. *zymogenes* were found in 58% to 73% of the background samples and represented a mean of 6.7% to 9.8% of the isolates. Atypical *S. faecalis*, capable of hydrolyzing starch, was recovered from 24%, 32%, 9% and 10% of the samples of raw sewage, Herring Run, Jones Falls and Gwynns Falls, respectively. The mean percent of the isolates for this strain of *S. faecalis* was 0.5% to 1.4%. The *liquefaciens* and *zymogenes* and atypical strains of *S. faecalis* were not found to predominate in any of the background samples. *S. bovis* and *S. equinus* similarly, were observed at mean levels of 7.5% to 9.9% of the isolates tested. The frequency of positive samples for *S. bovis* and *S. equinus* were 88.2%, 50.0%, 71.9% and 48.4% for raw sewage, Herring Run, Jones Falls and Gwynns

Table 16. OCCURRENCE OF SELECTED PATHOGENIC BACTERIA IN BACKGROUND SAMPLES, PERCENT

Sample site	*Salmonella* sp.	*P. aeruginosa*	*Staph. aureus*
A Raw sewage	100	100	93
B Herring Run	84	100	57
C Jones Falls	94	100	93
D Gwynns Falls	100	97	59
E Loch Raven reservoir	7	62	0

Table 17. OCCURRENCE OF VIRUSES IN BACKGROUND SAMPLES

Sample site	Number of samples	Occurrence*, %				
		Animal Virus	Poliovirus	Coxsackie virus B	Echovirus	Other
A Raw sewage	15	93	53	53	20	13[a]
B Herring Run	11	82	36	36	27	0
C Jones Falls	12	75	33	58	8	8[b]
D Gwynns Falls	14	79	57	50	29	21[a, b]
E Loch Raven reservoir	7	71	43	29	14	14[c]

* - Occurrence based on presumptive test of virus concentrates

a - Adenovirus

b - Reovirus

c - Not identified

Table 18. DISTRIBUTION OF FECAL STREPTOCOCCI IN BACKGROUND SAMPLES*

Fecal streptococci	Occurrence Isolates, mean % (positive samples, %)			
	A Raw sewage	B Herring Run	C Jones Falls	D Gwynns Falls
Enterococci	50.5 (100)	55.4 (100)	56.5 (100)	56.0 (100)
S. faecalis *S. faecium*	43.4 (100)	47.2 (97)	47.4 (100)	48.4 (97)
S. faecalis var. *liquefaciens* *zymogenes*	6.7 (74)	6.9 (70)	7.9 (59)	9.8 (58)
Atypical *S. faecalis*	0.4 (24)	1.4 (32)	0.6 (9)	0.5 (10)
S. bovis and *S. equinus*	9.9 (88)	8.7 (55)	7.8 (72)	7.5 (48)
False positive and non-fecal streptococci	37.0 (100)	34.3 (100)	34.7 (100)	36.0 (100)

* Insufficient data available for Loch Raven reservoir, sample site E.

Falls, respectively. False positive non-fecal streptococci were found in all the background samples and represented a mean of 34.4% to 37% of the isolates tested.

The geometric mean densities for the microorganisms assayed for each background sample station are given in Table 19. The raw sewage and Loch Raven reservoir provide information on the microbial water quality that can be expected under the worst and best conditions, respectively, in an urbanized area. Each of the urban streams contain high levels of each of the indicator microorganisms and would be judged contaminated regardless of the indicator of fecal contamination employed. The relative order of levels of pathogens in the urban streams was *P. aeruginosa* > *Staph. aureus* > Enterovirus > *Salmonella* sp. It should be stressed that the levels of enterovirus and *Salmonella* sp. are reported with a denominator 100-fold higher than the other microorganisms and represent a 100-fold more sensitive assay.

The relative levels of indicator and pathogenic microorganisms in the urban streams during the sampling period are shown graphically in the following three figures. Figure 24a shows the log density of each of the indicator groups of microorganisms by date for Herring Run (sample site B). Consistently high levels of total coliform, fecal coliform and fecal streptococci were observed throughout the year. Although variation can be seen in the data, there does not appear to be any marked variation with season. The levels of fecal coliform in Herring Run exceeded the recreational standard of 200 fecal coliforms/100 ml in 30 of 33 or 91% of the samples during the 13 month sampling period. The levels of pathogenic microorganisms in Herring Run can be seen in Figure 24b. Again, noticeable variation is shown but there is no apparent dependence upon season of the year. *Staph. aureus* was found at low levels in each sample. *Salmonella* sp. were consistently found in Herring Run and isolates were recovered in 27 of 32 or 84% of the samples.

The levels of indicator microorganisms in the Jones Falls are shown in Figure 25a. The total coliform, fecal coliform and fecal streptococci densities were somewhat higher than in Herring Run and no apparent seasonal variation was observed. All samples collected from the Jones Falls exceeded the fecal coliform recreational water standard by several orders of magnitude. The levels of *P. aeruginosa*, *Staph. aureus*, and *Salmonella* sp. (Figure 25b) are also considerably higher than in Herring Run. *P. aeruginosa* was the predominant pathogen followed by *Staph. aureus*. *Salmonella* was recovered from 29 of 31 or 94% of the samples collected from the Jones Falls.

Similar results are shown for Gwynns Falls in Figures 26a and 26b. High levels of indicators were observed with no apparent seasonal variation. The fecal coliform recreational water standard was met in only one sample during the sample period. The levels of pathogens follow the same order as in the previous urban streams. Seasonal variation again does not appear. A possible peak was observed for *P. aeruginosa* for the Gwynns Falls in September 1974 but was not observed in September of 1975. *Salmonella* was recovered from all samples collected in the Gwynns Falls.

Table 19. GEOMETRIC MEAN DENSITIES OF SELECTED PATHOGENS AND INDICATOR MICROORGANISMS IN BACKGROUND SAMPLES

	Sample site	Enterovirus PFU/10 l.	*Salmonella* sp. MPN/10 l.	*P. aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	Total coliform MPN/100ml	Fecal coliform MPN/100ml	Fecal strep. no./100ml	Entero-cocci no./100ml
A	Raw sewage	8.7×10^2	5.0×10^2	2.3×10^5	2.6×10^2	2.3×10^7	6.3×10^6	1.2×10^6	5.4×10^5
B	Herring Run	2.8×10^1	4.6	2.9×10^2	3.2	4.8×10^3	1.1×10^3	1.6×10^3	5.9×10^2
C	Jones Falls	6.0×10^1	9.1	2.1×10^3	9.5	4.0×10^4	1.5×10^4	1.6×10^4	4.9×10^3
D	Gwynns Falls	1.3×10^1	1.5×10^1	4.7×10^2	4.5	4.0×10^4	5.9×10^3	1.7×10^3	8.9×10^2
E	Loch Raven reservoir	5.9×10^1	0	3.1	2.5	2.6×10^1	1.5×10^1	1.0×10^1	2.0

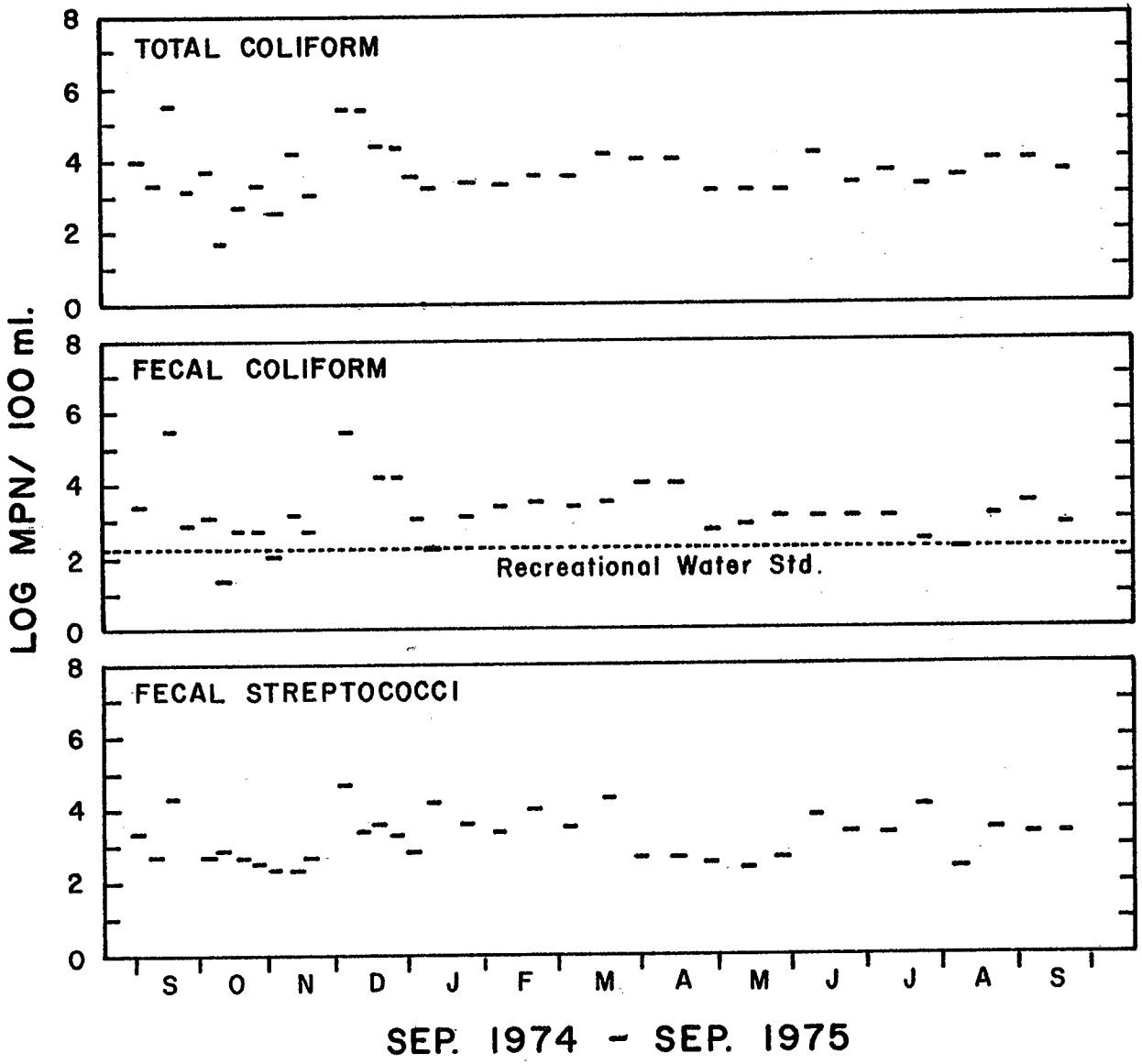


Figure 24a. Levels of indicator microorganisms in Herring Run, sample site B, during the sampling period.

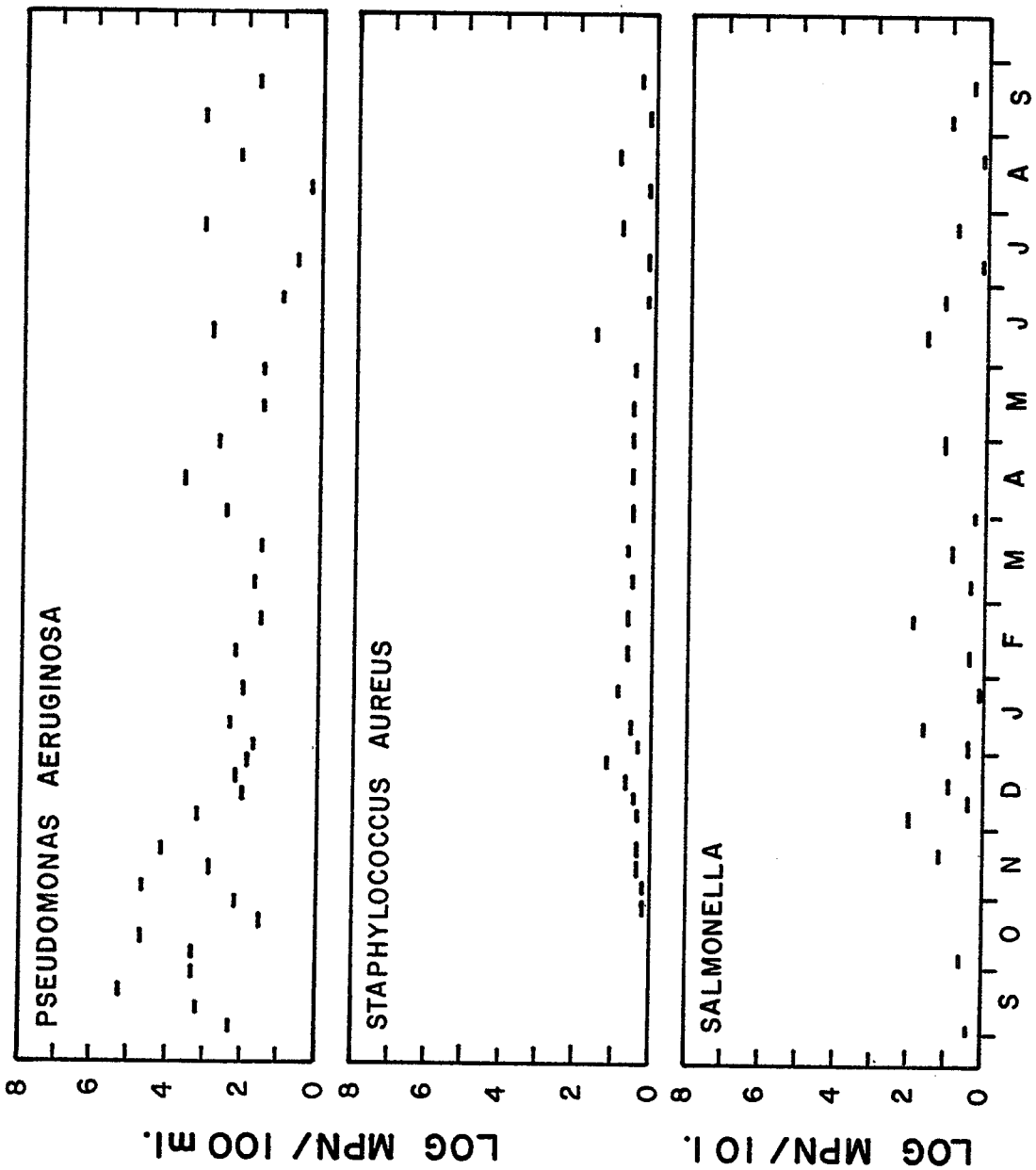


Figure 24b. Levels of pathogenic microorganisms in Herring Run, sample site B, during the sampling period.

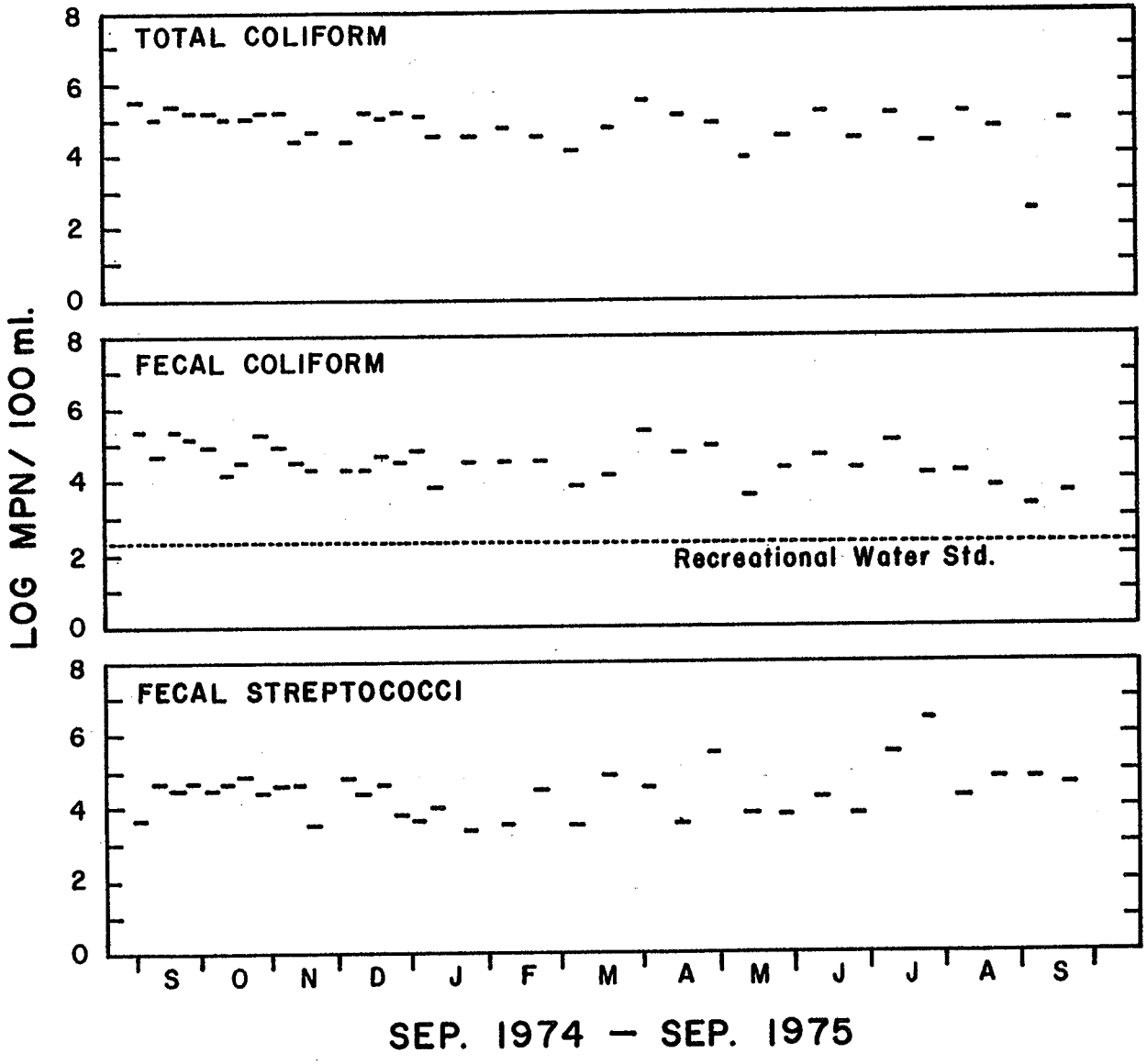


Figure 25a. Levels of indicator microorganisms in Jones Falls, sample site C, during the sampling period.

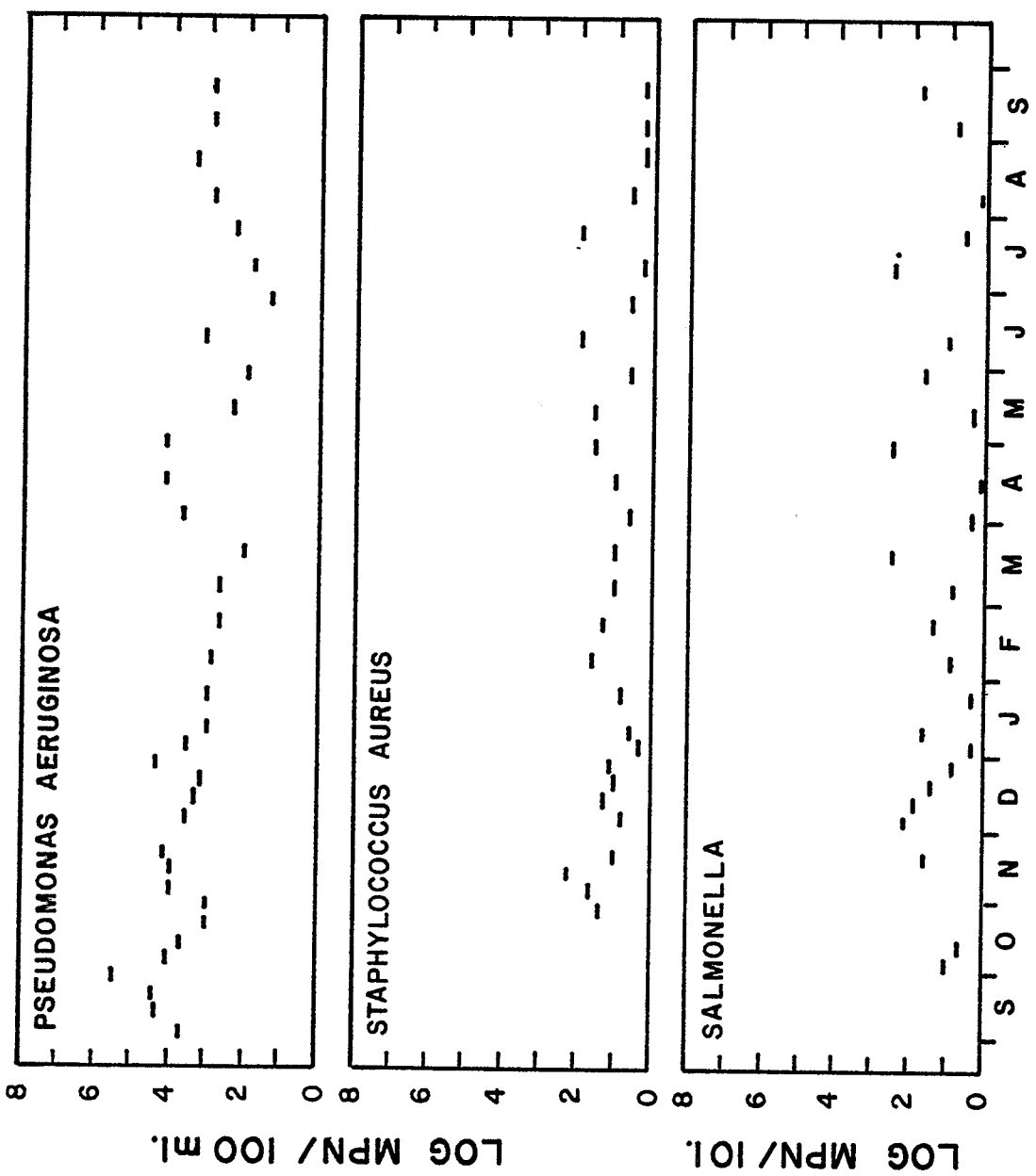


Figure 25b. Levels of pathogenic microorganisms in Jones Falls, sample site C, during the sampling period.

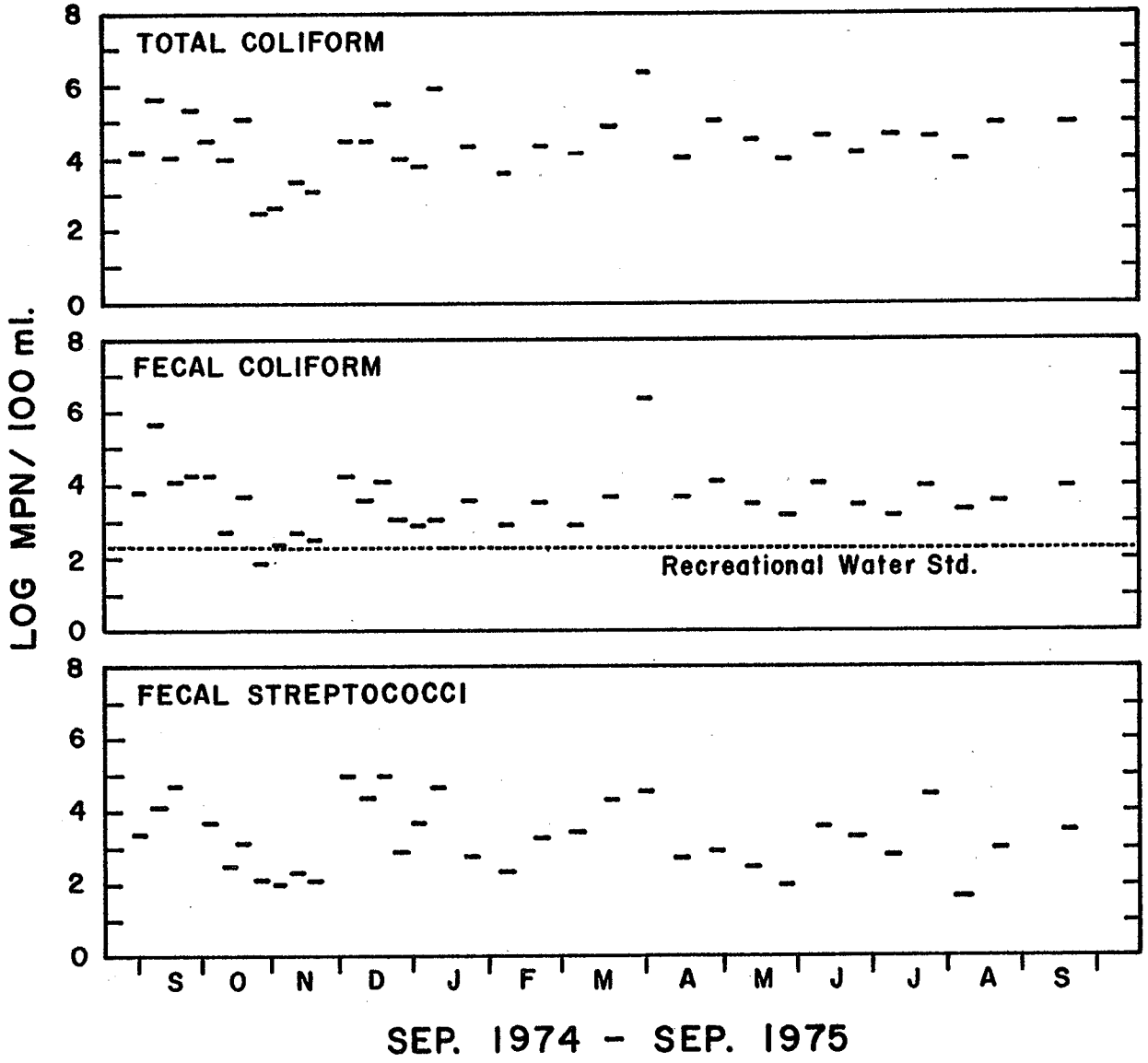


Figure 26a. Levels of indicator microorganisms in Gwynns Falls, sample site D, during the sampling period.

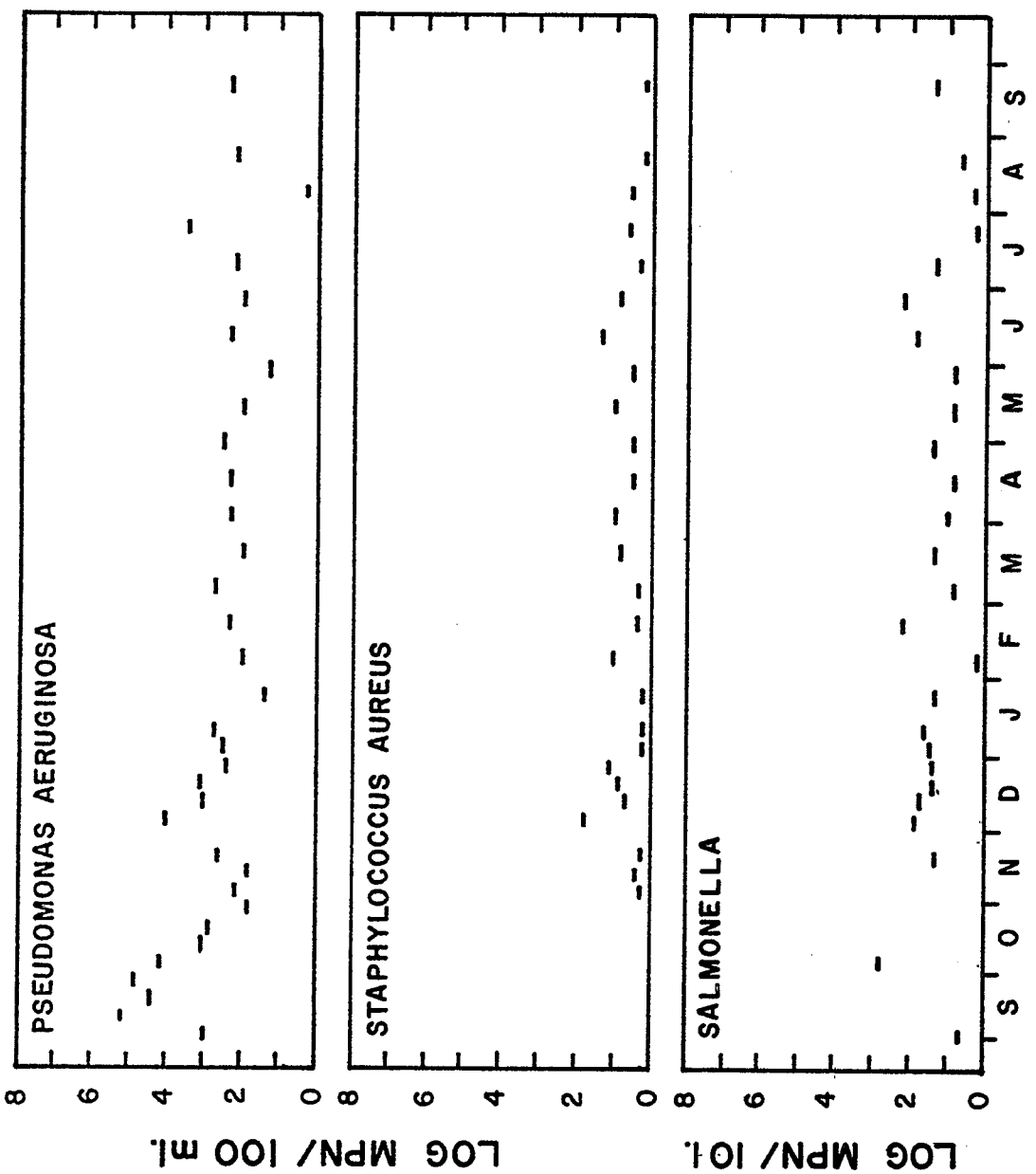


Figure 26b. Levels of pathogenic microorganisms in Gwynns Falls, sample site D, during the sampling period.

The effect of stream flow on the levels of fecal coliforms in Herring Run and Gwynns Falls is shown in Figures 27 and 28, respectively. Stream flow was determined at the time of sample collection. The minimum stream flow that could be estimated at Herring Run was 28 1/sec. (0.95 cfs). The highest recorded flow was 608 1/sec. (21.5 cfs) and is not recorded on the graph. During periods of low flow the levels of fecal coliform varied from just more than 10 to greater than 10^5 MPN/100 ml. There was no apparent relationship between stream flow and fecal coliform densities for Herring Run. The stream flow in the larger Gwynns Falls varied from 110 to 8,490 1/sec. (3.9 to 300 cfs). As in Herring Run, there appears to be little correlation between stream flow and levels of fecal coliforms.

The effect of previous rainfall prior to the time of sampling on the microbial quality was evaluated for the background samples. The levels of fecal coliform was compared to the antecedent or number of days since the last rainfall. Antecedent rainfall, in days, appears to have little effect on the fecal coliform density in raw sewage and urban streams (Figure 29).

Storm Samples

The occurrence of selected pathogenic bacteria in storm runoff is shown in Table 20. *Salmonella* sp. were recovered from all the samples collected at Stoney Run, Glen Avenue, and Howard Park, 96% of the samples collected at Jones Falls storm drain and Bush Street, and 52% of the Northwood samples. *P. aeruginosa* was found in all the storm samples at levels approaching those found for the indicator microorganisms. *Staph. aureus* was isolated from 83%, 71%, 95%, 100%, 96%, and 82% of the samples from Stoney Run, Glen Avenue, Howard Park, Jones Falls storm drain, Bush Street and Northwood, respectively. The lower relative recovery of *Staph. aureus* was due to the higher sensitivity limit for the *Staph. aureus* assay. No concentration procedure was employed and the maximum sample volume assayed was 10 ml.

Animal viruses were recovered at a high frequency in the storm runoff samples. Table 21 shows the occurrence of selected animal viruses for these samples. Animal viruses were recovered from all the samples at Stoney Run and Howard Park, 92% of the Glen Avenue, 83% of the Jones Falls and Northwood and 75% of the Bush Street samples. The predominant virus groups found were polioviruses and Coxsackie B viruses. Echovirus was observed at a lower frequency. Adenovirus was found in 1 of 12 samples at Bush Street and reoviruses were found at a similar frequency at Glen Avenue and Howard Park.

The distribution of fecal streptococci in the storm runoff samples is given in Table 22. The mean percent of isolates that were found for each component of the fecal streptococci for each storm sample site is shown. The number in parenthesis was the frequency with which the member microorganisms were observed. Enterococci were found in all samples and were 39.6% to 51.5% of the isolates tested. The major portion of the enterococcal group were typical strains of *S. faecalis* and *S. faecium*. A small percentage (1.3% - 7.1%) of the enterococci isolates were the *liquefaciens - zymogenes* varieties of *S. faecalis*

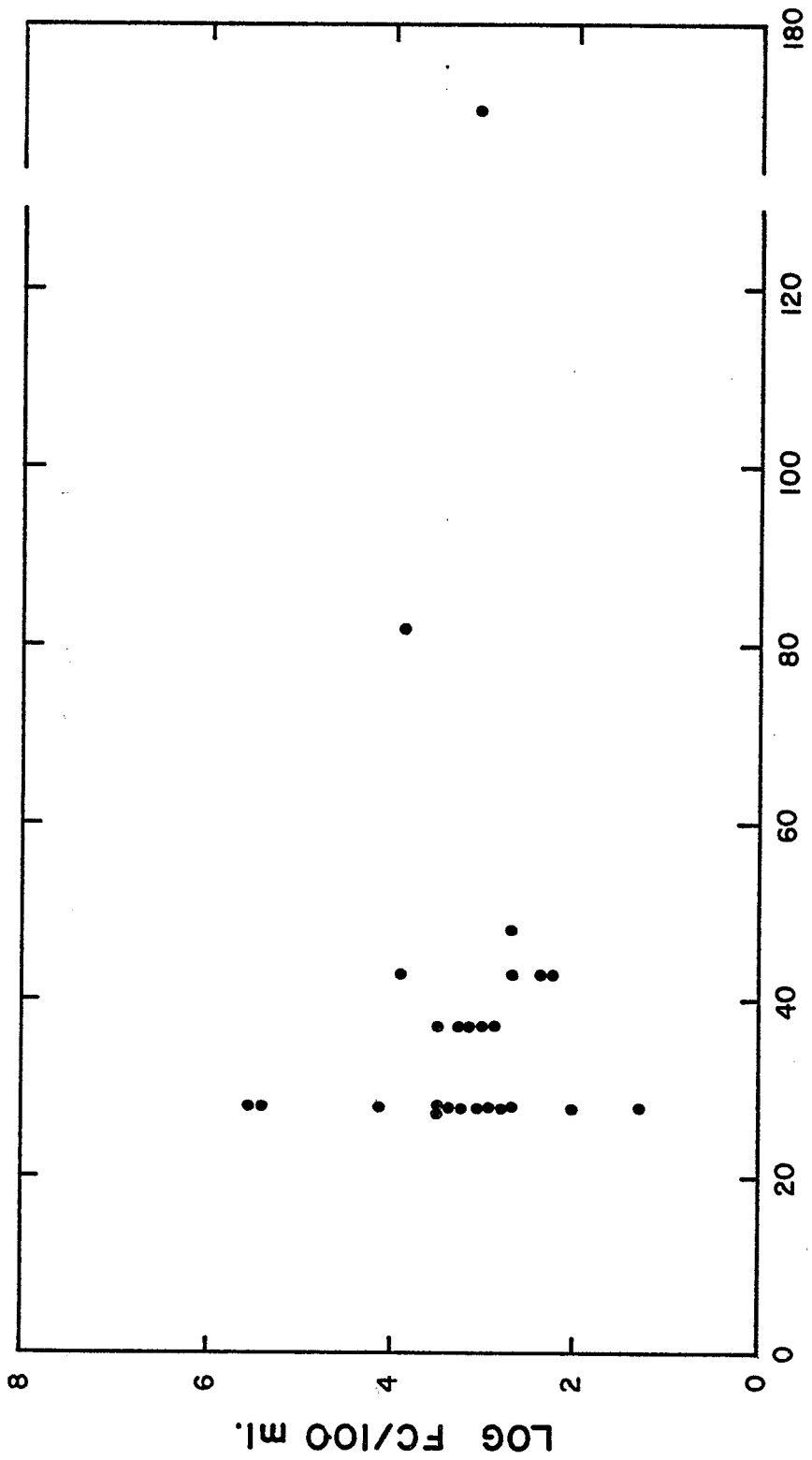


Figure 27. Effect of stream flow on the levels of fecal coliform in Herring Run, sample site B.

