Chapter 5

SURFACE WATER RUNOFF INTO THE NORTH BASIN

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The Berkeley waterfront is currently the focus of many development proposals. All proposed plans, from highrises to beaches, will utilize the Bay's water-edge resources. This has called much attention to the quality of Bay water. Though pollution enters the Bay from many sources, surface runoff threatens the Berkeley waterfront as a main pollution source. Surface runoff not only contributes 13 percent of the Bay's freshwater input during the rainy season (ABAG, 1980), but since the Berkeley waterfront lies at the base of a heavily developed and industrialized area which slopes towards the Bay, the waterfront is particularly susceptible to surface runoff problems.

This report focuses on the North Basin area of the waterfront which lies between the former Berkeley dump and Interstate 80 (Figure 1). Various Berkeley Waterfront Plans have proposed many new alternatives for the development of the area (Roma, 1984). Some of the more attractive plans open the area for recreational uses, including fishing, swimming, walking, birdwatching, windsurfing, jogging and beach games.

None of the proposed development plans, however, give adequate consideration to contamination from the surface water runoff into the Basin. Two storm drains empty directly into the Basin: the Virginia Street and Gilman Street drains (Figure 1). The litter, heavy metals, oil and grease, algae, and the suspended sediment spilling out the drains during rains will not be attractive or safe to potential recreational users.

This report will show the results of monitoring the Virginia Street and Gilman Street storm drains in Berkeley during rains. The parameters investigated include pH, dissolved oxygen (DO), total dissolved solids (TDS), grease and oil, debris and litter, heavy metals, and phosphate concentrations. Two main themes will be addressed: whether the polluted runoff meets standards established by various governing organizations (if standards do exist); and whether the concentrations of the emitted pollutants differ significantly between the two drains.

ABAG (1977) has pointed out several reasons why the surface runoff problem has previously been inadequately addressed. Until recently it has been much easier to focus on "point" sources of pollution, such as sewage treatment plants and industrial discharges. Data on "non point" sources, such as surface runoff through storm drains, are more difficult and expensive to collect, and because no precise standards are available for surface runoff, it is not easy even to determine whether a problem exists.

