CHAPTER 8

THE 'SCIENCE' AND 'METAPHYSICS' OF SUBMARINE OUTFALLS

In previous chapters we have considered the engineering and legal contexts in which the decisions were made to construct submarine ocean outfalls at Sydney's three major sewage outfall sites. In this chapter the criterion used in the design of these new outfalls and the physical, chemical, biological mechanisms upon which their performance depends will be considered. But more importantly this chapter is concerned with the way in which knowledge of these mechanisms, their importance and their role in outfall performance, is socially constructed and manipulated.

The ocean outfalls were purportedly designed to meet water quality criteria which were set down in the SPCC WP-1 guidelines. Caldwell Connell identified four aspects of the guidelines which directly influenced their design. These were maximum concentrations of restricted substances, maximum allowable variations of dissolved oxygen and pH, bacteriological standards for bathing waters and aesthetic impact. The performance of the submarine outfalls depended on four mechanisms; the initial dilution which would take place as the effluent rose from the sea bottom, subsequent dilution or dispersion once the effluent-seawater mixture reached equilibrium, movement of the effluent field under the influence of water currents and reduction of sewage organisms in the sea.[1] These principles have been used in the Board's public advertising campaign. An example is shown in figure 8.1.

DILUTION - IS IT THE POLLUTION SOLUTION?

The rationale behind extended ocean outfalls rests heavily upon dilution as a mechanism for reducing health risks and damage to the environment. Yet the design calculations and computer models for predicting dilution have been severely criticised and it had been argued that dilution was in fact overemphasised at the expense of natural mechanisms that cause an opposite effect of accumulation, including bioaccumulation of toxins, sedimentation of sludge particles and agglomeration of sewage particles with grease.

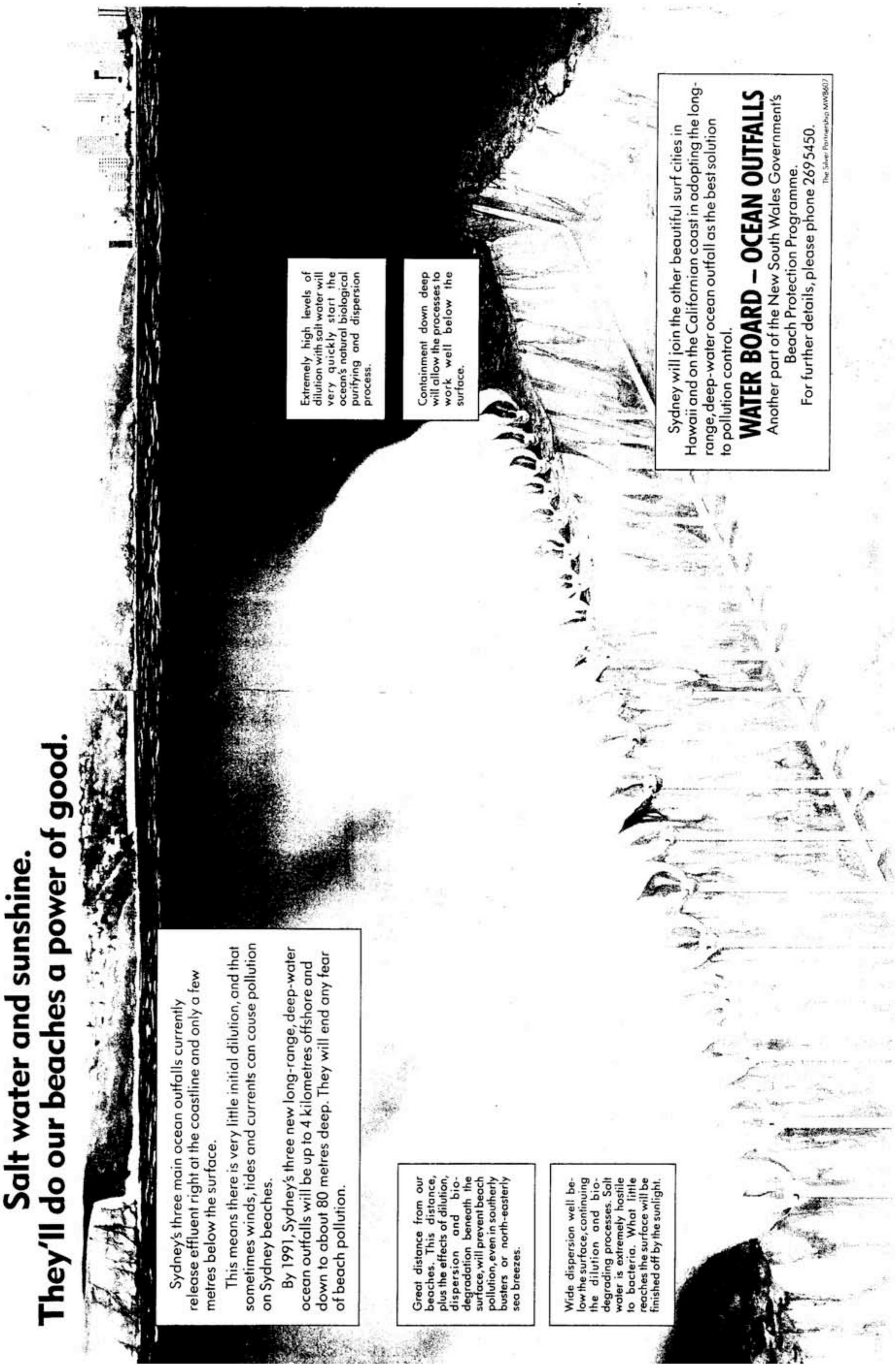
When the Environmental Impact Statements for the submarine outfalls went on display the SPCC undertook a detailed assessment of the oceanographic and hydraulic study and Robert Brain, an SPCC engineer, was recommended for this task as he was one of only two SPCC officers thought to have the necessary expertise to undertake the assessment of such highly technical and mathematically complex material.[2]

Brain made some fairly damaging criticisms of the theory used to predict the performance of the outfalls. Brain suggested that the sewage plumes would be very persistent and that the Malabar plumes would take a month to diffuse to quarter strength. As a result, he claimed, there would be permanent dead water

[1] Caldwell Connell, Sydney Submarine Outfall Studies, M.W.S.&D.B., 1976, pp10-12, p165.

[2] Internal memo by Principle Engineer-Water, Wastes & Chemicals, S.P.C.C., 31st January 1980.

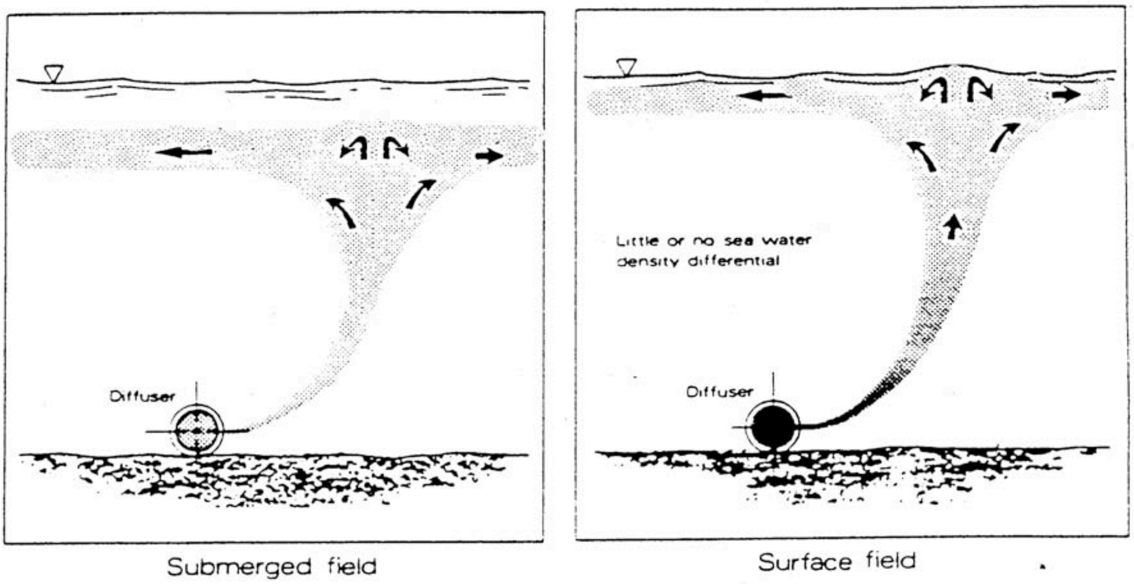
Figure 8.1 Sydney Water Board Advertisement (SMH 9/12/86)



behind the outfall possibly extending for several kilometres down current, which would be heavily contaminated with sewage and possibly anaerobic.[3]

Caldwell Connell had explained in their report that the sewage would be subject to two phases of dilution. The initial dilution phase would occur when the plume of sewage came out of the outlets of the submarine outfalls under pressure and rose towards the surface because it was lighter than the sea water. (see figure 8.2) This sewage plume would then reach an equilibrium which might be on the surface of the sea or below the surface. Subsequent dilution would occur as the seawater mass moved away from the outfall.[4] Thus calculations of how much dilution would take place were worked out in two stages and Brain criticised the theory used for both predictions.

Figure 8.2 Schematic Representation of Submarine Outfall



SOURCE: Caldwell Connell, Sydney Submarine Outfall Studies, MWS&DB, 1976, p41.