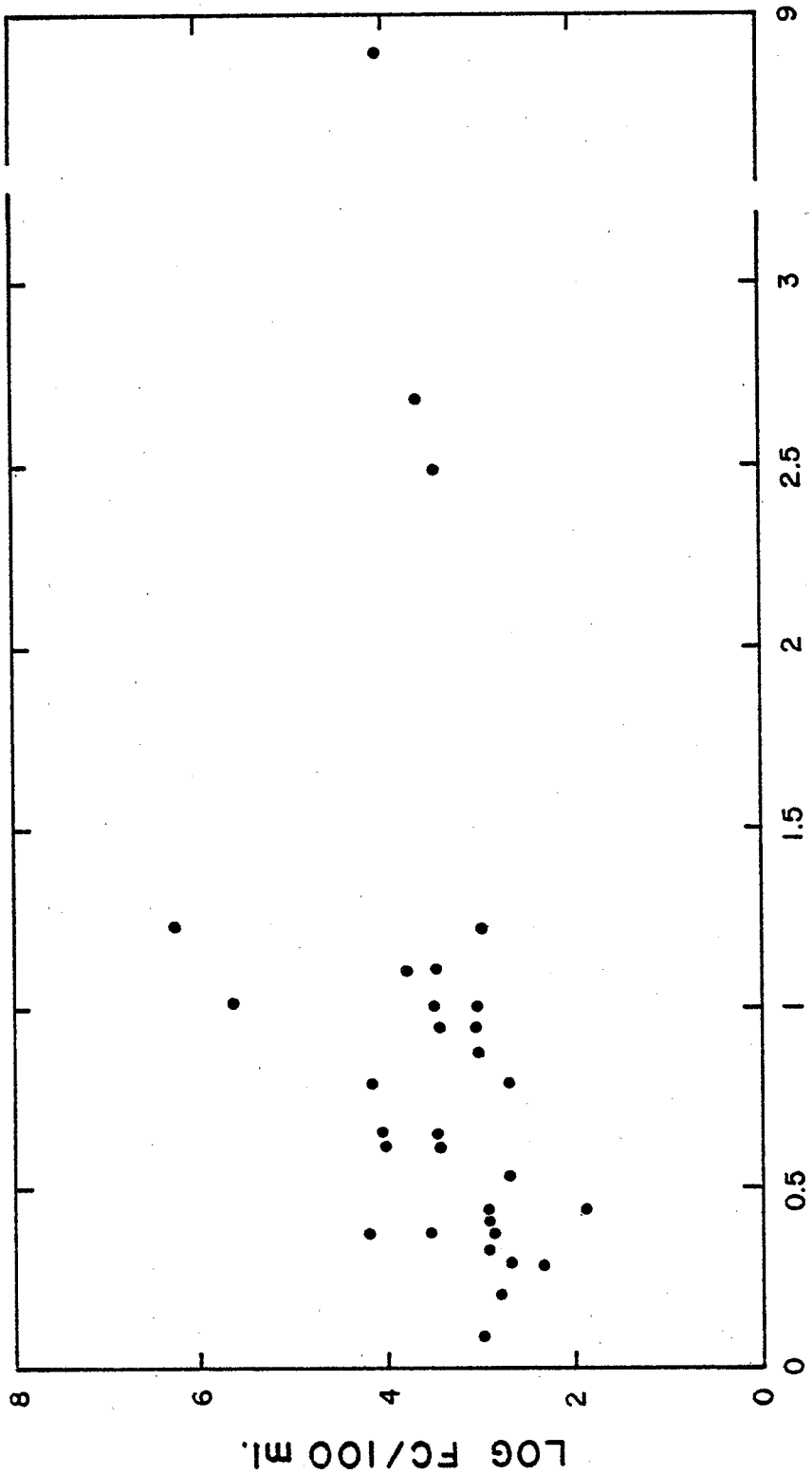


Figure 28. Effect of stream flow on the levels of fecal coliform in Gwynns Falls, sample site D.

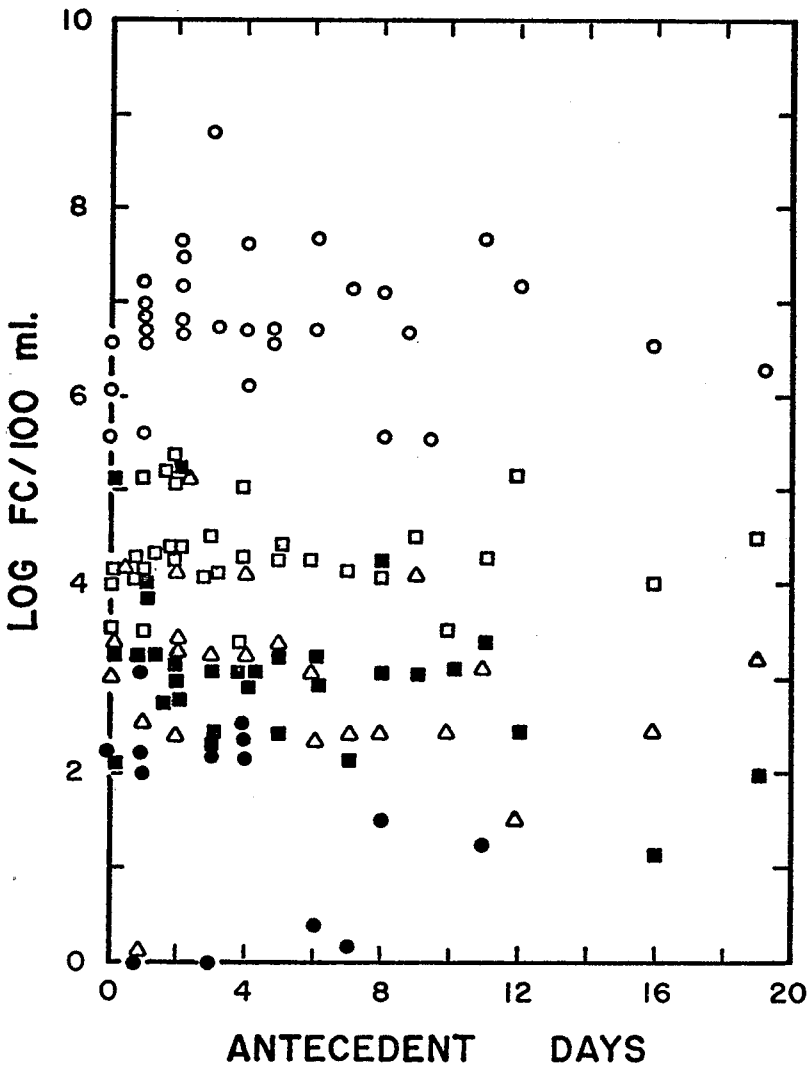


Figure 29. The effect of period in days since last rain storm on the fecal coliform density measured in the background samples, A, raw sewage (o), B, Herring Run (■), C, Jones Falls (□), D, Gwynns Falls (△), and E, Loch Raven (●).

Table 20. OCCURRENCE OF SELECTED PATHOGENIC BACTERIA IN STORMWATER SAMPLES

Sample site	Occurrence, %		
	Salmonella sp.	*P. aeruginosa*	*Staph. aureus*
F Stoney Run	100	100	83
G Glen Avenue	100	100	71
H Howard Park	100	100	95
K Jones Falls storm drain	96	100	100
L Bush Street	96	100	96
M Northwood	52	100	82

Table 21. OCCURRENCE OF SELECTED VIRUSES IN STORMWATER SAMPLES

Sample site	Occurrence, %				
	Animal virus	Poliovirus	Coxsackie virus B	Echovirus	Other
F Stoney Run	100	73	73	27	9[c]
G Glen Avenue	92	75	42	17	8[b]
H Howard Park	100	42	58	8	8[b]
K Jones Falls storm drain	83	67	50	33	8[c]
L Bush Street	75	25	42	25	8[a]
M Northwood	83	42	50	33	8[c]

a - Adenovirus

b - Reovirus

c - Not identified

Table 22. DISTRIBUTION OF FECAL STREPTOCOCCI IN STORMWATER SAMPLES

Fecal streptococci	Occurrence Isolates, mean % (positive samples, %)					
	F	G	H	K	L	M
	Stoney Run	Glen Avenue	Howard Park	Jones Falls storm drain	Bush Street	Northwood
Enterococci	45.4 (100)	38.8 (100)	39.7 (100)	40.4 (100)	39.6 (100)	51.5 (100)
S. faecalis *S. faecium*	38.0 (100)	37.4 (100)	33.6 (100)	32.6 (91)	32.8 (100)	46.7 (100)
S. faecalis var. *liquefaciens* and *zymogenes*	6.3 (62)	1.3 (30)	5.4 (58)	7.1 (43)	6.0 (50)	4.4 (35)
Atypical S. faecalis	0.2 (10)	0.3 (10)	0.5 (21)	0.7 (24)	0.8 (20)	0.5 (18)
S. bovis and *S. equinus*	15.4 (67)	10.5 (65)	17.2 (84)	17.5 (91)	17.4 (85)	8.5 (65)
False positive and non-fecal streptococci	38.8 (95)	48.1 (100)	41.8 (100)	41.5 (100)	41.1 (100)	38.1 (100)

and were found in 10% to 24% of the samples. *S. bovis* and *S. equinus* were recovered in 65% to 91% of the storm samples and represent 10.5 to 17.5% of the isolates. The false positive and non-fecal streptococci were found in all the storm samples and were 38.8% to 48.1% of the isolates.

The geometric mean densities of the selected pathogens and indicator microorganisms for each storm sample site are given in Table 23 to provide an indication of the relative microbial quality of the storm runoff at each location. The levels of indicators, *P. aeruginosa* and *Staph. aureus* are reported in the conventional units of MPN or number/100 ml while the levels of enterovirus and *Salmonella* sp. are reported as PFU/10 1 and MPN/10 1, respectively. The levels of total coliform, fecal coliform, fecal streptococci and enterococci suggest that the runoff at each location was heavily contaminated and from a microbiological standpoint was of poor quality. The densities of indicator microorganisms found in storm runoff were generally about 10-fold higher than that found in urban streams and approached the indicator densities of raw sewage. The levels of indicators in storm runoff was several orders of magnitude above that found in the reservoir samples. Regardless of the indicator employed, the runoff from each of the sample locations would be considered heavily contaminated. With the exception of Howard Park (H) and Northwood (M) the mean levels of indicators are surprisingly similar. The Howard Park sample, representative of a true combined system, contained consistently higher levels of indicators than the other stormwaters. Northwood, a small drainage area of storm runoff only, contained consistently lower levels of indicators than from the remaining runoff sites. The Jones Falls storm drain is known to receive some raw sewage but the ratio of raw sewage to runoff is believed to be small. The Stoney Run (F) and Glen Avenue (G) drainage areas contain bleeders from the sanitary sewers which occasionally operate during heavy rain storms. The Bush Street drain (L), although believed to carry only storm runoff, has a large low lying catchment area with many possibilities for sewage contamination.

The stormwater levels of enteroviruses, *Salmonella* sp., *P. aeruginosa* and *Staph. aureus* were several fold higher than that found in the urban streams but significantly lower than the levels in raw sewage. *P. aeruginosa* was the most predominant pathogen in stormwater followed by *Staph. aureus*, enteroviruses, and *Salmonella* sp. Howard Park samples from the combined sewer yielded considerably higher levels of pathogenic microorganisms than the other sampling locations.

Fairly reliable flow estimations were obtained at the time of sampling for three stations; Stoney Run (F), the Jones Falls storm drain (K), and the Northwood storm drain (M). Flow estimation at the remaining three stations were unreliable due to surcharging, loss of a velocity meter and washouts. Figure 30 shows the relationship of instantaneous flows to the levels of fecal coliforms determined at the time of sample collection for Stoney Run, the Jones Falls storm drain and Northwood. At low flows the range of levels of fecal coliforms was between 10^2 to almost 10^6/100 ml. A similar range of fecal coliform density was observed at moderate and high flows. There appeared to be little correlation between instantaneous discharge and the levels of microorganisms.

Table 23. GEOMETRIC MEAN DENSITIES OF SELECTED PATHOGENS AND INDICATOR MICROORGANISMS IN STORMWATER

	Sample site	Enterovirus PFU/10 1.	*Salmonella* sp. MPN/10 1.	*P. aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	Total coliform MPN/100ml	Fecal coliform MPN/100ml	Fecal strep. no./100ml	Entero-cocci no./100ml
F	Stoney Run	1.9×10^2	3.0×10^1	1.3×10^3	1.2×10^1	4.8×10^4	1.9×10^4	4.1×10^4	1.4×10^4
G	Glen Ave.	7.5×10^1	2.4×10^1	3.3×10^3	1.4×10^1	2.4×10^5	8.1×10^4	6.6×10^5	2.1×10^5
H	Howard Park	2.8×10^2	1.4×10^2	5.2×10^3	3.6×10^1	1.2×10^6	4.5×10^5	2.4×10^5	5.9×10^4
K	Jones Falls storm drain	3.0×10^1	2.5×10^1	6.6×10^3	4.0×10^1	2.9×10^5	1.2×10^5	2.8×10^5	8.7×10^4
L	Bush St.	6.9	3.0×10^1	2.0×10^3	1.2×10^2	3.8×10^5	8.3×10^4	5.6×10^5	1.2×10^5
M	Northwood	1.7×10^2	5.7	5.9×10^2	1.2×10^1	3.8×10^4	6.9×10^3	5.0×10^4	2.1×10^4

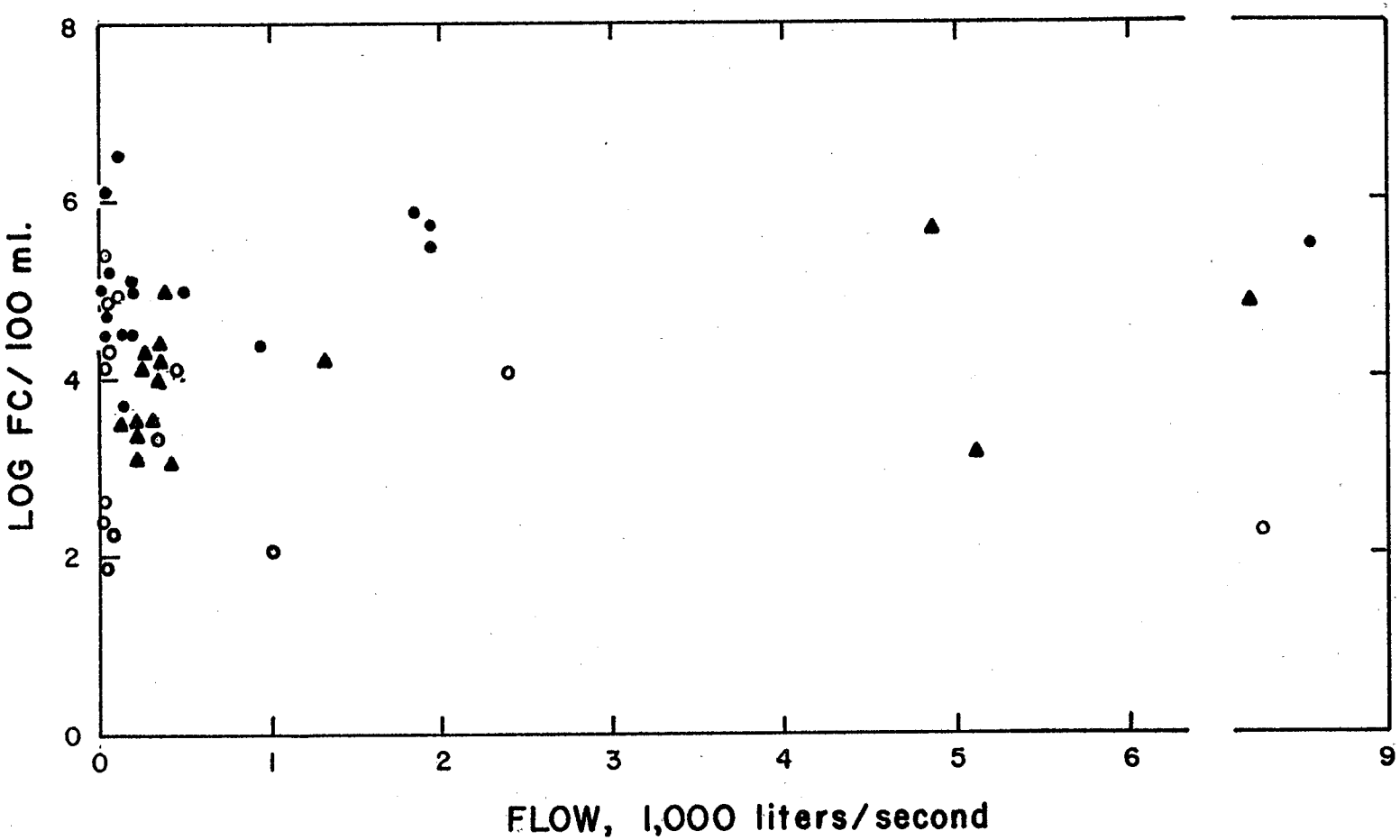


Figure 30. The relationship of stream flow at the time of sampling on the fecal coliform density in stormwater at F, Stoney Run (▲), K, Jones Falls (●), and M, Northwood (o).

The effect of the number of days since the last storm on the levels of fecal coliform is shown in Figure 31. Similar to that observed for the background samples, the levels of fecal coliform observed in the storm runoff appears to be independent of the time between storms.

RELATIONSHIP BETWEEN PATHOGENS AND INDICATORS

The relationship between indicator and pathogenic microorganisms was evaluated in the following Figures 32 through 35. The logarithm of the density of the pathogen was compared to the logarithm of the density of the indicator group of microorganisms for all samples. The lower sensitivity limit of the pathogen determination is a function of the volume of sample assayed. In cases where no pathogen was recovered the lower sensitivity limit was about one microorganism per unit volume. For purposes of graphic representation and statistical analysis the value of one was assigned to these samples. Since the logarithm of one is zero, the minimum detectable concentration points were plotted as zero logs in the graphs. Lines of best fit for background and storm samples were calculated by the method of least squares and presented on each graph. The correlation coefficients, r, were calculated for four groups of samples; all, background, storm and stream. These are presented in the upper left hand corner of each graph. In addition the 99% confidence intervals for each value of r are shown. The linear relationship between the levels of indicator and pathogenic microorganisms was tested by evaluating the null hypothesis for the correlation coefficient ($r = 0$). The significance of r was tested using the lower limit of the 99% confidence interval for r. Conclusions indicating a linear relationship are affected by the number of pairs of samples and the magnitude of r. The number of pairs for sample groups varied slightly for each comparison of pathogens and indicators. The numbers of the pairings of pathogenic bacteria and various indicators in the analysis for all, background, storm and stream samples were in the ranges 218 to 266, 119 to 136, 112 to 130 and 70 to 93, respectively.

The relationships between the levels of *Salmonella* sp. and total coliform, fecal coliform, fecal streptococci and enterococci are shown in Figures 32a, b, c, and d, respectively. The levels of *Salmonella* are presented as MPN/10 l and the levels of indicators are presented as MPN or number/100 ml. Thus, it should be recognized that the levels of *Salmonella* are 100-fold lower than the levels of indicator microorganisms. The data show considerable variation. However, the positive linear relationships between indicators and *Salmonella* for all the samples are unmistakable. The correlation coefficients for total coliform, fecal coliform, fecal streptococci and enterococci were 0.54, 0.59, 0.53 and 0.54, respectively, and are significant at the 1% level. There appears to be a reasonably good correlation between indicator and *Salmonella* for the overall data. Although fecal coliforms yielded the highest correlation coefficient, each of the indicator groups tested gave good linear relationships to the levels of *Salmonella*. The correlation coefficients for the background samples: raw sewage, urban streams and reservoir, showed somewhat higher correlation coefficients. The r values of 0.67 for total coliform, 0.72 for fecal coliform, 0.71 for fecal streptococci and 0.73 for enterococci were also significant at the 1% level. Again, little difference was observed for the linear relationships between the indicator groups and *Salmonella*. However,

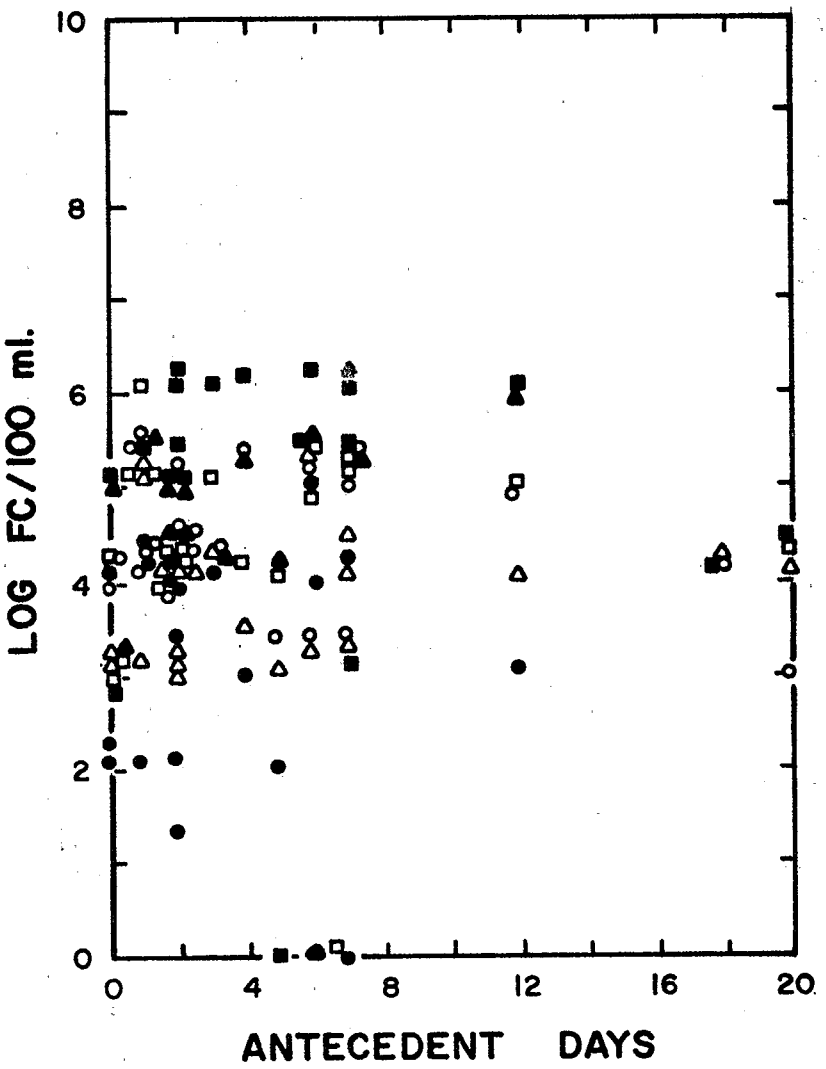


Figure 31. The effect of number of days since the last rainstorm on the fecal coliform density of stormwater at F, Stoney Run (△), G, Western Run (□), H, Howard Park (■), K, Jones Falls (▲), L, Bust St. (○), and M, Northwood (●).

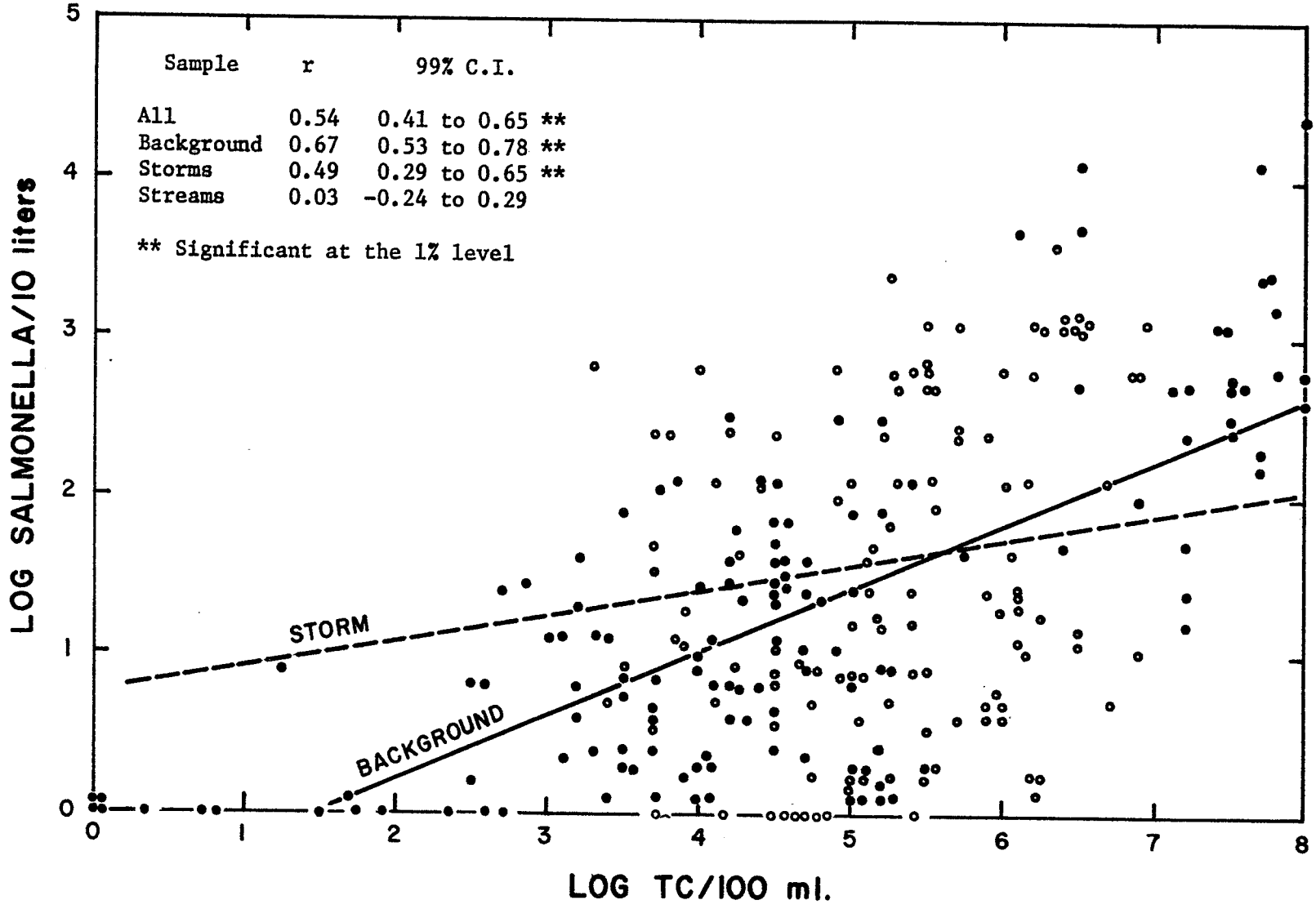


Figure 32a. Relationship between total coliform and *Salmonella* in background (solid point) and storm-water (open point) samples.

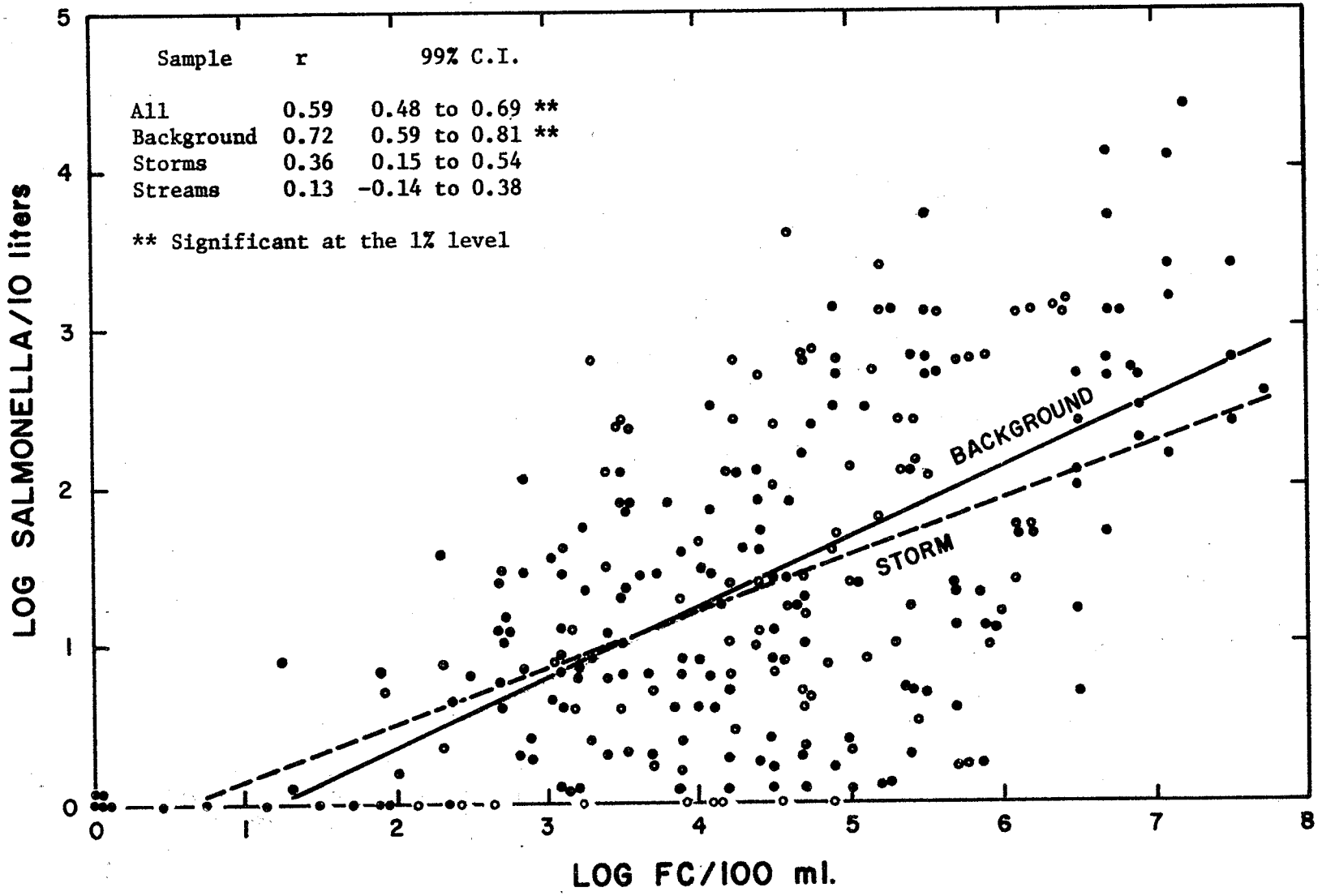


Figure 32b. **Relationship between fecal coliform and *Salmonella* in background (solid point) and storm-water (open point) samples.**

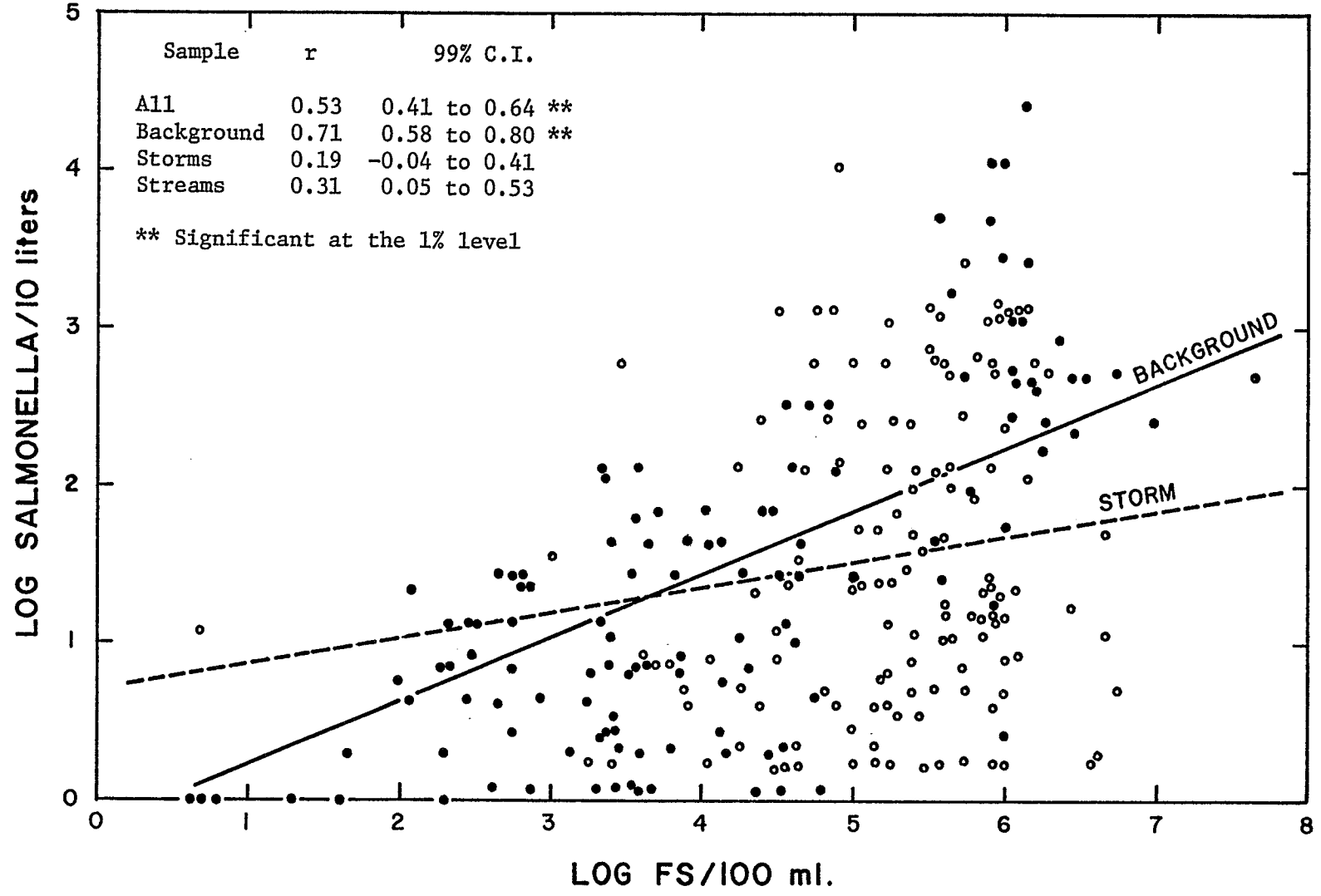


Figure 32c. Relationship between fecal streptococci and *Salmonella* in background (solid point) and stormwater (open point) samples.

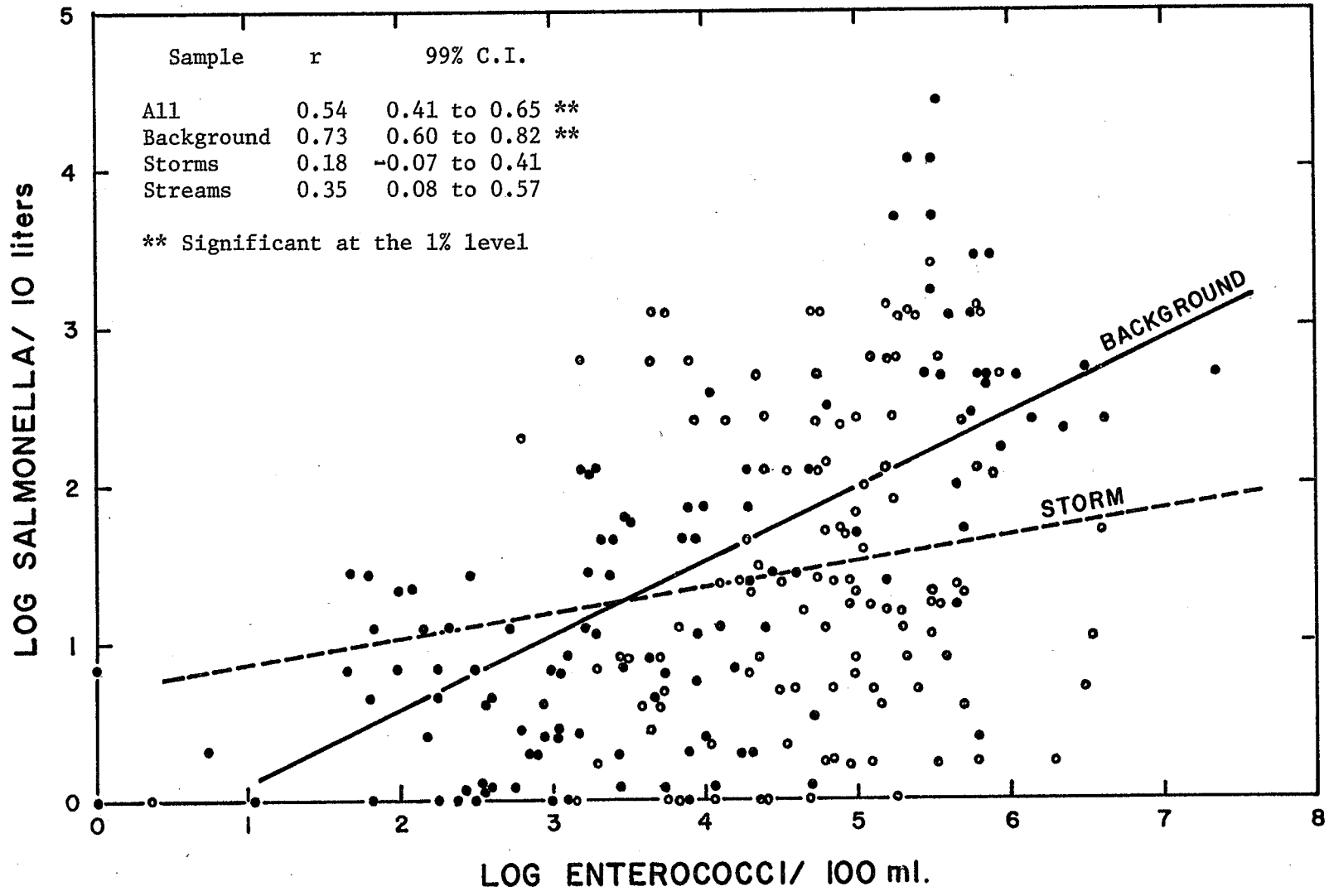


Figure 32d. Relationship between enterococci and *Salmonella* in background (solid point) and storm-water (open point) samples.

the correlation between *Salmonella* and indicators in the stormwater runoff was not so good. The low values of r were 0.49, 0.36, 0.19 and 0.18 for total coliform, fecal coliform, fecal streptococci and enterococci, respectively. Only the correlation between total coliform and *Salmonella* was significant at the 1% level. The remaining correlation coefficients were not significant at the 5% level in the storm samples. The samples collected from the three urban streams showed no correlation between the levels of *Salmonella* and indicator microorganisms.

The relationship between the levels of *P. aeruginosa* and the levels of total coliform, fecal coliform, fecal streptococci and enterococci are shown in Figures 33a, b, c and d, respectively. The densities of *P. aeruginosa* and indicator groups were reported in comparable units. Although *P. aeruginosa* is not an enteric pathogen it is associated with and commonly found in feces. The r values for "all" and background samples are highly significant at the 1% level and were the highest observed for the data. The total and fecal coliform appeared to correlate slightly better to the levels of *P. aeruginosa* than the streptococcal indicators. For the storm samples, the significant correlation was found at the 5% level for total and fecal coliforms. No correlation was observed for fecal streptococci and enterococci. *P. aeruginosa* was found to correlate at the 99% significance level only to fecal coliforms for the stream samples.