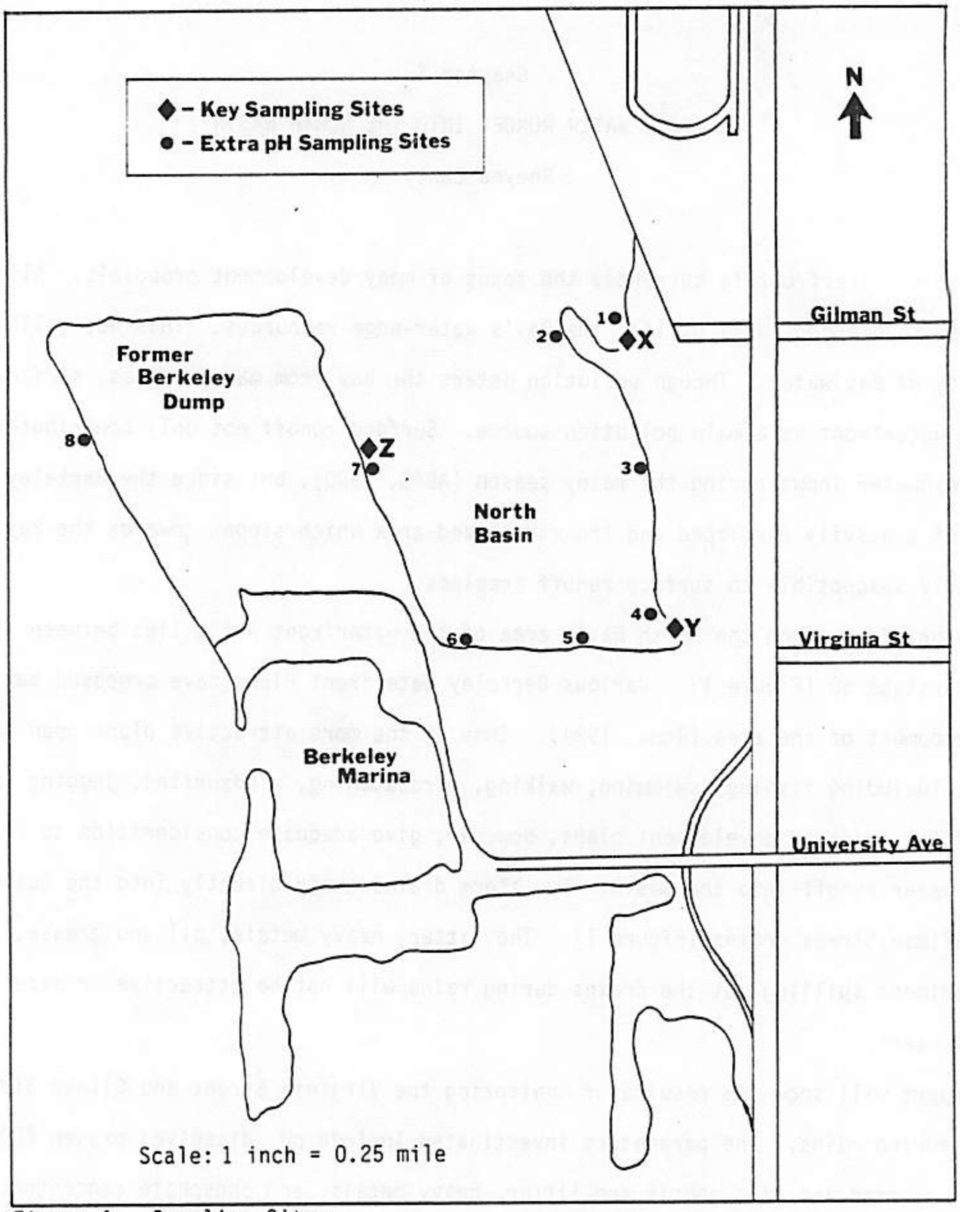

Figure 1. Sampling Sites
Base Map: City of Berkeley
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Water Quality Problems and the Current Standards

The Association of Bay Area Governments (ABAG) has identified seven major surface water problems in its Regional Surface Runoff Management Plan: siltation and erosion, grease and oil, debris and litter, bacterial contamination, nutrients and algal growth, heavy metals and other toxics, and organic waste (ABAG, 1977). In addition, the Water Quality Control Plan for the San Francisco Bay Basin outlines water quality objectives for inland surface waters which depend on intended use (RWQCB, 1982). (The Regional Water Quality Control Board [RWQCB] defines San Francisco Bay as estuarine waters which are protected by surface water standards.) The beneficial uses pertinent to the North Basin which serve as a basis for establishing the water quality standards for surface waters (except inland streams) include estuarine habitat, water contact recreation, non-contact water recreation and wildlife habitat. The following paragraphs explore each of the parameters investigated in this report and give the standards for the parameter. This information is also summarized in Table 1.

PROBLEM	CAUSE	EFFECT	STANDARD
Siltation & Erosion	Construction Non-maintained roads Open spaces	Makes water more turbid Covers fish spawning beds	TDS: 500mg/L daily (EPA, 1979)
Grease & Oil	Industrial activity Traffic Dumping of motor oil	Coats birds and aquatic life Toxic to aquatic life Makes recreational use undesirable	Wastes shall not contain oils, grease...in concentrations that result in visible film or coating on the surface of the water. (RWQCB, 1982)
Debris & Litter	Improper dumping General littering	Unsightly Makes recreational use undesirable	Waters shall not contain floating material...in concentrations that cause nuisance or adversely affect beneficial uses. (RWQCB, 1982)
Bacterial Contamination	Animal fecal material Soil organisms Sewer-pipe overflows	Diseases upon contact and ingestion Contaminates aquatic life	Fecal coliforms: 50 per 100ml Total coliforms: 240 per 100ml (Simonitch, 1983)
Nutrients & Algal growth	Industrial runoff Traffic Natural organic material	Causes low concentrations of dissolved oxygen	Phosphate: None Un-ionized amonia: 0.4mg/L as N maximum (RWQCB, 1982)
Heavy Metals Pesticides & Other toxics	Automobile operation Industrial runoff Runoff from refuse and garbage	Toxic to aquatic life	None
Organic wastes Low dissolved oxygen	Addition of organic material from: *soil / plants *industry *traffic	Oxygen is essential to most desirable forms of aquatic life	D.O. Minimum: 5.0 mg/L (RWQCB, 1982)