Caldwell Connell had calculated the initial dilution which would be achieved by the outfalls using a computer analysis based on traditional theories built upon the work of several researchers. These researchers had built up mathematical models of flow conditions achieved under laboratory conditions. For example, the theory of mixing of a turbulent jet discharging into a fluid of similar density, which had been developed in 1950 and shown to be a poor assumption, had been used by most investigators since that date. Similarly, the results of experiments carried out in 1956 with a circular jet discharging vertically into a stratified stagnant fluid of greater density had been used to predict the bounds of a submerged field of effluent under all conditions of current flow.[5]

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[3] R.Brain, internal report to S.P.C.C., 1980.

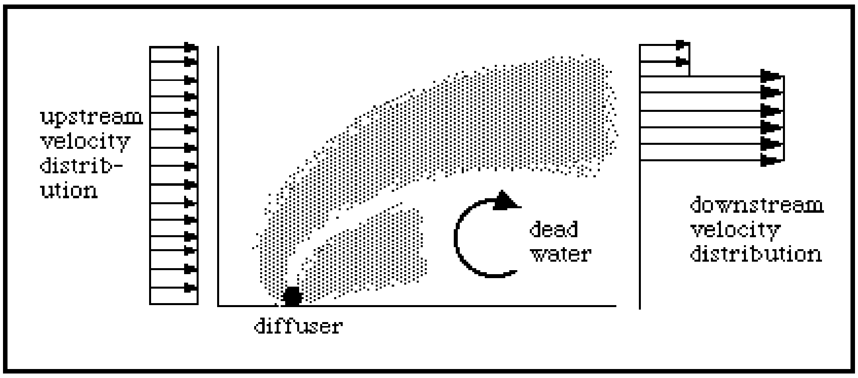
[4] Caldwell Connell, Sydney Submarine Outfall Studies, pp10-11.

[5] R.Brain, `Recent Developments in Ocean Outfall Diffuser Theory', Conference on Environmental Engineering. Townsville, 8-10 July 1981, pp113-4.

Caldwell Connell had admitted that their analysis did not consider the effect of currents in receiving waters but they assumed that subsurface currents would improve the mixing and dilution that they had predicted using `still water' results.[6] They stated that there was "no satisfactory mathematical basis for calculating the effect of current on a buoyant jet".[7] Brain placed far more significance on the effect of current on calculations of achievable dilution, arguing that the coastal currents of NSW were too large to assume them to be inconsequential. Such currents resulted in an asymmetric plume whereas traditional theory assumed a symmetrical plume and the Caldwell Connell report had in fact depicted a symmetrical plume in their report which would imply that dilution water had to be coming into both sides of the plume.[8]

In actual practice, Brain argued, while a current was flowing the plume from the upstream orifice would intercept all the diluting water whilst the downstream orifice would be left to discharge effluent without dilution into a dead zone of water where there was no flow. (see figure 8.3) Dilution would only occur if there was water available to dilute the effluent and this was not the case on the downstream side of the orifice.

Figure 8.3 Schematic Representation of Diffuser Operation



SOURCE: R.Brain, internal report to SPCC, 1980.

As a result of the SPCC repudiation of Caldwell Connell's first dilution model, the consultants put forward a modified dilution formulation which Brain insisted was even less applicable than the original one. The problem was that other SPCC staff were unable to assess Brain's reports properly. The principal engineer for his section wrote,

> While there may well be a flaw or flaws in the alternative theory proposed by Mr Brain, I am unable to find same in the argument presented by him in his report. Further, I believe the issue is of such importance, alleging as it does that the proposed extended outfall will not result in compliance with the ocean discharge criteria specified by the Commission in Environmental Design Guide WP-1, that we must either have Mr Brain's theory confirmed or refuted by competent

6 Caldwell Connell, Sydney Submarine Outfall Studies, p13

7 ibid., p13

8 ibid., figure 2.3, p16.

> mathematical assessors or, alternatively, submit his report (edited if necessary) to the Board and its consultants for their comments...[9]

Later, after he had retired, Brain publicly stated that the dilution provided by the submarine outfalls would only be about three times that already provided and that the sewage would reach the beaches almost as often as with the existing outfalls.[10] He tried to show that the Water board claim that the treated effluent would be diluted hundreds of times more than at the existing outfalls was impossible unless the average discharge velocity was over 500 metres per second, "or about the same speed as a Concorde aircraft".

> Why must the board persist in claims which any sixth form science student can show to be manifestly incorrect-is the case for the outfalls so poor that it dare not tell the truth? [11]

Whilst Brain raises doubts about the amount of dilution that will actually be achieved by the submarine outfalls, others have raised more fundamental doubts about the adequacy of dilution as a mechanism to deal with pathogenic or toxic material. Dilution is not the only mechanism that operates in ocean waters and some materials actually agglomerate. Between 1976 and 1981 the Australian Atomic Energy Commission (AAEC) carried out work for the Water Board to study the processes of ocean dispersion of sewage. Using a radioisotope, gold-198, the AAEC was able to label sewage solids before discharge into the ocean and then monitor their progress. They found that this isotope was an ideal label for grease and oil of sewage origin as well.[12]

The AAEC scientists differentiated between `conservative materials' in the sewage, which dispersed and moved similarly to water, and `non-conservative' materials such as grease, wax, scum, bacteria and other particulate matter which might be subject to several accumulative mechanisms such as slick formation, windrow formation, flocculates formation and agglomerated formation.[13]

It was found that most of the grease contaminating beach sands was of mineral origin and that about 20% of the grease entering the Malabar treatment plant was of mineral origin and could not be treated by a primary treatment plant. In fact primary treatment at Malabar only removed about 45% of the total grease arriving at the plant and most of that was the scum or floatable grease, and the sludge fraction or settleable grease. The dispersable grease was not removed at all and the sludge fraction which was not amenable to digestion (ie that of mineral origin) was added back into the effluent with the rest of the sludge.[14]

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9 P.Yates, Principle Engineer-Water, Wastes & Chemicals, internal S.P.C.C. memo, 10/6/80.

10 Manly Daily, 3rd May 1985.

11 Manly Daily, 21st November 1986.

12 A Davison et al, `Radioisotope Studies on the Paradox in Dispersion and Agglomeration of Sewage Greases Discharged from Ocean Outfalls', Proceedings of the Ninth Federal Convention of the Australian Waste-Water Association, Perth 1981, p23-8.

13 ibid., pp23-9.

14 A.Davison et al, `Investigations into Sewage Grease Behaviour in Coastal Waters', Water Science Technology 13(1), 1980, p501.

The study found that grease was extremely persistent in the ocean and did not dilute much even 5km from the discharge point and could even concentrate so that seven days later the tracer would still be found in the same concentration as at the beginning.[15] They noted, in particular, that wax or grease could interfere with the dispersion and purification of enteric bacteria which could be adsorbed into particulate matter and survive in grease accumulations where predators could not get to them, nor could the oxygen nor sunlight. There was, for this reason, a strong correlation between the grease content of beach sands and the bacteria count in adjacent waters and therefore the presence of grease was not just an aesthetic problem but also indicated a health problem.[16]

In this way bacteria and viruses could be carried to remote locations where the concentration of bacterial predators would be low and the die off rate much lower. For this reason, they suggested the extended submarine outfalls might have little benefit, especially since diffusion often decreases further from shore. Moreover, offshore outfalls might have the added disadvantage that

> offshore, outfalls may cause more beach pollution since the initial dispersion of the sewage before it meets the coast will allow deposition over a wide range of beaches many of which will not contain significant amounts of bacterial predators.[17]

Microbiologists have pointed out that faecal bacteria and human enteric viruses "tend to clump together in the water attached to particles and to each other". Also viruses are naturally embedded in faecal matter and remain associated with the solids even after treatment. Not only do these particles tend to protect the viruses and bacteria and thereby enhance their survival but particles tend to "collect" viruses and bacteria on their surfaces. Whilst viruses are unlikely to multiply without a host, bacteria can replicate and increase their numbers in ocean waters and sediments. Moreover viruses and bacteria can accumulate in sediments several kilometres from an outfall. Concentrations of enteroviruses in sediments may be 10 to 10,000 times greater than in the overlying waters. These can then be released when sediments are resuspended by wind or currents or when they are disturbed and can be taken up by marine organisms such as shellfish.[18]

It only takes as few as 10 to 100 bacteria, or a single virus to induce an infection or disease under appropriate conditions. A single ingested particle can contain a large dose of microorganisms because of the tendency for particles to attract

15 Anon, `Tracking Sewage-Where do the Grease Balls go?', Nuclear News 24, 1986.

16 A Davison et al, `Radioisotope Studies', p23-10; Anon, `Tracking Sewage-Where do the Grease Balls go?'

17 Davison et al, `Radioisotope Studies', p23-12.

18 V.A.Cooper & T.J.Lack, 'Environmental Effects of Discharges', The Public Health Engineer 14(5), January 1987, p22; U.S.Office of Technology Assessment, Wastes in Marine Environments, National Technical Information Service, 1987, p135; Margaret Loutit, 'The Fate of Certain Bacteria and Heavy Metals in Sewage Discharged Through an Ocean Outfall', 1985 Australasian Conference on Coastal and Ocean Engineering, Preprints of Papers - vol. 1, IEAust, IPENZ, NWSCO, 1985, pp211-220; C.D. Lewis, 'Fate Of Human Enteroviruses in Sewage Discharged into New Zealand Coastal Waters' in 1985 Australasian Conference on Coastal and Ocean Engineering, pp221-228; F.J.Austin, 'Pollution of the Coastal Environment by Human Enteric Viruses' in 1985 Australasian Conference on Coastal and Ocean Engineering, pp229-234.

viruses and bacteria on their surfaces. It is of no consolation to a swimmer who swallows such a particle that there are few such particles per ml of water. For all of these reasons the dilution mechanism is not adequate for dealing with water-borne disease.