The relationships between *Staph. aureus* and total coliform, fecal coliform, fecal streptococci and enterococci are shown in Figures 34a, b, c, and d, respectively. The levels of both pathogen and indicators are given in comparable units. Similar to the data presented for *Salmonella* and *P. aeruginosa* correlations were found at the 1% significance level for "all" and background samples. The values for the correlation coefficient were significantly higher for the latter samples. No significant correlation was observed between *Staph. aureus* and the indicator microorganisms for the storm and stream samples.

Figures 35a, b, c, and d show the correlation between the levels of enteric virus and the levels of the total coliform, fecal coliform, fecal streptococci and enterococci, respectively. The number of samples assayed for animal viruses was considerably lower than those assayed for the bacterial pathogens. The numbers of sample pairs in the analysis in each sample grouping ranged as follows: 94 to 123 for "all" samples, 46 to 57 for background samples, 54 to 66 for storm samples and 28 to 35 for stream samples. The 95% confidence intervals were calculated for correlation coefficients. In general, the correlations were poor and significant correlations at the 5% level were only found in the background sample group for total coliform and fecal coliform. Otherwise, no significant correlation between the levels of enteric viruses and indicators was observed.

INDICATOR RATIOS

The relationship between the levels of the indicator groups of microorganisms at each sample location is shown in the following series of graphs. The levels of total coliform, fecal streptococci and enterococci were compared to the levels of fecal coliforms. Theoretical

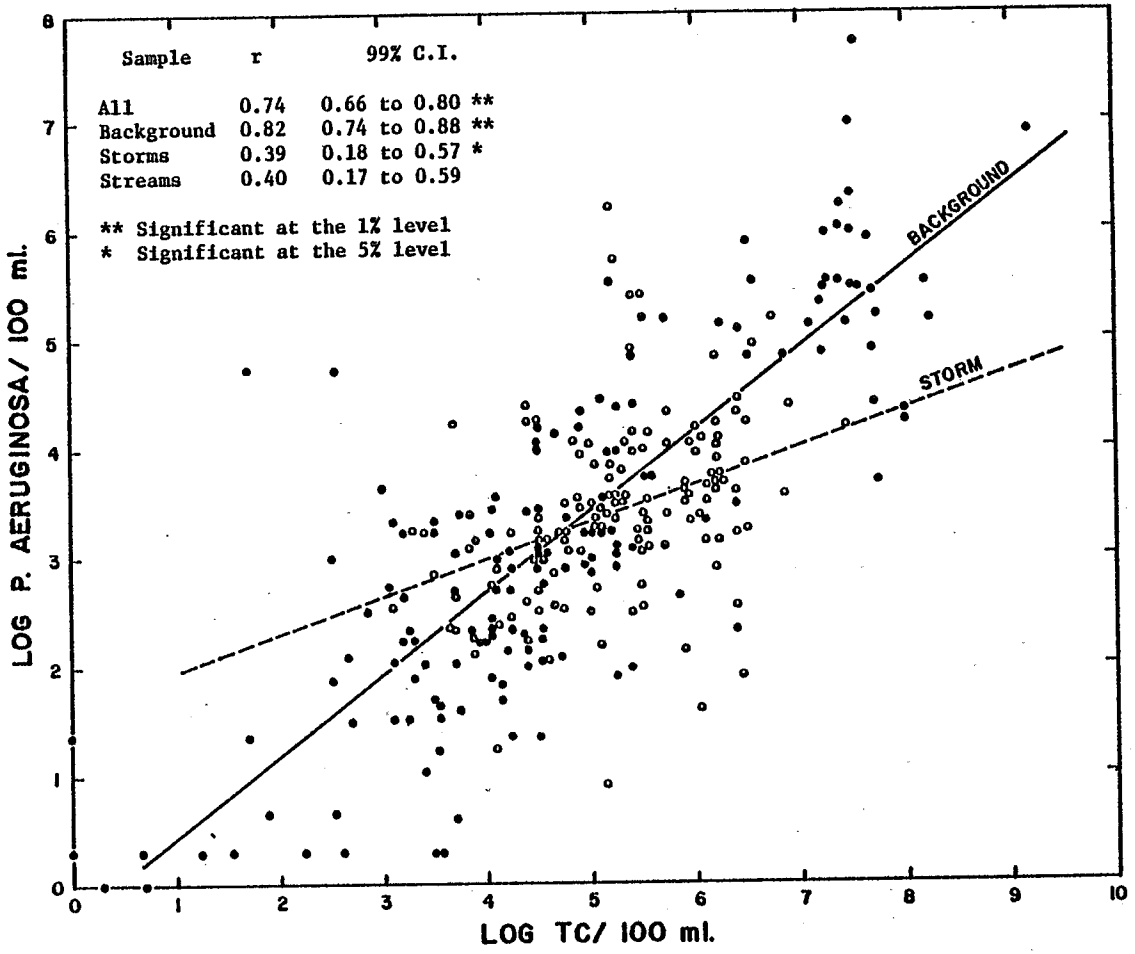


Figure 33a. Relationship between total coliform and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

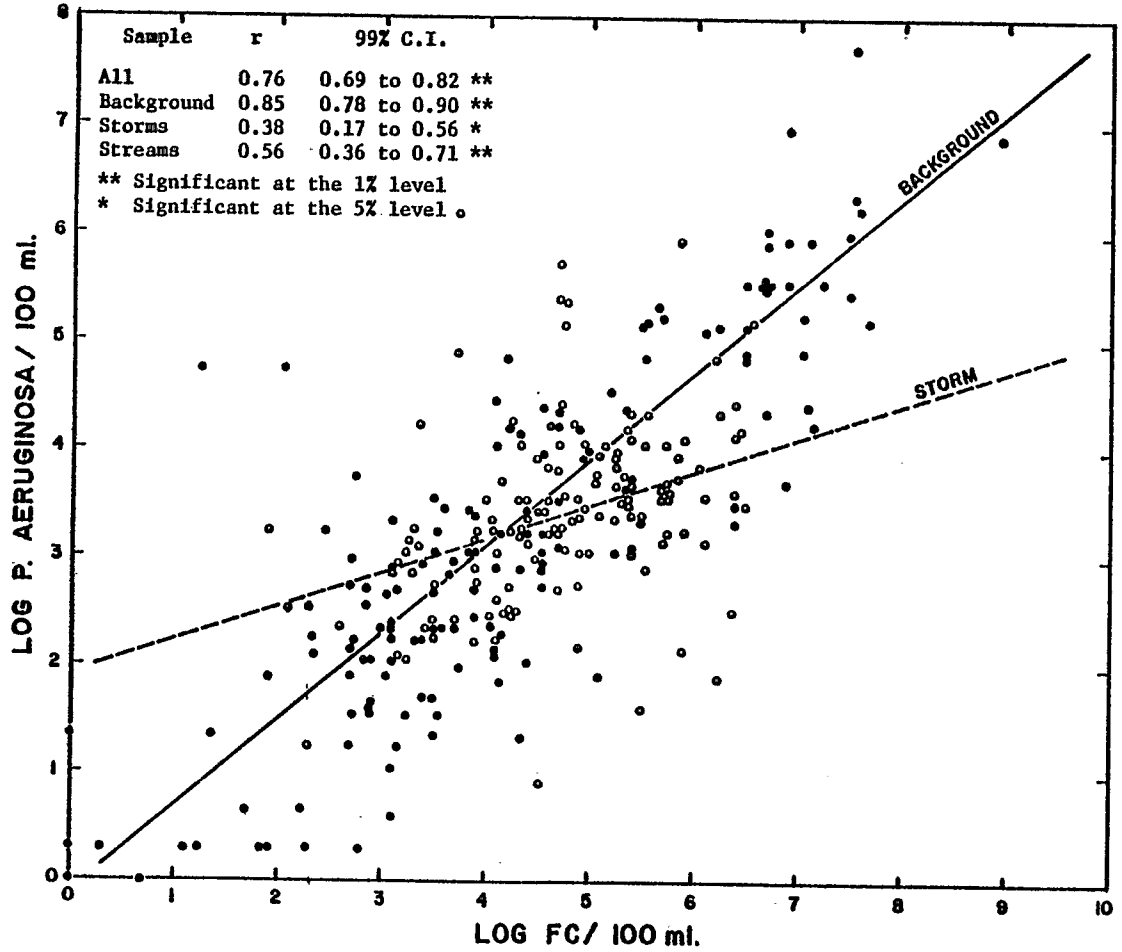


Figure 33b. Relationship between fecal coliform and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

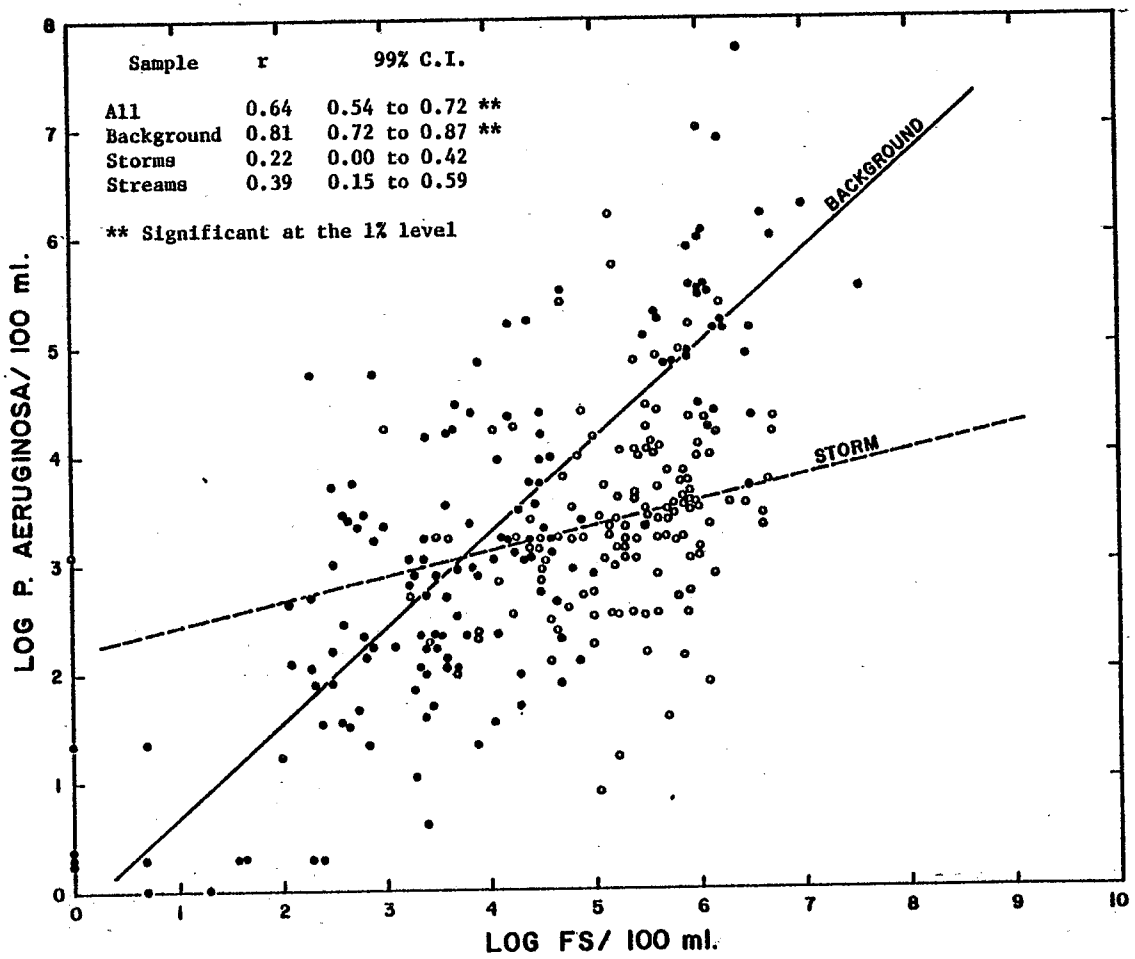


Figure 33c. Relationship between fecal streptococci and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

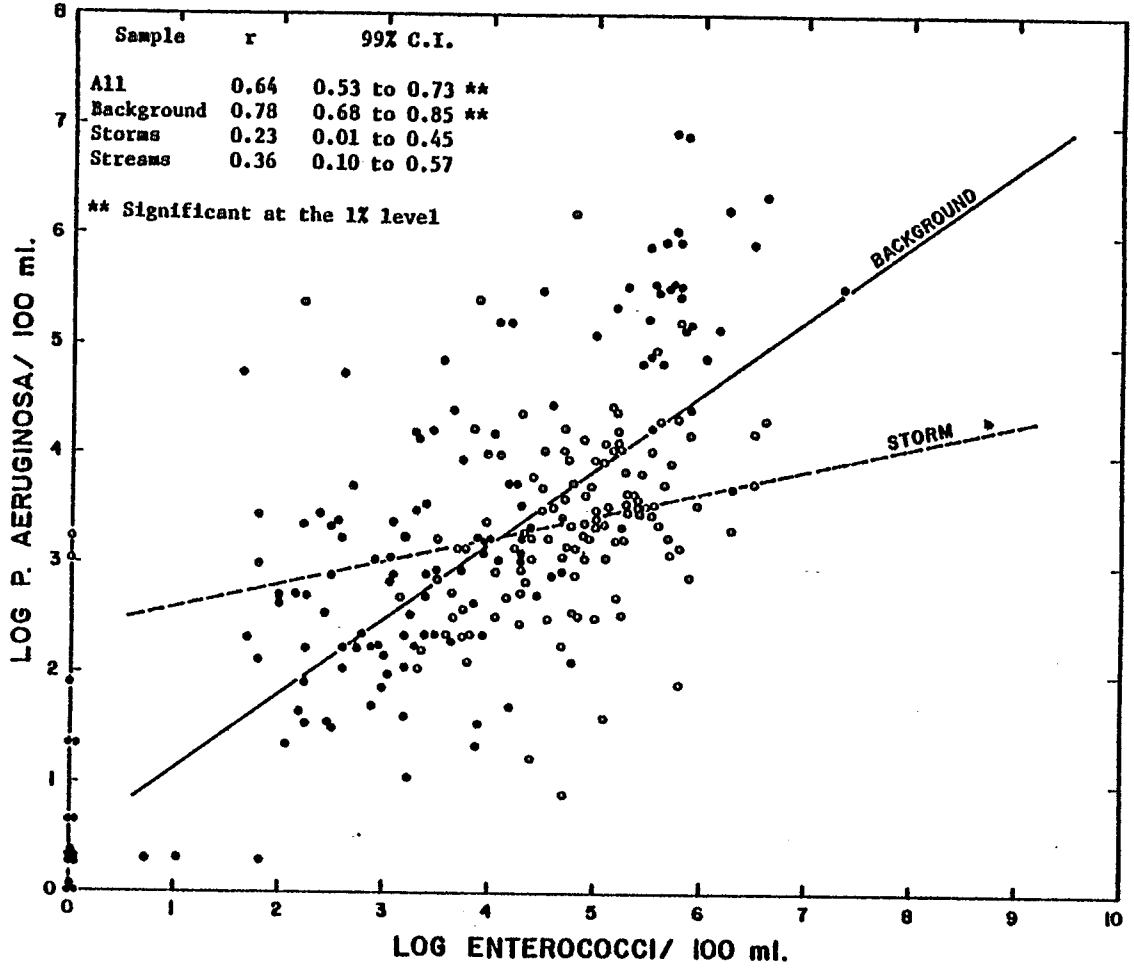


Figure 33d. Relationship between enterococci and *P. aeruginosa* in background (solid point) and stormwater (open point) samples.

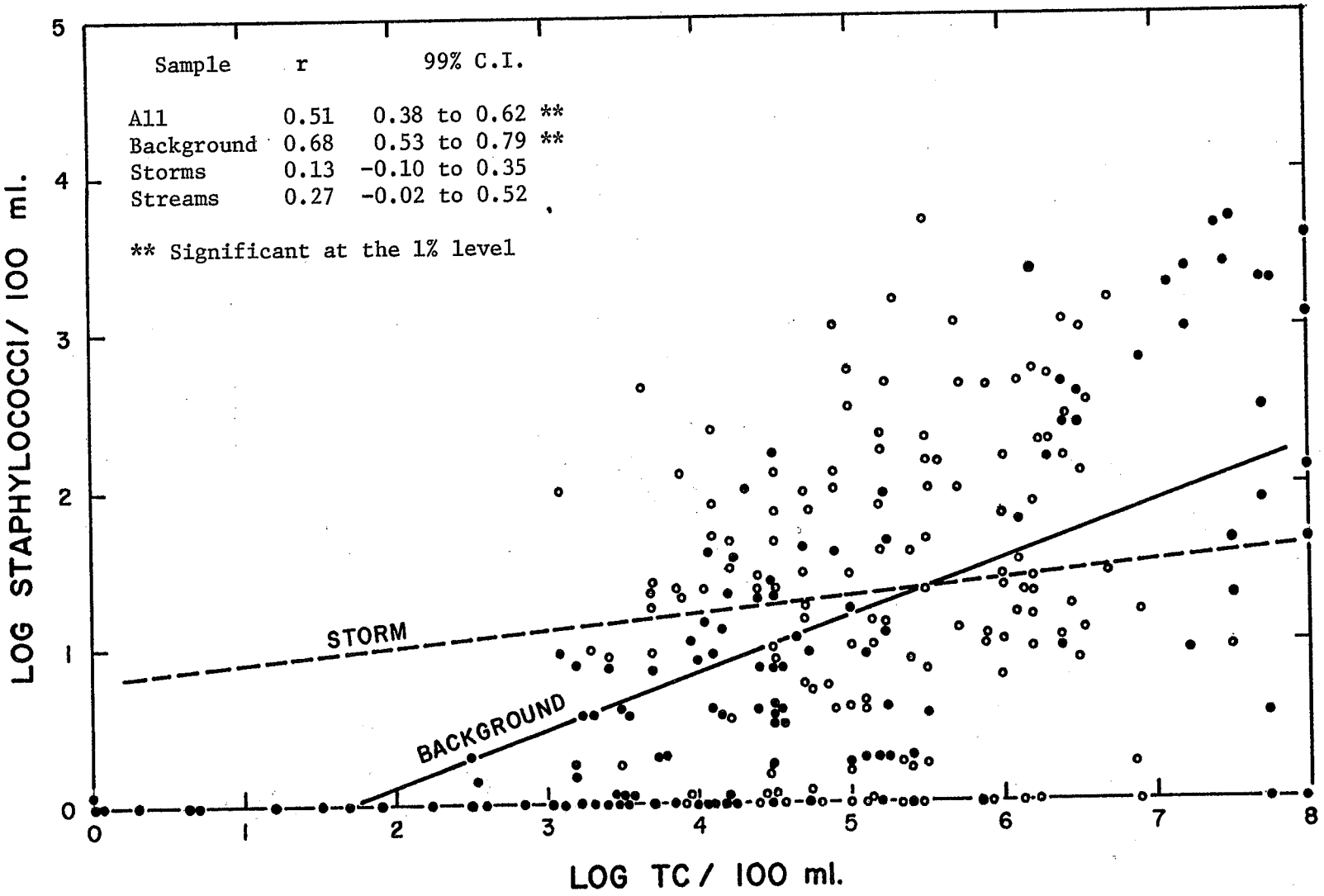


Figure 34a. Relationship between total coliform and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

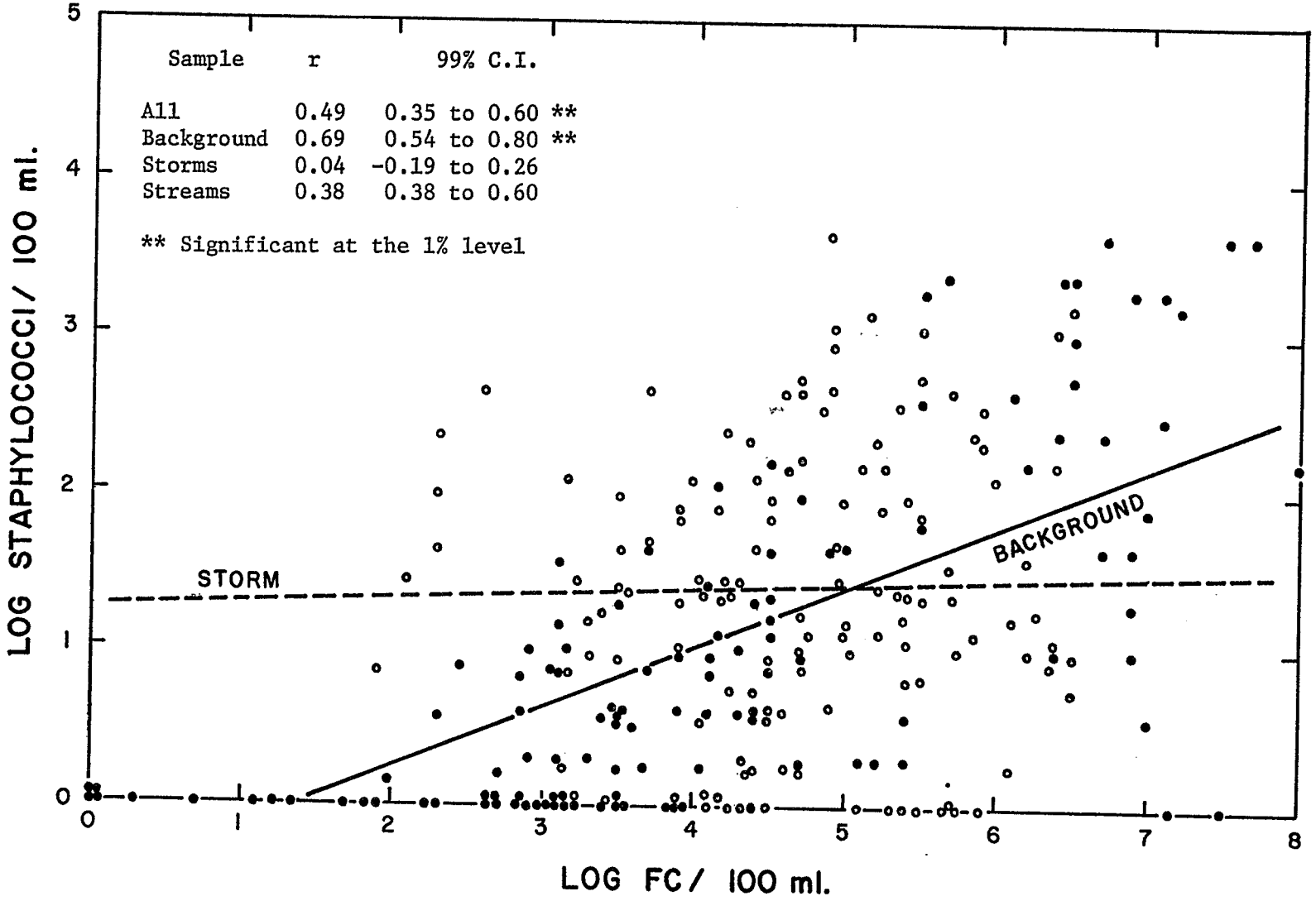


Figure 34b. Relationship between fecal coliform and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

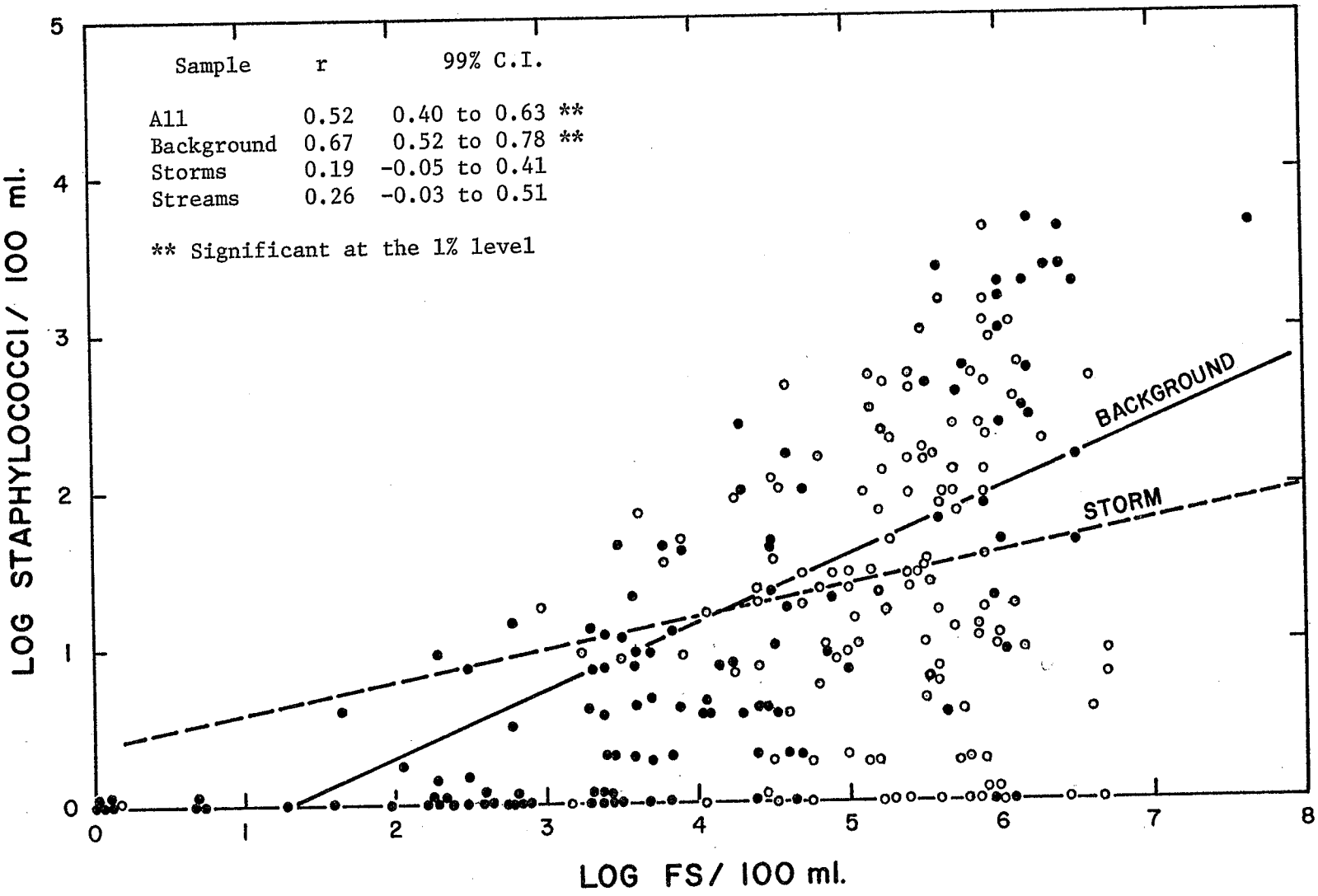


Figure 34c. Relationship between fecal streptococci and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

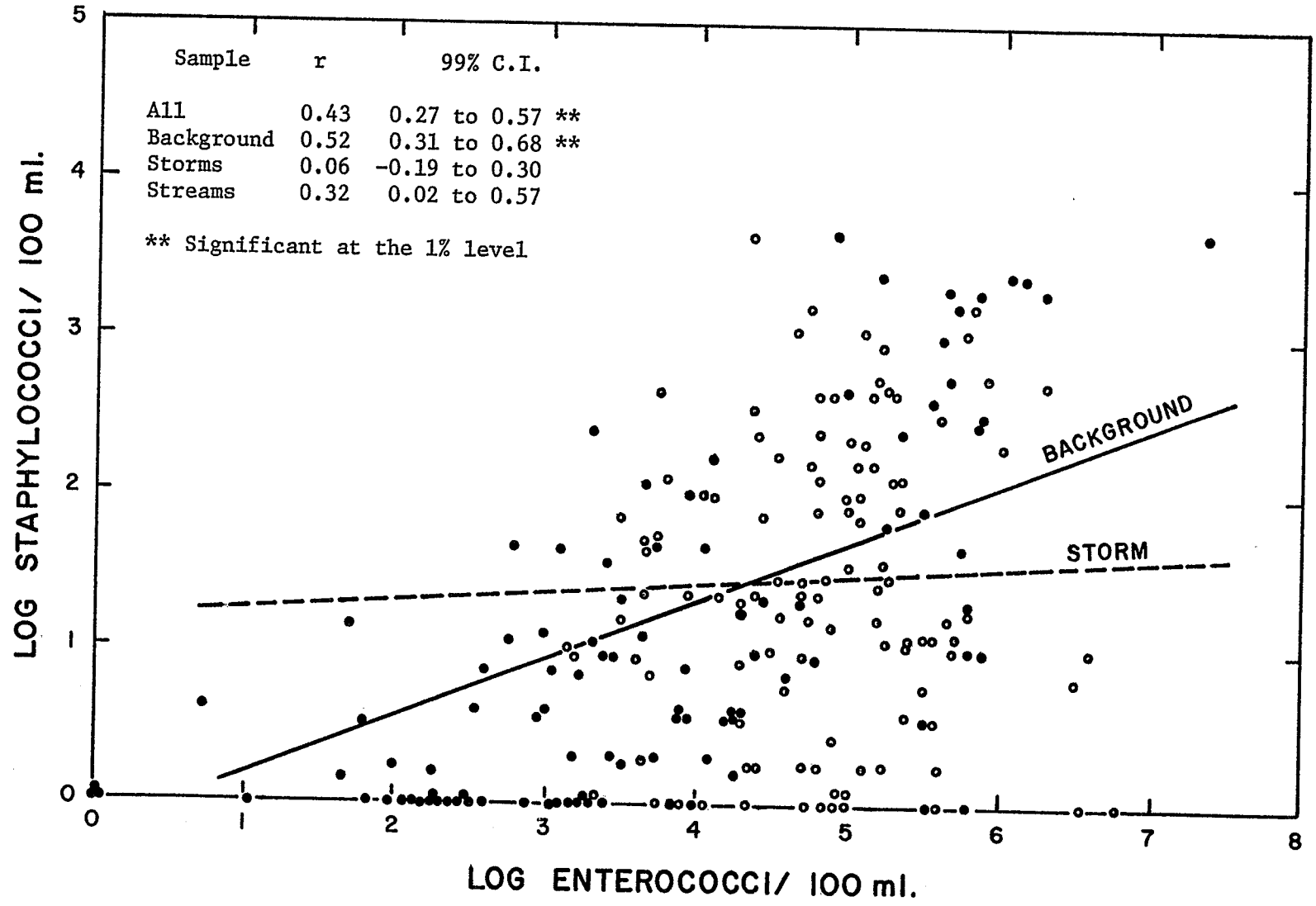


Figure 34d. Relationship between enterococci and *Staphylococcus aureus* in background (solid point) and stormwater (open point) samples.

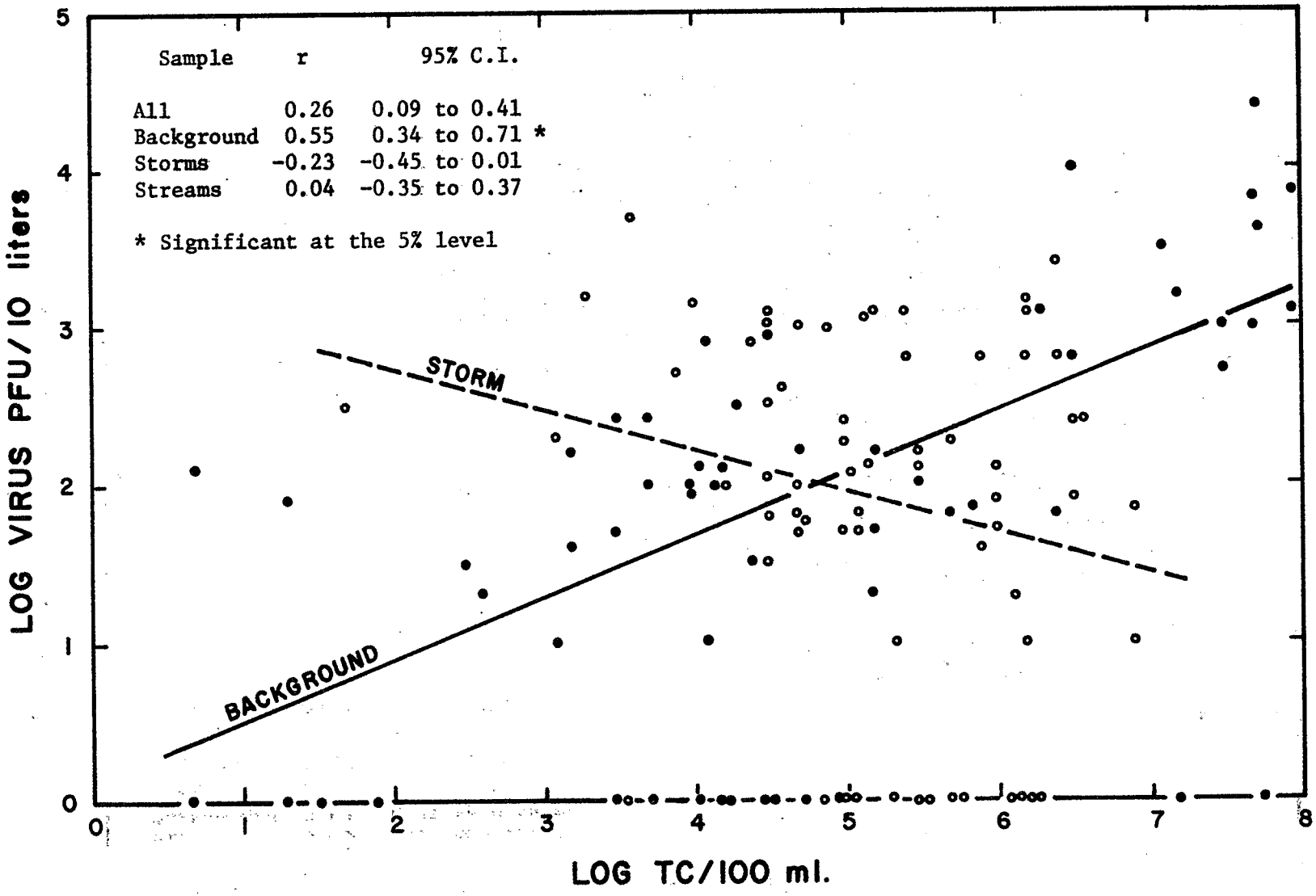


Figure 35a. Relationship between total coliform and enterovirus in background (solid point) and storm-water (open point) samples.

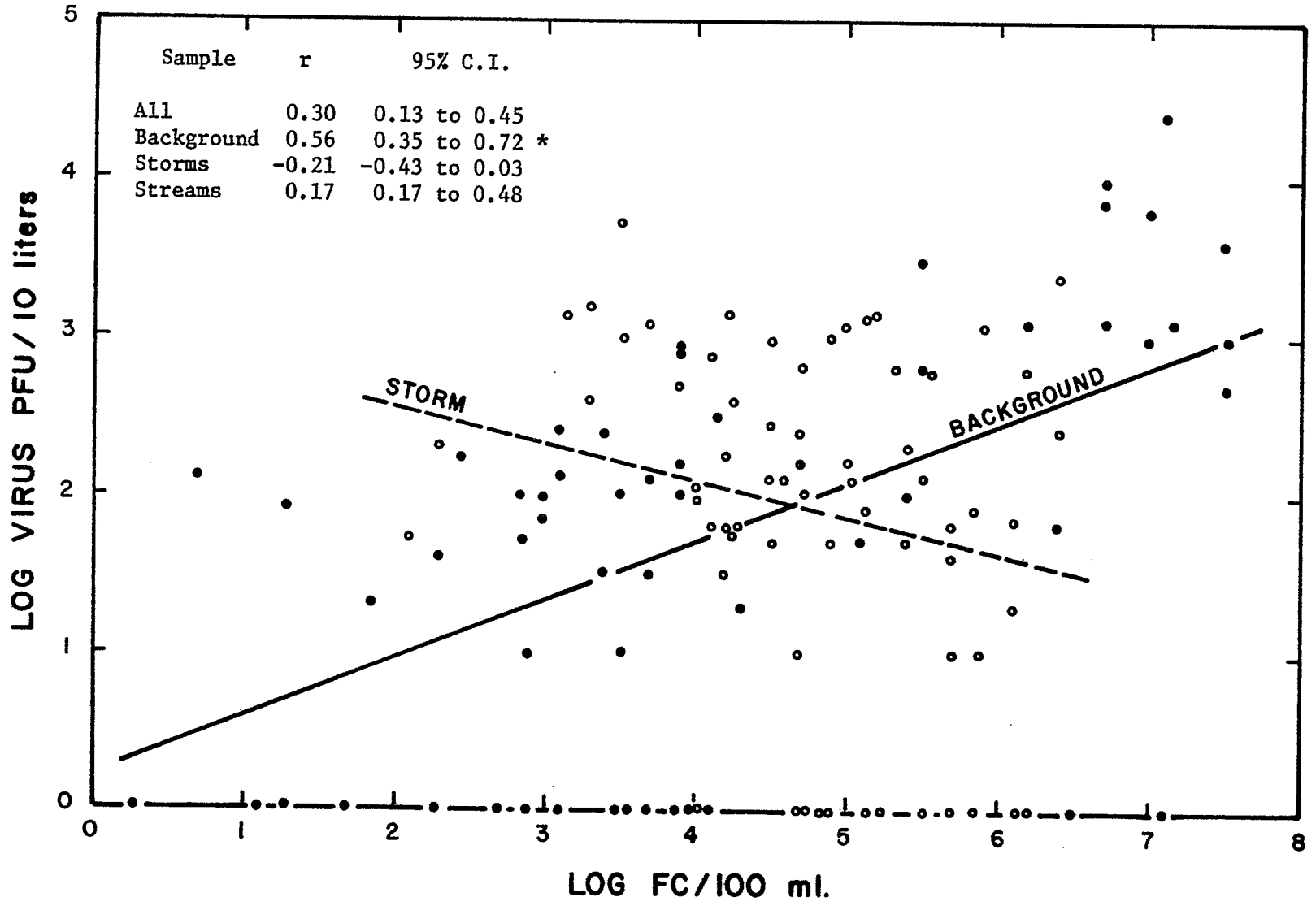


Figure 35b. Relationship between fecal coliform and enterovirus in background (solid point) and storm-water (open point) samples.