Table 1. Water quality parameters investigated for this report.

pH: pH is a term used to express the intensity of the acid or alkaline condition of water. Though ABAG (1977) does not specifically identify pH as a surface runoff problem, this report investigates pH because the RWQCB (1982) does set a standard pH range between 6.5 and 8.5. The criterion prevents or minimizes eye irritation of recreational users, and organisms prefer these relatively neutral conditions (neutral pH is 7) for survival. The standard also stipulates that controllable water quality factors shall not cause changes greater than 0.5 units in normal ambient pH levels (RWQCB, 1982).

Total Dissolved Solids (TDS): Construction, non-maintained roads and unprotected open spaces contribute to sediment loads in surface runoff. Excess dissolved and suspended solids can deposit and clog storm drains, or collect at the drain's discharge mouth and coat the basin floor with mud. The RWQCB requires only that sediment loads and discharge rates are not altered "in such a manner as to cause nuisance or adversely affect beneficial uses" (RWQCB, 1982, p. 3-3). The U.S. Environmental Protection Agency (EPA), however, has established a maximum TDS concentration of 500 milligrams per liter (mg/L) for surface runoff into the Bay.

Oil and grease: ABAG (1985) has recently completed a study on hydrocarbons in runoff to the Bay. Between 5.3 and 9.9 million pounds of oil and grease are believed to enter the Bay in a year from local runoff sources with average runoff. Automotive products are the largest constituent in runoff--even from undeveloped watersheds. Any oily sheen on water is not only a violation of the RWQCB's objectives, but is also highly undesirable from a recreational standpoint. Also, oil and grease can harm aquatic life by coating their bodies and through ingestion (ABAG, 1977).

Phosphates: Nutrients washed into the Bay from animal wastes, soil particles and industrial activity can promote growth of algae and larger plants. Excessive algal growth reduces shoreline recreational uses--particularly for swimmers and fishermen. Nutrients contribute to rapid growth of algae only if they are the limiting factor in an organism's basic needs. Experts believe that the lack of nutrients is not preventing the growth of algae in the Bay, but rather light penetration from turbidity is the limiting factor (RWQCB, 1982). However, this report does investigate total phosphate loads in the runoff in order to observe concentrations of a nutrient which is a common limiting factor in other aquatic ecosystems. Standards do not exist for nutrient loads entering the Bay through surface runoff.

Heavy metals: Heavy metals believed to be entering the Bay through surface water runoff include arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc (ABAG, 1980). Long-lasting pesticides and synthetic organic compounds are used commonly in the Bay's watershed areas. Heavy metals and some toxics are capable of biomagnification effects. They build up in certain marine organisms such as filter feeders until the accumulation becomes deadly either to the organisms themselves or to their predators (Goudie, 1984). Standards for any heavy metals or toxic substances have not been established. This report explores lead (Pb), zinc (Zn), cadmium (Cd), copper (Cu) and chromium (Cr) concentrations in the runoff water as indicators of heavy metal pollution, but does not address other toxics.