> Adsorption to particles and sedimentation appears to remove much of the effectiveness of effluent dilution for reducing viral pollution in the vicinity of marine sewage outfalls.[19]

Already, in the United States, the authorities fear that routine discharge of sewage effluent and the dumping of sewage sludge are introducing large numbers of viable microorganisms, including pathogens, into the coastal waters and oceans and that their densities in both the water and the sediments may be increasing.[20]

Assumptions of dilution are also central to the argument that industrial waste will be rendered harmless in the ocean. The SPCC WP-1 guidelines specify concentrations of restricted substances allowed at the boundary of an initial dilution zone. This zone is generally taken to be about 500 metres radius around the outfall and is the area of water in which the sewage is initially diluted. The guidelines assume that this mixing zone will be sacrificed and environmental standards do not have to be applied within this zone. The specified limits on concentrations of restricted substances (shown in the first colum of table 8.1) only apply to water beyond this zone where it is assumed the wastes have undergone some dilution.[21]

The setting of boundaries to this zone is fairly arbitrary and one commentator has noted that mixing zones were defined "to accomodate whatever level of performance that was going to be installed before discharge."[22] This setting aside of an area of sacrifice in which the guidelines do not apply, is of dubious wisdom, given that its boundaries are not netted and fish may still pass through and feed in this region and probably do given its nutrient richness.

The Board's consultants, Caldwell Connell, estimated that a dilution of 40:1 in this mixing zone would be needed to ensure that the SPCC requirements were met for all restricted substances except chlorinated hydrocarbons at Malabar.(see table 8.2) Their design of the submarine outfalls was therefore done to ensure that a 40:1 dilution at the boundary of the initial dilution zone could be met even in the worst circumstances (short of bypass of the submarine outfalls). Using this figure of 40:1, it is possible to see that the SPCC guidelines in fact allow huge amounts of restricted substances to be discharged into the ocean each year (see table 8.1 column 2)

It was estimated that a dilution of 125:1 would be required to meet the WP-1 Guidelines for chlorinated hydrocarbons but Caldwell Connell assumed that

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19 Lewis, 'Fate Of Human Enteroviruses', p226.

20 Office of Technology Assessment, Wastes in Marine Environments, p139.

21 S.P.C.C., Design Criteria for Ocean Discharge, WP-1.

22 Thomas C.Jorling, 'The Southern California Bight-Municipal Sewage Discharges: A Study in Ocean Pollution Management', in Virginia Tippie & Dana Kester, eds, Impact of Marine Pollution on Society, Praeger, Mass., 1982, p252.

TABLE 8.1

SPCC SCHEDULE OF RESTRICTED SUBSTANCES FOR OCEAN OUTFALL WATERS			
Substance	EXISTING WP-1		PROPOSED
	max. conc. at boundary of i.d.z. in mg/l	max. allowed in Malabar effluent in tonnes/yr *	50%ile conc at boundary of i.d.z. in mg/l
Arsenic	0.1	700	0.004
Cadmium	0.2	1400	0.0009
Total Chromium	0.02	140	0.008
Copper	0.2	1400	0.001
Lead	0.1	700	0.0018
Mercury	0.001	7	0.0001
Nickel	0.1	700	0.015
Silver	0.02	140	0.0001
Zinc	0.3	2100	0.007
Cyanide	0.2	1400	0.0003
Phenolic Compds	0.5	3500	0.003
Total Chlorine	1.0	7000	0.001
Ammonia (N)	5.0	35000	0.4
Total identifiable Chlorinated Hydrocarbons	0.002	14	n.a.

*assuming a dilution of 40:1 and a flow of 480 Ml/day

information from: SPCC, Design Criteria for Ocean Discharge & draft of proposed new

most of these chlorinated hydrocarbons were commercial solvents rather than pesticides and PCBs. They also argued that source control would be difficult because so many industries used these chlorinated solvents and that chlorinated solvents were less significant "from a biological standpoint" than pesticides and PCB's (they gave no evidence for this however).[23] By the time the Environmental Impact Statements came out in 1979, although the same estimates of concentrations were shown for all other restricted substances, chlorinated hydrocarbons had been replaced by "Total identifiable chlorinated hydrocarbons"

[23] Caldwell Connell, Sydney Submarine Outfall Studies, p166.

and the concentrations had miraculously fallen by more than eighty times so that a dilution of only 2:1 was required to keep chlorinated hydrocarbons within WP-1 limits.[24](see table 8.2)

TABLE 8.2

REQUIRED DILUTIONS OF RESTRICTED SUSTANCES IN MALABAR DISCHARGE						
CALDWELL CONNELL 1976				CALDWELL CONNELL 1979		
substance	Maximum allowable conc. mg/l	Effluent Conc. mg/l	minimum required dilution	minimum required dilution	Effluent Conc. mg/l	substance
Arsenic	0.1	< 0.1	1	1	< 0.1	Arsenic
Cadmium	0.2	0.1	1	1	0.1	Cadmium
Total Chromium	0.02	0.7	35	35	0.7	Total Chromium
Copper	0.2	0.4	2	2	0.4	Copper
Lead	0.1	0.3	3	3	0.3	Lead
Mercury	0.001	0.020	20	20	0.020	Mercury
Nickel	0.1	0.2	2	2	0.2	Nickel
Silver	0.02	< 0.02	1	1	< 0.02	Silver
Zinc	0.3	2.0	7	7	2.0	Zinc
Cyanide	0.2	< 1.0	5	5	< 1.0	Cyanide
Phenolic Cmpds	0.5	1.0	2	2	1.0	Phenolic Cmpds
Total Chlorine	1.0	0.00	0	0	0.00	Total Chlorine
.mmonia-N	5.0	28	6	6	28	Ammonia-N
Chlorinated hydrocarbons	0.002	0.25	125	2	0.003	Total Identifiable Chlorinated hydrocarbons

INFO FROM: Caldwell Connell Engineers, Sydney Submarine Outfall Studies, MWS&DB, 1976, p166 & Caldwell Connell Engineers, Environmental Impact Statement Malabar Water Pollution Control Plant, MWS&DB, 1979, p83.

Although WP-1 refers to maximum levels of restricted substances, Caldwell Connell uses mean figures for concentrations of restricted substances in the sewage effluent. This is somewhat misleading since the effluent is extremely variable and the mean is unlikely to bear much resemblence to maximum concentrations, particularly when the sludge is discharged during a few hours at night.

Table 8.1 also shows (column 3) just how much more restrictive the proposed changes to the WP-1 guidelines would have been. The levels were 50 percentile concentrations rather than maximum figures but the 90 percentile figure was not allowed to be more than twice the average concentration. The levels in the revised guidelines, were supposed to be based on "the best toxicological data available to the Commission" and were worked out so that there would be no

24 Caldwell Connell, Environmental Impact Statement Malabar Water Pollution Control Plant, M.W.S.&D.B., p83.

effects at the boundary of the initial dilution zone.[25] As explained in chapter 6 these proposed guidelines were not approved by the Clean Waters Advisory Committee after the Sydney Water Board and the Public Works Department expressed concerns that their installations and the proposed submarine outfalls would not be able to meet them.

Despite the SPCC desire to update WP-1 because the maximum levels of restricted substances are "so outdated that it cannot be scientifically justified"[26] the Board continues to use the old WP-1 guidelines to publicly justify the amount of toxic waste it discharges into the ocean. Moreover the old WP-1 was used as a basic design parameter for the design of the submarine outfalls although it is not based on the latest toxicological data but rather 1974 standards set for the convenience of the Water Board at the time.

There is some controversy over whether dilution is an adequate mechanism for dealing with wastes that can be accumulated and concentrated biologically in the ocean. The regulation of restricted substances in terms of concentrations reinforces this dependence on dilution. It is argued that total amounts of restricted substances being discharged into the sea might be a more meaningful measure of potential harm. Dr Tom Mullins, a marine chemist and previously director of pollution studies at the NSW Institute of Technology, was an early critic of the submarine ocean outfalls. One of his main criticisms was that insufficient research had been undertaken by the real experts in the area, the marine biologists, ecologists and oceanographers.

> Much has been said about the dilution and dispersal characteristics of sea water, but a third function is continually overlooked; that of concentration by both biological and physical-chemical means. The most common and well-documented examples of this are the selective absorption capabilities of fish, crustaceans, seaweeds and phytoplankton.[27]

He claimed that reports from California where a similar submarine ocean outfall was located had shown that the biological productivity around the outfall discharges had changed and that if the ability for the polluted water to mix with unpolluted water was restricted such change could be severe enough to "adversely affect the ecological balance, resulting in the destruction of, for example, shellfish beds." He pointed out that the ocean was not "a world-wide homogenous system" where everything was mixed and spread evenly, but rather that local effects predominated. This was shown in the case of New York Harbour where there was a 20 square mile path of "dead water" where marine life could not live.[28]

Moreover, Mullins was concerned that the oxygen demand of sewage decomposition in the sea had not been given sufficient attention although it "could result in fish and other ocean life smothering from lack of oxygen". His

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25 S.P.C.C., Design Criteria for Ocean Discharge, draft, 1987.