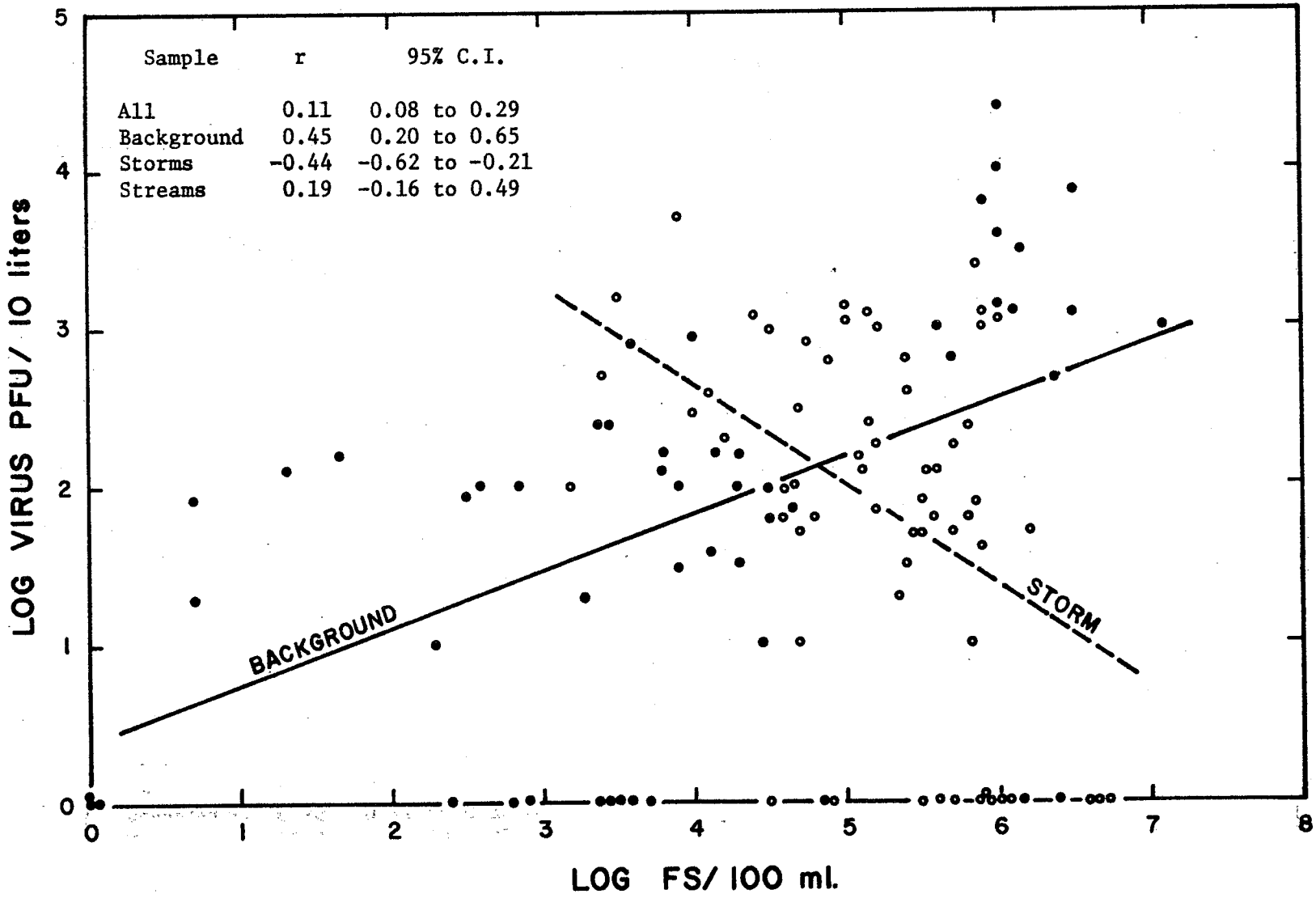


Figure 35c. **Relationship between fecal streptococci and enterovirus in background (solid point) and stormwater (open point) samples.**

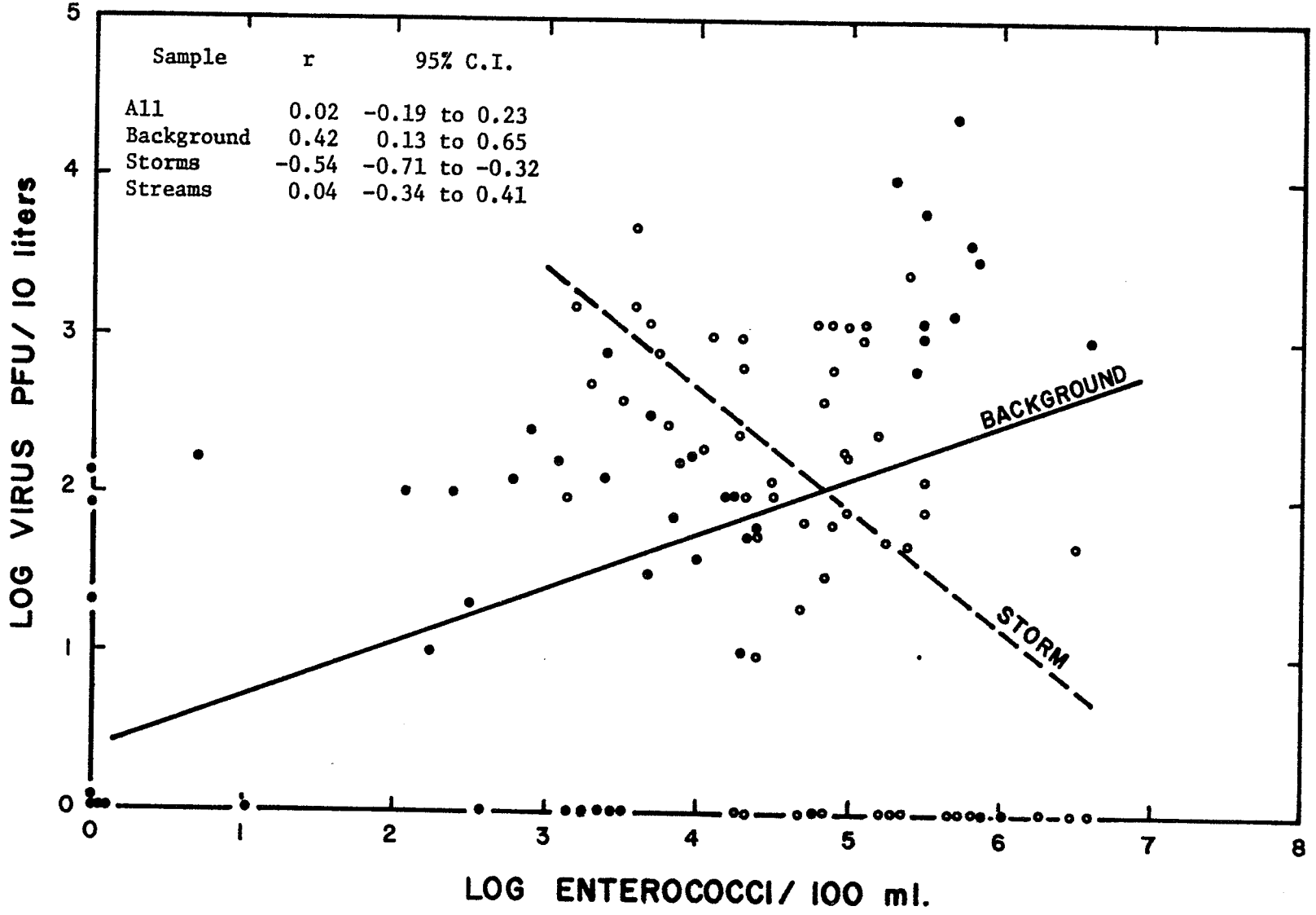


Figure 35d. Relationship between enterococci and enterovirus in background (solid point) and stormwater (open point) samples.

ratios are indicated by solid and dashed lines on each plot. The scatter of the data relative to the theoretical ratios can be seen. The ratios of total coliform to fecal coliform (FC/TC) and fecal coliform to fecal streptococci (FC/FS) are often used to evaluate the possible source of contamination. A FC/TC ratio of greater than 0.1 is believed to be indicative of sewage. A FC/FS ratio of 4.0 or greater is believed to be indicative of human feces and a ratio of 1.0 or less is believed to be indicative of animal feces.

Figure 36a shows the relative levels of total coliform, fecal streptococci and enterococci compared to the levels of fecal coliform for raw sewage taken at Back River Wastewater Treatment Plant, sample site A. The raw sewage provides a point of comparison for the data obtained for urban streams and storm runoff. FC/TC ratios in raw sewage lie between 0.01 to 1.0 with the large majority of samples having ratios of 0.1 to 1.0. The FC/FS ratios observed for raw sewage lie between 0.1 to 100 with 61% of the samples having ratios of 4.0 or greater. Similar relationships can be seen between enterococci to fecal coliform (FC/Ent). It should be noted that even in raw sewage a sizable variation between the ratios of indicators was observed.

The relationship between the levels of fecal coliforms and the other bacterial indicators in the urban streams: Herring Run, Jones Falls and Gwynns Falls is shown in Figures 36b, c and d, respectively. FC/TC ratios lie predominantly between 0.1 and 1.0 for Herring Run and Jones Falls. In the Gwynns Falls similar ratios predominate but more samples were found to have FC/TC ratios less than 0.1. Significant variability in FC/FS ratios was observed for the urban streams. About 20%, 42% and 22% of the samples had FC/FS ratios of 4.0 or greater in Herring Run, Jones Falls and Gwynns Falls, respectively. The frequency of samples with FC/FS ratios of 1 or less was 46% in Herring Run, 27% in Jones Falls and 33% in Gwynns Falls. A large portion of the samples in each of the urban streams had FC/FS ratios in the intermediate range of between 1.0 and 4.0. Similar results were obtained with enterococci levels when compared to fecal coliform data.

The relationships between the indicator groups of microorganisms for the storm samples are shown by site in Figure 37a through 37f. FC/TC ratios in the large majority of the samples collected at each of the storm locations lie between 0.1 to 1.0. FC/FS ratios found in the storm samples are markedly different from those observed for the background samples. More than 90% of the samples collected at Stoney Run (Figure 37a), Glen Avenue (Figure 37b), Bush Street (Figure 37e) and Northwood Figure 37f) had FC/FS ratios less than 4.0. Greater than 80% of the samples from these stations had FC/FS ratios of 1.0 or less. Only 18% and 12% of the samples collected at Howard Park (Figure 37c) and the Jones Falls storm drain (Figure 37d) had FC/FS ratios of 4.0 or greater. The frequency of samples of these stations with FC/FS ratios of 1.0 or less was 41% for Howard Park and 76% for the Jones Falls storm drain. Ratios of FC/Ent. appeared to shift up slightly for the storm runoff samples compared to the FC/FS. In each case a larger percentage of samples had FC/Ent. ratios greater than 1.0. Unfortunately, the significance of FC/Ent. ratios have not been evaluated.

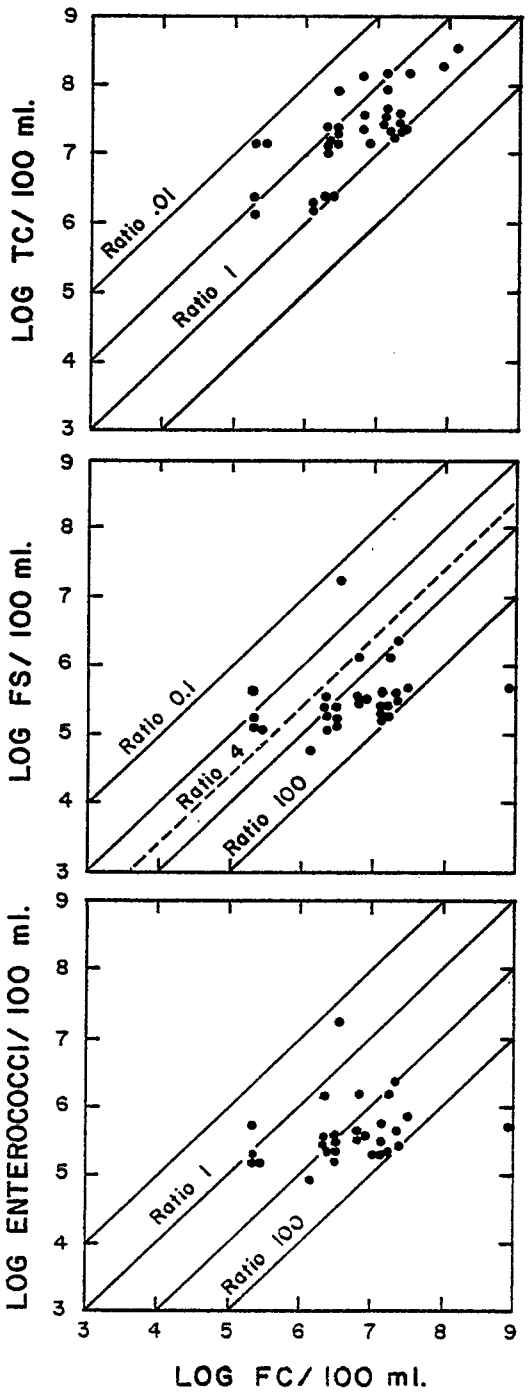


Figure 36a. Back River raw sewage, site A. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

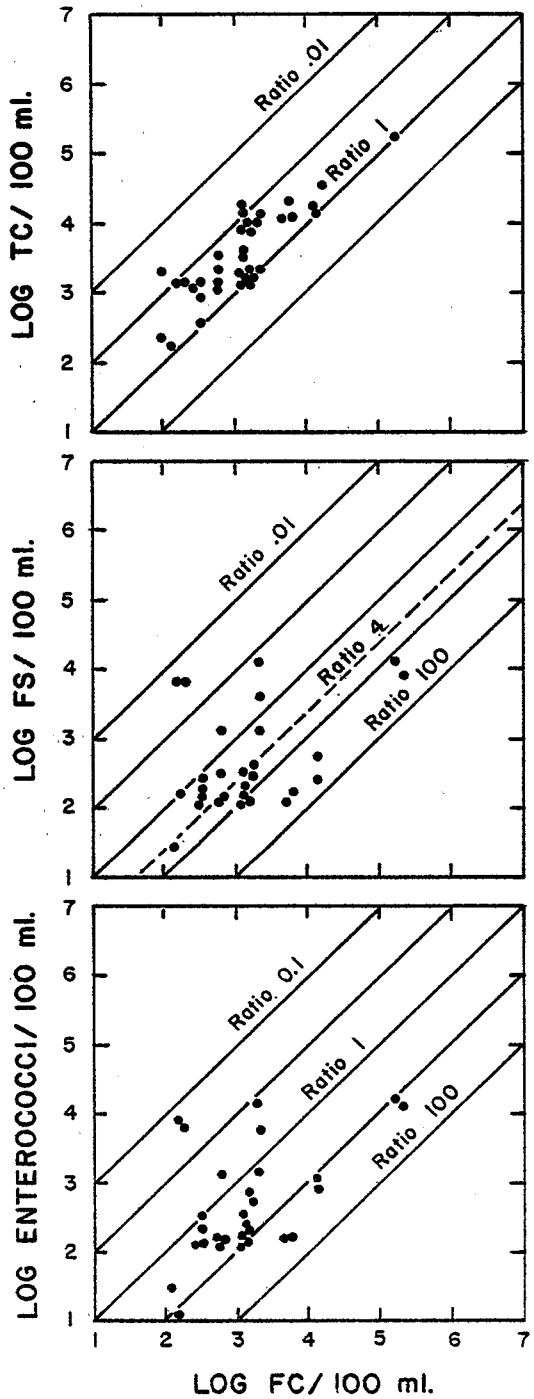


Figure 36b. Herring Run, site B. Ratio of fecal coliform to total coliform, fecal streptococci and enterococci.

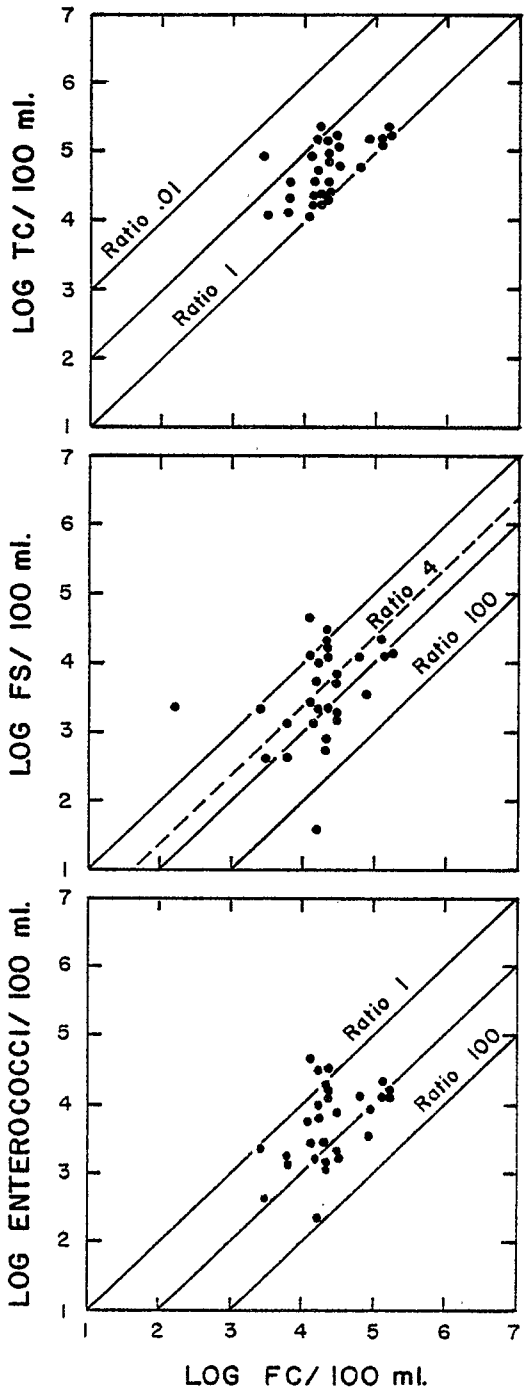


Figure 36c. Jones Falls, site C. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

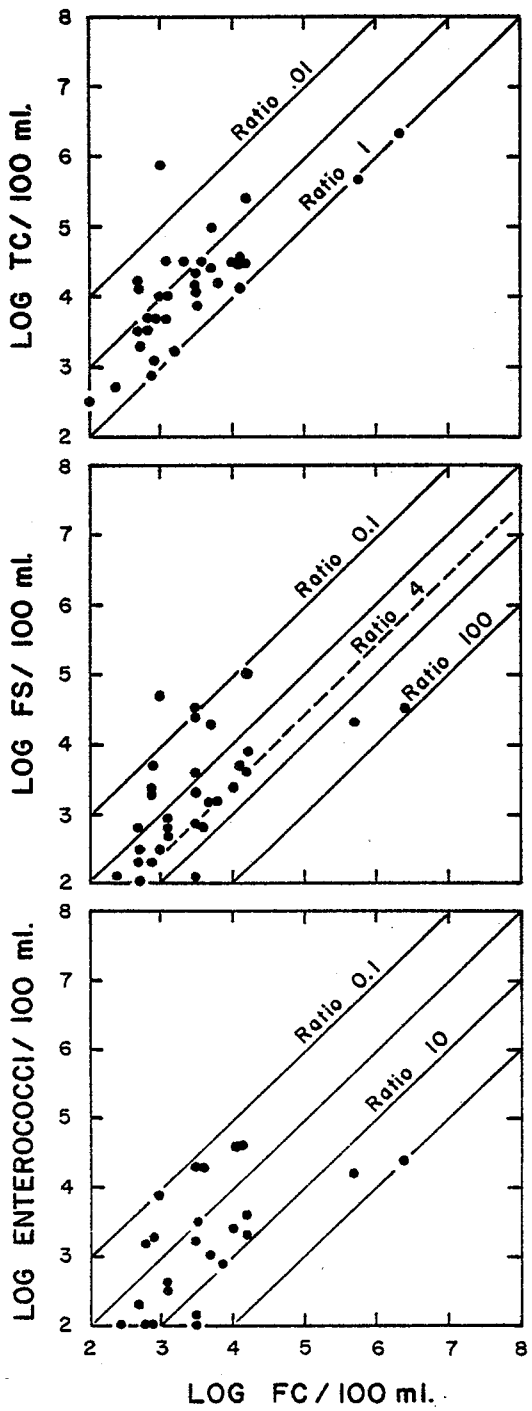


Figure 36d. Gwynns Falls, site D. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

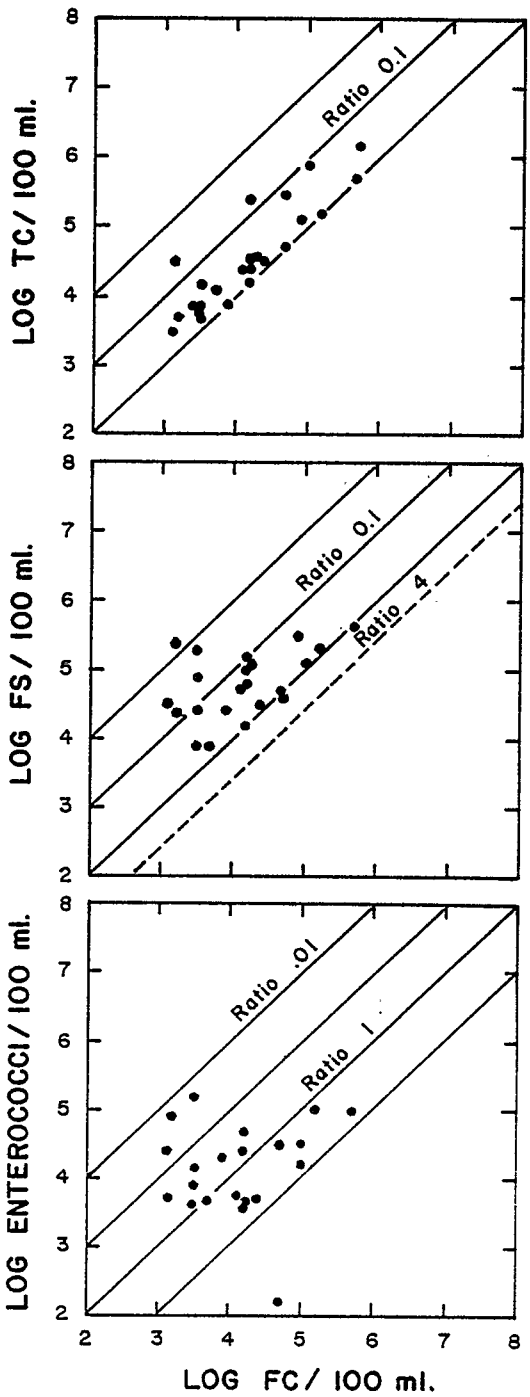


Figure 37a. Stoney Run stormwater , site F. Ratio of fecal coliform to total coliform, fecal streptococci and enterococci.

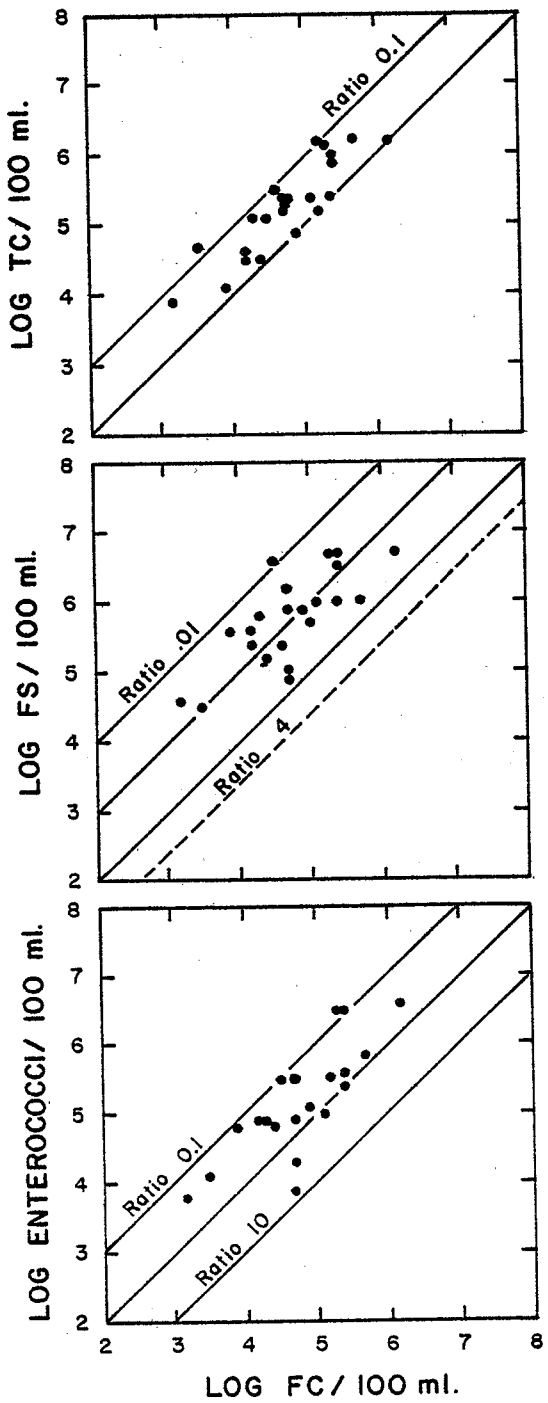


Figure 37b. Glen Avenue stormwater, site G. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

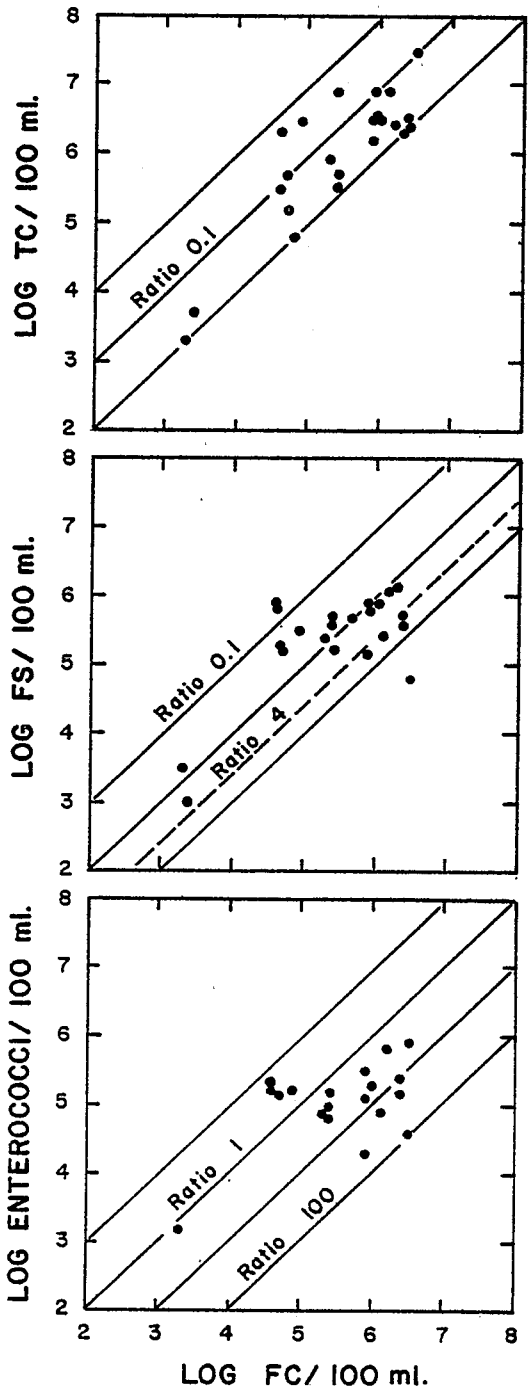


Figure 37c. Howard Park combined sewer, site H. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

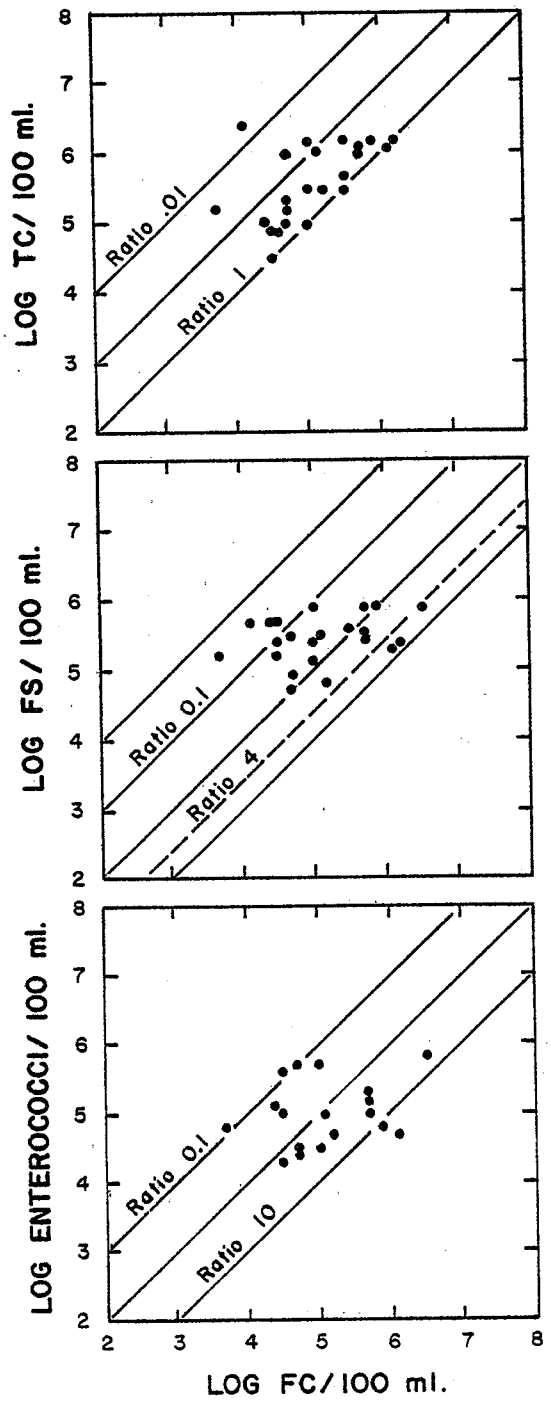


Figure 37d. Jones Falls stormwater, site K. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

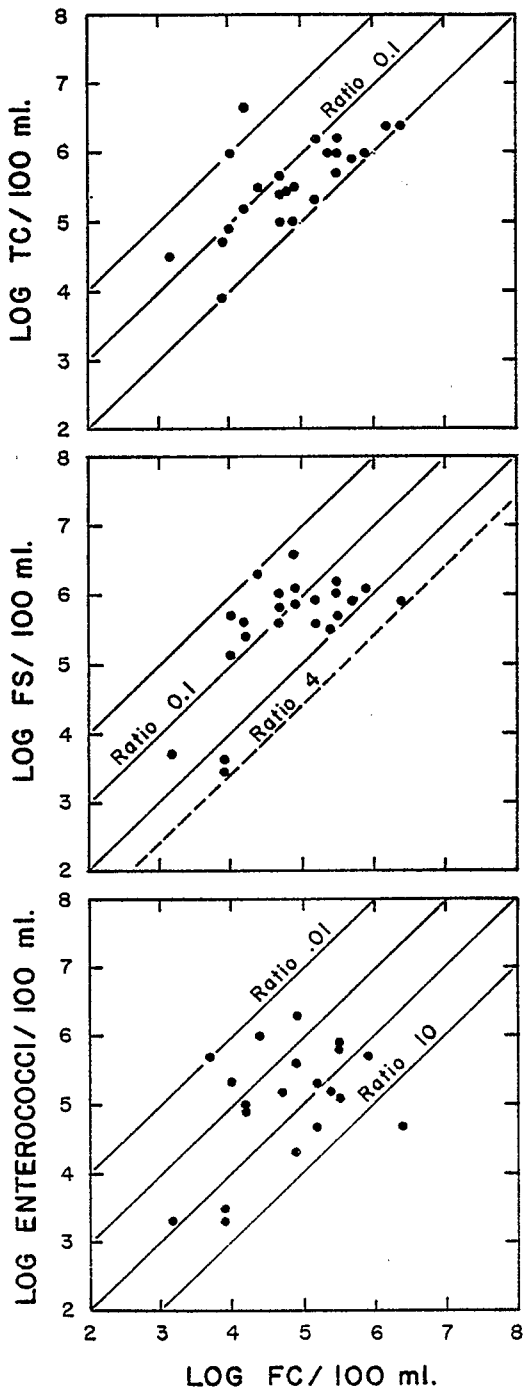


Figure 37e. Bush Street stormwater, site L. Ratio of fecal coliform to total coliform, fecal streptococci and enterococci.

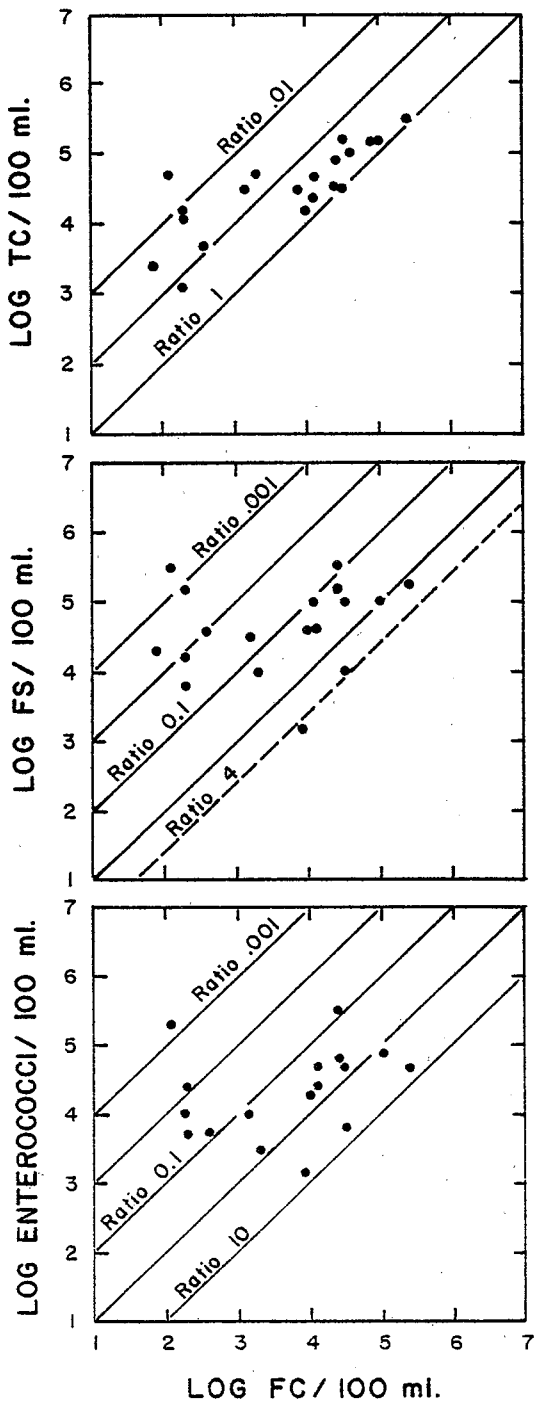


Figure 37f. Northwood stormwater, site M. Ratio of fecal coliform to total coliform, fecal streptococci, and enterococci.

DISCUSSION

SAMPLING

It is evident from the tables and graphs presented in the Results section that there was a wide variation in the levels of each of the selected microorganisms for each of the samples collected at each of the sampling locations. Differences of several orders of magnitude between the minimum and maximum densities of each microbial group were observed. This wide variation was not unexpected particularly in storm runoff. Each sample was a "grab" sample and reflects the microbial quality of the water at the time the sample was taken. Betson and Buckingham (4) observed differences of several orders of magnitude in the levels of indicator bacteria over a span of two minutes. Factors that will influence the levels of microorganisms in each of the water samples are numerous and the relationship between each of these factors are complex. The magnitude and intensity of the rainfall within each catchment area and the time, magnitude and intensity of the antecedent storm are parameters associated with each storm event that will influence the levels of microorganisms. The flow and the temporal discharge characteristics for a given storm drain will vary with each storm event and be affected by many factors including the topography, land use, relative impervious areas, vegetation and type of soil in the drainage area. In addition, the flow time to a given observation point, even in a very small catchment, will influence the magnitude of flow. The source and magnitude of the microbial flora in the drainage area along with the relative volume of water conveyed will dramatically influence the levels of microorganisms found. The drainage area characteristics mentioned above along with the density of animal populations (including man) and general sanitary conditions in the area will influence the microbial quality of the runoff. The mean levels of total and fecal coliforms observed by Geldreich *et al.* (5) in rainwater was less than 1/100 ml. Betson and Buckingham (4) reported the levels of total and fecal coliforms for various sampling points within a well maintained residential area with sanitary sewers. A portion of their data is reproduced in Table 24. The rainwater becomes contaminated at the earth's surface and the degree of contamination varied dramatically with sampling location. The waters collected from roof downspouts and foundations had lower levels of total and fecal coliforms than any of the samples where the rainwater flowed over the land. The wide variation in the magnitude of the density of microorganisms from various sources coupled with the wide variation in the magnitude of flows from different types of drainage areas and the infinite permutations and combination of these factors provide some insight into the nature of the wide variabilities in the densities of microorganisms observed.

ENUMERATION OF PATHOGENIC MICROORGANISMS

A major objective of this investigation was to provide information on the levels of selected pathogenic microorganisms in the urban aquatic environment. The recovery of pathogens from water has been recognized to be heavily dependent on the methods, techniques and procedures employed.