Dissolved oxygen: Organisms which decompose organic pollutants, such as plant and animal matter and animal excrement, consume the oxygen in the water, the biological oxygen demand (BOD). If the amount of organic matter in the water exceeds the capacity for organisms to assimilate the material, the oxygen in the water will be depleted. In response, fish and other organisms which depend on certain levels of oxygen will leave or die (ABAG, 1977). The RWQCB's standard for the Bay states that the dissolved oxygen (DO) content should not fall below 5.0 mg/L.

Debris and litter: The only source of debris and litter in the Bay's watershed is careless and thoughtless disposal of solid wastes. Surface water then transports it to the Bay (ABAG, 1977). The greatest impact of debris and litter is its reduction of the aesthetic beauty of the Bay's shoreline. The RWQCB regulates floating material by stating that: "Waters shall not contain floating material . . . in concentrations that cause nuisance or adversely affect beneficial uses" (RWQCB, 1982, p. 3-3).

Bacterial contamination: Bacterial contamination was not investigated in this report but will be discussed briefly below.

Past Studies

Many studies have been made on the surface water runoff problem in general. McElroy and others (1976) have investigated the effects of rainfall intensity and timing of storm water runoff. Most studies have found a "first flush" effect in which the first samples taken in the watershed during storms have the highest BOD and suspended solids levels. Season and antecedent dry periods may have little effect on storm water quality. The time distribution of rain intensity during a tropical storm of given frequency and duration has little effect on the pollution load washing from the watershed.

Other studies of runoff have been made specifically in the Bay Area. ABAG (1980) studied pollutant emissions into the Bay by urban runoff. Table 2 summarizes the results which are of interest to this report. The first column shows local inputs contributed to the Bay with the monitoring averaged over a whole year. The second column illustrates the contribution of urban runoff just during the rainy season.

	Fraction of local inputs to Bay (%)	Fraction of local inputs to Bay / Oct.-April (%)
BOD	19	32
Total Suspended Solids	5	9
Total Phosphates	1	2
Heavy Metals	43	60
Oil and Grease	28	44

Table 2. Relative Contribution of Urban Runoff to San Francisco Bay
Source: ABAG, 1980

Methodology

The key samples drawn for the investigation of surface runoff were taken from the mouths of the Virginia Street and Gilman Street drains (X and Y, Figure 1). The bottles used to draw and store all the samples are of the narrow-mouth, pressure patent stopper type. The bottles are made of glass, which is not believed to affect the chemistry of the water for the parameters which require water storage (Brown et al., 1970). The sample bottles were washed with tap water and hydrochloric acid. They were then rinsed three times each with distilled water, triple-distilled water, and finally with the water to be tested at the site.

Samples were drawn on three days during periods of coinciding rains and low tides between December 2, 1985 and January 29, 1986. At any time other than low tide, the Bay water flows as much as a half mile up into the drains, and sampling is impossible. Tidal water reaches the drain mouth even twenty minutes before or after the lowest tide of the cycle. Because none of the samples were taken during a "first flush" period, usually high levels of contamination were not expected.

Dissolved oxygen and pH measurements were made immediately at the site with portable iodometric and colorimetric kits respectively. A control pH was also taken during each sampling on the west side of the Basin (Z, Figure 1) in order to check the difference between the water already in the basin and in-flowing waters from the drains. Due to consistently high pH values at the control site, an additional set of pH tests was taken on February 2nd around the perimeter of the Basin (sites 1-8, Figure 1) in order to check the distribution of pH values in the Basin. At sites 1 and 4, water was drawn as the tide was coming in but while the water line was still about 15 feet from the drain mouths.

The TDS test used Whatman #2 filters to filter 75 milliliters (ml) of runoff water. The filtered solids were dried in an oven at 180°C. Twenty ml of the filtered water were dried on a steam bath and then placed in the 180°C oven. The weights of both filtrable and nonfiltrable solids were combined to determine the TDS.