26 S.P.C.C., Design Criteria for Ocean Discharge, Clean Waters Advisory Committee Meeting, 10th September 1987, p25.

27 Sydney Morning Herald, 3rd June 1970.

28 ibid.

own research into oxygen concentrations in the ocean had been restricted because there was a lack of interest in the problem, and therefore a lack of facilities. He claimed that he had already found that fish life was being forced farther out from the coast.[29]

DISPERSAL - AND WHAT HAPPENS TO THE SLUDGE?

Caldwell Connell argue that after the sewage is initially diluted as it rises toward the surface of the sea it is diffused as the seawater mass moves along. Brain criticised the basis on which Caldwell Connell worked out the coefficient for their diffusion equations. Caldwell Connell had used six die experiments. The first two had been somewhat unsatisfactory so they had changed the dye type for the subsequent four experiments. The dye had been released in three different shapes and under different conditions and monitored for some hours.[30] (see figure 8.4) Brain expressed grave doubts as to whether dye experiments could predict the movement of sewage fields.

> There appears to be a complete unawareness that there will be a profound velocity difference at the edges of the surfaced plume and that, in the case of the submerged plume, there will also be the same profound velocity difference between the upper face of the plume and the ocean water layers above.[31]

According to the traditional diffusion theory, which was used by Caldwell Connell, the plume would be expected to bleed away at the edges and the centre would remain highly persistent. In practice the edges of the sewage field could be observed to be sharp and the plume tended to break up into sharp-edged patches. Brain argued that in fact there was little evidence of subsequent dilution and that the initial dilution be assumed to be the final dilution for the purposes of calculating beach pollution levels.[32]

Dispersion is the primary mechanism which Caldwell Connell rely on to deal with contaminated particles of sludge likely to settle out of the sewage field and the ocean waters. With reference to the disposal of sludge, the 1976 Caldwell Connell report had advised that if the Board selected ocean disposal for the sludge then they recommended that it be disposed of via a separate sludge outfall pipeline in preference to using the effluent outfall.[33] The Board decided to discharge the sludge with the effluent, despite this advice, but just to be on the safe side they are constructing the effluent outfall pipes to have smaller sludge pipes embedded in them so that the sludge can be discharged separately if necessary. The disposal of sludge with primary effluent via a deep water diffuser is unique in the world. Elsewhere the preferred method of disposal to sea is by

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[29] Telegraph, 22nd May 1970.

[30] Caldwell Connell, Sydney Submarine Outfall Studies, pp72-3.

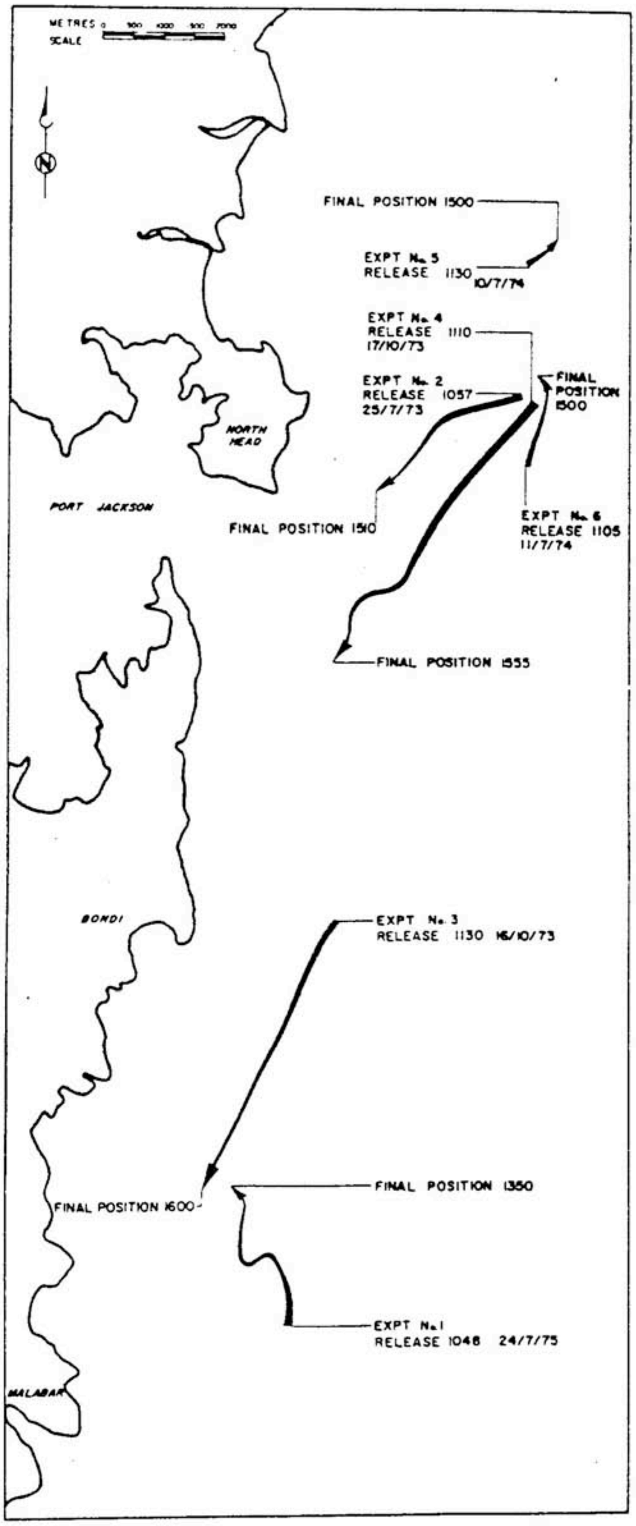
[31] R.Brain, internal report to S.P.C.C., 1980.

[32] R.Brain, `Sludge Disposal and Design Criteria for Ocean Outfall Discharge', Symposium on Sludge Management and Disposal, Surfers Paradise, 30 June-2nd July 1982, p9-5; Brain, `Recent Developments in Ocean Outfall Diffuser Theory', p116

[33] Caldwell Connell, Sydney Submarine Outfall Studies, px.

barging it out some miles although in some places separate sludge pipelines are used.[34]

Figure 8.4 Location of Dye Diffusion Experiments



Source: Caldwell Connell, Sydney Submarine Outfall Studies, MSW&DB, 1976, p. 72.

34 Ralph Kaye, 'Technical Support Paper-Sludge Disposal Policy', presented at Clean Waters Advisory Committee Meeting, 10th September 1987, p11.

In the Environmental Impact Statements for the submarine outfalls it was noted that benthic organisms were impoverished and altered in composition close to the existing outfalls.[35] Nevertheless the possibility of toxic substances such as heavy metals, pesticides and PCB's in the sediments being concentrated up the food chain was dismissed as unlikely since no serious accumulation of these toxic materials had been observed in sediments near the existing outfalls.[36]

Sediment samples were taken using a Shipek Grab Sampler in the vicinity of the outfalls and measured for concentrations of heavy metals and pesticides. The location of sediment sampling is shown in figure 8.5. Only three locations for sediment samples are indicated and, especially at North Head, they are taken quite a distance away from the existing outfalls. No rationale is given for why these spots are chosen and whether they were likely places for sedimentation. In a confidential report the SPCC noted

> The statistical significance of single samples and the validity of a sampling technique which does not segregate undisturbed surface material must be brought into question.[37]

Nevertheless, the sample taken off Malabar contained elevated levels of heavy metals and elevated levels of DDT and DDE further out to sea.[38] (The content of the other two samples is not disclosed.) Caldwell Connell assigned no importance to this finding and argued that although "the presence of transient sludge layers" on the ocean floor were noted by SCUBA divers, this material "appeared to be deposited only during periods of low current velocities and was dispersed under the normal current regime."[39]

Jump Camera photographs taken at 45m of depth and deeper off the North Head outfall, and therefore at some distance from the shoreline discharge, also failed to show any accumulation of sediments which could be likened in particle size to digested sludge. This together with the observation that benthic organisms were abundant (a meaningless observation considering the earlier observation in the same document that they were impoverished near the outfall), were sufficient justification for Caldwell Connell to assume that sludge did not accumulate.[40]

It was argued that the discharge of sludge with the effluent would facilitate the dispersion of the particulate matter and the dilution achieved would mean the effect of the sludge on the receiving water would be minimal. Any particles which might settle on the bottom would be swept away very quickly by bottom currents and "a significant portion of the digested sludge particles would be consumed by marine organisms" (not necessarily a preferred outcome!) thus minimising

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35 Caldwell Connell, Environmental Impact Statement North Head Water Pollution Control Plant, M.W.S.&D.B., p31.