Table 24. LEVELS OF TOTAL AND FECAL COLIFORMS AT VARIOUS SITES WITHIN A DRAINAGE AREA. DATA TAKEN FROM BETSON AND BUCKINGHAM (4)

Sample site	Time	MPN/100 ml	
		Total coliform	Fecal coliform
Gage (Q = 0.3 cfs) (8.5 1/sec.)	1156	510,000	7,300
Foundation and roof drain tile	1207	4,500	<10
Street gutter sample below litter pile	1208	1,240,000	25,000
Roof downspout - no trees near house	1224	100	<10
Gage (Q = 1.4 cfs) (39.6 1/sec.)	1229	460,000	27,000
Roof downspout - trees overhanging roof	1234	2,500	740
Overland flow at curb	1250	360,000	21,400
Overland flow and gutter flow	1258	470,000	58,000
Gage (Q = 6.2 cfs) (175.4 1/sec.)	1303	340,000	44,000
Gage (Q = 3.8 cfs) (107.5 1/sec.)	1323	360,000	26,000
Gage (Q = 0.3 cfs) (8.5 1/sec.)	1749	43,000	8,400
Culvert draining street	1753	30,000	800
Roof downspout - trees overhanging	1800	<10	<10
Foundation and roof drain tile	1802	1,800	10
Street gutter near gage (West)	1806	26,000	3,000
Gage (Q = 0.16 cfs) (4.5 1/sec.)	1807	58,000	18,000

Salmonella

Salmonella in water has been a major concern for the last 75 years. The majority of the information in the literature, however, has been qualitative in nature and data have been reported as frequency of isolation. Table 25 shows the frequency of detection of *Salmonella* at different levels of fecal coliforms in the current study and a comparison to similar data reported in the literature. The levels of fecal coliforms in raw sewage exceeded 2,000/100 ml in each sample, and *Salmonella* was isolated in every case. The samples collected and assayed from an upland reservoir contained low levels of fecal coliforms. *Salmonella* was isolated from one of 14 samples. Only three samples taken from the urban streams had less than 200 fecal coliform/100 ml and *Salmonella* was found in each of these samples. At fecal coliform densities of 201 to 2,000 and greater than 2,000/100 ml the frequency of isolation of *Salmonella* was 91 and 96%, respectively. The storm runoff samples had only one sample with less than 200 fecal coliforms/100 ml and 12 samples with between 201 to 2,000 fecal coliforms/100 ml. *Salmonella* was recovered in the low fecal coliform level sample and in 83% of the latter samples. Storm samples with fecal coliform levels greater than 2,000/100 ml were 95% positive for *Salmonella*. The overall *Salmonella* isolation was 28%, 89% and 96% for the samples with 0-200, 201-2,000 and greater than 2,000 fecal coliforms/100 ml, respectively. The frequency of *Salmonella* isolation for all the samples compares favorably with the fresh water data reported by Geldreich and Van Donsel (44) but differs significantly from the estuary data reported by these authors and Brezenski and Russomanno (45).

Recently, limited data on the levels of *Salmonella* in water have been reported. Table 26 shows a comparison of the range in the density of *Salmonella* reported for various types of surface water to the information obtained in the Johns Hopkins study. Each of the procedures for the enumeration of *Salmonella* was multiple dilution technique with a MPN estimate of density. All the data in Table 26 were corrected to MPN/10 1 for comparison. Enrichment, plating media and recovery techniques differed from laboratory to laboratory. The levels of *Salmonella* in sewage varied from less than 300 to 1,100,000 *Salmonella*/10 1. The ranges observed in the Baltimore sewage are much lower than that reported by Cheng *et al.* (46) but similar in orders of magnitude to the reports of Kampelmacher and van Noorle Jansen (47), Phirke (48), and Kenner and Clark (19). The ranges in the levels of *Salmonella* in Baltimore sewage significantly overlap the ranges reported by the latter workers. The urban streams in Baltimore appear to contain lower levels of *Salmonella* than the river and creek samples collected by Kenner and Clark (19). The levels of *Salmonella* in storm runoff reported by these authors were similar to the levels observed in Baltimore. Geldreich *et al.* (5) reported 4,500 *Salmonella*/100 ml (450,000/10 1) in one storm sample from a business district but was unable to isolate *Salmonella* from other storm samples.

An important aspect of the current study has been the inclusion of seeded *Salmonella* controls to evaluate the steps in the recovery of *Salmonella*. Table 27 shows the frequency of recovery of the seeded *Salmonella* for each sample station. Three distinct controls were performed to evaluate the recovery procedure. A streptomycin resistant

Table 25. COMPARISON OF THE FREQUENCY OF DETECTION OF *SALMONELLA* WITH THE LEVELS OF FECAL COLIFORMS*

Report	Sample	Fecal Coliform Range MPN/100ml	Fecal Coliform Number of samples in range	*Salmonella* Number of samples positive	*Salmonella* Percent positive
This study	raw sewage	0-200	0		
		201-2000	0		
		>2000	32	32	100
	urban streams	0-200	3	3	100
		201-2000	34	31	91
		>2000	55	53	96
	upland reservoir	0-200	14	1	7
		201-2000	0		
		>2000	0		
	storm runoff	0-200	1	1	100
		201-2000	12	10	83
		>2000	123	117	95
	overall total	0-200	18	5	28
		201-2000	46	41	89
		>2000	210	202	96
Geldreich & Van Donsel (44)	fresh water	0-200	29	19	27
		201-2000	27	53	70
		>2000	54	33	98
	estuary	0-200	258	33	13
		201-2000	91	40	44
		>2000	75	45	60
Brezenski & Russomanno (45)	estuary	0-200	34	6	18
		201-2000	43	13	30
		>2000	73	43	59

*The frequency of detection of *Salmonella* with alternative fecal coliform ranges can be seen in Appendix F.

Table 26. COMPARISON OF THE LEVELS OF *SALMONELLA* FOUND IN SURFACE WATER AND SEWAGE

Sample	# of samples	Range of *Salmonella* MPN/10 liters	Reference
Sewage	3	20,000	Kampelmacher and Van Noorle Jansen (47), 1970
Sewage	8	11,000 to 1,100,000	Cheng *et al.* (46), 1971
Sewage	17	700 to 25,000	Phirke (48), 1974
Sewage	15	<300 to 150,000	Kenner and Clark (19), 1974
Sewage	34	3 to >27,000	This study
River	8	150 to >30,000	Kenner and Clark (19), 1974
Creek	2	450 to 1,200	Kenner and Clark (19), 1974
Urban streams	94	<0.9 to 320	This study
Storm runoff	2	20 to 150	Kenner and Clark (19), 1974
Storm runoff	140	<0.9 to >11,000	This study

Table 27. FREQUENCY OF RECOVERY OF SEEDED *SALMONELLA* AFTER EXPOSURE TO THE SAMPLE, CONCENTRATION ON DIATOMACEOUS EARTH, AND ENRICHMENT AND PRIMARY PLATING

Sample station	% of the samples positive		
	Exposure [a]	Concentration	Enrichment with primary plating
Background			
Raw sewage	100	100	0
Herring Run	100	88	67
Jones Falls	100	88	17
Gwynns Falls	100	82	33
Loch Raven	100	100	83
Storm drain			
Stoney Run	100	79	0
Glen Ave.	100	93	25
Howard Park	95	100	0
Jones Falls	95	79	0
Bush Street	100	86	50
Northwood	100	67	25
All samples	99	87	30

[a] Recovery of the seeded *Salmonella* after exposure to the sample was considered positive if less than 90% inactivation was observed.

strain of *Salmonella typhimurium* was used as the test organism. Sample toxicity to the seeded *Salmonella* was evaluated by exposure of the *Salmonella* seed to each sample for the length of time necessary to process the sample in the laboratory. The recovery of the seeded *Salmonella* after exposure to the sample was considered positive if less than 90% inactivation was observed. The concentration with diatomaceous earth for low levels of seeded *Salmonella* was evaluated by the recovery of streptomycin resistant *Salmonella* from seeded replicates of each sample after filtration. Streptomycin was included in the enrichment medium to minimize the effect of other microorganisms and favor growth of the seeded *Salmonella*. The overall recovery of seeded *Salmonella* was evaluated by incorporating an additional seeded replicate and testing the *Salmonella* isolated after enrichment and primary plating (no streptomycin) for streptomycin resistance. Recovery of streptomycin resistant *Salmonella* was considered positive.

Only two storm samples were found to cause more than 90% inactivation of the seeded *Salmonella*. The test organism was consistently recovered after exposure to the water samples from the different sources and indicated that the water samples were not bactericidal to the seeded *Salmonella*. After concentration on diatomaceous earth, the seed *Salmonella* was recovered in 67% to 100% of the samples depending on sample station. The *Salmonella* seed was recovered in 87% of all samples. This suggests that the diatomaceous earth concentration procedure for the recovery of low levels of *Salmonella* from large volumes of water was effective. After enrichment and primary plating, the recovery of the seeded *Salmonella* decreased markedly and was recovered in only 30% of the samples. The frequency of recovery for the overall culture procedure varied with the sample site. In general, the samples with the higher levels of microorganisms yielded poorer recoveries, and samples with low levels of microorganisms yielded better recoveries.

The *Salmonella* seeding experiments conducted simultaneously with replicates of the background and storm runoff samples provided useful information to evaluate the *Salmonella* data presented and to point out problem areas in the recovery procedures. Essentially no acute bactericidal effect was observed for the aquatic samples. The concentration of low levels of *Salmonella* on diatomaceous earth appears to be a viable method. The culturing methods, once the bacteria are concentrated, however, have certain limitations. As a result, the levels of *Salmonella* reported in this and probably other studies, are under estimates of the actual levels. This underscores the need for the development of more efficient enrichment media.

In sewage there was a noticeable seasonal variation in the levels of *Salmonella* with a peak density of 27,000/10 l in the late summer. The comparison of the levels of *Salmonella* in sewage with the incidence of salmonellosis in Baltimore City is shown in Figure 38. Note the parallel in peaks in late summer for *Salmonella* density and incidence of the disease.

Enteric Viruses

Samples for the assay of enteric viruses were shipped by bus from Baltimore, Maryland, generally immediately after collection, to Syracuse,

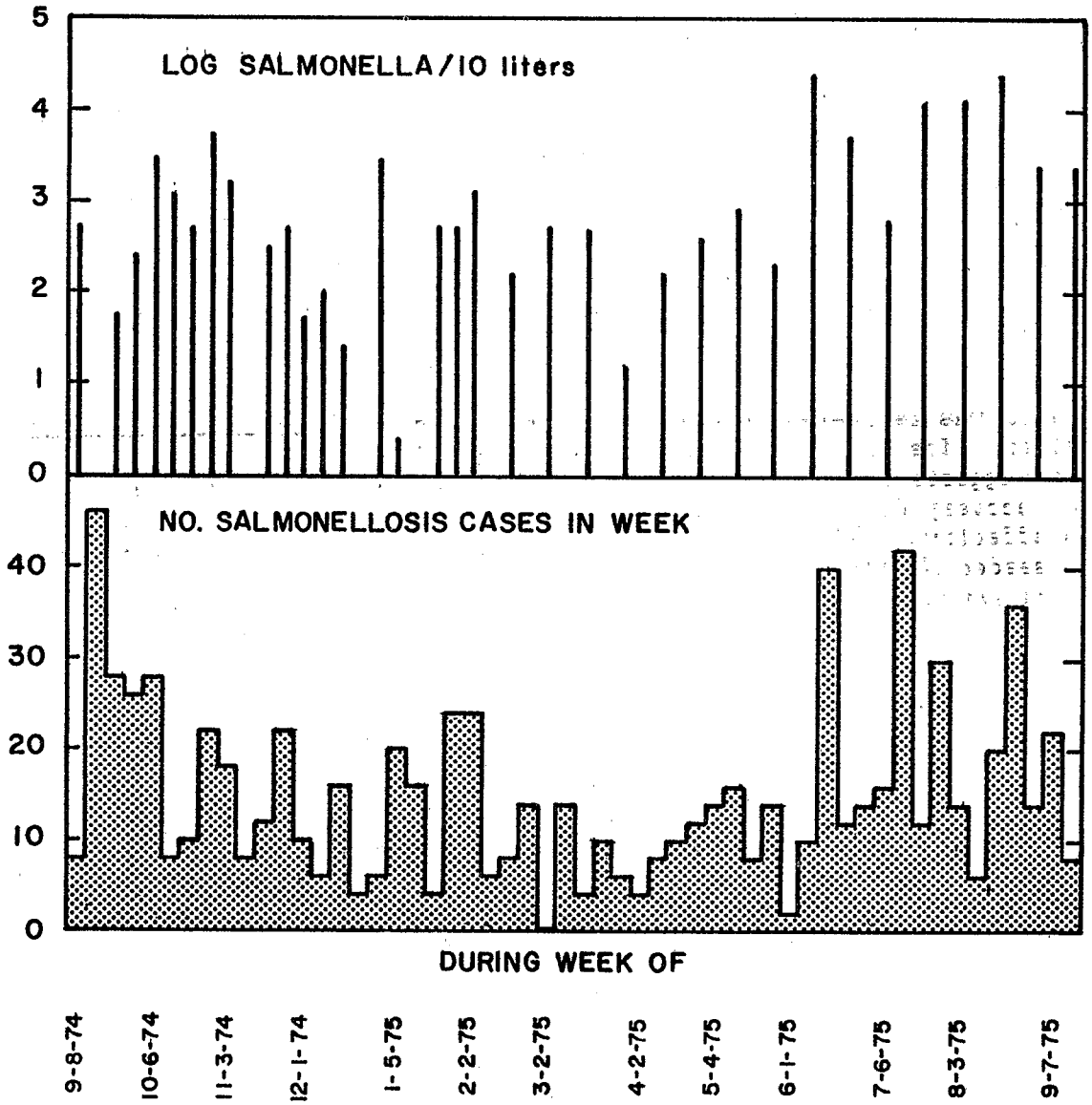


Figure 38. Comparison of the levels of *Salmonella* in sewage with the incidence of salmonellosis in Baltimore City.

New York. Concentration procedures were initiated as soon as possible. Trivalent oral poliovaccine thermal controls were included in each sample to evaluate the eight to ten hour transit time. Irregular recoveries and noticeable losses were observed in some of the early samples. The initial control losses were due to inadequate aeration of the control samples to remove the chloroform included as a preservative. Traces of chloroform noticeably reduced the plating efficiency. After correcting the problem, average recoveries of 84% to 96% of the expected values were observed and suggested that the shipping procedure had a minimal effect on the viruses.

In a large sampling study such as this, unusual observations occur which need further study or some special attention. For example, samples D8 and D15 (Appendix C. Station D, Gwynns Falls, run no. 9 and no. 15) appeared to have extraordinarily high titers and a broad spectrum of viruses. It is possible that samples were obtained when "hot samples were in the pipe" or that solids with adsorbed viruses had settled near the sampling point and were leaking viruses. Nevertheless, the distribution of viruses among nearest neighbors showed that the titers were most probably due to condensation on lids of the Microtest II plates which spread the inoculum from low dilutions to high ones. The above two samples were omitted from the subsequent analysis.

This condensation problem was eliminated by carrying out the inoculations in a laminar flow hood, placing the lidless plates on sterile cafeteria trays and covering the first tray with an inverted second tray. The plates were then incubated in a humidified, five percent CO_2 atmosphere.

The level of viruses in raw sewage provides a reasonable means of comparing the virus data to other reports. Although the physical, chemical and biological characteristics of raw sewage are quite variable, the raw sewage samples were more similar than were stream and storm samples which were highly dependent upon local conditions. High levels of viruses were obtained in most sewage samples. These were principally poliovirus and Coxsackievirus B. There were no clear trends toward a seasonal productivity of either type of enteroviruses. Roughly equal numbers of Coxsackie and polio isolations were made. It is not clear from these data whether it was the output of a generally infected population or the yield from a small number of very productive shedders. The levels of enteroviruses observed here were of the same order of magnitude of sewage enteroviruses as reported by Dahling *et al.* (36) and by Kalter and Millstein (49). Metcalf *et al.* (50) calculated the numbers of enteric viruses discharged from two activated sludge type waste treatment plants in Houston. The largest number of virus isolates were polioviruses. In the Houston sewage effluents, however, echoviruses were nearly as frequent as polioviruses and Coxsackievirus B isolations were very much in the minority. These ratios undoubtedly fluctuate normally and individual types rise and decline frequently. Sabin polio strains are artificially maintained by continuing immuinzation programs.

The use of the presumptive analysis allowed rapid identification of about two-thirds of the samples; the other third (42/130) required a confirmed test for single plaques from positive isolates. The value of the confirmed test is shown by the fact that of the 42 presumptive

guesses, only 12 were correct. The other 30 guesses failed to predict some types or indicated others which could not be verified.

In the presumptive test polioviruses are suppressed with IgG and Coxsackie B viruses with the nonpermissive HEL cells. Ostensibly this should increase the number of adenovirus isolations. However, only five samples were found to have DNA viruses with typical adenovirus morphology. Certainly this must be low and one can conclude that the screening method and/or the concentrating techniques have failed to identify the wild adenoviruses. A partial explanation of this failure may be the pH at which the adsorption-filtration was conducted (pH 4.5). Fields and Metcalf (43) reported that at pH 4.7, 31% of adenovirus 5 was inactivated, and at pH 3.5, 39% was lost. The three reovirus isolates probably indicate that the wild reoviruses also underwent a similar degradation at pH 4.5 (50).

Plaque forming units were almost always lower than predicted by $TCID_{50}$ titrations in presumptive tests. This was not unexpected since the TCID50 was based on four wells per dilution and thus provides a large degree of error. The presence of agar and neutral red appears to suppress plaque formation during primary isolations of many groups other than enteroviruses.

Virus isolations were made from the majority of samples from the urban streams (Appendix C) during dry weather flows. The $TCID_{50}$ titers were at minimal levels for detection by this method. Since the samples could not be diluted very far, difficulty with toxic residues was experienced in many samples and this may, in part, explain the instances where no viruses were recovered. The distribution of virus types resembled the pattern seen with sewage from the Back River Treatment Plant.

Six stormwater flows were examined. Viruses were isolated from all of them. For the most part there were few perceptible differences from the urban streams in the titers, the distribution of types, or in the number of isolates without viruses. The principal difference between them is in the fact that the high "bursts" of stormwater viruses were more frequent than in urban streams and greater in amplitude. It suggests that storms may have actually flushed sewage solids without large dilution effects.

Loch Raven reservoir, site E, was included as background information on a relatively uncontaminated natural water. Enteroviruses were found in three of seven samples. An echovirus of unknown serotype and poliovirus I with vaccine strain genetic markers (d^-T^-) were identified. However, the titers were low and the possibility of a laboratory contamination could explain the occurrence. However, the finding of virus in the raw water for Baltimore City is not unusual. For example, Foliguet *et al.* (51) detected virus in 81% of the raw water in France. Chang (52) suggested that 30 PFU/1 could be expected in moderately polluted raw water sources. In this regard, the highest virus concentration in the Loch Raven reservoir was 13 PFU/1 with a mean of all samples throughout the study of only 6 PFU/1.

Since the examination of samples for enterovirus was less extensive than for other pathogens, it must be acknowledged that the presence of trace levels of virus in the clean waters of the Loch Raven reservoir deserve some discussion. The question arises how was it possible to isolate only one confirmed *Salmonella* throughout the study, but on three separate occassions enteroviruses were found? While it is possible for raw sewage to enter the reservoir through the failure of a sewage pumping station on the metropolitan sanitary district, no such failure was known to have occurred. Furthermore, the normal indicator of pollution gave no suggestion of an unusual entrance of sewage. The mean total coliform concentration of Loch Raven during the study was a MPN 26/100 ml.

Rather than to postulate an explanation such as differential decay rates between viruses and bacteria in several months of storage in the reservoir, it would be useful to look more closely at the virus recovery techniques for opportunities for false negatives and positives. This is supported by the fact that cleaner waters produced almost as many positive virus isolations as the sewage polluted waters. Table 28 summarizes the recovery of viruses for dirty to clean waters.

To suggest that the Loch Raven waters contain one virus particle/ 1.771 does not seem reasonable in view of the fact that only one *Salmonella*/130 l was isolated. The ratio of virus to *Salmonella* in raw sewage was 2 to 1 or 1 virus/10 ml and 1 *Salmonella*/19 ml which seems more reasonable than the 70 to 1 in Loch Raven. It is also difficult to accept the findings that 100% of the samples contained viruses at Northwood compared to only 87% in raw sewage. Any conclusions reached from these data should be tentative and be reserved for future confirmation.

Pseudomonas aeruginosa

No serious difficulties were encountered in the enumeration of *P. aeruginosa*. It should be emphasized that the calculations of the MPN were based on a series of biochemical characteristics and not solely on the growth in asparagine broth and confirmation on acetamide. The levels of *P. aeruginosa* observed in sewage and streams were of the same order of magnitude as those reported by Levin and Cabelli (30) for sewage and Cabelli *et al.* (53) in fresh water. The densities in stormwater were generally 10-fold higher than the urban streams and often approached and sometimes exceeded the levels of indicator microorganisms. *P. aeruginosa* was the most predominant and ubiquitous pathogen observed in this study. It was found in all sewage and storm samples, in nearly all stream samples, and in 62% of the samples from Loch Raven reservoir.

Staphylococcus aureus

Serious problems were observed in the enumeration of *Staph. aureus*. The conventional media recommended for this pathogen do indeed support its growth with a particular colony morphology but are not sufficiently selective for use in water. Many microorganisms not commonly encountered at relatively high densities in clinical samples will mask the presence of *Staph. aureus* in water samples.

Table 28. RECOVERY AND LEVEL OF ENTERIC VIRUSES WITH RESPECT TO THE MEAN LEVELS OF TOTAL COLIFORMS

Site	Virus isolation frequency, %	Coliform index per 100 ml	Virus density	
			TC/virus	ml/virus
Raw sewage	87	2.3×10^7	2.2×10^6	10
Howard Park (stormwater)	100	1.1×10^6	7.1×10^5	64
Jones Falls Drain (stormwater)	75	4.3×10^5	1.3×10^6	300
Bush Street (stormwater)	42	3.5×10^5	1.0×10^6	285
Northwood (stormwater)	100	3.4×10^5	6.6×10^5	195
Western Run (stormwater)	82	1.6×10^6	8.0×10^5	50
Jones Falls (stream)	84	4.0×10^4	5.5×10^4	138
Gwynns Falls (stream)	67	4.0×10^4	2.9×10^5	726
Stoney Run (stormwater)	91	3.1×10^4	8.5×10^4	273
Herring Run (stream)	73	4.9×10^3	1.7×10^4	345
Loch Raven (reservoir)	43	2.6×10^1	4.6×10^2	1,770

The levels of *Staph. aureus* presented in this study were MPN members estimates based on the demonstration of coagulase positive staphylococci. *Staph. aureus* is not found in large numbers in water except in swimming pools (54). The highest levels of *Staph. aureus* were observed in raw sewage presumably from the human intestinal tracts, and the bath and wash waters. *Staph. aureus* was also observed in the majority of stream samples at low levels. However, the storm samples contained significantly higher levels of *Staph. aureus* than the urban streams. With the exception of the Northwood station (site M), this pathogen was recovered from 96% or more of the storm runoff samples.

DISTRIBUTION OF FECAL STREPTOCOCCI

Considerable effort was directed toward enumerating the members of the fecal streptococcal group to provide an insight into the usefulness of this indicator in storm runoff. According to *Standard Methods* (16) the fecal streptococci are considered synonymous with "Lancefield's Group D Streptococcus" and include *S. faecalis*, *S. faecium*, *S. durans* and their varieties or biotypes, *S. bovis* and *S. equinus*. *S. durans* in this study was considered a variety of *S. faecium*. The more restrictive term enterococcus refers to all of the above species except *S. bovis* and *S. equinus*. These two species of streptococci are believed to be indicative of animal feces and dieaway rapidly in the aquatic environment. The *liquefaciens* and *zymogenes* biotypes of *S. faecalis* and atypical *S. faecalis* are believed to be ubiquitous and have little sanitary significance (31). In the heavily contaminated urban aquatic environment *S. faecalis* var. *liquefaciens* and *zymogenes* were found in a significant percentage (30% to 73.5%) of the samples and support the contention of their relative ubiquity. However, these varieties were never observed to be predominant fecal streptococci in either background or routine samples. Only an average of 1.3 to 9.8% of the isolates tested belonged to this subgroup. Atypical *S. faecalis* was observed as less than 1.6% of the isolates in from 9% to 23% of the samples.

The percentage of isolates and the frequency of isolation of *S. bovis* and *S. equinus* differed from stream and storm runoff samples. Approximately 8% of the isolates obtained from the urban streams were *S. bovis* and *S. equinus* and were found in 48 to 72% of the samples. The isolates from four of the six storm sites had 15 to 17% *S. bovis* and *S. equinus* in 66 to 91% of the samples. The remaining two sites were just slightly higher in both percent of isolates and frequency of isolation than the stream samples. The higher levels of *S. bovis* and *S. equinus* in the storm sample suggests a stronger influence of animal feces on the microbial quality.

Enterococci were the predominant group in the fecal streptococci isolates. However, high levels of false positive, not fecal streptococci isolates, were observed in all the samples. Slightly more than 35% of the isolates from background samples belonged to this group. A noticeable increase (35% to 42%) in the number of false positive non-fecal streptococci were found in the storm samples.

The occurrence of false positive non-fecal streptococci on KF medium has been reported. Pavlova *et al.* (32) found 18.6% of the isolates

obtained from food, sewage, and feces to be non-fecal streptococci. Facklam and Moody (55) indicated that many kinds of streptococci can grow and give the appropriate reactions on KF medium. Mossel (56) showed that KF support the growth of *Staph. aureus* and Raibaud *et al.* (57) reported overgrowth from *Lactobacilli*.

The ratio of indicator microorganisms has been employed to provide some insight into the source of microbial contamination. A firm FC/TC ratio has been difficult to establish (58). The FC/FS ratio, however, has been utilized more frequently (31, 59, 60, 61) to determine whether the pollution was of human or animal origin. The basis for the FC/FS ratio can be found in the early literature (62, 63, 64). More recent studies demonstrated that the fecal streptococci were present in greater numbers than coliform bacteria in the feces of animals (5, 65, 66, 67, 68, 69). In human feces, however, fecal coliforms were found in greater numbers than fecal streptococci. Geldreich and Kenner (31) reported that FC/FS ratios for human feces and wastewater were greater than 4.0 and for animal feces, separate stormwater systems and farm drainage are less than 0.7. The ratios between 0.7 and 4.0 are difficult to interpret. The authors also suggested that the FC/FS ratios should be applied carefully and that the ratios are most meaningful when the microbial density data are collected at outfalls into the stream. Upon entering the stream the levels of each of the microorganisms may be affected by numerous environmental factors and differential microbial die-away. They also concluded that the value of the FC/FS ratio for stream samples would only be useful during the initial 24 hours of downstream travel from the point of discharge. Table 29 shows the frequency of occurrence of FC/FS ratios at the sample stations in Baltimore. The majority of the samples from raw sewage had a FC/FS ratio of greater than 4.0. However, 12% of the samples had a FC/FS ratio of less than 1.0. The distribution of the FC/FS ratio in the urban streams was difficult to interpret. A large percentage of samples lie in the grey area between animal and human contamination. If FC/FS ratio above 1.0 is considered to be of human origin, then in 54%, 73% and 77% of the samples for each of the streams there was a suggestion of the presence of significant levels of contamination with human fecal material. The FC/FS ratios in the large majority of the storm samples were less than 1.0. At the stations representative of combined sanitary sewage and storm runoff, only 18% and 12% of the samples had FC/FS ratios greater than 4.0. In fact, 41% and 76% of these samples indicated animal contamination. In a large portion of storm samples the presence of human contamination was masked.

The data obtained in the stream and storm samples emphasize the difficulties with the application of FC/FS ratio. The flow times from the points of contamination to the points of observation for the urban streams in this study are well within the 24 hours suggested by Geldreich and Kenner (31). This was also the case for the storm drains, although it was impossible to evaluate the time between the deposition of animal feces and their incorporation into the storm runoff. Interpretation of the FC/FS ratio less than 4.0 leave much to be desired. Too many factors will influence the densities of fecal coliform and fecal streptococci. The magnitude of these densities along with the volume of water which carries the contamination, combined with the numerous environmental factors that will affect the levels of these microorganisms, make the

Table 29. FREQUENCY OF OCCURRENCE OF THE FC/FS RATIO AT EACH SAMPLE STATION

	Sample station	Ratio FC/FS: Less than 1.0	1.0 to 4.0	Greater than 4.0
	Background Samples			
A	Raw sewage	12	27	61
B	Herring Run (stream)	46	34	20
C	Jones Falls (stream)	27	31	42
D	Gwynns Falls (stream)	33	45	22
E	Loch Raven reservoir	ID	ID	ID
	Storm Samples			
F	Stoney Run (storm runoff)	82	12	6
G	Glen Avenue (storm runoff)	89	5	6
H	Howard Park (combined sewage)	41	41	18
K	Jones Falls storm drain (combined sewage)	76	12	12
L	Bush Street (storm runoff)	81	13	6
M	Northwood (storm runoff)	92	0	8

useful application of the FC/FS ratio difficult in the urban environment. The determination of these microorganisms and the calculation of the FC/FS ratio for a storm outfall or a stream must be recognized to be the net result of an innumerable number of contamination events of variable sources and magnitudes and the effects of many different localized environmental conditions that alter the microbial populations. Effectively, the presence of human contamination may be obscured. The FC/FS ratio was not intended nor should it be employed as a "magic number" to evaluate the source of contamination in a complex system.

RELATIONSHIP BETWEEN INDICATOR AND PATHOGENIC MICROORGANISMS

The evaluation of the naturally occurring relationships between indicator and pathogenic microorganisms in the urban aquatic environment was an important objective of the present study. The correlations for the levels of total coliform, fecal coliform, fecal streptococci and enterococci and bacterial pathogens were highly significant at the 1% level when all of the samples and the background samples were considered. However, little or no correlations were found between indicator and pathogenic bacteria in the storm and stream samples. In each case where significant correlations were observed, large numbers of samples, raw sewage and reservoir samples were considered. The raw sewage samples contained relatively high levels and the reservoir samples contained very low levels of indicator and pathogenic bacteria. The latter two samples play a large role in defining the regression line. Despite the variability observed, the levels of microorganisms at a given sample station were surprisingly similar. A large majority of the samples were found in a one to two log range. It should be stressed that most of the microbial assays were MPN estimates of the bacterial densities. The 95% confidence interval for a five place multiple tube procedure span almost a factor of ten around the MPN. Whether the lack of correlation between indicator and pathogen simply reflects the poor precision for the MPN or that the indicators are less meaningful in these samples remains to be determined.

Significant correlations at the 95% level were observed between the levels of enteric viruses and total coliform and fecal coliform in the background samples. No significant correlation was observed when all the samples, or the storm and stream samples were considered separately. Negative correlations, although not significant, were often observed for the storm samples. The uniformly poor bacterial indicator-virus correlation may be explained by 1) the smaller number of samples assayed, 2) the different response between virus and bacteria to the environment, 3) the difference in survival, and 4) the difficulties associated with concentration, recovery and assay of low levels of virus.

Despite the poor correlations between indicator and pathogens observed for several sample categories, the overall ratio of pathogen to indicator provides a useful tool to evaluate the relative order of magnitude of the presence of these microorganisms. The ratio of pathogen to indicator varied considerably from sewage to clean water. The overall ratios obtained in this study are given in Table 30. *P. aeruginosa* was so abundant, either in fact or through multiplication in the field,

Table 30. OVERALL RATIO OF PATHOGENS TO INDICATOR MICROORGANISMS

Microorganisms	Ratio
P. aeruginosa to TC	1 : 45
P. aeruginosa to FC	1 : 14
P. aeruginosa to FS	1 : 18
P. aeruginosa to ENT.	1 : 5
Staph. aureus to TC	1 : 4,780
Staph. aureus to FC	1 : 1,410
Staph. aureus to FS	1 : 2,000
Staph. aureus to ENT.	1 : 630
Salmonella to TC	1 : 141,000
Salmonella to FC	1 : 105,000
Salmonella to FS	1 : 147,000
Salmonella to ENT.	1 : 45,500
Enteric virus to TC	1 : 151,000
Enteric virus to FC	1 : 50,000
Enteric virus to FS	1 : 85,500
Enteric virus to ENT.	1 : 40,700

that the levels of common indicators of pollution were only an order of magnitude greater than this pathogen. *Staph. aureus*, however, was less abundant and *Salmonella* sp. and enteric virus almost rare compared to the indicator microorganism.

QUALITY OF URBAN SURFACE WATERS

It has been shown from results of the study that the water quality of the urban streams based on detailed examination of the levels of pathogens and indicators of pollution was uniformly poor. The recovery of pathogenic bacteria and viruses was accomplished in almost every sample examined throughout the period of study. Only three samples out of 92 taken from the urban streams met the 200 fecal coliform MPN/100 ml for recreational water use (National Technical Advisory Council Standard, NTAC) (70). The mean fecal coliform density was, in fact, in the order of 6,000/100 ml with a range of 200 to 2.4 million MPN/100 ml, and this certainly is not an acceptable quality for water contact recreation. The levels of microorganisms in the urban streams was independent of season, flow and the number of days since the last rainfall. This apparent independence, relative to factors that have been repeatedly demonstrated to have an effect on the microbial quality, was not surprising. It has been long recognized that the seasonal variation and effect of rainfall on the bacterial quality of surface waters are dependent on the overall condition of the stream. Kisskalt (71) in 1906 compared the seasonal fluctuations in the levels of bacteria in a good quality and a highly polluted stream. In the clean stream the levels of bacteria were highest during periods of rain or high water. In the highly polluted stream the levels of bacteria were higher during periods of low flow. Frost and Streeter (72) in 1924 reported little seasonal fluctuations in the level of bacteria in the Ohio River below Cincinnati. They concluded that the normal fluctuations in the bacterial count were masked by the effect of the pollution from the city. The consistently high levels of indicator microorganisms, routine recovery of pathogenic bacteria and enteric viruses, and the absence of normal fluctuation levels of microorganisms suggest a high level of continuous pollution. Although the identification of the sources of contamination within an urban environment were well beyond the scope of the present investigation, it is difficult to conceive of any other source but raw sewage that would possess the necessary magnitude of microbial content and continuous presence to yield the observed data for the urban streams.

HEALTH HAZARD

It has been hypothesized that an urban area supplied with separate sewer systems for stormwater and for sanitary sewage will have cleaner, less hazardous, urban streams than those with combined systems. There is no doubt that the hypothesis is supported where properly constructed separate sewer systems are provided in new towns and subdivisions where none of the defects of age, overloading and poor maintenance has appeared.

The area for study is believed to represent a rather typical old, central city with a growing suburban belt, a situation shared by metropolitan areas throughout the United States. The study area, unlike many along the Eastern seaboard, is primarily one of separate sewers

and open channels for the convenience of storm runoff through existing and proposed recreational areas. The population's contact with the urban streams is heavy and will increase as playgrounds and parks are extended in the future. An important aspect of assessing the public health threat from contact with these urban streams is the density of pathogens recovered as was summarized in Tables 19 and 23.

Pseudomonas aeruginosa was the most abundant pathogen in all the streams. The mean MPN/100 ml was 1×10^3 with a range from 3×10^0 to 3.5×10^5. This secondary pathogen is of interest because of its association with eye and ear infections, its resistance to antibiotics and proclivity for invading individuals in debilitated states. Infections with *P. aeruginosa* are the most dreaded, second only to antibiotic resistant strains of streptococcus. The organism is rather ubiquitous and is known to be discharged in the feces. Among other organisms proposed as possible indicators of recreational water quality, *P. aeruginosa* has the advantage of allegedly being of human rather than of animal origin (73). The city sewage had relatively large numbers of *P. aeruginosa* averaging 2.2×10^5/100 ml as compared to an average of 7.0×10^6 fecal coliform/100 ml (1:32). However, there were numerous samples which gave a *P. aeruginosa* MPN equal to or in excess of the fecal coliform MPN. This had been found in other studies and were attributed to possible multiplication under natural conditions. This may be an explanation for the peak numbers of *P. aeruginosa* at all study sites during the late summer months when water temperatures were in the 18-26°C range and stream flows were low. Should this, in fact, be the characteristics of this pathogen, its usefullness as a recreational water quality indicator is limited. The least square fit of fresh and estuarine water data reported by Cabelli *et al.* (53) gave 12 *P. aeruginosa* MPN/100 ml at the National Technical Advisory Council suggested standard of 200 FC/100 ml, whereas, the stormwater in this study gave 63/100 ml. In both instances the data were quite variable. The inability of past studies to show any relationship between levels of *P. aeruginosa* in bathing waters and ear infections weakens the public health concern for the abundance of the organism in urban streams. It must be cautioned, however, that the urban runoff studied had concentrations two orders of magnitude higher than values observed in bathing beach studies.

The skin which is exposed to the external environment provides an environment for a variety of microorganisms. *Staph. aureus*, the coagulase-positive organism, is an important human pathogen and is responsible for a wide spectrum of clinical diseases. Usually boils, carbuncles, abscesses, and impetigo are the common skin leasions seen. Obviously, staphlococcal infections may develop anywhere since the organism is indigenous on the skin. Direct contact with infected individuals are the most important sources and asymptomatic staphylococcal carriers and air play very minor roles. However, prolonged contact with water carrying concentrations of a wide variety of *Staph. aureus* strains, some antibiotic resistant or highly virulent, could be an important factor in the infection of cuts and abrasions acquired while playing in the urban streams. The presence of *Staphylococci* in raw sewage is believed to be primarily contributed by the bath and laundry waters and had a mean concentration of 820 MPN/100 ml with a maximum of 4,600 to a minimum of 42/100 ml. In the urban streams the concentrations of *Staphylococci* were not impressively high. The mean concentration

was 5 MPN/100 ml with a minimum of less than 1 and a maximum 93/100 ml. At the NTAC suggested standard of 200 FC/100 ml the calculated concentration of *Staph. aureus* was 2.25/100 ml. Unfortunately, little information is available to correlate the degree of risk associated with the levels of *Staph. aureus* in the water.