The heavy metals were tested with an Atomic Absorption Spectrophotometry technique. According to Standard Methods (APHA, 1985), 5 ml of concentrated nitric acid should be added to the samples when drawn in order to avoid absorption of some of the metals from the glass. This step was inadvertently omitted. About a week prior to the absorption test the nitric acid was added. The extent of absorption into the glass or the amount redissolved cannot be quantitatively determined. However, since heavy metals are known to be highly soluble in nitric acid, the metals likely redissolved, and the omission is not expected to change the results.

Phosphates were measured using the Vanadomolybdophosphoric Acid Colorimetric Method (APHA, 1985). The sulfuric acid-nitric acid digestion process in correlation with a stannous chloride procedure was used to determine the total phosphorous content.

Floating material and oil and grease were observed qualitatively.

Results

The pH ranged from 7.6 to 9.4 for the key samples taken at the drains (Table 3). All but one sample fell within the permissible pH range set by the RWQCB. The control pH on the west side of the basin had a consistent pH of 9.0 at every sampling period. The additional set of pHs tested in February showed that 8.5 may be a more likely normal ambient pH (Table 4).

	Date	pH	DO mg/L	TDS mg/L	PO_4^{3-} mg/L	Pb µg/L	Zn µg/L	Cd µg/L	Cu µg/L	Cr µg/L
Standard		6.5-8.5[a]	5.0[a]	500[b]	--	--	--	--	--	--
Virginia St	12/1	7.6	9.3	1491	.66	.22	.43	.02	.09	.02
	12/2	7.6	6.8	590	.35	.21	1.20	.01	.08	.03
	1/29pm	7.6	9.0	512	.64	.11	.31	.01	.07	.02
	Average	7.6	8.4	864	.55	.18	.65	.01	.08	.02
Gilman St	12/1	7.6	8.4	668	.44	.14	.51	.01	.14	.03
	12/2	9.4	5.2	356	.50	.13	.62	.01	.14	.04
	1/29am	7.6	6.4	525	.46	.14	.86	.01	.18	.02
	1/29pm	7.0	7.2	223	.44	.10	.56	.00	.10	.02
	Average	7.4	6.8	443	.46	.13	.53	.01	.14	.03

a: RWQCB, 1982
b: EPA, 1979

Table 3. Water quality standards and the values measured for this report

The pH found at sites 4, 5, and 7 violate the water quality standard. The pH at site 7 may be abnormally high due to leaching from the former Berkeley dump, or because a rusty barge known to house residents is located about 20 feet north of the site. Sites 4 and 5 could be near leaching contaminants because the area between University Avenue and the North Basin (often called the meadow) is also a former garbage dump.

Site*	pH
1	8.5
2	8.5
3	8.5
4	8.6
5	9.0
6	8.5
7	8.8
8	8.5

Table 4. February 2nd pH test results.
* Site locations shown on Figure 1.

Comparisons between the ambient water and the surface runoff from the drains show that every runoff sample had a pH value that differed from the ambient pH (8.5) by more than 0.5 units--a violation of the standard. All of the pHs were lower than 8.5 (7.0-7.6) except for the pH taken at the Gilman Street drain on December 2nd (9.4). It seems unusual that the normal ambient pH for the basin found in this report equals the highest value in the permissible range. Conomos and others (1979) recorded the average pH in the Bay across from the Golden Gate at 8.2 with a range of 7.8 to 8.5 for 1969-77. Therefore, values recorded in this report are consistent with those found in past studies.

The TDS ranged from 223 mg/L to 1,491 mg/L (Table 3). Most of the concentrations found in the samples violated the EPA standard. The Virginia Street watershed exceeded the standard at every sampling and flushed the highest single concentration, whereas the Gilman Street watershed exceeded the standard in only two out of four samplings.

An oily sheen was seen on the runoff during every sampling at the drains. The contamination at the Gilman Street drain always looked greater than at the Virginia Street drain. But, in late November before any samples were drawn, a hydrocarbon pollutant spill poured into the Gilman Street drain about 1 mile from its mouth. How long the residue continued or will still continue to slough off during rains cannot be determined. But, the heavy film observed at the Gilman Street drain was probably completely dominated by remnants of the spill. Therefore, this report cannot determine which drain contributes more oil and grease under normal conditions.