36 Caldwell Connell, Environmental Impact Statement Malabar, p72.

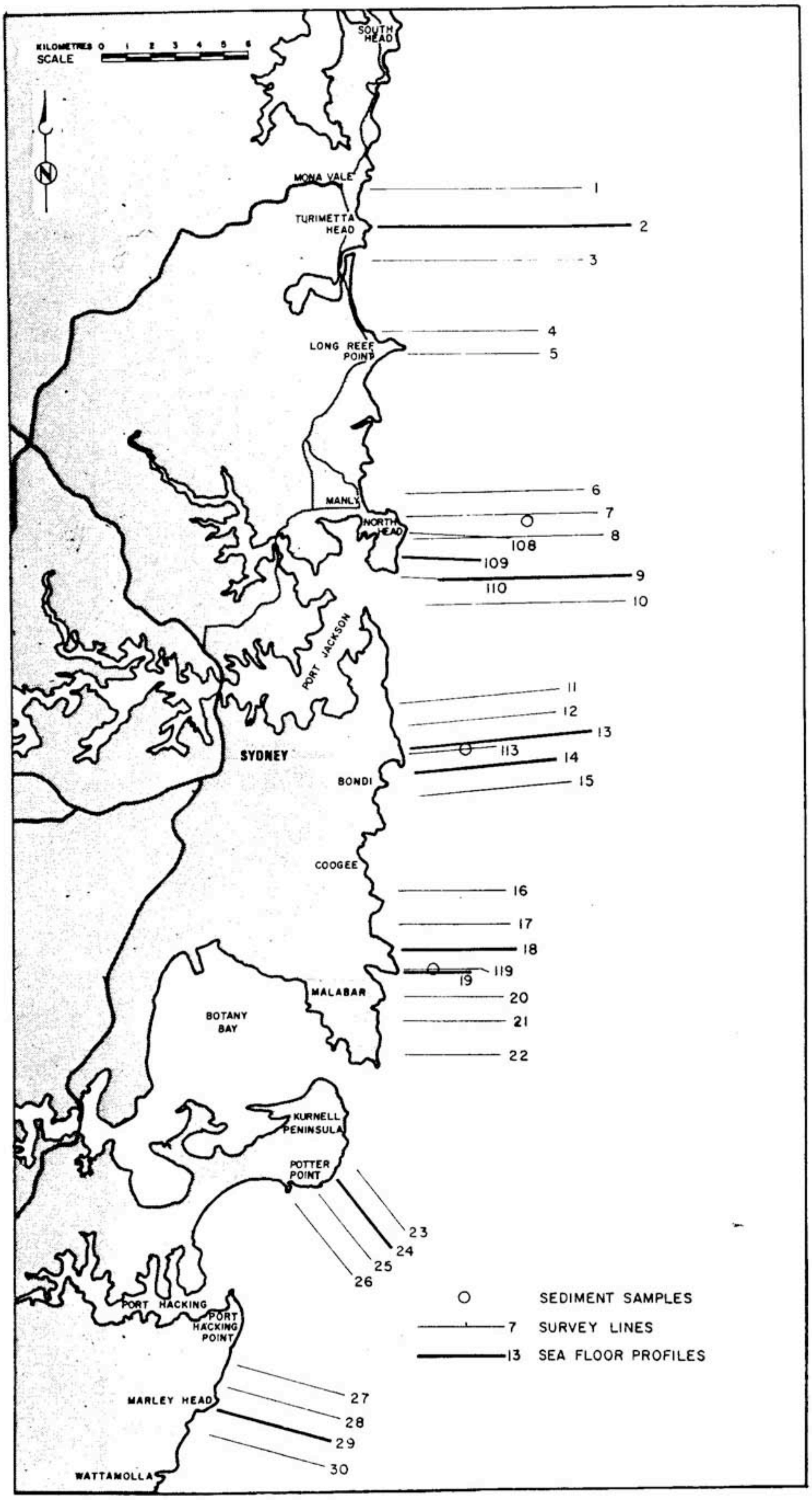
37 Kaye, 'Sludge Disposal Policy', p13.

38 Caldwell Connell, Environmental Impact Statement Malabar, p43.

39 Caldwell Connell, Environmental Impact Statement North Head, pp31-32.

40 ibid., p53.

Figure 8.5 Location of Sediment Samples



Source: Caldwell Connell, Sydney Submarine Outfall Studies, MWS&DB, 1976, p. 138.

localised sedimentation of small particles or reduction of phytoplankton productivity because of turbidity.[41]

Others who read the environmental impact statements were less optimistic. A major concern of the Department of Mineral Resources was the potential accumulation of deposits of solid particles which might in turn lead to a concentration of heavy metals and toxic chemicals in the fine fractions of sediments (the "muds and oozes"). They were sceptical of the claims that ocean current velocities/settling times/particle sizes, were such that wide dispersion of solid particles would occur. "It is difficult to understand that these particles do not go somewhere specific where they accumulate."[42]

The Board countered that it had calculated that the fastest settling particles would travel 14km before settling and that bottom currents would generally be strong enough to re-suspend most particles of sewage origin (other than sand and soil particles). They did not expect any significant accumulations and this was born out by observation made near the existing outfalls where raw and partially treated sewage had been discharged for 60 years. By their own calculations it seeems they might have been looking in the wrong place if they were looking near the outfalls and yet expected the particles to travel 14km before settling.

Mullins, also criticised the dubious reasoning of the Board in this case. What happens to sludge at the existing outfalls, he pointed out, may be quite different from what will happen in deeper and stiller water where the submarine outfalls will discharge. Caldwell Connell admit themselves, in seeming self-contradiction to other parts of their 1976 report, that

> Transitory solids deposits of variable thickness and extent were noted. No conclusions can be drawn from this existing condition, however, regarding the impact which digested sludge would have if it were discharged through a long submarine outfall into deep offshore waters.[43]

Even an internal Water Board report went so far as to say that the effect of digesting the sludge, as at Malabar, was to stabilise the organic fraction and render the sludge more settleable, which would be a disadvantage in the sea because it would be more likely to settle out and accumulate on the ocean bottom where ocean currents were low.[44] But this was a report arguing that full primary treatment should not be installed at North Head and it suited their purposes at that time.

The Australian Museum had conducted ecological surveys of nearshore waters during the 1970s. They claimed that particles from the diffuser which fell into the mud/clay range would be likely to be deposited in a relatively stable region of mud and that heavy metals and other industrial wastes which might behave like

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41 ibid., p53.

42 Dept of Mineral Resources, submission on Submarine Outfall Environmental Impact Statements, 1980.

43 Caldwell Connell, Sydney Submarine Outfall Studies, p152.

44 MWS&DB, North Head and Ocean Outfall Re-evaluation of Treatment and Disposal Options, September 1977, pp2-7.

mud or clay sized particles were likely to also be deposited in this stable zone of muddy sediment. Such materials could then be assimilated by benthic organisms and enter the tissue of fish passing through the area. "Such a situation could be harmful since the professional fishing grounds of Sydney are located in this region."[45]

Dr A Jones, marine ecologist with the Australian Museum, was more guarded in the Museum's submission on the EIS. It should perhaps be pointed out that the director of the Museum, Dr F H Talbot had been appointed to be a member of the Board (a new position was created at the time) in 1972.[46] Nonetheless their carefully worded submission did not inspire confidence. It started off

> it seems unlikely that any severe ecological damage will ensue although there will certainly be changes, especially in benthic feeding type. Intense sedimentation and low dissolved oxygen levels are likely to stress the fauna but this is expected to be transitory and not severe.[47]

His submission went on to say that the major ecological effect would be an increase in productivity because of the discharge of nutrients and that this was not a problem but that potential difficulties arose from consideration of the ecosystem. Some toxins were concentrated along food chains and this had caused the closure of some fisheries elsewhere where samples of fish have had high levels of toxins in their tissues or have suffered pollution related diseases. Moreover, Jones explained, the maintenance of benthic communities "is highly dependent on the successful settlement of pelagic larvae which may be more susceptible to pollution".

Despite all these criticisms, Caldwell Connell again concluded in 1982 that there would not be any long-term accumulation of sludge on the seabed. Caldwell Connell had done very little investigation into the actual presence of sludge accumulation and had relied instead on a computer model to tell them where sludge from the new outfalls would go to rather than conducting any empirical experiments with sludge in the ocean. They again argued that it would be widely dispersed, mostly in suspension and the sludge that was deposited would be resuspended during severe storms or taken up by marine organisms. So although they rejected the idea that the sludge accumulated they did not reject the idea that the sludge particles provided a pathway into the food chain for toxic metals.

The Board used the Caldwell Connell data to argue, in 1982, that the potential annual increases in sediment heavy metal concentrations represented only one to three percent of the average natural background concentrations which themselves varied over a wide range.[48] However, Caldwell Connell had measured concentrations of heavy metals in sea water at Palm Beach, Shelly Beach and North Head to get "typical" background levels of metals in the ocean offshore

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45 Kaye, 'Sludge Disposal Policy', p14.

46 Sydney Morning Herald, 27th July 1972.

47 Australian Museum, submission on Submarine Outfall Environmental Impact Statements, 1980.

48 MWS&DB, Disposal of Digested Sludge to the Ocean: Malabar & Bondi Water Pollution Control Plants, December 1982, p27.

from Sydney.[49] At least two and probably all three of these locations would have background levels affected by previous sewage discharges.

The Board also admitted that potential existed for the concentration of metals through the food chain but argued that available evidence indicated that this would not occur "to an extent likely to cause a hazard to humans or marine animals",[50]

> Furthermore, monitoring of diposal options in the U.K. and the west coast of the USA have failed to show any serious environmental or public health consequences.[51]

This contrasts with an SPCC finding that adverse impacts of sludge disposal to the ocean have been observed all over the world. The SPCC report cited reports, most of which predated the Board's report, that showed that in the New York Bight many benthic invertebrates seemed to have disappeared, in particular the crustacea and molluscs which are an important food organism for fish. At the Hyperion outfall in Los Angeles it was found that even when diluted by 600 times sludge was slightly toxic to the development of sea urchin embryos. Numerous diseases in marine organisms had been associated with sludge discharges in the States and in Germany.[52]

Even the model which Caldwell Connel used to reject the idea of accumulation was criticised and the same SPCC report as mentioned above noted that the predictions were based on laboratory conditions that might not be relevant to actual conditions.[53] The report also noted that "the accumulation of trace metals and organics in the vicintiy of sludge disposal areas" was well documented and Sydney oceanographic conditions similar to those off Los Angeles and elsewhere where accumulation had taken place.[54] They observed that

> None of the studies undertaken off Sydney thus far have attempted to account for the fate of the sludge which has been discharged through the existing shoreline outfalls.[55]

THE SURFACING OF THE SEWAGE FIELD - DOES IT MATTER?