The primary human enteric disease-producing bacterial agents associated with the ingestion of water are: *Salmonella typhi* (typhoid fever), *Salmonella paratyphi-A* (paratyphoid fever), *Salmonella* species (salmonellosis), *Shigella* species (bacillary dysentery) and cholera. Today all of these organisms but *Salmonella* and *Shigella* are epidemiological curiosities having been brought under control by environmental sanitation practices and maintenance.

The assessment of the potential health hazard from the *Salmonella-Shigella* organisms in the urban waterways will depend upon the numbers of organisms ingested, the virulence of the bacterial strain, the susceptability of genetically heterogenous human populations, the age and physiological state of individuals, the multiplicity of factors affecting the immunity of the host, and the interaction of the pathogen with the microbial flora and food in the gastrointestinal tract.

MacKenzie and Livingstone (74) indicated that the *Salmonella* infecting dose varies with susceptibility, and is smaller for infants and the aged. Species and strain differences gave different levels of organisms to produce clinical illness. In healthy adult volunteers fed experimental dosages, the minimal numbers causing symptoms varied enormously from 10^5 to 10^9 cells. Comparable data for typhoid fever (75) showed that a dose of 10^3 organisms produced no disease, whereas, 10^5 typhoid bacteria resulted in illness of 28% of persons exposed. The estimated typhoid LD50 (76) was placed at 10^7 organisms. In general it was stated:

> "There are so many gaps in our understanding of the infectivity of *Salmonellae* that it is not possible to give any reliable figure for the infecting dose in man".

In any case, the number of *Salmonella* required to be ingested is relatively large compared to the evidence regarding *Shigella* as shown below:

Infective Dose of Enteric Pathogens

Shigella	10^1 to 10^2
Salmonella	10^5
Escherichia coli	10^8
Vibrio cholerae	10^8

In the urban streams the mean *Salmonella* density was low with a MPN of 8.7/10 1 (8.7×10^{-2} MPN/100 ml). The minimum was less than 1/10 1 and a maximum of 320/10 1. At the NTAC suggested standard of 200 FC/100 ml the most probable number of *Salmonella* was 5.8/10 1. If this water is consumed at the maximum possible intake per day of 2 1/capita, the number of *Salmonella* ingested at the worst condition

(32/1) would be only 64 organisms. Thus, the salmonellosis health hazard in water contact with urban streams is believed to be small. The density of *Salmonella* in stormwater exceeded 10,000/10 l in only one case. If we use a value of 10,000 *Salmonella* /10 l for a similar calculation, the number of *Salmonella* ingested per day would be 2,000 organisms and is still more than a factor of 10 lower than the infective dose listed above. This coupled with the highly unlikely event of consuming 2 liters of stormwater make the health hazard also small.

Shigellosis, on the other hand, may present a problem because for reasons already discussed in the section under analytical methods. There is every reason to believe that *Shigella* sp. are consistently present in the sewage and in the urban runoff. The reported cases of shigellosis in the city peak at the same late summer period as salmonellosis but are only 0.7 of the reported cases of the latter. The degree of health hazard cannot be verified until methods for the isolation and enumeration of *Shigella* under varying environmental conditions have been accomplished. The Dubuque, Iowa episode (77) where the transmission of shigellosis by swimming in a contaminated river supports this concern. The study revealed a mean FC MPN/100 ml of 17,500 in samples of water in the swimming area. This is greatly in excess of the NTAC suggested standard of 200 FC/100 ml. *S. sonnei* was isolated from a sample of the river water containing 400 FC/100 ml. While the density of *Shigella* organisms per unit volume was not determined, the role of this pathogen could be a hazard in view of the evidence of fecal contamination.

The exact quantity of enteroviruses which must be ingested to produce injurious infections is not known. Poliovirus infection by the oral route has been studied and Sabin (78) reported that non-human primates and man did not have comparable susceptibility. He reported that if fewer than 10 tissue culture doses of vaccine poliovirus were ingested by a human, the virus would bypass the pharynx but infect the intestines. If only one poliovirus particle ordinarily infected a cell, thousands of virus units must be defective. The literature is contradictory in this regard since some claim that a much lower concentration can infect children, while others feel that more than 10^4 tissue culture doses of vaccine are needed to infect infants (79). Despite this, the authors of several reviews of the problem of viral minimal infective dose (MID) (80,81,82,83) have generally arrived at the conclusion that one tissue culture infective dose ($TCID_{50}$) correlates well with one MID for a broad spectrum of viruses. This principle applies to both water and airborne infections (80) and is based not only on work with experimental animals but administration of viruses to humans as well. It is particularly germane to this discussion that these observations on MID included human viruses such as polioviruses 1 and 3 (84,81), coxsackievirus A21 (85), coxsackievirus B4 (86), rhinovirus (80) and adenovirus (80).

Admittedly the viruses achieved their high degree of efficiency after careful instillation of the inoculum under optimal conditions with minimum interference from environmental factors and host resistance factors. Nevertheless the potential for establishing the infection warrants concern. It should be noted that infection does not always lead to overt disease.

Whether or not this potential will be realized is largely a matter of probability and frequency of contact. If enough of a polluted water supply is consumed, infections are inevitable. It probably makes no difference whether it is small amounts consumed by numerous individuals or larger quantities consumed by fewer persons. One simply cannot destroy viral infectivity by diluting the viruses.

In contrast to this, a rather large number of viable cells of bacterial pathogens must be consumed by a single host to establish an infection. In a very dilute suspension it is impossible to consume enough quantities to establish the infective dose. A comparison of the bacterial and viral health hazards involve unknown factors such as the influence of particle aggregations. Thus, even though the infective agents are diluted to low levels, the occurrence of clusters of virions or microbial cells may defeat protection offered by the average low concentration.

Goldfield in 1976 (87) reviewed the epidemiological evidence for the transmission of virus diseases by the water route. He concluded, similar to Mosely in 1965 (88), that the demonstrated health hazard of viruses in water has been limited to an occasional outbreak of infectious hepatitus associated with the direct consumption of contaminated water and raw shellfish, a rare occurrence of poliomyelitis, and adenovirus infection associated with swimming pools. At present, the etiology of acute infectious non-bacterial (viral) gastroenteritis remains unclear. Thus, even though viruses are detected at low levels in urban waterways and storm runoff, and the minimum infective dose may be small, the epidemiological information at present indicates that the threat to health is low.

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APPENDICES

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

September 1974				October 1974			
	Site				Site		
Day	W	A	CH	Day	W	A	CH
1	0	0	0.04	1	0	0	0
2	0	0	0.08	2	0	0	0
3	0.55	0	1.04	3	0	0	0
4	0	0	0.02	4	0	0	0
5	0	0	0	5	0	0	0
6	1.40	1.65	1.53	6	0	0	0
7	0.60	0	0.50	7	0	0	0
8	0	0	0	8	0	0	0
9	0	0	0	9	0	0	0
10	0	0	0	10	0	0	0
11	0	0	0.03	11	0	0	0
12	0	0	0	12	0	0	0
13	0.75	0.45	0.52	13	0	0	0
14	0.10	0.20	0.16	14	0	0	0
15	0	0	0	15	0.45	0.40	0.58
16	0	0	0	16*	0.65	0.55	0.76
17	0	0	0	17	0	0	0
18	0	0	0	18	0	0	0
19	0	0	0	19	0	0	0
20	0	0	0	20	0	0	0
21	0.45	0.25	0.36	21	0	0	0
22	0	0	0	22	0	0	0
23	0	0	0	23	0	0	0
24	0	0	0	24	0	0	0
25	0	0	0	25	0	0	0
26	0	0	0	26	0	0	0
27	0	0	0	27	0	0	0
28	1.50	1.65	1.73	28	0	0	0
29	0	0	0	29	0	0	0
30	0	0	0	30	0	0	0
				31	0	0	0
Total	5.35	4.20	6.01		1.10	0.95	1.34

* Storms sampled

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

	November 1974				December 1974		
	Site				Site		
Day	W	A	CH	Day	W	A	CH
1	0	0	0	1	2.25	2.50**	3.87
2	0	0	0	2	0.05	0	0.08
3	0	0	0	3	0	0	0
4	0	0	0	4	0	0	0
5*	0.65	0.40	0.58	5	0	0	0
6	0	0	0	6	0	0	0
7	0	0	0	7	0.35	0.20	0.15
8	0	0	0	8	1.00	1.15	1.28
9	0	0	0	9	0	0	0
10	0	0	0	10	0	0	0
11	0	0	0	11	0	0	0
12*	0.55	0.75	0.65	12	0	0	0
13	0	0	0	13	0.05	0.05	0
14	0.15	0.05	0.06	14	0.10	0.15	0.15
15	0.05	0.10	0.12	15	0.05	0	0.05
16	0	0	0	16*	2.20	1.70	2.09
17	0	0	0	17	0	0	0
18	0	0	0	18	0	0	0
19	0	0	0	19	0	0	0
20	0.15	0.15	0.10	20	0	0	0
21	0	0	0	21	0	0	0.03
22	0	0	0	22	0	0	0
23	0	0	0	23	0	0	0
24	0	0	0	24	0	0	0
25	0.30	0.25	0.26	25	0	0	0
26	0	0	0	26	0	0	0
27	0	0	0	27	0	0	0
28	0	0	0	28	0	0	0
29	0	0	0	29	0	0	0
30	0	0	0	30	0	0	0
				31	0.40	0.40	0.36
Total	1.85	1.70	1.77		6.05	6.15**	8.06

* Storms sampled

** Estimates based on Customs House data

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

	January 1975			February 1975			
	Site				Site		
Day	W	A	CH	Day	W	A	CH
1	0	0	0	1	0	0	0
2	0	0	0	2	0.05	0	0.06
3	0	0	0	3	0	0	0
4	0	0	0.01	4	0.15	0.40	0.41
5	0	0	0	5*	0.50	0.25	0.34
6*	0.45	0	0.44	6	0.05	0	0.05
7	0	0	0	7	0	0	0
8	0.40	0	0.22	8	0	0	0
9	0.15	0	0.38	9	0	0	0
10	0	0	0	10	0	0	0
11*	0.15	0	0.16	11	0	0	0
12	0	0	0	12	0.45	0.40	0.43
13*	0.45	0.50	0.58	13	0	0	0
14	0	0	0	14	0	0	0
15	0	0	0	15	0	0	0
16	0	0	0	16	0	0	0
17	0	0	0	17	0.15	0	0.15
18	0.70	0.50	0.55	18	0	0	0
19	0.20	0.45	0.38	19	0	0	0
20*	0.30	0.10	0.20	20	0	0	0
21	0	0	0	21	0	0	0
22	0	0	0	22	0	0	0
23	0	0	0	23*	0.50	0.20	0.65
24	0.10	0.25	0.02	24	0.40	0	0.36
25	0.35	0	0.42	25	0	0	0
26	0	0	0	26	0	0	0
27	0	0	0	27	0	0	0
28	0	0	0	28	0	0	0
29	0	0	0				
30	0	0	0				
31	0.20	0.15	0.24				
Total	3.45	1.95	3.60		2.25	1.25	2.50

* Storms sampled

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

	March 1975				April 1975		
	Site				Site		
Day	W	A	CH	Day	W	A	CH
1	0	0	0	1	0	0	0
2	0	0	0	2	0	0	0
3	0	0	0	3*	0.10	0.15	0.30
4	0	0	0	4	0	0	0
5	0	0	0	5	0	0	0
6	0	0	0	6	0	0	0
7	0	0	0.05	7	0	0.10	0
8	0	0	0	8	0	0	0
9	0	0	0	9	0	0	0
10	0.10	0	0.09	10	0	0	0
11	0	0	0	11	0	0	0
12*	0.45	0.55	0.43	12	0	0	0
13	0.10	0	0.03	13	0	0	0
14	0.95	0.70	1.10	14	0	0	0
15	0	0	0	15*	0.30	0.35	0.42
16	0.05	0	0.09	16	0	0.05	0
17	0.20	0	0.29	17	0	0	0
18	0	0	0	18	0	0	0.02
19	1.85	1.85	2.34	19	0	0	0.14
20	0	0	0	20	0	0	0
21	0	0	0	21	0	0	0
22	0	0	0	22	0	0	0
23	0	0	0	23	0.05	0	0.05
24	0.55	0.60	0.88	24	0.45	0.75	0.37
25	0	0	0	25	1.05	0.90	1.47
26	0	0	0	26	0	0.05	0
27	0	0	0	27	0	0	0
28	0	0	0	28	0	0.05	0.02
29	0.10	0.10	0.08	29	0.10	0.25	0.25
30	0.40	0.40	0.53	30	0	0	0
31	0	0	0				
Total	4.75	4.20	5.91		2.05	2.65	3.04

* Storms sampled

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

	May 1975				June 1975		
	Site				Site		
Day	W	A	CH	Day	W	A	CH
1*	0.85	0.45	0.71	1	.5**	.5**	0.49
2	0	0	0	2	0**	0**	0
3	0.20	0.10	0.14	3	0**	0**	0
4	1.65	1.55	1.95	4	0**	0**	0
5	0	0	0.02	5	1.1**	1.1**	1.15
6*	0.20	0.30	0.48	6	0**	0**	0.15
7	0	0	0	7	0	0	0
8	0	0	0	8	0	0	0
9	0	0	0	9	0	0	0
10	0	0	0	10	0	0	0
11	0	0	0	11*	0.30	0	0.26
12	0.35	0.65	0.89	12	0.50	0.55	0.39
13	0.20	0.30	0.08	13	0.75	0.30	0.15
14	0	0	0	14	0	0	0
15	0.10	0	0.14	15	0	0	0
16	0.25	0	0.21	16	0	0	0.05
17	0	0	0	17	0	0	0
18	0	0	0	18	0	0	0
19	0	0	0	19	0	0	0
20	0	0	0	20	0	0	0
21	0	0	0	21	0	0	0
22	0	0.40	0.58	22	0	0	0
23	0	0	0	23	0	0	0
24	0	0.30	1.77	24	0	0	0
25	0	0	0	25	0	0	0.04
26	0	0	0	26	0.05	0	0.16
27	0	0	0	27	0	0	0.11
28	0	0	0	28	0.95	0.80	0.55
29	0	0	0	29	0.20	0.10	0.20
30	.1**	0	0.15	30*	0	0	0
31	.8**	0	0.86				
Total	4.70**	4.05	8.08		4.35**	3.35**	3.70

* Storms sampled

** Estimates based on Customs House data

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

	July 1975				August 1975		
	Site				Site		
Day	W	A	CH	Day	W	A	CH
1	0	0	0	1	0	0	0
2	0	0	0	2	0	0	0
3	ND	ND	0.50	3	0	0	0
4	ND	ND	0	4	0.50	0.40	0.73
5	ND	ND	0	5	0.10	0.35	0.07
6	ND	ND	0	6*	0.15	0	0.23
7	ND	ND	0	7	0	0	0
8	ND	ND	0	8	0	0	0
9	ND	ND	0	9	0	0	0
10*	ND	ND	4.66	10	0	0	0
11	ND	ND	0	11	0	0	0
12	ND	ND	0	12	0	0	0
13	ND	ND	3.85	13*	0.60	0.45	0.69
14*	ND	ND	1.66	14	1.05	1.45	1.31
15	ND	ND	0.02	15	0	0	0
16	ND	ND	0	16	0.20	0.25	0.17
17	ND	ND	0	17	0	0.05	0.04
18	ND	ND	0	18	0	0	0
19	0	0	0	19	0	0	0
20	0.70	0.45	0.83	20	0	0	0
21	0	0	0	21	0	0	0
22	0	0	0	22	0	0	0
23	0	0	0	23	0	0	0
24	0.15	0	0.19	24	0	0	0
25	0	0	0	25	0	0	0
26	0	0	0	26	0	0	0
27*	0	0	0	27	0	0	0
28	0	0	0.02	28	0	0	0
29	0	0	0	29	0	0	0
30	0	0	0	30	0	0	0
31	0	0	0	31	0	1.35	0.50
Total	11.0**	11.0**	11.68		2.60	4.30	3.74

* Storms sampled

** Estimates based on Customs House data

ND No Data

APPENDIX A. Daily Precipitation in Inches at the Customs House (CH), Woodbourne (W) and Ashburton (A) in Baltimore City from September 1, 1974 to September 30, 1975.

Daily Precipitation (inches)

September 1975

	Site		
Day	W	A	CH
1	0.25	0	0.25
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0.7
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0.02
12*	0.65	0.45	0.55
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18*	0.45	0.45	0.68
19	0.05	0.15	0.10
20	0	0	0
21	0	0	0
22	0.60	0	0.67
23	2.30	1.15	2.40
24	1.00	1.55	1.15
25	1.70	1.40	1.55
26	1.15	1.40	1.35
27	0	0	0
28	0	0	0
29	0	0	0
30	0	0	0
Total	8.15	6.55	8.79

* Storms sampled

APPENDIX B. Levels of Bacteria, Station A - Raw Sewage

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
07/17/74	1	$>2.9 \times 10^8$	3.5×10^7	3.5×10^6	7.0×10^3	ND	LSL
07/23/74	2	5.4×10^8	1.7×10^8	ND	ND	ND	LSL
07/30/74	3	2.8×10^8	7.9×10^7	2.4×10^6	7.9×10^4	ND	LSL
08/05/74	4	1.3×10^8	8.0×10^6	5.4×10^5	ND	ND	1.4×10^3
08/12/74	5	3.3×10^7	2.3×10^7	ND	3.5×10^5	ND	ND
09/09/74	7	3.3×10^7	3.3×10^7	5.2×10^6	9.2×10^5	ND	5.6×10^2
09/16/74	8	1.7×10^7	4.9×10^6	9.8×10^5	3.5×10^5	ND	5.3×10^1
09/23/74	9	3.5×10^7	3.5×10^7	1.2×10^7	2.3×10^6	ND	2.6×10^2
09/30/74	10	2.4×10^7	2.4×10^7	4.1×10^6	1.7×10^6	ND	$>2.9 \times 10^3$
10/07/74	11	2.4×10^7	4.9×10^6	1.1×10^6	1.1×10^6	ND	1.2×10^3
10/14/74	12	3.5×10^7	4.6×10^6	1.2×10^6	3.5×10^5	ND	4.8×10^2
10/21/74	14	2.9×10^6	4.9×10^6	8.3×10^5	7.9×10^5	ND	5.1×10^3
10/28/74	15	5.4×10^7	1.1×10^7	4.4×10^5	1.7×10^5	3.6	1.7×10^3
11/04/74	16	2.6×10^6	$>2.6 \times 10^6$	2.0×10^4	3.3×10^3	2.4×10^2	ND
11/11/74	18	3.5×10^7	7.9×10^6	1.1×10^6	9.2×10^6	4.5×10^1	2.8×10^2
11/18/74	20	1.7×10^7	7.9×10^6	1.1×10^6	9.2×10^5	9.4	5.1×10^2
12/02/74	21	2.4×10^6	1.3×10^6	3.4×10^5	1.3×10^5	4.6×10^2	4.8×10^1
12/09/74	22	7.0×10^6	3.3×10^6	9.7×10^5	7.0×10^4	5.8×10^2	1.0×10^2
12/17/74	24	1.6×10^7	4.6×10^5	3.9×10^5	2.2×10^5	2.4×10^3	2.6×10^1
12/24/74	25	1.6×10^8	1.7×10^7	1.1×10^6	3.5×10^5	1.7×10^3	$>2.7 \times 10^3$
01/06/75	26	3.5×10^7	7.9×10^6	9.5×10^5	3.5×10^5	2.0×10^1	$>2.7 \times 10^3$
01/20/75	30	3.5×10^6	3.3×10^5	5.4×10^5	7.0×10^4	3.9×10^2	5.1×10^2
01/27/75	31	$>2.4 \times 10^7$	5.4×10^6	4.5×10^7	3.3×10^5	4.6×10^3	5.1×10^2
02/03/75	32	1.7×10^7	3.3×10^6	1.1×10^6	3.3×10^5	9.3×10^2	1.2×10^3
02/17/75	34	2.8×10^7	3.3×10^6	1.8×10^6	1.4×10^5	2.4×10^3	2.7×10^2
03/03/75	36	1.3×10^7	3.3×10^5	1.4×10^6	1.4×10^5	2.1×10^3	4.9×10^2
03/17/75	38	1.6×10^7	3.3×10^6	2.7×10^6	7.9×10^4	2.4×10^3	4.9×10^2
03/31/75	39	4.6×10^7	1.3×10^7	9.4×10^5	9.2×10^5	2.4×10^3	2.2×10^2
04/14/75	41	1.72×10^8	4.9×10^7	1.7×10^6	$>1.6 \times 10^5$	4.6×10^3	1.7×10^2
04/28/75	43	$>1.6 \times 10^9$	9.2×10^8	1.6×10^6	7.9×10^6	2.9×10^2	4.3×10^2
05/12/75	46	3.5×10^7	3.5×10^7	2.4×10^6	5.4×10^7	4.6×10^3	8.3×10^2
05/19/75	47	5.4×10^7	7.9×10^6	3.0×10^6	5.0×10^3	2.4×10^3	2.2×10^2
06/10/75	48	2.2×10^6	1.7×10^6	3.1×10^6	1.4×10^5	1.5×10^2	2.7×10^4
06/24/75	50	1.3×10^6	3.3×10^5	3.8×10^5	2.3×10^3	6.1×10^1	5.1×10^3
07/07/75	52	9.2×10^7	4.9×10^6	3.3×10^6	2.3×10^4	4.5×10^1	6.1×10^2
07/21/75	55	3.4×10^6	4.9×10^6	9.9×10^5	3.5×10^5	2.6×10^2	1.2×10^4
08/04/75	57	4.9×10^7	1.1×10^7	8.0×10^5	7.8×10^4	7.8×10^1	1.2×10^4
08/18/75	60	9.2×10^7	1.4×10^7	1.3×10^6	1.7×10^4	LSL	2.7×10^4
09/02/75	61	5.4×10^7	1.3×10^7	1.4×10^6	2.7×10^4	3.3×10^2	2.7×10^3
09/16/75	63	5.4×10^7	3.5×10^7	9.5×10^5	2.8×10^5	LSL	2.7×10^3
Geom. Mean		2.2×10^7	6.3×10^6	1.4×10^6	2.3×10^5	2.6×10^2	5.0×10^2

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station B - Herring Run

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
07/17/74	1	1.1×10^4	2.3×10^3	2.2×10^3	ND	ND	LSL
07/23/74	2	3.3×10^3	1.7×10^3	2.2×10^3	ND	ND	LSL
07/30/74	3	5.4×10^4	2.4×10^4	1.7×10^4	2.2×10^3	ND	LSL
08/05/74	4	3.3×10^4	7.9×10^3	7.9×10^3	ND	ND	LSL
08/12/74	5	2.3×10^2	1.3×10^2	8.0×10^2	3.4×10^3	ND	ND
09/09/74	7	9.2×10^3	2.2×10^3	1.3×10^3	1.7×10^2	ND	2.0
09/16/74	8	2.8×10^3	ND	8.0×10^2	1.7×10^3	ND	ND
09/23/74	9	3.5×10^5	3.5×10^5	1.6×10^4	1.6×10^5	ND	ND
09/30/74	10	1.3×10^3	7.9×10^2	1.0×10^3	2.2×10^3	ND	ND
10/07/74	11	5.4×10^3	1.3×10^3	4.5×10^2	2.4×10^3	ND	4.1
10/14/74	12	5.0×10^1	LSL	7.5×10^2	5.4×10^4	ND	1.2
10/21/74	14	5.4×10^2	5.4×10^2	4.5×10^2	3.3×10^1	ND	2.7×10^1
10/28/74	15	1.6×10^3	5.4×10^2	3.0×10^2	1.7×10^2	LSL	4.4
11/04/74	16	3.5×10^2	1.1×10^2	1.9×10^2	5.4×10^4	LSL	6.7
11/11/74	18	1.7×10^4	1.4×10^3	2.0×10^2	4.9×10^2	LSL	6.7
11/18/74	20	9.2×10^2	5.4×10^2	5.3×10^2	5.4×10^3	6.8×10^1	1.3×10^1
12/02/74	21	2.4×10^5	2.4×10^5	4.0×10^4	1.3×10^3	2.0	1.3×10^2
12/09/74	22	$\geq 2.4 \times 10^5$	ND	2.4×10^3	9.4×10^1	ND	2.6
12/17/74	24	2.4×10^4	1.3×10^4	3.8×10^3	1.4×10^2	4.0	6.7
12/24/74	25	1.4×10^4	1.4×10^4	1.9×10^3	7.0×10^1	1.3	LSL
01/06/75	26	3.5×10^3	7.9×10^2	5.6×10^2	4.6×10^1		2.6
01/20/75	30	1.7×10^3	2.1×10^2	1.3×10^4	2.3×10^2	3.6	4.38×10^1
01/27/75	31	2.4×10^3	1.3×10^3	3.9×10^3	1.1×10^2	7.3	1.17
02/03/75	32	2.2×10^3	2.2×10^3	2.3×10^3	1.7×10^2	3.6	2.63
02/17/75	34	3.5×10^3	3.5×10^3	1.1×10^4	3.4×10^1	3.6	7.01×10^1
03/03/75	36	3.3×10^3	2.4×10^3	2.8×10^3	4.9×10^1	LSL	2.04
03/17/75	38	1.4×10^4	3.3×10^3	2.0×10^4	4.9×10^1	3.6	6.72
03/31/75	39	1.09×10^4	7.9×10^3	4.1×10^2	2.78×10^2	LSL	1.12
04/14/75	41	1.09×10^4	7.0×10^3	4.2×10^2	2.78×10^3	LSL	LSL
04/28/75	43	1.1×10^3	4.9×10^2	3.1×10^2	5.2×10^2	LSL	1.3×10^1
05/12/75	46	1.3×10^3	7.9×10^2	2.3×10^2	3.3×10^1	LSL	LSL
05/19/75	47	1.7×10^3	1.7×10^3	3.9×10^2	3.3×10^1	LSL	LSL
06/10/75	48	1.7×10^4	1.3×10^3	8.0×10^3	7.9×10^2	3.6×10^1	4.4×10^1
06/24/75	50	2.4×10^3	1.3×10^3	2.1×10^3	1.1×10^1	LSL	1.3×10^1
07/07/75	52	5.4×10^3	1.3×10^3	2.7×10^3	4	2.0	1.2
07/21/75	55	1.6×10^3	2.8×10^2	1.4×10^4	1.7×10^3	7.4	5.8
08/04/75	57	3.3×10^3	2.0×10^2	2.4×10^2	ND	LSL	LSL
08/18/75	60	9.2×10^3	1.4×10^3	3.5×10^3	1.7×10^2	1.1×10^1	1.2
09/02/75	61	1.1×10^4	3.3×10^3	2.5×10^3	1.7×10^3	4.8	1.1×10^1
09/16/75	63	5.4×10^3	7.9×10^2	2.7×10^3	4.0×10^1	2.0	2.63
Geom. Mean		4.8×10^3	1.1×10^3	1.5×10^3	2.9×10^2	3.2	4.6

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station C - Jones Falls

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
07/17/74	1	7.9×10^4	4.9×10^4	1.1×10^4	9.2×10^2	ND	LSL
07/23/74	2	1.1×10^4	1.1×10^4	1.7×10^4	2.4×10^2	ND	LSL
07/30/74	3	3.3×10^5	1.7×10^5	4.6×10^4	5.4×10^3	ND	LSL
08/05/74	4	1.3×10^5	4.9×10^4	9.2×10^4	ND	ND	2.0
08/12/74	5	1.7×10^5	1.3×10^5	4.9×10^3	2.3×10^4	ND	ND
09/09/74	7	3.3×10^5	2.3×10^5	2.3×10^4	5.4×10^3	ND	ND
09/16/74	8	7.9×10^4	4.9×10^4	1.5×10^4	2.3×10^4	ND	ND
09/23/74	9	2.3×10^5	2.3×10^5	3.2×10^4	2.4×10^4	ND	ND
09/30/74	10	1.6×10^5	1.6×10^5	5.3×10^4	3.5×10^5	ND	ND
10/07/74	11	1.4×10^5	9.4×10^4	1.3×10^4	9.2×10^3	ND	2.6
10/14/74	12	9.2×10^4	1.4×10^4	1.4×10^4	1.7×10^3	ND	2.0
10/21/74	14	9.2×10^4	3.5×10^4	5.9×10^4	9.2×10^2	ND	1.2
10/28/74	15	1.7×10^5	1.7×10^5	2.3×10^4	1.1×10^3	2.0	1.2
11/04/74	16	1.7×10^5	9.2×10^4	3.2×10^4	9.2×10^3	4.6×10^1	1.2
11/11/74	18	3.3×10^4	3.5×10^4	3.6×10^4	9.4×10^3	1.8×10^2	1.3×10^1
11/18/74	20	4.6×10^4	2.1×10^4	2.6×10^3	1.4×10^4	1.1×10^1	4.4×10^1
12/02/74	21	2.4×10^4	2.4×10^4	7.6×10^4	2.7×10^3	2.0	1.3×10^2
12/09/74	22	1.6×10^5	2.4×10^4	2.6×10^4	1.7×10^3	LSL	7.0×10^1
12/17/74	24	9.2×10^4	3.5×10^4	4.2×10^4	1.7×10^3	1.7×10^1	2.7×10^1
12/24/74	25	1.7×10^5	3.5×10^4	7.1×10^3	$>2.4 \times 10^4$	1.2×10^1	8.2
01/06/75	26	1.3×10^5	4.9×10^4	4.0×10^3	3.5×10^3	2.0	2.0
01/20/75	30	3.3×10^4	7.9×10^3	1.1×10^4	1.1×10^3	4.3×10^1	4.38×10^1
01/27/75	31	3.5×10^4	3.5×10^4	2.4×10^3	1.1×10^3	7.3	2.63
02/03/75	32	5.4×10^4	3.5×10^4	3.3×10^3	7.9×10^2	4.3×10^1	7.88
02/17/75	34	3.5×10^4	3.5×10^4	3.1×10^4	5.4×10^2	2.3×10^1	2.72×10^1
03/03/75	36	1.3×10^4	7.9×10^3	4.2×10^3	4.9×10^2	9.1	6.72
03/17/75	38	5.4×10^4	1.3×10^4	7.3×10^4	1.3×10^2	9.1	3.21×10^2
03/31/75	39	3.4×10^5	2.4×10^5	3.3×10^4	5.42×10^3	3.6	2.04
04/14/75	41	1.3×10^5	4.9×10^4	4.6×10^3	1.72×10^4	9.1	1.17
04/28/75	43	7.9×10^4	7.9×10^4	3.5×10^4	1.6×10^4	4.3×10^1	3.2×10^2
05/12/75	46	1.1×10^4	4.9×10^3	6.1×10^3	2.2×10^2	4.3×10^1	2.2×10^1
05/19/75	47	3.5×10^4	2.4×10^4	4.7×10^3	1.1×10^2	3.6	4.4×10^1
06/10/75	48	1.7×10^5	4.9×10^4	1.8×10^4	1.3×10^3	9.3×10^1	1.1×10^1
06/24/75	50	3.3×10^4	2.3×10^4	8.5×10^3	2.2×10^1	4.0	.88
07/07/75	52	1.7×10^5	1.3×10^5	5.1×10^4	8.4×10^1	2.0	3.2×10^2
07/21/75	55	2.2×10^4	1.4×10^4	1.3×10^4	2.0×10^2	1.1×10^2	4.4
08/04/75	57	1.7×10^5	2.2×10^4	2.0×10^3	7.9×10^2	4.0	1.2
08/18/75	60	5.4×10^4	7.9×10^3	6.7×10^3	2.4×10^3	LSL	.88
09/02/75	61	ND	ND	7.3×10^3	9.2×10^2	2.0	6.13
09/16/75	63	9.2×10^4	4.7×10^3	4.9×10^3	9.2×10^2	1.8	7.0×10^1
Geom. Mean		4.0×10^4	1.5×10^4	1.5×10^4	2.1×10^3	9.5	9.1

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station D - Gwynns Falls

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
07/17/74	1	2.2×10^4	2.7×10^3	ND	2.2×10^2	ND	LSL
07/23/74	2	7.9×10^3	5.0×10^2	2.0×10^2	2.8×10^2	ND	LSL
07/30/74	3	3.5×10^5	1.1×10^5	3.5×10^4	2.8×10^3	ND	LSL
08/05/74	4	3.3×10^4	1.1×10^4	1.3×10^3	ND	ND	6.1
08/12/74	5	2.2×10^3	8.0×10^2	4.6×10^2	1.6×10^5	ND	ND
09/09/74	7	1.7×10^4	7.0×10^3	1.7×10^3	1.1×10^3	ND	4.1
09/16/74	8	5.4×10^5	4.9×10^5	2.3×10^4	1.7×10^5	ND	ND
09/23/74	9	1.3×10^4	1.3×10^4	5.5×10^3	2.8×10^4	ND	ND
09/30/74	10	2.4×10^5	1.6×10^4	8.5×10^3	7.0×10^4	ND	ND
10/07/74	11	3.5×10^4	1.7×10^4	3.8×10^3	1.6×10^4	ND	1.3×10^2
10/14/74	12	1.3×10^4	5.0×10^2	3.0×10^2	9.4×10^2	ND	1.3×10^1
10/21/74	14	9.2×10^4	4.6×10^3	1.7×10^3	7.0×10^2	ND	6.1
10/28/74	15	3.4×10^2	8.0×10^1	LSL	7.0×10^1	3.6×10^1	6.7
11/04/74	16	4.6×10^2	2.3×10^2	1.2×10^2	1.3×10^2	3.6×10^1	4.4
11/11/74	18	2.2×10^3	4.9×10^2	2.1×10^2	8.0×10^1	ND	1.3×10^1
11/18/74	20	1.7×10^3	3.3×10^2	1.2×10^2	4.6×10^2	1.7	2.2×10^1
12/02/74	21	3.3×10^4	1.3×10^4	$>1.0 \times 10^5$	1.1×10^4	2.6×10^1	7.0×10^1
12/09/74	22	3.5×10^4	3.3×10^3	2.4×10^4	1.1×10^3	4.0	7.0×10^1
12/17/74	23	3.5×10^5	1.3×10^4	1.0×10^5	7.9×10^2	6.8	2.7×10^1
12/24/74	25	1.1×10^4	1.3×10^3	6.0×10^2	2.1×10^2	1.4×10^1	2.7×10^1
01/06/75	26	7.0×10^2	7.0×10^2	5.1×10^3	3.3×10^2	LSL	27.2
01/20/75	30	7.0×10^5	1.1×10^3	4.5×10^4	4.6×10^2	LSL	4.38×10^1
01/27/75	31	2.1×10^4	3.3×10^3	7.0×10^2	2.2×10^1	LSL	2.19×10^1
02/03/75	32	1.3×10^3	7.9×10^2	LSL	1.1×10^2	9.1	2.04
02/17/75	34	7.0×10^3	3.3×10^3	2.2×10^3	2.2×10^2	LSL	1.34×10^2
03/03/75	36	4.9×10^3	7.0×10^2	2.4×10^3	4.9×10^2	LSL	6.72
03/17/75	38	2.4×10^4	5.4×10^3	1.9×10^4	9.4×10^1	7.3	2.72×10^1
03/31/75	39	$\geq 2.4 \times 10^6$	$\geq 2.4 \times 10^6$	3.4×10^4	2.21×10^3	9.3×10^1	1.26×10^1
04/14/75	41	3.3×10^3	1.3×10^3	5.5×10^2	2.21×10^3	LSL	6.7
04/28/75	43	3.3×10^4	4.0×10^3	6.0×10^2	2.8×10^3	3.0	2.7×10^1
05/12/75	46	1.1×10^4	1.1×10^3	3.0×10^2	7.9×10^1	7.3	8.2
05/19/75	47	3.5×10^3	4.9×10^2	1.0×10^2	1.7×10^1	LSL	5.8
06/10/75	48	1.7×10^4	3.3×10^3	3.6×10^3	2.2×10^2	2.1×10^1	6.1×10^2
06/24/75	50	5.4×10^3	7.0×10^2	2.1×10^3	1.09×10^2	6.8	1.2×10^2
07/07/75	52	1.6×10^4	4.9×10^2	6.7×10^2	1.41×10^2	LSL	2.7×10^1
07/21/75	55	1.3×10^4	3.3×10^3	2.8×10^4	3.5×10^3	4.0	2.0
08/04/75	57	3.3×10^3	7.0×10^2	4.5×10^1	ND	4.0	2.0
08/18/75	60	3.5×10^4	1.3×10^3	8.3×10^2	1.7×10^2	LSL	4.4
09/02/75	61	ND	ND	ND	ND	ND	ND
09/16/75	63	3.5×10^4	1.1×10^4	3.3×10^3	2.3×10^2	LSL	2.7×10^1
Geom. Mean		4.0×10^4	5.9×10^3	1.7×10^3	4.7×10^2	4.5	1.5×10^1

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station E - Loch Raven Reservoir

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
03/17/75	38	LSL	LSL	LSL		LSL	LSL
03/31/75	39	LSL	LSL	5.0	2.3×10^1	LSL	LSL
04/14/75	41	LSL	LSL	LSL	LSL	LSL	LSL
04/28/75	43	1.7×10^1	1.7×10^1	2.0×10^2	2.0	LSL	0.88
05/12/75	46	5.0	5.0	2.0×10^1	LSL	LSL	LSL
05/19/75	47	2.0	LSL	LSL	LSL	LSL	LSL
06/10/75	48	4.0×10^2	7.0×10^1	5.0	0	LSL	LSL
06/24/75	50	1.7×10^2	8.0×10^1	4.0×10^1	0	LSL	LSL
07/07/75	52	4.9×10^1	2.3×10^1	<5.0	2.3×10^1	LSL	LSL
07/21/75	55	3.4×10^2	1.7×10^2	ND	4.5	LSL	LSL
08/04/75	57	4.5	2.0	<5.0	ND	LSL	LSL
08/18/75	60	ND	ND	ND	ND	ND	ND
09/02/75	61	3.3×10^1	1.3×10^1	<5.0	2.0	LSL	LSL
09/16/75	63	7.9×10^1	4.9×10^1	ND	4.5	LSL	LSL
Geom. Mean		2.6×10^1	1.5×10^1	1.0×10^1	3.1	<2.5	0