Phosphate concentrations ranged from 0.35 mg/L to 0.66 mg/L. The Virginia Street drain led in average phosphate concentrations--supporting the two highest single loads.

Zinc concentrations were the highest of the heavy metals in both drains. Cadmium and chromium were the least abundant. Copper and lead concentrations varied between the drains with copper dominant in the Gilman Street samples and the Virginia Street samples dominant in the lead concentrations.

Every sample met the dissolved oxygen standard. One sample taken at the Gilman Street drain approached the limit with 5.2 mg/L, but most of the samples were well above the standard.

Not much debris and litter came out of the drains while samples were being drawn; therefore the parameter could not be analyzed quantitatively. The Virginia Street drain outlet seemed to be a common area for direct dumping of wastes--making it difficult to determine the source of the litter. However, a few cardboard containers, styrofoam, a magazine and many leaves and other organic debris were seen floating out of the Virginia Street drain into the basin. Very little debris floated out of the Gilman Street drain.

Discussion

A final parameter that must be discussed in this report is bacterial contamination. Simonitch (1983) investigated bacterial contamination in the Virginia Street and Gilman Street drains using the indicator microorganism fecal coliforms, which has similar qualities as the pathogen bacteria. Fecal contamination and native soil organisms wash down the drains and lead to the presence of pathogenic microorganisms. Microbial pathogens may be agents of typhoid fever, cholera, and infectious hepatitis (Simonitch, 1983).

Simonitch (1983) reports that all of the fecal coliform counts and all but one of the total coliform counts were far greater at both sites than RWQCB recommended standards. For example, fecal coliforms for contact recreational use areas should not exceed 50 per 100 ml; however, the sample counts ranged from 4,000 to 92,000 per 100 ml. Total coliforms for contact recreational waters should not exceed 240 per 100 ml; Simonitch (1983) found counts ranging from 7,000 to 94,000 per 100 ml.

Addressing the first main theme--whether the polluted urban runoff meets the established standards (when they exist)--one can clearly see that it does not. Only the DO concentrations met the standard; pH, oil and grease, debris and litter, bacterial contamination, and TDS did not. But, how does one evaluate the parameters which do not have standards for ambient concentrations in the Bay, or standards for non-point source emissions?

Phosphate concentrations can be compared to those observed in the past. In 1976-77, several Bay Area counties and ABAG found the average for urban runoff to be around 0.50 mg/L (ABAG, 1977), which is very similar to the average concentrations found in this report (0.45-0.55 mg/L).

Heavy metal pollutant loading into the Bay by surface runoff may be compared to metal contamination from municipal discharge. The calculations which follow use chromium (Cr) as an example to explore the pollutant loading from the East Bay Municipal Utility District's (EBMUD) service area.

The daily maximum limit for total Cr in municipal treated wastewater discharge into inland surface waters is 0.01 mg/L (RWQCB, 1982, Table 4-1). The average discharge of treated wastewater to San Francisco Bay by EBMUD is 7,700 million gallons per year (2.9×10^{10} L/yr) during periods of rainfall (Camp Dresser and McKee <u>et al</u>., 1985b). Therefore, the maximum allowable total Cr discharge is 291 kilograms/year (kg/yr). According to the EBMUD Wet Weather Facilities Plan Update, EBMUD discharges 1,300 pounds per year during periods of rainfall (Camp Dresser and McKee <u>et al</u>., 1985b, Figure 2-2). This is equivalent to 590 kg/yr. EBMUD's estimates originate in studies done by the EPA in the 1970s and by ABAG in 1979-1980 (Wallis, 1986, personal communication). These figures indicate that EBMUD is emitting almost two times the Cr concentration that the standard allows.