Another important mechanism which the submarine outfalls were designed to achieve is a submerged field. This mechanism is important, according to Caldwell Connell, so that aesthetic nuisances can be minimised and to prevent sewage from reaching bathing waters.[56] As discussed in chapter 5, if the ocean waters are stratified so that the top layers are warmer and therefore less dense

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[49] Caldwell Connell, Analysis of Oceanographic Data and Review of Ocean Outfall Design Concepts, MWS&DB, July 1980, p5.

[50] MWS&DB, Disposal of Digested Sludge to the Ocean: Malabar & Bondi Water Pollution Control Plants, December 1982, p27.

[51] ibid., p29.

[52] Kaye, 'Sludge Disposal Policy', pp7-9.

[53] ibid., p12.

[54] ibid., pp5,11.

[55] ibid., p25.

[56] Caldwell Connell, Sydney Submarine Outfall Studies, p168.

than the bottom layers, and if the sewage is released so that it is mixed with the cooler, denser layers at the bottom of the ocean before it reaches the ocean surface then the sewage field will be trapped below the top warmed layers of water.

This phenomenon, which was shown diagramatically in figure 8.1, was first observed to occur on the West Coast of the United States. However, the conditions there differ significantly from those off Sydney and there is some speculation that a submerged field is less likely to occur off Sydney. In particular, the waters off California have the top layers warmed by the sun and the bottom layers cooled by a cold current coming down from the North whereas in Sydney, as Brain has argued, stratification would be far more "trivial" because

> The East Australia Current is warm and inhibits stratification; further in the vicinity of Sydney it tends to form back-eddies which may recirculate sewage. It does not follow, therefore, that a successful Californian design will transplant to Australia with equally good results.[57]

Caldwell Connell had defended their assumptions about currents by comparing the predictions of their computer model with actual flows at existing outfalls in the United States. At West Point submarine outfall the position of the submerged field was measured with its upper boundary at 21m depth and its lower boundary at 42m depth. The model had predicted an upper boundary at 26m depth and a lower boundary at 38m. Caldwell Connell concluded that

> Considering the computer program does not include the effects of currents, the correspondence between the measured and the predicted boundaries of the field is considered to be very good.[58]

Brain did not agree. He argued that actual field thickness was 21m as compared to a predicted thickness of 12m and that such an error over a total depth of 50m was significant. With an error of that size, he pointed out, only the March/April period could be counted on for producing a submerged field with any reliability.[59]

Brain also suspected that adequate consideration had not been given to the turbulence generated between the submerged plume and the layer of seawater above it. This would cause, claimed Brain, rapid entrainment and the probable emergence of a surface plume. Brain also felt that the Malabar diffuser had been underdesigned. His first report suggested that, if all his criticisms were supported, there would be "massive increases in beach faecal bacterial densities above those given in the EIS's".[60]

Brain argued that a submerged field would only be achieved for short periods during the summer months and even then grease and floatables would surface and be subject to on-shore surface currents.[61] When there was a surface field

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57 Brain, `Sludge Disposal and Design Criteria for Ocean Outfall Discharge', p9-9.

58 Caldwell Connell, Sydney Submarine Outfall Studies, p14.

59 R.Brain, internal report to S.P.C.C., 1980.

60 ibid.

61 For example, Manly Daily, 14th December 1985.

conditions at the beaches would be even worse than existing conditions. The Board themselves admit that the field would not be submerged for much of the time in winter.(see table 8.3) They state for example that in the worst winter months the field will not be submerged any of the time and at North Head during the winter period as a whole the field will only be submerged 9% of the time, and in the worst summer month it will be submerged 76% of the time.[62]

TABLE 8.3

WATER BOARD PREDICTIONS OF PROPORTION OF SUBMERGED FIELDS

Time Period	Water quality Criterion	Performance North Head	Performance Bondi	Performance Malabar
Summer Period	>90%	91%	96%	96%
Worst month in summer	--	76%	94%	94%
Winter Period	--	9%	31%	36%
Worst month in winter	--	0%	0%	0%

M: Caldwell Connell, Environment Impact Statement, North Head WPCP, MWS&DB, 1979, p64 &
MWS&DB, Environment Impact Statement, Bondi WPCP, MWS&DB, 1979, p52 &
Caldwell Connell, Environment Impact Statement, Malabar WPCP, MWS&DB, 1979, p82.

As has been discussed in chapter 4 when the sewage comes to the surface it is blown on the wind for many kilometres and when the wind is onshore the beaches are easily polluted. Many swimmers and surfers are aware of this and realise that the actual distance the outfalls are from the coast provide insignificant protection. Richard Gosden from Stop the Ocean Pollution (STOP) pointed out, in 1985, that the sewage already travels much further than the proposed 2 to 4 km that the outfalls will extend. Beaches such as Long Reef had been closed several times that summer because of pollution, although the Manly outfall was 7.5km away.[63]

STOP also criticised the practice of separating the sludge from the effluent and then discharging it with the effluent. They noted that Caldwell Connell had based their design and predictions of a submerged field occuring on the separate discharge of sludge which had led to an initial design with many more finer diffusers. The later decision to add sludge to the effluent had necessitated fewer dispersal points with larger openings. This, STOP argued, would probably reduce the diffusion possible and lessen the chances of achieving a submerged field.[64]

STOP likened the submarine outfalls to the strategy used in Europe some years before where smoke stacks from coal burning power stations were made higher because of local pollution. This facilitated the further spread of acid rain throughout the whole continent and STOP argued that the submarine outfalls would, likewise ensure the further spreading of sewage pollution up and down

62 Caldwell Connell, Environmental Impact Statement North Head, p64.

63 Richard Gosden, `Sewerside Culture', Engineering and Social Responsibility 2(2), March 1985, pp6-7.

64 Richard Gosden, 'Truth Surfacing on Submerged Field', Engineering and Social Responsibility 2(7), August 1985, p5; Southern Courier, 25th June 1986.

the coast.[65] A surface field arising from the extended ocean outfalls offered no improvement over the existing outfalls in terms of sewage field reaching bathing waters.

Drogue experiments were carried out by engineers between 1958 and 1978 to predict the movement of surface fields. The trajectories of these drogues were plotted and are shown in figures 8.6, 8.7 & 8.8. Those trajectories with an arrow represented the number of occasions on which an effluent field reached shore. In other words, the drogue experiments purported to show that 43% of the time at North Head, 23% of the time at Bondi and 39% of the time at Malabar the sewage field would have reached shore and affected nearby beaches.[66]

However there is some doubt that the drogues were indicative of a surface field. The drogues were submerged at depths of about 2 metres below the surface of the water so as to minimise wind influence[67] in the time honoured way that early engineers carefully avoided the affect of the winds (as explained in chapter 4). This refusal to acknowledge the role of the wind on a surface sewage field in drogue experiments was despite the common knowledge amongst surfers and admissions from engineers from as far back as 1936 (see chapter 4) that the wind is a primary influence on the movement of a sewage field. In fact Caldwell Connell observed that currents at 2 m depth do not correlate with wind speed and direction and that "wind driven currents are confined to a surface layer less than 2 m deep." [68] Therefore their drogue experiments are not relevant to the movement of the top 2m of water nor any surface field within that water.

If wind directions had been considered as the prime movers of the floating sewage field then the prevailing onshore winds during summer would have ensured that the estimate of shoreward travelling surface fields, at least those in the top metre of so of ocean, was at least 50%. when winds are onshore for 50% of the time in Summer. This is the figure that is in fact used by the Water Board in 1983 in its application to the SPCC.[69] (see table 8.4)

Caldwell Connell argued that when the sewage field was submerged that it would be carried southwards by the current. The Department of Mineral Resources pointed out that the East Australian Current was not a single feature and that it was the eddys generated by that "current", which came close inshore, which were the prime cause of the "episodic southwards water movement".[70] Mullins claimed that it was wrong to consider masses of water as so large that they were well mixed and homogeneous.[71] Similarly a letter writer to the Herald argued that the "holy" east Australian current was not a simple north/south current "but a series of giant eddies , tens to hundreds of kilmetres in diameter,

65 S.T.O.P., `Sydney's Toxic Waste Dump: the Pacific', submission to Waverley Municipal Council, June 1986, p1.

66 Caldwell Connell, Analysis of Oceanographic Data, p23.

67 ibid., p23.