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station F - Stoney Run

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
10/16/74	13	3.5×10^5	4.9×10^4	5.3×10^4	2.4×10^5	ND	6.1×10^2
11/05/74	17	$>2.4 \times 10^5$	1.7×10^4	9.8×10^4	3.3×10^2	2.0	2.9
11/12/74	19	1.3×10^4	4.9×10^3	8.4×10^3	2.3×10^2	4.9×10^1	5.0
12/16/74	23	5.4×10^3	1.7×10^3	2.4×10^5	1.1×10^3	2.7×10^1	5.17×10^1
01/06/75	27	1.1×10^4	1.7×10^4	1.1×10^5	5.4×10^2	2.3×10^1	6.12×10^2
01/11/75	28	1.7×10^4	3.3×10^3	1.9×10^5	1.7×10^3	4.3×10^1	2.56×10^2
01/13/75	29	3.5×10^4	2.4×10^4	3.1×10^4	1.8×10^3	4.3×10^1	$>1.33 \times 10^3$
01/20/75	30	7.0×10^3	3.1×10^3	2.5×10^4	$>2.4 \times 10^3$	2.3×10^1	2.56×10^2
02/05/75	33	2.6×10^4	1.7×10^4	1.7×10^4	1.8×10^4	2.8×10^1	1.33×10^2
02/12/75	35	4.9×10^3	3.3×10^3	8.0×10^3	2.2×10^2	9.0	3.89
03/12/75	37	3.3×10^4	1.4×10^3	2.4×10^4	1.4×10^3	7.3	3.89
04/03/75	40	7.9×10^3	7.9×10^3	2.3×10^4	1.41×10^3	2.0×10^1	2.11×10^1
04/15/75	42	2.4×10^4	1.3×10^4	5.6×10^4	4.0×10^2	LSL	$>1.3 \times 10^3$
05/01/75	44	3.3×10^4	1.7×10^4	6.5×10^4	1.7×10^3	2.3×10^1	2.7×10^2
05/06/75	45	5.4×10^3	3.3×10^3	8.0×10^4	4.8×10^2	2.3×10^1	2.6×10^2
06/11/75	49	3.5×10^3	1.3×10^3	3.1×10^4	7.0×10^2	1.8	3.5
06/30/75	51	1.6×10^6	5.4×10^5	ND	4.9×10^3	2.2×10^1	6.1×10^2
07/10/75	53	1.3×10^5	7.9×10^4	3.0×10^5	1.48×10^2	4.5	4.2×10^1
07/14/75	54	1.7×10^5	1.7×10^5	1.9×10^5	2.3×10^3	2.2×10^1	6.7×10^1
07/27/75	56	4.9×10^4	4.9×10^4	4.2×10^5	1.7×10^3	1.7×10^1	2.2
08/06/75	58	7.0×10^3	2.3×10^3	LSL	1.3×10^3	LSL	1.2×10^1
08/13/75	59	9.2×10^4	1.7×10^4	1.7×10^5	3.2×10^2	LSL	6.1
09/12/75	62	7.9×10^5	1.1×10^5	1.2×10^5	4.9×10^3	1.0×10^1	2.5×10^1
09/18/75	64	5.6×10^4	5.4×10^5	3.7×10^5	1.7×10^3	LSL	1.67
Geom. Mean		4.8×10^4	1.9×10^4	4.1×10^4	1.3×10^3	1.2×10^1	3.0×10^1

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station G - Glen Avenue

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
10/16/74	13	2.4×10^5	4.9×10^4	1.6×10^6	2.6×10^5	ND	6.2×10^2
11/05/74	17	2.4×10^5	5.4×10^4	9.2×10^4	1.4×10^4	ND	$>1.1 \times 10^4$
11/12/74	19	1.7×10^5	1.7×10^5	5.2×10^5	7.0×10^3	1.3×10^1	2.6×10^3
12/16/74	23	1.3×10^4	7.9×10^3	4.3×10^5	7.9×10^2	7.9×10^1	1.33×10^2
01/06/75	27	2.4×10^5	4.9×10^4	8.4×10^4	2.4×10^4	7.8	2.45×10^1
01/11/75	28	2.8×10^5	4.0×10^4	2.4×10^5	1.7×10^3	1.5×10^2	7.78
01/13/75	29	3.5×10^4	2.4×10^4	1.7×10^5	1.4×10^3	1.3×10^2	1.28×10^1
01/20/75	30	7.9×10^3	1.4×10^3	3.8×10^4	1.3×10^2	1.2×10^2	1.28×10^1
02/05/75	33	5.4×10^4	3.3×10^3	3.4×10^4	ND	9.3×10^1	2.39×10^1
02/23/75	35	7.9×10^4	7.9×10^4	8.3×10^5	1.1×10^3	1.1×10^3	6.12×10^2
03/12/75	37	3.3×10^4	1.7×10^4	2.3×10^5	3.4×10^2	LSL	2.39×10^1
04/03/75	40	1.3×10^5	3.3×10^4	1.2×10^6	2.78×10^3	3.6	LSL
04/15/75	42	2.4×10^5	1.3×10^5	9.2×10^5	9.2×10^3	LSL	7.8
05/01/75	44	1.3×10^5	2.2×10^4	6.8×10^5	1.7×10^3	LSL	2.6×10^1
05/06/75	45	1.4×10^5	2.3×10^5	2.8×10^6	3.5×10^3	LSL	1.7×10^1
06/10/75	49	4.6×10^4	1.7×10^4	3.7×10^5	3.5×10^2	5.6	1.1×10^1
06/30/75	51	1.6×10^6	1.7×10^5	ND	7.9×10^3	2.6×10^1	1.2×10^1
07/10/75	53	ND	ND	ND	ND	ND	ND
07/14/75	54	7.9×10^5	2.3×10^5	9.8×10^5	3.3×10^3	1.1×10^1	5.0
07/27/75	56	9.4×10^5	2.3×10^5	5.2×10^6	1.6×10^4	6.1	5.0
08/06/75	58	$>1.6 \times 10^5$	5.4×10^4	7.3×10^5	3.5×10^3	ND	2.1×10^1
08/13/75	59	1.4×10^6	2.2×10^5	4.6×10^6	5.6×10^3	LSL	1.1×10^1
09/12/75	62	$>1.6 \times 10^6$	1.6×10^6	4.8×10^6	2.1×10^4	9.3	5.2×10^1
09/18/75	64	1.7×10^6	4.9×10^5	9.3×10^5	1.4×10^3	LSL	LSL
Geom. Mean		2.4×10^5	8.1×10^4	6.6×10^5	3.3×10^3	1.4×10^1	2.4×10^1

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station H - Howard Park

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
10/16/74	13	1.7×10^5	4.9×10^4	1.5×10^5	5.4×10^5	ND	6.2×10^2
11/05/74	17	3.5×10^6	7.0×10^4	3.2×10^5	1.7×10^4	9.2×10^2	1.4×10^3
11/12/74	19	4.9×10^3	2.3×10^3	1.0×10^3	1.7×10^4	1.7×10^1	3.5×10^1
12/16/74	23	3.5×10^6	1.1×10^6	7.2×10^5	7.0×10^3	1.3×10^2	1.50×10^1
01/06/75	27	3.5×10^6	7.9×10^5	1.4×10^5	1.8×10^3	3.5×10^2	1.33×10^1
01/11/75	28	5.4×10^5	4.9×10^4	1.7×10^5	1.1×10^4	4.6×10^2	3.89
01/13/75	29	2.4×10^6	2.4×10^6	3.5×10^5	2.8×10^4	1.5×10^2	$>1.33 \times 10^3$
01/20/75	30	7.9×10^6	2.3×10^5	3.7×10^5	2.4×10^4	1.6×10^1	6.12×10^2
02/05/75	33	ND	ND	3.0×10^3	1.8×10^3	9.1	6.12×10^2
02/23/75	35	1.7×10^6	7.9×10^5	8.7×10^5	1.3×10^4	2.1×10^2	1.72×10^1
03/12/75	37	7.9×10^5	2.2×10^5	2.4×10^5	4.6×10^3	4.6×10^2	2.56×10^2
04/03/75	40	2.8×10^7	2.9×10^6	1.4×10^6	$>1.6 \times 10^4$	9.3	$\geq 1.334 \times 10^3$
04/15/75	42	2.4×10^6	2.4×10^6	7.0×10^5	4.0×10^3	1.1×10^1	1.2×10^3
05/01/75	44	5.4×10^5	2.4×10^5	5.1×10^5	2.4×10^3	9.3×10^1	2.7×10^2
05/06/75	45	2.2×10^6	4.0×10^4	8.1×10^5	3.5×10^3	4.6×10^2	1.2×10^3
06/11/75	49	ND	ND	ND	ND	ND	ND
06/30/76	51	3.5×10^6	2.4×10^6	ND	1.41×10^4	8.2	1.3×10^3
07/10/75	53	7.9×10^6	8.0×10^5	6.7×10^5	1.41×10^2	LSL	1.1×10^1
07/14/75	54	3.3×10^5	2.3×10^5	1.7×10^5	3.5×10^2	2.2×10^1	1.3×10^2
07/27/75	56	2.8×10^6	1.7×10^6	1.2×10^6	8.0×10^1	1.7×10^1	1.3×10^3
08/06/75	58	3.5×10^5	4.1×10^4	4.9×10^5	1.7×10^3	1.8	8.3×10^1
08/13/75	59	7.0×10^6	1.3×10^6	1.7×10^5	3.7×10^3	1.8	1.3×10^3
09/12/75	62	3.5×10^6	7.0×10^5	7.1×10^5	9.2×10^4	1.3×10^1	6.1×10^2
09/18/75	64	5.6×10^4	3.5×10^5	6.3×10^4	3.1×10^3	5.5	5.0
Geom. Mean		1.2×10^6	4.5×10^5	2.4×10^5	5.2×10^3	3.6×10^1	1.4×10^2

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station K - Jones Falls Storm Drain

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
10/16/74	13	$\geq 1.6 \times 10^6$	$\geq 1.6 \times 10^6$	2.7×10^5	7.0×10^4	ND	3.3
11/05/74	17	$\geq 2.4 \times 10^6$	1.3×10^4	4.6×10^5	1.7×10^3	2.7×10^2	9.4×10^1
11/12/74	19	5.4×10^6	3.5×10^6	8.0×10^5	1.6×10^5	1.6×10^3	1.3×10^2
12/16/74	23	1.7×10^5	4.9×10^4	3.4×10^5	3.3×10^3	1.7×10^2	5.00
01/06/75	27	3.3×10^4	3.3×10^4	1.6×10^5	9.4×10^2	7.0×10^1	6.12
01/11/75	28	1.6×10^6	1.1×10^5	7.9×10^5	5.4×10^3	1.5×10^1	2.39×10^1
01/13/75	29	9.2×10^4	9.2×10^4	2.5×10^5	1.1×10^4	1.4×10^1	1.33×10^2
01/20/75	30	3.3×10^5	1.7×10^5	6.9×10^4	9.2×10^3	1.5×10^2	1.33×10^3
02/05/75	33	1.7×10^5	5.0×10^3	1.4×10^5	1.6×10^6	4.6×10^2	1.67
02/23/75	35	1.7×10^6	7.0×10^5	7.5×10^5	5.4×10^3	2.4×10^2	LSL
03/12/75	37	1.4×10^5	9.4×10^4	1.3×10^5	1.1×10^3	9.3×10^1	2.22
04/03/75	40	1.3×10^6	4.9×10^5	2.4×10^5	4.6×10^3	4.6×10^2	1.17×10^1
04/15/75	42	1.3×10^6	1.3×10^6	1.8×10^5	1.4×10^3	1.6×10^1	2.6×10^1
05/01/75	44	1.1×10^6	1.3×10^5	3.4×10^5	2.4×10^3	1.5×10^2	4.1×10^1
05/06/75	45	7.9×10^4	3.3×10^4	2.5×10^5	9.2×10^3	9.3×10^1	1.0×10^2
06/11/75	49	7.9×10^4	3.5×10^4	5.5×10^5	2.8×10^3	3.7	ND
06/30/75	51	1.6×10^6	3.5×10^5	ND	1.09×10^4	2.1×10^1	1.3×10^3
07/10/75	53	3.3×10^5	3.3×10^5	3.7×10^5	2.6×10^3	6.8	6.1×10^2
07/14/75	54	1.3×10^6	4.9×10^5	8.3×10^5	3.1×10^3	3.4×10^1	2.1×10^1
07/27/75	56	1.1×10^5	4.9×10^4	7.2×10^4	1.8×10^3	1.0×10^1	3.9
08/06/75	58	9.2×10^4	2.4×10^4	5.5×10^5	3.3×10^3	1.8	1.7
08/13/75	59	2.2×10^5	4.9×10^4	4.7×10^4	6.4×10^3	1.8	1.3×10^2
09/12/75	62	9.2×10^5	5.4×10^5	2.9×10^5	1.1×10^4	1.1×10^1	6.1×10^2
09/18/75	64	ND	ND	7.6×10^5	2.1×10^4	1.8	1.7×10^1
Geom. Mean		2.9×10^5	1.2×10^5	2.8×10^5	6.6×10^3	4.0×10^1	2.5×10^1

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station L - Bush Street

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
10/16/74	13	2.4×10^5	4.9×10^4	3.8×10^5	7.5×10^4	ND	1.8×10^1
11/05/74	17	3.5×10^4	1.7×10^3	5.0×10^3	1.1×10^2	7.9×10^1	6.7
11/12/74	19	5.4×10^4	7.9×10^3	4.3×10^3	1.7×10^3	7.0×10^1	8.3
12/16/74	23	1.1×10^5	7.0×10^4	1.2×10^6	2.3×10^3	2.3×10^1	8.34
01/06/74	27	1.1×10^5	4.9×10^4	6.5×10^5	4.9×10^2	9.3	1.56×10^1
01/11/75	28	9.2×10^5	1.1×10^4	1.4×10^5	2.2×10^3	7.3	3.89
01/13/75	29	1.1×10^6	2.6×10^5	3.5×10^5	1.3×10^4	4.3×10^1	1.33×10^2
01/20/75	30	$\geq 2.4 \times 10^6$	$\geq 2.4 \times 10^6$	7.6×10^5	3.3×10^2	4.6×10^2	1.50×10^1
02/05/75	33	5.4×10^6	1.7×10^4	2.4×10^5	ND	4.3×10^2	5.00
02/23/75	35	7.9×10^3	7.9×10^3	2.5×10^3	1.7×10^2	LSL	LSL
03/12/75	37	5.4×10^5	5.4×10^4	9.4×10^5	1.3×10^3	9.3×10^1	2.56×10^2
04/03/75	40	9.4×10^5	7.0×10^5	1.2×10^6	9.2×10^3	LSL	2.06×10^1
04/15/75	42	2.21×10^5	1.41×10^5	3.6×10^5	1.10×10^4	1.5×10^1	5.1×10^2
05/01/75	44	3.3×10^5	8.0×10^4	8.5×10^5	5.4×10^2	3.6	5.1×10^2
05/06/75	45	3.5×10^5	2.3×10^4	1.9×10^6	3.5×10^3	2.4×10^2	5.1×10^2
06/10/75	49	7.9×10^4	9.4×10^3	5.3×10^5	3.5×10^3	2.9×10^1	8.3
06/30/75	51	2.4×10^6	1.6×10^6	ND	2.21×10^4	4.0	1.3×10^3
07/10/75	53	7.9×10^5	4.9×10^5	8.4×10^5	3.45×10^3	ND	3.9
07/14/75	54	1.1×10^6	3.1×10^5	5.2×10^5	3.8×10^1	9.2	5.0
07/27/75	56	3.5×10^5	7.0×10^4	3.8×10^6	2.2×10^3	5.5	LSL
08/06/75	58	1.6×10^5	1.4×10^4	4.1×10^5	4.9×10^3	1.8	1.8×10^1
08/13/75	59	$>1.6 \times 10^6$	1.7×10^5	7.2×10^5	4.5×10^3	LSL	1.3×10^3
09/12/75	62	5.4×10^5	3.5×10^5	1.1×10^6	2.2×10^4	1.4×10^1	1.3×10^3
09/18/75	64	1.7×10^6	3.3×10^5	1.4×10^6	7.8×10^2	LSL	1.2×10^2
Geom. Mean		3.8×10^5	8.3×10^4	5.6×10^5	2.0×10^3	1.2×10^2	3.0×10^1

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX B. Levels of Bacteria, Station M - Northwood

Date	Run Number	Total Coliform MPN/100ml	Fecal Coliform MPN/100ml	Fecal Streptococci no./100ml	*Pseudomonas aeruginosa* MPN/100ml	*Staph. aureus* MPN/100ml	*Salmonella* MPN/10 liters
12/16/74	23	2.4×10^4	1.3×10^4	1.0×10^5	1.8×10^2	2.3×10^1	LSL
01/06/75	27	3.3×10^4	7.9×10^3	1.7×10^3	4.9×10^2	2.0	LSL
01/11/75	28	2.4×10^3	8.0×10^1	1.8×10^4	1.7×10^3	7.0	5.00
01/13/75	29	1.7×10^5	7.9×10^4	ND	3.5×10^3	4.3×10^1	LSL
01/20/75	30	4.6×10^3	4.0×10^2	4.4×10^4	2.3×10^2	4.6×10^2	LSL
02/05/75	33	1.7×10^4	$<2.0 \times 10^2$	6.0×10^3		4.3×10^1	7.78
02/23/75	35	5.4×10^4	1.3×10^4	3.6×10^4	1.1×10^3	LSL	LSL
03/12/75	37	1.3×10^3	2.0×10^2	1.7×10^4	3.5×10^2	9.3×10^1	2.22
04/03/75	40	3.48×10^4	1.4×10^3	3.1×10^4	9.2×10^3	LSL	LSL
04/15/75	42	4.6×10^4	2.0×10^3	1.2×10^4	7.0×10^2	1.5×10^1	7.8
05/01/75	44	1.7×10^4	1.1×10^4	4.1×10^4	2.8×10^2	4.0	4.3×10^1
05/06/75	45	1.3×10^4	2.0×10^2	1.7×10^5	1.7×10^1	2.4×10^2	LSL
06/11/75	49	5.4×10^4	1.3×10^2	3.0×10^5	3.4×10^2	2.4×10^2	LSL
06/30/75	51	1.1×10^5	4.0×10^4	ND	7.9×10^3	4.0	1.7
07/10/75	53	ND	ND	ND	ND	ND	ND
07/14/75	54	1.4×10^5	3.3×10^4	1.1×10^5	<8.0	LSL	2.6×10^2
07/27/75	56	7.0×10^4	2.3×10^4	3.7×10^5	1.1×10^4	LSL	1.1×10^1
08/06/75	58	3.5×10^4	2.4×10^4	1.5×10^5	2.3×10^3	LSL	5.2×10^1
08/13/75	59	3.5×10^4	3.5×10^4	1.1×10^4	1.7×10^4	LSL	LSL
09/12/75	62	1.4×10^5	9.2×10^4	1.1×10^5	2.6×10^3	1.4×10^1	5.2×10^1
09/18/75	64	3.5×10^5	2.4×10^5	2.0×10^5	1.2×10^3	LSL	3.3
Geom. Mean		3.8×10^4	6.9×10^3	5.0×10^4	5.9×10^2	1.2×10^1	5.7

ND - No Data
LSL - Lower sensitivity limit of the assay. No microorganisms recovered.

APPENDIX C. Levels of Enteric Viruses

Station A
Raw Sewage

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
09/16/74	8	1.4×10^3	1.3×10^3	2.1×10^1	1.4×10^3
09/23/74	9	1.3×10^3	1.3×10^3	0	1.0×10^3
10/28/74	15	1.0×10^3	2.3×10^3	0	1.1×10^3
01/20/75	30	8.5×10^2	1.1×10^3	0	6.0×10^2
03/03/75	36	2.7×10^3	1.6×10^3	0	3.0×10^3
03/17/75	38	$<3.2 \times 10^1$	$<3.2 \times 10^1$	0	0
03/31/75	39	4.0×10^4	1.3×10^3	0	2.7×10^4
05/12/75	46	1.3×10^3	1.3×10^3	0	5.0×10^2
06/10/75	48	1.3×10^3	0	1.3×10^2	1.3×10^3
07/07/75	52	8.5×10^3	0	1.3×10^3	7.2×10^3
07/21/75	55	1.3×10^4	4.0×10^3	1.3×10^2	9.9×10^3
08/04/75	57	4.0×10^4	$<3.2 \times 10^1$	0	6.6×10^3
08/18/75	60	2.2×10^3	8.5×10^1	0	1.3×10^3
09/02/75	61	0	0	0	0
09/16/75	63	4.0×10^3	$<3.2 \times 10^1$	0	4.0×10^3

Station B
Herring Run

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	Pfu/10 liter
01/20/75	30	1.3×10^2	0	0	4.0×10^1
03/03/75	36	1.3×10^2	4.0×10^2	0	2.5×10^2
03/17/75	38	1.1×10^2	0	0	1.1×10^2
03/31/75	39	1.1×10^2	2.1×10^1	0	1.1×10^2
05/12/75	46	0	3.2×10^1	8.5×10^1	1.0×10^1
06/10/75	48	1.3×10^2	0	8.5×10^1	1.3×10^2
07/07/75	52	2.2×10^3	0	0	2.4×10^2
07/21/75	55	0	0	1.3×10^2	1.7×10^2
08/04/75	57	0	3.2×10^1	$<3.2 \times 10^1$	0
09/02/75	61	0	0	0	0
09/16/75	63	0	0	0	0

Station C
Jones Falls

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/20/75	30	1.3×10^3	0	1.3×10^2	8.9×10^2
03/03/75	36	1.3×10^3	8.5×10^2	0	8.5×10^2
03/17/75	38	0	0	0	0
03/31/75	39	1.3×10^3	1.3×10^2	0	1.0×10^2
05/12/75	46	1.1×10^2	1.4×10^2	0	1.2×10^2
06/10/75	48	0	0	0	1.7×10^2
07/07/75	52	1.1×10^2	0	0	5.0×10^1
07/21/75	55	2.7×10^2	4.0×10^2	1.3×10^2	3.2×10^2
08/04/75	57	8.5×10^1	8.5×10^1	0	2.0×10^1
08/18/75	60	1.3×10^2	0	0	1.5×10^2
09/02/75	61	1.3×10^2	0	0	3.0×10^1
09/16/75	63	0	0	0	0

Station D
Gwynns Falls

Date	Run no.	TCID50/ 10 liter BGM	HEp-2	HEL	Pfu/10 liter
09/16/74	8	8.5×10^1	1.3×10^2	1.3×10^2	6.0×10^1
09/23/74	9	1.3×10^2	$>4.0 \times 10^5$	$>4.0 \times 10^5$	3.1×10^5
10/28/74	15	1.3×10^5	1.3×10^4	2.2×10^4	3.7×10^4
01/20/75	30	8.5×10^1	2.3×10^2	1.3×10^2	7.0×10^1
03/03/75	36	1.3×10^2	1.7×10^2	$<3.2 \times 10^1$	1.0×10^2
03/17/75	38	0	1.3×10^2	0	3.0×10^1
03/31/75	39	8.5×10^1	1.3×10^2	$<3.2 \times 10^1$	6.0×10^1
05/12/75	46	1.3×10^2	1.3×10^2	0	9.0×10^1
06/10/75	48	0	0	0	0
07/07/75	52	0	0	0	0
07/21/75	55	6.8×10^1	0	$<3.2 \times 10^1$	1.0×10^1
08/04/75	57	3.2×10^1	-	0	5.0×10^1
08/18/75	60	3.2×10^1	0	0	0
09/16/75	63	0	0	0	0

APPENDIX C. Levels of Enteric Viruses

Station E
Loch Raven Reservoir

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
03/17/75	38	1.3×10^2	0	0	0
03/31/75	39	1.3×10^2	1.3×10^2	1.3×10^2	8.0×10^1
05/12/75	46	1.3×10^2	0	0	1.3×10^2
06/10/75	48	1.3×10^2	0	0	2.0×10^1
08/04/75	57	0	1.3×10^2	0	0
09/02/75	61	0	0	0	0
09/16/75	63	0	0	0	0

Station F
Stoney Run

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/07/75	27	1.3×10^2	4.0×10^4	1.3×10^3	1.4×10^3
02/23/75	35	4.6×10^3	2.3×10^3	1.3×10^2	5.3×10^3
03/12/75	37	1.3×10^2	0	1.3×10^3	1.3×10^3
04/16/75	42	1.3×10^3	1.3×10^3	1.3×10^2	8.3×10^2
05/01/75	44	1.3×10^2	0	0	6.0×10^1
06/12/75	49	1.3×10^2	0	0	0
06/30/75	51	8.5×10^1	0	3.2×10^1	1.0×10^1
07/11/75	53	1.3×10^2	0	0	5.0×10^1
07/25/75	56	1.3×10^2	0	0	1.1×10^2
08/13/75	59	1.3×10^2	0	0	1.8×10^2
09/12/75	62	1.3×10^2	0	0	1.3×10^2

Station G
Glen Avenue

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/07/75	27	4.0×10^3	1.3×10^2	$<3.2 \times 10^1$	6.4×10^2
02/05/75	33	1.0×10^3	1.3×10^2	1.3×10^2	1.0×10^3
02/23/75	35	$>1.0 \times 10^3$	2.3×10^3	2.6×10^2	9.6×10^2
03/12/75	37	1.3×10^2	0	0	3.0×10^1
04/16/75	42	1.3×10^3	1.3×10^3	1.4×10^4	1.2×10^3
05/01/75	44	1.3×10^2	0	0	6.0×10^1
06/12/75	49	1.3×10^2	0	0	6.0×10^1
06/30/75	51	1.4×10^3	8.5×10^1	1.3×10^2	1.4×10^3
07/11/75	53	$<3.2 \times 10^1$	8.5×10^1	0	-
07/25/75	56	5.6×10^1	0	0	5.0×10^1
08/13/75	59	0	0	0	0
09/12/75	62	0	0	$<3.2 \times 10^1$	0

Station H
Howard Park

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/07/75	27	2.2×10^3	1.3×10^2	0	2.4×10^2
02/05/75	33	1.3×10^3	1.6×10^2	1.3×10^2	1.6×10^3
02/23/75	35	$>1.0 \times 10^3$	$>1.0 \times 10^3$	1.3×10^3	1.3×10^3
03/12/75	37	1.3×10^3	8.5×10^1	$<3.2 \times 10^1$	6.3×10^2
04/16/75	42	4.0×10^3	8.5×10^2	$<3.2 \times 10^1$	2.7×10^3
05/01/75	44	1.3×10^2	-	-	1.8×10^2
06/12/75	49	-	-	-	
06/30/75	51	2.3×10^2	$<3.2 \times 10^1$	8.5×10^1	2.3×10^2
07/04/75	53	$<3.2 \times 10^1$	$<3.2 \times 10^1$	0	1.0×10^1
07/25/75	56	$>1.0 \times 10^3$	$>1.0 \times 10^3$	$<3.2 \times 10^1$	toxic
08/13/75	59	8.5×10^1	$<3.2 \times 10^1$	0	7.0×10^1
09/12/75	62	1.3×10^2	1.3×10^2	0	8.0×10^1

APPENDIX C. Levels of Enteric Viruses

Station K
Jones Falls Storm Drain

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/07/75	27	1.0×10^3	2.3×10^2	0	1.1×10^3
02/05/75	33	$>1.0 \times 10^3$	8.5×10^1	1.3×10^2	1.2×10^3
02/23/75	35	$>1.0 \times 10^3$	$>1.0 \times 10^3$	$>1.0 \times 10^3$	0
03/12/75	37	1.3×10^2	1.3×10^2	1.1×10^2	1.5×10^2
04/16/75	42	1.9×10^2	1.1×10^2	0	2.0×10^1
05/01/75	44	1.1×10^2	0	$<3.2 \times 10^1$	8.0×10^1
06/12/75	49	1.3×10^2	1.3×10^2	0	5.0×10^1
06/30/75	51	2.7×10^2	1.0×10^3	0	6.1×10^2
07/11/75	53	1.3×10^2	2.1×10^1	0	1.3×10^2
07/25/75	56	-	-	-	0
08/13/75	59	0	$<3.2 \times 10^1$	1.3×10^2	1.0×10^1
09/12/75	62	0	0	0	0

Station L
Rush Street

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/07/75	27	2.6×10^2	3.2×10^1	2.3×10^2	2.5×10^2
02/05/75	33	-	5.8×10^1	0	3.7×10^2
02/23/75	35	3.2×10^2	2.1×10^2	0	4.8×10^2
03/12/75	37	3.2×10^1	3.2×10^1	1.3×10^2	0
04/16/75	42	2.1×10^1	0	0	0
05/01/75	44	0	0	0	0
06/12/75	49	0	0	0	0
06/30/75	51	7.4×10^2	1.0×10^2	$<3.2 \times 10^1$	6.0×10^2
07/11/75	53	3.2×10^1	0	0	4.0×10^1
07/25/75	56	-	-	-	0
08/13/75	59	0	0	$<3.2 \times 10^1$	0
09/12/75	62	0	0	0	0

Station M
Northwood

Date	Run no.	TCID50/10 liter BGM	HEp-2	HEL	pfu/10 liter
01/07/75	27	1.3×10^3	0	1.3×10^2	1.1×10^2
02/05/75	33	-	-	-	-
02/23/75	35	1.3×10^2	1.3×10^2	0	6.0×10^1
03/12/75	37	1.7×10^2	1.3×10^2	1.3×10^2	2.1×10^2
04/16/75	42	1.0×10^2	0	0	3.6×10^2
05/01/75	44	1.0×10^2	0	0	1.0×10^2
06/12/75	49	1.4×10^2	$<3.2 \times 10^1$	$<3.2 \times 10^1$	5.0×10^1
06/30/75	51	1.3×10^2	$<3.2 \times 10^1$		1.2×10^2
07/11/75	53	-	-	-	-
07/25/75	56	1.3×10^2	0	1.1×10^2	1.2×10^2
08/13/75	59	2.2×10^2	1.3×10^2	1.3×10^2	2.9×10^2
09/12/75	62	1.3×10^2	1.3×10^3	$>1.0 \times 10^3$	1.2×10^3

APPENDIX D. Distribution of Fecal Streptococci, Station A - Raw Sewage

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	%	*S. faecalis* var. *liquefaciens* and *symogenes* no.	%	Atypical *S. faecalis* no.	%	Enterococci no.	%	S. bovis and S. equinus no.	%	False positive no.	%
09/09/74	7	5.2×10^6	8	1	13	4	50	0	0	5	63	1	13	2	26
09/16/74	8	9.8×10^5	16	6	38	2	13	0	0	8	50	0	0	8	50
09/23/74	9	1.2×10^7	40	13	32	2	5	0	0	15	38	7	18	18	45
09/30/74	10	4.1×10^6	83	31	37	0	0	3	4	34	41	2	2	47	57
10/07/74	11	1.1×10^6	82	33	40	4	5	4	5	41	50	1	1	40	49
10/14/74	12	1.2×10^6	73	17	23	5	7	0	0	22	30	8	11	43	59
10/21/74	14	8.3×10^5	48	17	35	1	2	0	0	18	38	5	10	25	52
10/28/74	15	4.4×10^5	38	24	63	2	5	0	0	26	68	5	13	7	18
11/04/74	16	2.0×10^4	19	18	95	0	0	0	0	18	95	0	0	1	5
11/11/74	18	1.1×10^6	30	14	47	1	3	0	0	15	50	5	17	10	33
11/18/74	20	1.1×10^6	36	18	50	2	6	0	0	20	56	1	3	12	33
12/02/74	21	3.4×10^5	33	8	24	0	0	1	3	9	27	7	21	17	52
12/09/74	22	9.7×10^5	48	20	42	3	6	0	0	23	48	4	8	21	44
12/17/74	24	3.9×10^5	20	6	30	2	10	0	0	8	40	2	10	10	50
12/24/74	25	1.1×10^6	40	15	38	4	10	0	0	19	48	4	10	16	40
01/06/75	26	9.5×10^5	34	20	59	2	6	0	0	22	65	3	9	7	21
01/20/75	30	5.4×10^5	29	13	45	1	3	1	3	15	52	5	17	9	31
01/27/75	31	4.5×10^7	32	16	50	0	0	0	0	16	50	2	6	13	41
02/03/75	32	1.1×10^6	29	10	34	1	3	0	0	11	38	3	10	14	48
02/17/75	34	1.8×10^6	18	11	61	3	17	0	0	14	78	0	0	3	17
03/03/75	36	1.4×10^6	28	13	46	1	4	0	0	14	50	3	11	11	39
03/17/75	38	2.7×10^6	5	1	20	1	20	0	0	2	40	0	0	3	60
03/31/75	39	9.4×10^5	35	17	49	0	0	0	0	17	49	1	3	17	49
04/14/75	41	1.7×10^6	46	20	43	3	7	0	0	23	50	7	15	16	35
04/28/75	43	1.6×10^6	44	15	34	4	10	1	2	20	45	3	7	21	48
05/12/75	46	2.4×10^6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
05/19/75	47	3.0×10^6	49	27	55	3	6	1	2	31	63	3	6	15	31
06/10/75	48	3.1×10^6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/10/75	48	2.3×10^7	39	23	59	3	7	0	0	26	67	1	3	12	31
06/10/75	48	6.0×10^7	47	29	62	7	15	0	0	36	77	5	11	6	13
06/24/75	50	3.8×10^5	31	13	42	1	3	1	3	15	48	4	13	12	39
07/07/75	52	3.3×10^6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/21/75	55	9.9×10^5	49	11	22	0	0	0	0	11	22	5	10	27	55
08/04/75	57	8.0×10^5	50	19	38	0	0	0	0	19	38	11	22	13	26
08/18/75	60	1.3×10^6	50	13	26	0	0	0	0	13	26	17	34	20	40
09/02/75	61	1.4×10^6	49	24	49	2	4	0	0	26	53	10	20	13	27
09/16/75	63	9.5×10^5	49	30	61	0	0	2	2	32	65	2	2	15	31
Number				34		34		34		34		34		34	
Mean				43.4		6.7		0.4		50.5		9.9		37	
Standard deviation				15.8		9.2		.92		15.7		7.7		14.7	
Positive samples, %				100		73.5		23.5		100		88.2		100	

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station B - Herring Run

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	%	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	%	Atypical *S. faecalis* no.	%	Enterococci no.	%	S. bovis and S. equinus no.	%	False positive no.	%
09/09/74	7	1.3×10^3	5	1	20	1	20	1	20	3	60	0	0	2	40
09/16/74	8	8.0×10^2	16	8	50	0	0	0	0	8	50	0	0	8	50
09/23/74	9	1.6×10^4	36	22	61	4	11	0	0	26	72	0	0	10	28
09/30/74	10	1.0×10^3	6	1	17	0	0	0	0	1	17	0	0	5	83
10/07/74	11	4.5×10^2	67	53	79	1	1	0	0	54	81	0	0	13	19
10/14/74	12	7.5×10^2	16	8	50	1	6	0	0	9	56	0	0	7	44
10/21/74	14	4.5×10^2	18	11	61	1	6	0	0	12	67	2	11	4	22
10/28/74	15	3.0×10^2	10	6	60	0	0	0	0	6	60	0	0	4	40
11/04/74	16	1.9×10^2	34	8	24	0	0	0	0	8	24	0	0	26	76
11/11/74	18	2.0×10^2	20	16	80	2	10	0	0	18	90	0	0	2	10
11/18/74	20	5.3×10^2	26	14	54	7	27	0	0	21	81	0	0	5	19
12/02/74	21	4.0×10^4	35	16	46	1	3	0	0	17	49	5	14	11	31
12/09/74	22	2.4×10^3	37	17	46	0	0	0	0	17	46	9	24	9	24
12/17/74	24	3.8×10^3	19	2	11	2	11	1	5	5	26	5	26	8	42
12/24/74	25	1.9×10^3	18	7	39	1	6	1	6	9	50	5	27	4	22
01/06/75	26	5.6×10^2	40	18	45	6	15	0	0	24	60	7	18	8	20
01/20/75	30	1.3×10^4	31	21	68	1	3	0	0	22	71	2	6	7	23
01/27/75	31	3.9×10^3	20	0	0	2	10	0	0	2	10	4	20	14	70
02/03/75	32	2.3×10^3	23	5	22	3	13	1	4	9	39	5	22	9	39
02/17/75	34	1.1×10^4	7	4	57	1	14	0	0	5	71	0	0	1	14
03/03/75	36	2.8×10^3	25	6	24	1	4	0	0	7	28	16	64	1	4
03/17/75	38	2.0×10^4	5	4	80	0	0	0	0	4	80	0	0	1	20
03/31/75	39	4.1×10^2	47	30	64	1	2	0	0	31	66	2	4	14	30
04/14/75	41	4.2×10^2	46	23	50	1	2	2	4	26	57	15	33	5	11
04/28/75	43	3.1×10^2	49	18	37	4	8	0	0	22	45	1	2	26	53
05/12/75	46	2.3×10^2	39	30	77	1	3	0	0	31	79	0	0	8	21
05/19/75	47	3.9×10^2	50	19	38	19	38	1	2	39	78	1	2	10	20
06/10/75	48	8.0×10^3	46	12	26	2	4	1	2	15	33	1	2	30	65
06/10/75	48	8.5×10^2	49	41	84	5	10	0	0	46	94	0	0	3	6
06/10/75	48	3.7×10^3	49	25	51	5	10	0	0	30	61	14	29	5	10
06/24/75	50	2.1×10^3	50	35	70	5	10	0	0	40	80	0	0	10	20
07/07/75	52	2.7×10^3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/21/75	55	1.4×10^4	50	31	62	0	0	0	0	31	62	0	0	11	22
08/04/75	57	2.4×10^2	44	1	2	0	0	1	2	2	5	0	0	42	95
08/18/75	60	3.5×10^3	50	8	16	0	0	0	0	8	16	0	0	42	84
09/02/75	61	2.5×10^3	44	32	73	0	0	1	2	33	75	2	5	9	20
09/16/75	63	2.7×10^3	49	27	55	0	0	1	2	28	57	2	4	19	39
Number					36		36		36		36		36		36
Mean					47.2		6.9		1.4		55.4		8.7		34.3
Standard deviation					23.2		8.4		3.6		23.4		14.1		23.7
Positive samples, %					97.2		69.4		31.6		100		50		100