Observed average concentrations of total Cr found in the samples taken from the Virginia Street and Gilman Street drains is 0.03 µg/L (micrograms/L). The total surface runoff into the Bay from EBMUD's district area is 15,000 million gallons per year (5.7×10^{10} L/yr) during periods of rainfall (Camp Dresser and McKee <u>et al</u>., 1985b, Figure 1-2). Therefore, assuming that the Virginia Street and Gilman Street drains represent an average for all drains in EBMUD's district, the total Cr load from surface runoff is 1.7 kg/yr. The average discharge of total Cr by surface runoff according to EBMUD's Wet Weather Facilities Plan Update is 13,000 pounds per year (5,900 kg/yr) during periods of rainfall (Camp Dresser and McKee <u>et al</u>., 1985b, Figure 2-2). Again, EBMUD's estimates come from the 1970 EPA and 1979-1980 ABAG studies (Wallis, 1986, pers. comm.). EBMUD values for surface runoff loading used in the Wet Weather Study are 3,500 times greater than the amount calculated from this report. The Wet Weather Study indicates that surface runoff is a far greater contributor of Cr to the Bay; whereas values from this report show that municipal discharge leads surface runoff for Cr loading by a significant amount.

The second main theme of interest is whether the Virginia Street and Gilman Street drains differ significantly in their contribution of pollutants to the Basin. The Virginia Street drain is the larger of the two and collects surface runoff as far east as Shattuck Avenue (Figure 2). The three highest land uses in the area include industry, medium intensity residential and low intensity residential. The ratio