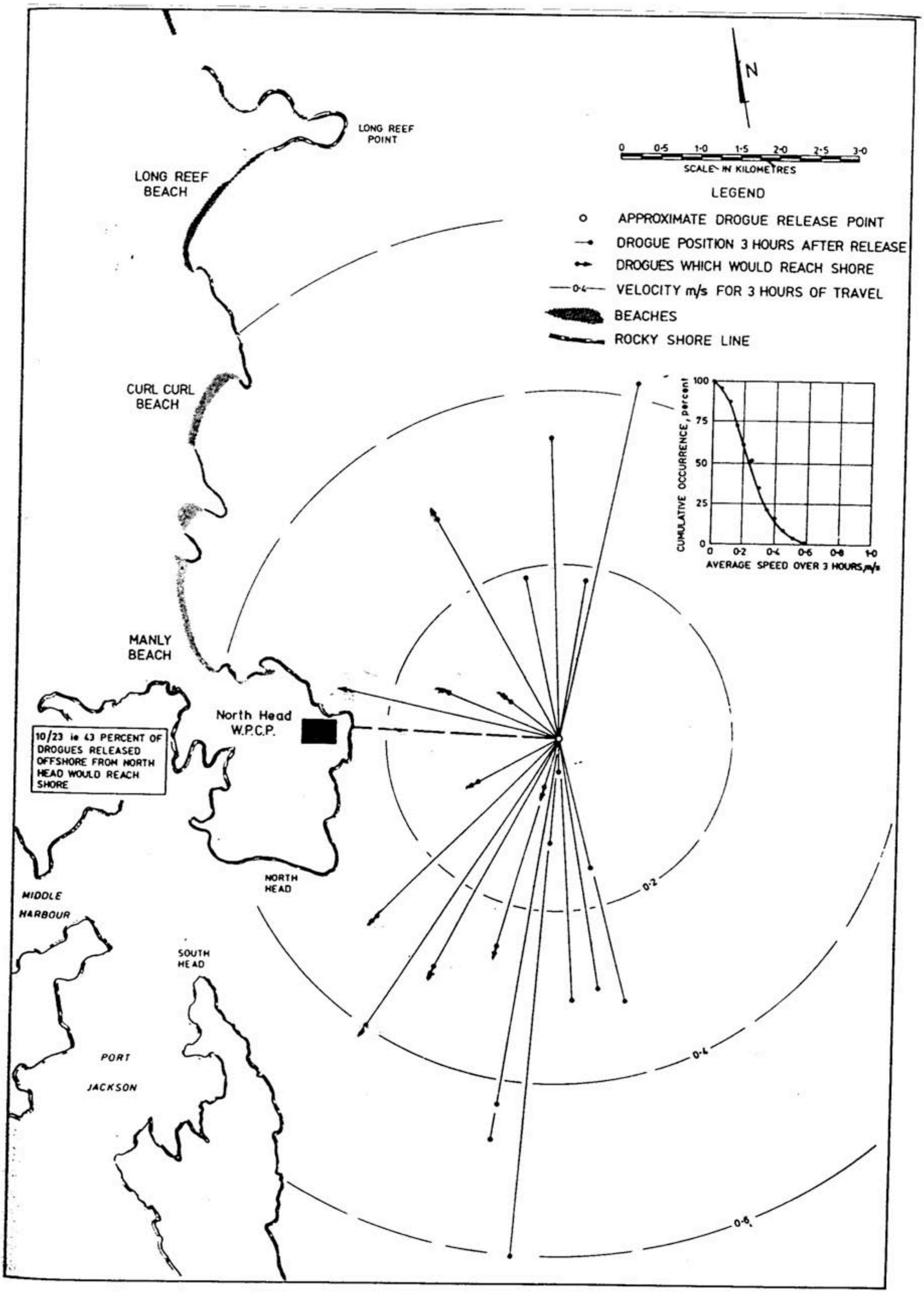
68 Caldwell Connell, Sydney Submarine Outfall Studies, p47.

69 Clean Waters Advisory Committee meeting, business papers, 8th September 1983, p18.

70 Dept of Mineral Resources, submission on Submarine Outfall Environmental Impact Statements, 1980.

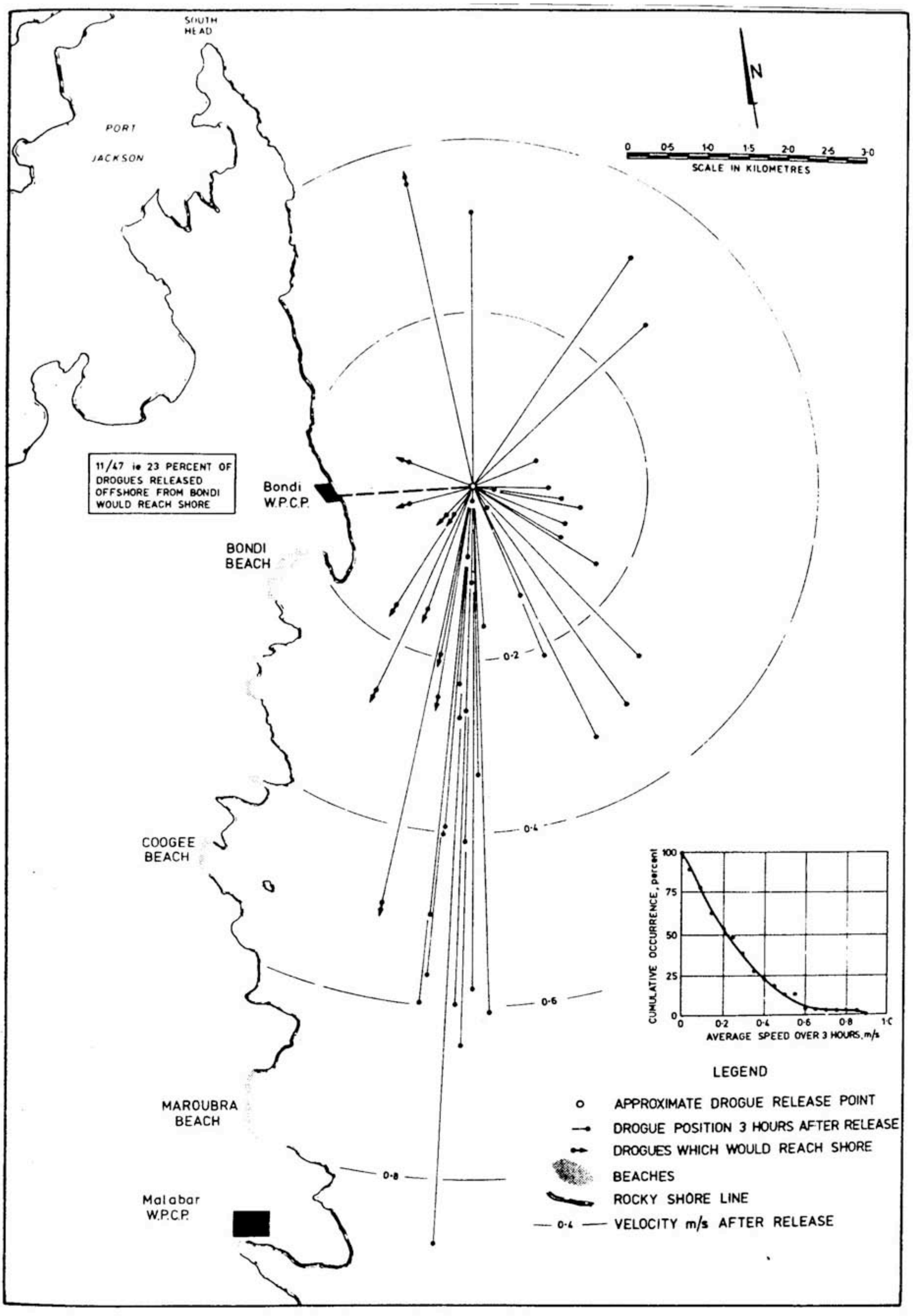
71 Weekly Courier, 15th July 1981.