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station C - Jones Falls

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium*		*S. faecalis* var. *liquefaciens* and *symogenes*		Atypical *S. faecalis*		Enterococci		S. bovis and S. equinus		False positive	
				no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
09/09/74	7	2.3×10^4	6	1	17	3	50	0	0	4	67	0	0	2	33
09/16/74	8	1.5×10^4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/23/74	9	3.2×10^4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/30/74	10	5.3×10^4	40	25	63	0	0	0	0	25	63	0	0	15	38
10/07/74	11	1.3×10^4	63	36	57	7	11	2	3	45	71	8	13	10	16
10/14/74	12	1.4×10^4	68	22	32	4	6	0	0	26	54	3	4	39	57
10/21/74	14	5.9×10^4	40	33	83	0	0	0	0	33	83	1	3	6	15
10/28/74	15	2.3×10^4	40	18	45	3	8	0	0	21	53	3	8	16	40
11/04/74	16	3.2×10^4	18	3	17	0	0	0	0	3	17	6	33	9	50
11/11/74	18	3.6×10^4	35	10	29	3	9	0	0	13	37	1	3	21	60
11/18/74	20	2.6×10^3	25	15	60	5	20	0	0	20	80	2	8	3	12
12/02/74	21	7.6×10^4	36	18	50	4	11	1	3	23	64	2	6	10	28
12/09/74	22	2.6×10^4	26	10	38	0	0	0	0	10	38	4	15	9	35
12/17/74	24	4.2×10^4	19	9	47	0	0	0	0	9	47	3	16	7	37
12/24/74	25	7.1×10^3	37	20	54	3	8	0	0	23	62	2	5	12	32
01/06/75	26	4.0×10^3	41	27	66	1	2	0	0	28	68	5	12	8	20
01/20/75	30	1.1×10^4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/27/75	31	2.4×10^3	34	11	32	5	15	0	0	16	47	3	9	15	44
02/03/75	32	3.3×10^3	30	9	30	3	10	0	0	12	40	1	3	16	53
02/17/75	34	3.1×10^4	9	8	89	0	0	0	0	8	89	0	0	1	11
03/03/75	36	4.2×10^3	33	5	15	14	42	0	0	19	58	1	3	13	39
03/17/75	38	7.3×10^4	7	6	86	0	0	0	0	6	86	0	0	1	14
03/31/75	39	3.3×10^4	43	16	37	6	14	0	0	22	51	3	7	10	23
04/14/75	41	4.6×10^3	49	25	51	6	12	0	0	31	63	0	0	18	37
04/28/75	43	3.5×10^4	48	14	29	1	2	0	0	15	31	0	0	33	69
05/12/75	46	6.1×10^3	49	5	10	0	0	0	0	5	10	0	0	44	90
05/19/75	47	4.7×10^3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/10/75	48	1.8×10^4	48	23	48	1	2	0	0	24	50	6	13	18	38
06/10/75	48	5.7×10^3	46	34	74	0	0	0	0	34	74	9	20	3	7
06/10/75	48	1.5×10^4	49	41	84	6	12	0	0	47	96	0	0	1	2
06/24/75	50	8.5×10^3	50	44	88	3	6	0	0	47	94	1	2	2	4
07/07/75	52	5.1×10^4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/21/75	55	1.3×10^4	50	18	36	0	0	0	0	18	36	17	34	13	26
08/04/75	57	2.0×10^3	35	1	3	0	0	5	14	6	17	0	0	29	83
08/18/75	60	6.7×10^3	50	10	20	0	0	0	0	10	20	13	26	26	52
09/02/75	61	7.3×10^3	50	30	60	7	14	0	0	37	74	1	2	11	22
09/16/75	63	4.9×10^3	50	34	68	0	0	0	0	34	68	3	6	12	24
Number					32		32		32		32		32		32
Mean					47.4		7.9		0.6		56.5		7.8		34.7
Standard deviation					24.4		11.6		2.5		23.0		9.4		21.6
Positive samples, %					100		59.4		9.4		100		71.9		100

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station D - Gwynns Falls

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	*S. faecalis* and *S. faecium* %	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	*S. faecalis* var. *liquefaciens* and *zymogenes* %	Atypical *S. faecalis* no.	Atypical *S. faecalis* %	Enterococci no.	Enterococci %	S. bovis and S. equinus no.	S. bovis and S. equinus %	False positive no.	False positive %
09/09/74	7	1.7×10^3	4	0	0	2	50	0	0	2	50	0	0	2	50
09/16/74	8	2.3×10^4	40	20	50	3	8	3	8	26	65	2	5	12	30
09/23/74	9	5.5×10^4	33	20	61	5	15	0	0	25	76	0	0	8	24
09/30/74	10	8.5×10^3	19	6	32	1	5	1	5	8	42	0	0	11	58
10/07/74	11	3.8×10^3	60	27	45	5	8	0	0	32	53	4	7	24	40
10/14/74	12	3.0×10^2	9	2	22	0	0	0	0	2	22	0	0	7	77
10/21/74	14	1.6×10^3	7	5	71	0	0	0	0	5	71	0	0	2	29
10/28/74	15	$<1.0 \times 10^2$	3	3	100	0	0	0	0	3	100	0	0	0	0
11/04/74	16	1.2×10^2	24	13	54	0	0	0	0	13	54	1	4	10	42
11/11/74	18	2.1×10^2	21	19	90	2	10	0	0	21	100	0	0	0	0
11/18/74	20	1.2×10^2	24	16	67	2	8	1	4	19	79	0	0	5	21
12/02/74	21	$>1.0 \times 10^5$	26	15	58	3	12	0	0	18	69	1	4	6	23
12/09/74	22	2.4×10^4	22	16	73	1	5	0	0	17	77	1	5	4	19
12/17/74	24	1.0×10^5	26	9	35	1	4	0	0	10	38	3	12	13	50
12/24/74	25	6.0×10^2	12	1	8	0	0	0	0	1	8	2	17	8	67
01/06/75	26	5.1×10^3	25	9	36	0	0	0	0	9	36	11	44	4	16
01/20/75	30	4.5×10^4	31	4	13	1	3	0	0	5	16	6	19	20	65
01/27/75	31	7.0×10^2	12	2	17	0	0	0	0	2	17	0	0	10	83
02/03/75	32	$<2.0 \times 10^2$	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
02/17/75	34	2.2×10^3	11	7	64	1	9	0	0	8	73	0	0	3	27
03/03/75	36	2.4×10^5	27	1	4	0	0	0	0	1	4	9	33	17	63
03/17/75	38	1.9×10^4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
03/31/75	39	3.4×10^4	42	14	33	17	40	0	0	31	74	4	10	7	17
04/14/75	41	5.5×10^2	9	4	44	1	11	0	0	5	56	4	44	0	0
04/28/75	43	6.0×10^2	10	1	10	0	0	0	0	1	10	0	0	9	90
05/12/75	46	3.0×10^2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
05/19/75	47	1.0×10^2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/10/75	48	3.6×10^3	50	39	78	4	8	0	0	43	86	5	10	2	4
06/10/75	48	1.8×10^3	44	28	64	8	18	0	0	36	82	3	7	5	11
06/10/75	48		39	31	79	2	5	0	0	33	84	5	13	1	3
06/24/75	50	2.1×10^3	50	39	78	2	4	0	0	41	82	0	0	9	18
07/07/75	52	6.7×10^2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/21/75	55	2.8×10^4	50	36	72	0	0	0	0	36	72	0	0	14	28
08/04/75	57	4.5×10^1	8	1	12	0	0	0	0	1	12	0	0	7	88
08/18/75	60	8.3×10^2	49	24	49	0	0	0	0	24	49	0	0	25	51
09/02/75	61	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/16/75	63	3.3×10^3	50	40	80	0	0	0	0	40	80	0	0	9	18
Number					31		31		31		31		31		31
Mean					48.4		9.8		0.5		56		7.5		36
Standard deviation					27.9		9.1		1.8		28.6		12.3		27.4
Positive samples, %					96.8		58.1		9.7		100		48.4		90.3

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci Station E - Loch Raven Reservoir - Insufficient Data

APPENDIX D. Distribution of Fecal Streptococci, Station F - Stoney Run

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	*S. faecalis* and *S. faecium* %	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	*S. faecalis* var. *liquefaciens* and *zymogenes* %	Atypical *S. faecalis* no.	Atypical *S. faecalis* %	Enterococci no.	Enterococci %	S. bovis and S. equinus no.	S. bovis and S. equinus %	False positive no.	False positive %
10/16/74	13	5.3×10^2	33	9	27	2	6	0	0	11	33	2	6	20	61
11/05/74	17	9.8×10^3	49	18	37	3	6	1	2	22	45	6	12	21	43
11/12/74	19	8.4×10^3	42	26	62	0	0	1	2	27	64	3	7	12	29
12/16/74	23	2.4×10^5	21	3	14	4	19	0	0	7	33	0	0	14	66
01/06/75	27	1.1×10^5	41	1	2	1	2	0	0	2	4	27	66	11	27
01/11/75	28	1.9×10^5	31	28	90	0	0	0	0	28	90	0	0	3	10
01/13/75	29	3.1×10^4	39	6	15	0	0	0	0	6	15	7	18	26	67
01/20/75	30	2.5×10^4	34	12	35	0	0	0	0	12	35	0	0	22	65
02/05/75	33	1.7×10^4	34	4	12	6	18	0	0	10	29	10	29	14	41
02/12/75	35	8.0×10^3	33	8	24	3	9	0	0	17	52	3	9	19	58
03/12/75	37	2.4×10^4	27	11	41	6	22	0	0	17	63	0	0	8	30
04/03/75	40	2.3×10^4	21	12	57	6	29	0	0	18	86	3	14	0	0
04/15/75	42	5.6×10^4	50	3	6	2	4	0	0	5	10	27	54	18	36
05/01/75	44	6.5×10^4	45	13	29	4	9	0	0	17	38	16	36	12	27
05/06/75	45	8.0×10^4	47	7	15	1	2	0	0	8	17	16	34	23	49
06/11/75	49	3.1×10^4	50	35	70	2	4	0	0	37	74	2	4	11	22
06/30/75	51	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/10/75	53	3.0×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/14/75	54	1.9×10^5	48	23	48	1	2	0	0	24	50	0	0	24	50
07/27/75	56	4.2×10^4	50	42	84	0	0	0	0	42	84	0	0	6	12
08/06/75	58	<5.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
08/13/75	59	1.7×10^5	47	26	55	0	0	0	0	26	55	1	2	17	36
09/12/75	62	1.2×10^5	50	26	52	0	0	0	0	26	52	0	0	22	44
09/18/75	64	3.7×10^5	49	12	24	0	0	0	0	12	24	16	33	20	41
Number					21		21		21		21		21		21
Mean					38		6.3		0.2		45.4		15.4		38.8
Standard deviation					25.1		8.5		0.6		25.2		19.4		18.9
Positive samples, %					100		61.9		10.4		100		66.6		95.2

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station G - Glen Avenue

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	*S. faecalis* and *S. faecium* %	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	*S. faecalis* var. *liquefaciens* and *zymogenes* %	Atypical *S. faecalis* no.	Atypical *S. faecalis* %	Enterococci no.	Enterococci %	S. bovis and S. equinus no.	S. bovis and S. equinus %	False positive no.	False positive %
10/16/74	13	1.6×10^4	40	20	50	0	0	0	0	20	50	0	0	20	50
11/05/74	17	9.2×10^4	45	36	80	1	2	0	0	37	82	2	4	6	13
11/12/74	19	5.2×10^5	25	13	52	1	4	0	0	14	56	1	4	10	40
12/16/74	23	4.3×10^5	20	3	15	0	0	0	0	3	15	3	15	12	60
01/06/75	27	8.4×10^4	40	8	20	1	3	0	0	9	23	7	18	13	33
01/11/75	28	2.4×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/13/75	29	1.7×10^5	34	10	29	3	9	0	0	13	38	4	12	16	47
01/20/75	30	3.8×10^4	34	5	15	1	3	0	0	6	18	2	6	25	74
02/05/75	33	3.4×10^4	33	13	39	0	0	0	0	13	39	9	27	11	33
02/12/75	35	8.3×10^5	28	4	14	0	0	1	4	4	14	14	50	9	32
03/12/75	37	2.3×10^5	23	6	26	1	4	0	0	7	30	0	0	16	70
04/03/75	40	1.2×10^6	35	10	29	0	0	0	0	10	29	1	3	24	69
04/15/75	42	9.2×10^5	37	4	11	0	0	0	0	4	11	0	0	33	89
05/01/75	44	6.8×10^5	45	6	13	0	0	0	0	6	13	6	13	33	73
05/06/75	45	2.8×10^6	47	6	13	0	0	0	0	6	13	22	47	19	40
06/11/75	49	3.7×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/30/75	51	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/10/75	53	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/14/75	54	9.8×10^5	50	12	24	0	0	0	0	12	24	0	0	36	72
07/27/75	56	5.2×10^6	50	29	58	0	0	0	0	29	58	0	0	21	42
08/06/75	58	7.3×10^5	49	22	45	0	0	0	0	22	45	3	6	24	49
08/13/75	59	4.6×10^6	50	38	76	0	0	0	0	38	76	0	0	12	24
09/12/75	62	4.8×10^6	44	34	77	0	0	0	0	34	77	0	0	9	20
09/18/75	64	9.3×10^5	50	31	62	0	0	1	2	32	64	2	4	16	32
Number					20		20		20		20		20		20
Mean					37.4		1.3		0.3		38.8		10.5		48.1
Standard deviation					23.5		2.3		1.0		23.5		14.9		21.0
Positive samples, %					100		30		10		100		65		100

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station H - Howard Park

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	*S. faecalis* and *S. faecium* %	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	*S. faecalis* var. *liquefaciens* and *zymogenes* %	Atypical *S. faecalis* no.	Atypical *S. faecalis* %	Enterococci no.	Enterococci %	S. bovis and S. equinus no.	S. bovis and S. equinus %	False positive no.	False positive %
10/16/74	13	1.5×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/05/74	17	3.2×10^5	15	7	47	0	0	0	0	7	47	0	0	8	53
11/12/74	19	1.0×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12/16/74	23	7.2×10^5	40	8	20	3	8	0	0	11	28	9	23	20	50
01/06/75	27	1.4×10^5	25	3	12	1	4	0	0	4	16	8	32	11	44
01/11/75	28	1.7×10^5	26	17	65	5	19	0	0	22	85	1	4	3	12
01/13/75	29	3.5×10^5	37	13	35	2	5	0	0	15	41	6	16	16	43
01/20/75	30	3.7×10^5	32	12	38	2	6	0	0	14	44	2	6	15	47
02/05/75	33	3.0×10^3	8	3	38	1	13	0	0	4	50	0	0	3	38
02/12/75	35	8.7×10^5	34	4	12	0	0	1	3	5	15	3	9	26	76
03/12/75	37	2.4×10^5	17	6	35	0	0	0	0	6	35	1	6	10	57
04/03/75	40	1.4×10^6	28	12	43	3	11	0	0	15	54	0	0	13	46
04/15/75	42	7.0×10^5	48	8	17	9	19	1	2	18	38	8	17	22	46
05/01/75	44	5.1×10^5	48	7	15	2	4	0	0	9	19	15	31	24	50
05/06/75	45	8.1×10^5	48	9	19	2	4	0	0	11	23	20	42	17	35
06/11/75	49	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
06/30/75	51	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/10/75	53	6.7×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/14/75	54	1.7×10^5	49	16	37	0	0	0	0	16	37	20	41	13	27
07/27/75	56	1.2×10^6	50	25	50	0	0	0	0	25	50	13	26	6	12
08/06/75	58	4.9×10^5	50	17	34	0	0	0	0	17	34	9	18	24	48
08/13/75	59	1.7×10^5	50	14	28	0	0	1	2	15	30	25	50	10	20
09/12/75	62	7.1×10^5	47	23	49	0	0	0	0	23	49	2	4	22	47
09/18/75	64	6.3×10^4	49	22	45	5	10	1	2	28	59	1	2	20	41
Number					19		19		19		19		19		19
Mean					33.6		5.4		0.5		39.7		17.2		41.8
Standard deviation					14.8		6.4		1.0		17.0		15.9		15.6
Positive samples, %					100		57.9		21.1		100		84.2		100

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station K - Jones Falls Storm

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium*		*S. faecalis* var. *liquefaciens* and *zymogenes*		Atypical *S. faecalis*		Enterococci		S. bovis and S. equinus		False positive	
				no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
10/16/74	13	2.7×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/05/74	17	4.6×10^5	35	0	0	0	0	0	0	0	0	6	17	29	83
11/12/74	19	8.0×10^5	40	28	70	2	5	0	0	30	75	1	3	9	23
12/16/74	23	3.4×10^5	20	1	5	1	5	0	0	2	10	5	25	13	65
01/06/75	27	1.6×10^5	36	5	14	0	0	0	0	5	14	18	50	12	33
01/11/75	28	7.9×10^5	30	22	73	1	3	0	0	23	77	0	0	7	23
01/13/75	29	2.5×10^5	36	5	14	0	0	0	0	5	14	16	44	15	42
01/20/75	30	6.9×10^4	34	2	6	25	74	0	0	27	79	1	3	6	18
02/05/75	33	1.4×10^5	35	10	29	6	17	0	0	16	46	6	17	13	37
02/12/75	35	7.5×10^5	32	3	9	0	0	0	0	3	9	17	53	12	28
03/12/75	37	1.3×10^5	26	0	0	0	0	0	0	0	0	4	15	21	81
04/03/75	40	2.4×10^5	30	16	53	8	27	1	3	25	83	0	0	5	17
04/15/75	42	1.8×10^5	23	5	22	1	4	1	4	7	30	1	4	15	65
05/01/75	44	3.4×10^5	46	15	33	0	0	0	0	15	33	14	30	17	37
05/06/75	45	2.5×10^5	47	14	30	5	11	1	2	20	43	15	32	12	26
06/11/75	49	5.5×10^5	50	21	42	2	4	0	0	23	46	6	12	21	42
06/30/75	51	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/10/75	53	3.7×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/14/75	54	8.3×10^5	49	17	35	0	0	0	0	17	35	9	18	23	47
07/27/75	56	7.2×10^4	50	33	66	0	0	0	0	33	66	4	8	11	22
08/06/75	58	5.5×10^5	49	11	22	0	0	1	2	12	24	13	27	24	49
08/13/75	59	4.7×10^4	48	26	54	0	0	0	0	26	54	3	6	19	40
09/12/75	62	2.9×10^5	47	25	53	0	0	2	4	27	57	1	2	19	40
09/18/75	64	7.6×10^5	50	27	54	0	0	0	0	27	54	1	2	21	42
Number					21		21		21		21		21		21
Mean					32.6		7.1		0.7		40.4		17.5		41.5
Standard deviation					23.5		16.8		1.4		26.7		16.6		18.8
Positive samples, %					90.5		42.9		23.8		90.5		90.5		100

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station L - Bush Street

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	*S. faecalis* and *S. faecium* %	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	*S. faecalis* var. *liquefaciens* and *zymogenes* %	Atypical *S. faecalis* no.	Atypical *S. faecalis* %	Enterococci no.	Enterococci %	S. bovis and S. equinus no.	S. bovis and S. equinus %	False positive no.	False positive %
10/16/74	13	3.8×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
11/05/74	17	5.0×10^3	10	4	40	0	0	0	0	4	40	1	10	5	50
11/12/74	19	4.3×10^3	22	15	68	1	5	0	0	16	73	2	9	4	18
12/16/74	23	1.2×10^6	24	7	29	0	0	1	4	8	33	4	17	9	38
01/06/75	27	6.5×10^5	35	6	17	2	8	0	0	8	23	12	34	11	31
01/11/75	28	1.4×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/13/75	29	3.5×10^5	31	10	32	4	13	0	0	14	45	5	16	12	39
01/20/75	30	7.6×10^5	33	2	6	0	0	0	0	2	6	0	0	31	94
02/05/75	33	2.4×10^5	31	5	16	3	10	0	0	9	29	8	26	13	42
02/12/75	35	2.5×10^3	5	3	60	1	20	0	0	4	80	0	0	1	20
03/12/75	37	9.4×10^5	22	4	18	8	36	0	0	12	55	4	18	6	27
04/03/75	40	1.2×10^6	28	8	29	4	14	0	0	12	43	0	0	16	57
04/15/75	42	3.6×10^5	34	5	15	0	0	0	0	5	15	6	18	23	67
05/01/75	44	8.5×10^5	39	8	21	1	3	1	3	10	26	14	36	14	36
05/06/75	45	1.9×10^6	48	19	40	4	8	0	0	23	48	11	23	14	29
06/11/75	49	5.3×10^5	50	19	38	1	2	0	0	20	40	7	14	23	46
06/30/75	51	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/10/75	53	8.4×10^5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/14/75	54	5.2×10^5	49	10	20	0	0	1	2	11	22	15	31	20	41
07/27/75	56	3.8×10^6	49	24	49	0	0	0	0	24	49	11	22	13	27
08/06/75	58	4.1×10^5	49	11	22	0	0	0	0	11	22	15	31	22	45
08/13/75	59	7.2×10^5	47	14	30	0	0	0	0	14	30	16	34	17	36
09/12/75	62	1.1×10^6	48	26	54	0	0	0	0	26	54	2	4	19	40
09/18/75	64	1.4×10^6	48	25	52	0	0	3	6	28	58	2	4	18	38
Number					20		20		20		20		20		20
Mean					32.8		6.0		0.8		39.6		17.4		41.1
Standard deviation					16.9		9.2		1.7		18.9		12.1		17.1
Positive samples, %					100		50		20		100		85		100

ND - No Data

APPENDIX D. Distribution of Fecal Streptococci, Station M - Northwood

Date	Run number	Fecal streptococci no./100ml	Number of isolates tested	*S. faecalis* and *S. faecium* no.	%	*S. faecalis* var. *liquefaciens* and *zymogenes* no.	%	Atypical *S. faecalis* no.	%	Enterococci no.	%	S. bovis and S. equinus no.	%	False positive no.	%
12/16/74	23	1.0×10^5	14	7	50	0	0	0	0	7	50	1	7	3	21
01/06/75	27	1.7×10^3	27	23	85	0	0	0	0	23	85	0	0	2	7
01/11/75	28	1.8×10^4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/13/75	29	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
01/20/75	30	4.4×10^4	32	4	13	0	0	0	0	4	13	5	16	22	69
02/05/75	33	6.0×10^3	35	6	17	21	60	0	0	27	77	0	0	8	23
02/12/75	35	3.6×10^4	35	22	63	0	0	0	0	22	63	0	0	13	37
03/12/75	37	1.7×10^4	35	21	60	1	3	0	0	22	63	1	3	12	34
04/03/75	40	3.1×10^4	44	16	36	0	0	0	0	16	36	4	9	24	55
04/15/75	42	1.2×10^4	44	10	23	2	5	0	0	12	27	5	11	27	61
05/01/75	44	4.1×10^4	28	12	43	0	0	1	4	13	46	2	7	13	46
05/06/75	45	1.7×10^5	46	7	15	0	0	0	0	7	15	24	52	15	33
06/11/75	49	3.0×10^5	47	27	57	1	2	0	0	28	60	1	2	18	38
06/30/75	51	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/10/75	53	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
07/14/75	54	1.1×10^5	49	21	43	1	2	1	2	23	47	12	24	14	29
07/27/75	56	3.7×10^5	50	47	94	0	0	0	0	47	94	0	0	1	2
08/06/75	58	1.5×10^5	47	19	40	0	0	0	0	19	40	0	0	28	60
08/13/75	59	1.1×10^4	48	30	63	0	0	0	0	30	63	0	0	18	38
09/12/75	62	1.1×10^5	50	35	70	0	0	0	0	35	70	1	2	14	28
09/18/75	64	2.0×10^5	49	11	22	1	2	1	2	13	27	6	12	30	61
Number					17		17		17		17		17		17
Mean					46.7		4.4		0.47		51.5		8.5		38.1
Standard deviation					24.3		14.4		1.1		23.5		13.1		18.9
Positive samples, %					100		35.3		17.6		100		64.7		100

ND - No Data

APPENDIX E. Physical and Chemical Characteristics

Date	Run no.	Station A Raw sewage pH	Station A Raw sewage Temp °C	Station A Raw sewage Flow l/sec	Station B Herring Run pH	Station B Herring Run Temp °C	Station B Herring Run Flow l/sec	Station C Jones Falls pH	Station C Jones Falls Temp °C	Station D Gwynns Falls pH	Station D Gwynns Falls Temp °C	Station D Gwynns Falls Flow l/sec
07/17/74	1	ND	ND	7443	ND	ND	<28.3	ND	ND	ND	ND	184
07/23/74	2	ND	ND	6566	ND	ND	<28.3	ND	ND	ND	ND	.113
07/30/74	3	ND	ND	6792	ND	ND	<28.3	ND	ND	ND	ND	1217
08/05/74	4	6.9	22	6566	7.5	23	<28.3	7.7	24	7.7	13	1132
08/12/74	5	ND	ND	6566	7.7	18	<28.3	7.6	22	6.8	20	113
09/09/74	7	7.0	26	6792	7.6	19	<28.3	7.6	19	7.7	18	1132
09/16/74	8	7.0	24	7245	7.7	19	<28.3	7.7	19	7.6	18	1047
09/23/74	9	6.8	ND	6792	7.1	15	<28.3	7.6	17	7.3	17	708
09/30/74	10	ND	23	ND	ND	15	<28.3	ND	16	ND	16	849
10/07/74	11	7.4	19	6368	7.8	14	<28.3	7.9	15	7.7	14	396
10/14/74	12	7.0	22	7245	7.8	15	<28.3	7.1	16	7.7	16	311
10/16/74	13	ND	ND	ND	ND	ND		ND	ND	ND	ND	ND
10/21/74	14	6.8	19	6792	7.7	5	<28.3	7.1	8	7.1	5	368
10/28/74	15	7.4	20	6792	7.8	9	<28.3	7.8	9	7.8	9	452
11/04/74	16	6.4	22	7245	7.4	15	<28.3	7.5	16	7.6	15	340
11/11/74	18	7.2	20	8094	7.8	8	<28.3	7.8	10	7.6	7	509
11/18/74	20	7.3	19	5915	7.8	5	<28.3	7.8	8	7.6	5	623
12/02/74	21	7.2	15	10584	7.8	8	<28.3	7.6	8	7.3	8	8490
12/09/74	22	6.7	18	6368	7.2	6	<28.3	7.3	7	7.3	6	2490
12/17/74	24	7.4	18	8981	7.7	6	<28.3	7.8	6	7.1	8	15565
12/24/74	25	6.6	16	6572	7.7	6	<28.3	7.8	5	7.5	4	877
01/06/75	26	7.3	15	6792	7.6	1	<28.3	7.8	2	7.5	1	226
01/20/75	30	7.2	ND	9638	7.6	4	28.3	7.6	5	7.4	4	110
01/27/75	31	7.2	13	6615	7.6	5	<28.3	7.3	ND	7.5	3	1140
02/03/75	32	6.9	ND	11171	7.6	2	<28.3	7.8	3	7.6	1	332
02/17/75	34	6.8	ND	6566	7.4	10	<28.3	7.7	10	7.5	9	622
03/03/75	36	7.3	14	6566	7.9	3	<28.3	8.1	3	7.8	2	425
03/17/75	38	ND	14	8107	ND	5	608.5	ND	7	ND	5	2689
03/31/75	39	7.1	14	7011	7.8	ND	45.3	8.0	7	7.6	5	1274
04/14/75	41	6.5	13	6135	6.9	6	82.1	6.8	8	7.1	7	962
04/28/75	43	6.9	ND	6573	7.2	ND	48.1	7.3	13	7.2	7	1019
05/12/75	46	ND	ND	ND	ND	ND	36.8	ND	ND	ND	16	1274
05/19/75	47	ND	ND	7143	ND	ND	36.8	ND	ND	ND	18	792
06/10/75	48	6.7	20	6573	7.4	17	36.8	7.7	19	7.4	17	962
06/24/75	50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	455
07/07/75	52	7.0	ND	ND	7.7	23	170	8.0	23	7.9	ND	ND
07/14/75	54	ND	ND	ND	ND	22	ND	ND	ND	ND	ND	ND
07/21/75	55	7.0	22	7886	7.9	22	85	8.0	ND	7.8	23	821
08/04/75	57	6.9	24	7886	7.7	24	43	7.9	25	7.8	26	396
08/18/75	60	ND	ND	ND	ND	23	37	ND	23	ND	23	1019
09/02/75	61	6.9	23	6572	7.3	22	37	7.1	ND	ND	ND	ND
09/16/75	63	7.0	ND	7229	7.6	ND	28	7.6	20	7.8	ND	623

ND - No Data

APPENDIX E. Physical and Chemical Characteristics

Station E Loch Raven Reservoir				Station F Stoney Run					Station G Glen Avenue		Station H Howard Park		
Date	Run no.	pH	Temp °C	Date	Run no.	pH	Temp °C	Flow l/sec	pH	Temp °C	pH	Temp °C	Flow l/sec
03/17/75	38	ND	7	11/05/74	17	6.8	ND	340	6.8	ND	6.9	ND	ND
03/31/75	39	7.8	ND	11/12/74	19	7.8	10	47	7.2	ND	7.8	ND	ND
04/14/75	41	7.2	9	12/16/74	23	6.6	9	5094	6.7	9	6.9	ND	15565
04/28/75	43	7.0	ND	01/06/75	27	7.2	3	1307	7.2	5	7.2	4	5000
05/12/75	46	ND	ND	01/11/75	28	7.2	10	<181	7.6	13	7.6	14	0
05/19/75	47	ND	ND	01/13/75	29	ND	6	<354	ND	16	ND	8	966
06/10/75	48	7.3	19	01/20/75	30	7.4	4	<283	7.6	4	7.8	3	450
06/24/75	50	ND	ND	02/05/75	33	7.5	5	<254	7.2	4	7.5	3	0
07/07/75	52	7.5	22	02/23/75	35	7.6	11	<141	7.6	12	6.8	12	700
07/14/75	54	ND	22	03/12/75	37	ND	7	463	ND	7	ND	7	450
07/21/75	55	7.8	22	04/03/75	40	7.0	ND	ND	6.7	ND	6.3	ND	ND
08/04/75	57	7.8	24	04/15/75	42	7.1	10	333	6.7	12	7.2	10	10
08/18/75	60	ND	ND	05/01/75	44	ND	ND	ND	ND	ND	ND	ND	ND
09/02/75	61	7.1	21	05/06/75	45	ND	ND	1781	ND	ND	ND	ND	ND
09/16/75	63	7.2	ND	06/11/75	49	6.6	18	420	7.1	ND	ND	ND	ND
				06/28/75	51	6.0	ND	4856	7.0	ND	6.6	ND	ND
				07/10/75	53	ND	23	6701	ND	ND	ND	ND	ND
				07/27/75	56	7.3	ND	ND	6.8	24	6.7	22	ND
				08/06/75	58	ND	23	4	ND	ND	ND	ND	ND
				08/13/75	59	ND	24	257	ND	ND	ND	24	ND
				09/12/75	62	7.1	ND	385	7.5	ND	7.3	ND	ND
				09/18/75	64	7.2	18	ND	6.9	ND	7.4	ND	ND

ND - No Data

APPENDIX E. Physical and Chemical Characteristics

Date	Run no.	Station K Jones Falls Storm Drain pH	Temp °C	Flow l/sec	Station L Bush Street pH	Temp °C	Flow l/sec	Station M Northwood pH	Temp °C	Flow l/sec
11/05/74	17	7.2	ND	ND	6.9	ND	ND	ND	ND	ND
11/12/74	19	7.2	18	113	7.4	18	ND	ND	ND	ND
12/16/74	23	7.1	9	ND	7.1	9	ND	6.8	9	453
01/06/75	27	7.3	6	140	7.1	6	ND	7.1	5	109
01/11/75	28	7.8	14	3	6.8	13	254	7.6	12	<28.3
01/13/75	29		8	204	ND	8	ND	ND	8	71
01/20/75	30	7.6	8	58	7.4	5	ND	7.5	5	42
02/05/75	33	7.5	4	138	7.2	5	99	7.5	3	85
02/23/75	35	6.8	12	1849	7.5	15	ND	6.7	12	27
03/12/75	37	ND	9	500	ND	9	750	ND	8	65
04/03/75	40	6.4	ND	ND	6.7	14	52	6.1	13	ND
04/15/75	42	7.0	12	32	6.8	11	ND	6.9	10	340
05/01/75	44	ND	ND	200	ND	ND	536	ND	12	2377
05/06/75	45	ND	ND	20	ND	ND	ND	ND	ND	6792
06/11/75	49	6.7	20	50	6.7	ND	87	6.6	ND	1019
06/28/75	51	6.9	ND	8500	6.8	ND	ND	6.7	ND	ND
07/10/75	53	ND	23	1900	ND	ND	ND	ND	ND	ND
07/27/75	56	7.0	ND	ND	6.7	22	71	6.7	22	14
08/06/75	58	ND	25	925	ND	23	0	ND	23	28
08/13/75	59	ND	ND	48	ND	24	ND	ND	23	42
09/12/75	62	7.1	ND	925	6.9	ND	190	7.1	ND	113
09/18/75	64	6.8	21	ND	6.9	ND	0	7.4	ND	57

ND - No Data

APPENDIX F. Frequency of Detection of *Salmonella* and Animal Virus with the Levels of Fecal Coliforms.

Fecal Coliform	*Salmonella*				Animal Virus			
Range MPN/10ℓ	No. of Samples	No. of Samples Positive	% Positive	Genetic Mean MPN/10ℓ	No. of Samples	No. of Samples Positive	% Positive	Genetic Mean PFU/10ℓ
0 - 14	7	0	0	LSL	2	1	50	11.2
15 - 200	10	5	50	1.5	8	4	50	7.9
201 - 400	6	4	67	4.5	2	2	100	79.4
401 - 1,000	12	16	94	9.3	3	5	60	8.7
1,001 - 2,000	23	21	91	8.1	7	6	86	126.0
2,001 - 10,000	35	33	94	12.4	20	15	75	56.9
>10,000	175	169	97	83.9	79	65	82	95.5

GLOSSARY

background samples: Water samples collected on a routine basis, regardless of rainfall to obtain background information on the microbiol levels in the urban aquatic environment. In this study, the background samples consisted of raw sewage, a reservoir and three urban streams.

bleeder: Intentional sanitary sewage overflow from sewage interceptors. The overflows are diverted directly or indirectly into the storm drainage system.

combined sewer: A sewer intended to receive both wastewater and storm or surface runoff.

dry weather flow: The flow in storm or sanitary sewers that contains no stormwater.

enterococci: Members of the fecal streptococcal group containing the species *S faccalis* and *s. faecium.*

F.C.: fecal coliform

first flush: The initial portion of a storm or combined sewer discharge.

F.S.: fecal streptococci

grab sample: A single sample collected at neither a set time or flow.

MPN: Most probable number - that number of microorganisms per unit volume that, in accordance with stastical theory, would be more likely than any other number to yield the observed test result. The MPN is generally computed from the number of positive findings from a multiple - portion - decimal dilution planting.

stormwater: The water resulting from a precipitation event which may stay on the land surface, percolate into the ground, runoff into a body of water, enter a storm sewer or enter a combined sewer, infiltrate a sanitary sewer or evaporate.

stormwater runoff: The stormwater which flows overland.

T.C: Total coliform

urban stream: A course of running water flowing in a particular direction in definite channel through an urban area and discharging into some other stream or body of water.

urban runoff: The stormwater runoff which flow overland through urban areas.

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT Microbiological quantitative assays of Baltimore City urban runoff were conducted throughout a 12 month period to show the relationships to several factors such as separate or combined sewer flow, urban characteristics of drainage area, rainfall, and quantity of flow during and between rain storms. In general, there was a consistently high recovery of both pathogenic and indicator organisms throughout the study except for Shigella sp. which is believed to have been present but could not be isolated due to interferences during the culture procedure. There appeared to be little relationship between pathogen recovery and season of the year, amount of rainfall, period of the antecedent rainfall, and stream flow. The most concentrated pathogens were Pseudomonas aeruginosa and Staphylococcus aureus at levels ranging from 10^3 to 10^5 and from 10^0 to 10^3/100ml, respectively. Salmonella and enteroviruses, though frequently isolated, were found at levels of only 10^0 to 10^4/10 l of urban runoff. The background samples (sewage, urban streams and reservoirs) between storms gave good positive correlation between indicators and pathogens at a 95 to 99% level of confidence, whereas, the stormwater had no or poor correlation. The ratios of indicators, such as FC/FS, gave some indications of pollution by human sewage, but it was the presence of enteroviruses that definitely showed the mixing of sewage with rain water, whether in a storm sewer or in the combined sewer overflow. The logical solution would point to the removal of sanitary sewage overflows rather than the disinfection of all urban runoff for removing the health hazard and improving the quality of urban runoff.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Microorganisms, Bacteria, Viruses, Storm sewers, Streams, Urban areas	Urban stormwater microorganisms, Pathogenic microorganisms enumeration	13 B

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