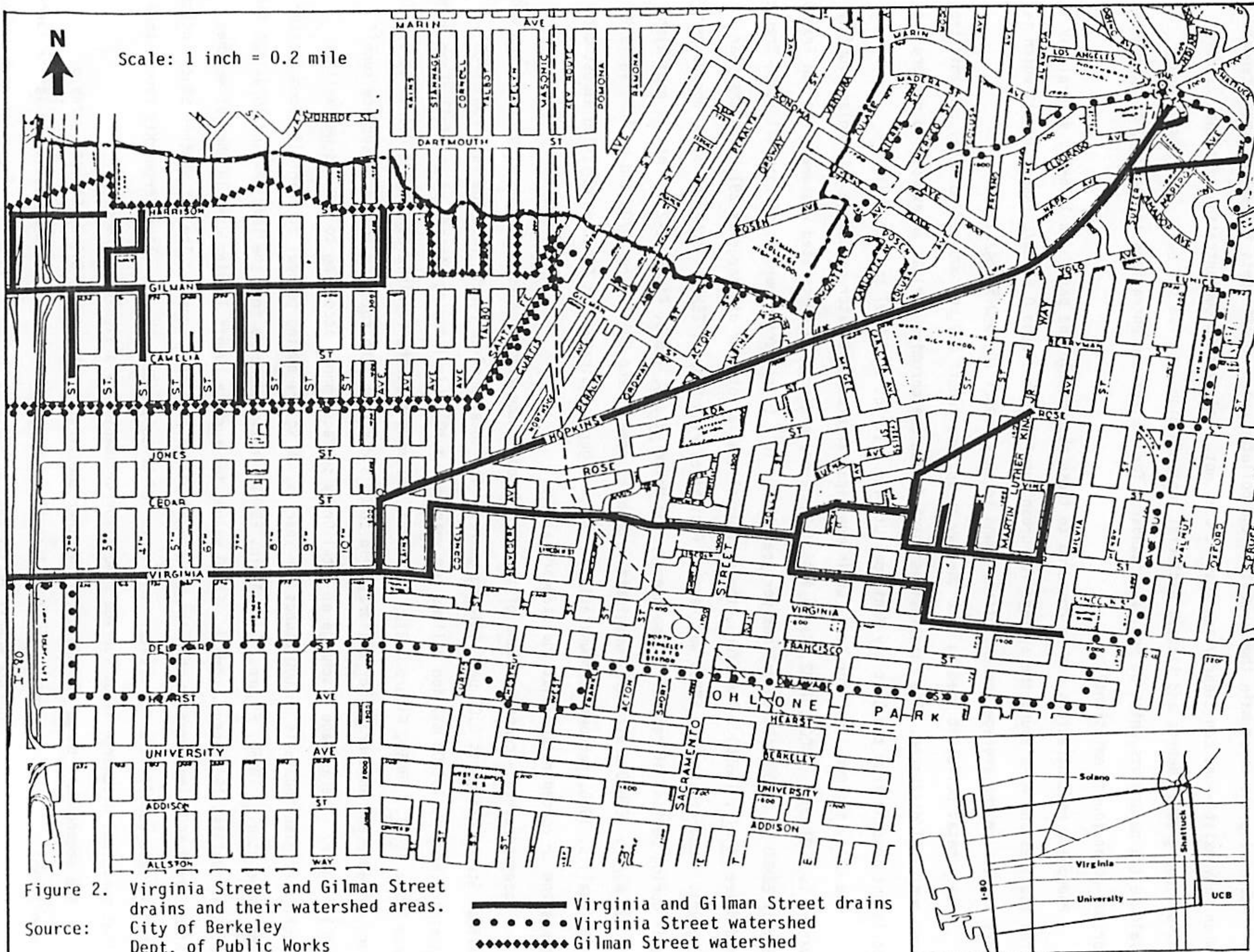

Figure 2. Virginia Street and Gilman Street drains and their watershed areas.

Source: City of Berkeley
Dept. of Public Works
Engineering Division

of these land uses in the Virginia Street drainage area is approximately 1:4:5, respectively (Camp Dresser and McKee et al., 1985a). The Gilman Street drain watershed extends only as far east as Santa Fe Avenue, but it collects runoff in a much more industrial area. The highest land use types in the Gilman Street area include medium residential and industry with a ratio of about 1:4 (Camp Dresser and McKee et al., 1985a).

McElroy and others (1974) studied the relation of storm waters to land use, investigating environmental quality, land surface characteristics and population density. The study shows that industry contributes most heavily to total suspended solids, with open space and streets a close second and third. Industry, open space and residential use increase BOD concentrations with industry again the greatest contributor.

The Virginia Street drain had higher DO concentrations on average, but contributed more TDS. The higher TDS concentrations in the more residential area conflict with results found in the studies by McElroy and others (1974). One would have expected the Gilman Street drain to have higher concentrations with its greater industrial land use. However, the higher DO concentrations found in the runoff from the Virginia Street drain are consistent with McElroy and others' (1974) studies. The greater BOD in runoff from industrial watersheds will reduce the DO concentrations, which can be seen by the lower DO concentrations in the Gilman Street drain runoff.

Overall, the Virginia Street drain dominated (though not overwhelmingly) in heavy metal concentrations, debris and litter, TDS loads, total phosphate concentrations and a more consistently lower pH. The Virginia Street drain's larger watershed may have contributed to these results. Therefore, no solid conclusions can be drawn in this report about the effect of industrially or residentially dominated watersheds on urban runoff.

Conclusion

Plans for development of the Berkeley waterfront must consider the effects of storm water runoff. Health hazards have been identified in this report, including heavy metal contamination, high pH levels, and grease and oil. Potential disturbers of the esthetic beauty of the North Basin have also been identified, including debris and litter, suspended sediment and mud, and algae. The massive, cavernous drains will also be disturbing, and possibly hazardous to young beach explorers.

But are any of these parameters controllable? ABAG (1980) has recommended a variety of control measures which can be summarized as four basic approaches: (1) reduce accumulation of pollutants prior to runoff, (2) reduce the peak flow or volume of runoff, (3) control land use in sensitive areas, and (4) treat and store the runoff. Non-point sources of pollution are so elusive, however, that any attempt to meet current standards will be very difficult and costly. The most probable fate of the drains will have to be diversion; either to the municipal treatment facility or to another discharge point into the Bay.

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