Figure 8.6 Path of Free Floating Drogues Released from North Head



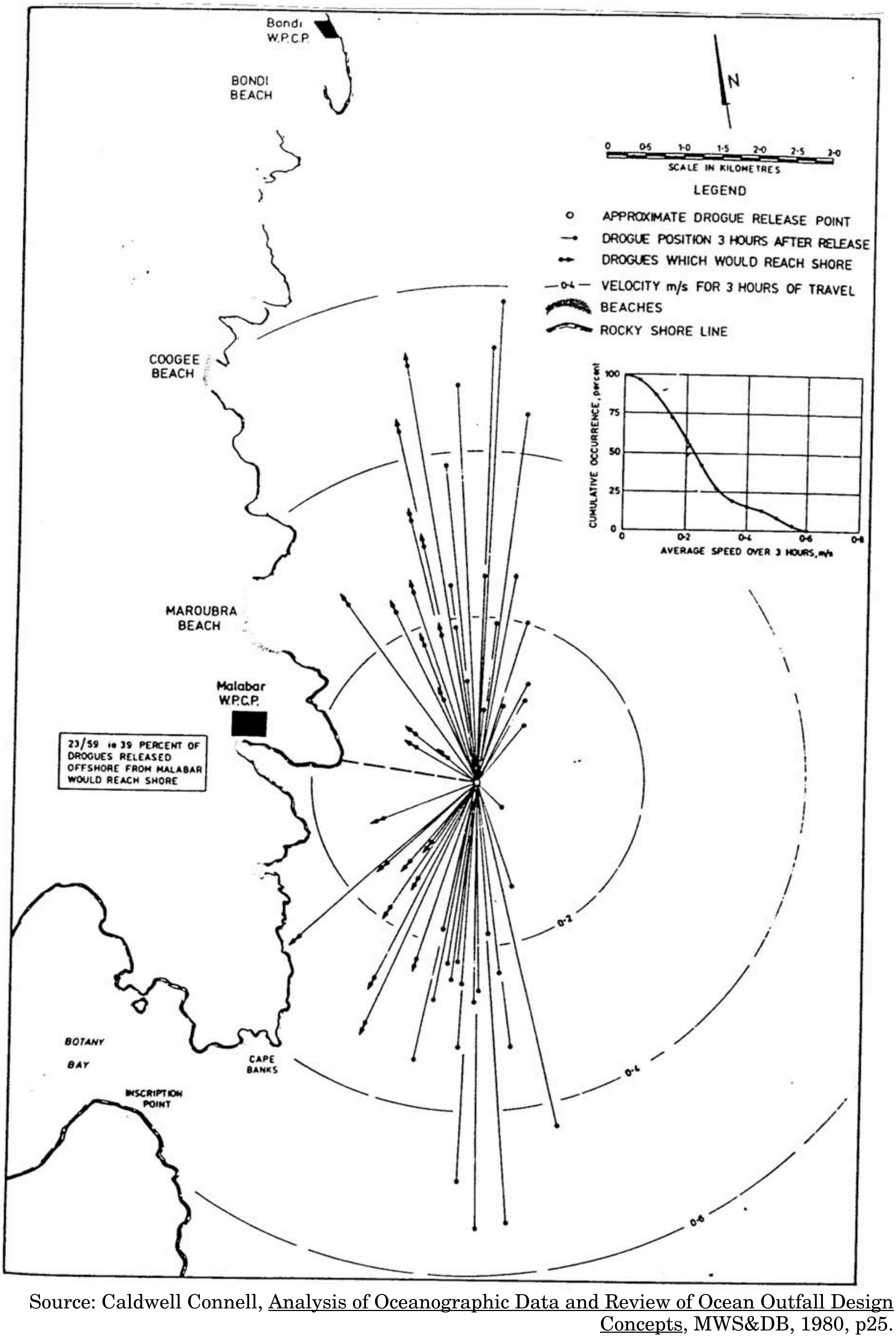
Source: Caldwell Connell, Analysis of Oceanographic Data and Review of Ocean Outfall Design Concepts, MWS&DB, 1980, p24.

Figure 8.7 Path of Free Floating Drogues Released Offshore from Bondi



Source: Caldwell Connell, Analysis of Oceanographic Data and Review of Ocean Outfall Design Concepts, MWS&DB, 1980, p25.

Figure 8.8 Path of Free Floating Drogues Released from Malabar



Source: Caldwell Connell, Analysis of Oceanographic Data and Review of Ocean Outfall Design Concepts, MWS&DB, 1980, p25.

which actually hold shore waters against the coast." He cited CSIRO research which he claimed showed that eddy pressure counteracted any dispersal mechanism.[72] Brain has also pointed out that, whilst the waters off California have a strong constant ocean current going down the coast, the Sydney currents are not constant, rather they "whirl around and form giant eddies, sometimes they stop altogether for days at a time."[73]

TABLE 8.4

SEASONAL BEHAVIOUR OF THE SEWAGE FIELD					
Season	Prob. of Surface Field	Prob. of Onshore Current	Prob. of Reaching Shore	Prob. that Shore is a Beach	Prob. of Reaching Any Beach
Summer	4%	50%	2%	100%	2%
Winter	80%	50%	40%	100%	40%

SOURCE: Clean Waters Advisory Committee Meeting, Business Papers, 8th September 1983, p18

TABLE 8.5

SEASONAL BEHAVIOUR OF THE SEWAGE FIELD					
Season	Prob. of Surface or Submerged Field	Prob. of Onshore Movement	Prob. of Reaching Shore	Prob. that Shore is a Beach	Prob. of Reaching Any Beach
Summer	surface 4% submerged 96%	50% 42%	2% 40%	100%	42%
Winter	surface 80% submerged 20%	50% 42%	40% 8%	100%	48%

The reliance of the Board and Caldwell Connell on the East Australian Current is not even supported by their own research. In the 1976 Caldwell Connell study, currents were measured and observed and it was noted that at Bondi onshore currents were observed a significant percentage of the time throughout the year and that at North Head and Malabar they were observed in all seasons except spring.[74] For summer when the submerged field is supposed to be working best,

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72 Sydney Morning Herald, 21st December 1988.
73 Sun-Herald, 23rd October 1988.
74 Caldwell Connell, Sydney Submarine Outfall Studies, p59.

Caldwell Connell show 35% of currents going onshore at the mid-depths of the sea at North Head, 50% at Bondi and 50% at Malabar.[75]

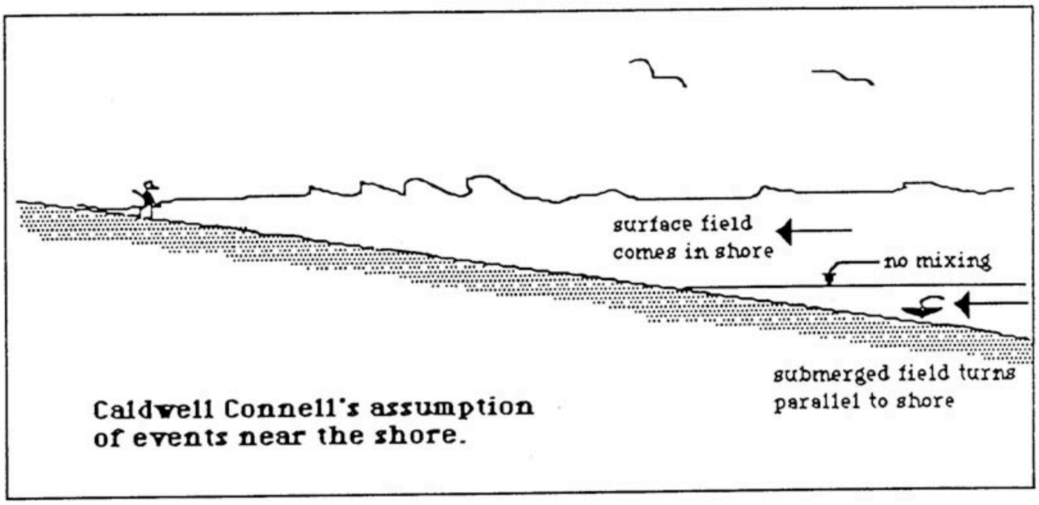
In a later Caldwell Connell study in 1980 it was found that the frequency of onshore currents throughout the year was 40% for North Head, 30% for Bondi and 42% for Malabar. Current meters had been installed in the vicinity of the proposed outfall diffusers at 30 metres depth.[76] However it seems that Caldwell Connell was determined not to interpret the results as reflecting poorly on their prediction of the field being carried away by a southerly current. The conclusion of I.G.Wallis, Principal Investigations Engineer of Caldwell Connell, was that long term discharges were carried south although his own investigations showed that up to 42% of currents would carry sewage toward shore.[77]

In the report tendered by the Water Board to the SPCC as part of its application for approval for the Malabar submarine ocean outfall in 1983[78] the following table was given.

Although the Board may have overestimated onshore winds for the winter time, table 8.4 incorporates an assumption that the submerged fields will not come on shore at all yet Caldwell Connell have found that 30-40% of submerged fields will travel shoreward. The following table, table 8.5, is a modification of the above table showing that the affect of the shoreward travelling submerged field coming onshore inflates the probability of sewage reaching any beach quite considerably.

However Caldwell Connell assumed that submerged fields which travelled towards the shore would remain submerged and turn parallel to the shore before coming in. (see figure 8.9)

Figure 8.9



[75] ibid., pp51-56.

[76] Caldwell Connell, Analysis of Oceanographic Data, pp15,20.

[77] I.G.Wallis, 'Ocean Currents Offshore from Sydney', Sixth Australian Conference on Coastal & Ocean Engineering, IEAust, 1983, p210.

[78] Clean Waters Advisory Committee meeting, business papers, 8th September 1983, p18.

Caldwell Connell based this supposition on their studies of the density contours in the ocean which they found did not slope up towards the shore "to any significant degree" and they assumed, therefore, that the top boundary of the submerged field would remain horizontal and not mix with the overlying layers of seawater even as the waters become shallower and stratification was not sustained.[79] However their density contours were done in water that was between 30 and 65 metres deep[80] and these results cannot be sensibly extrapolated to the much shallower water near the beach.

They said that "upward mixing could occur in the surf zone, where the stratification is broken down"[81] but contended,

> For the purposes of this report, we have considered that the surf zone extends to a water depth of 7m. A submerged field therefore, is defined as one whose top boundary is at least 7m from the water surface. Taking all factors into account, it is considered that submerged fields could become surface fields and be carried to the shore very infrequently and that this possibility need not be considered in preliminary design.[82]

This statement is less than convincing and there does not seem to be any good reason why the submerged field would turn away rather than come on into shallower waters where it would be mixed with the surf zone. This possibility was not investigated by Caldwell Connell or by the Water Board and no research was undertaken to support their assumptions.

Submerged fields are not necessarily preferrable to surface fields if sewage can still reach shore. Brain contended that submerged fields would hang around for a long time, the bacteria in them protected from the sunlight in the deeper water, and occasionally remixing with beach waters. The SPCC were also worried about the inhibited die-off of bacteria in deep water where sunlight could not penetrate. Caldwell Connell claimed, in 1983, that they had based the die-off rates on "the most extensive set of field experiments carried out, to date, in the world" and that since ultra violet light was not the major cause of the observed die-off rates it was not appropriate to allow for the effect of attenuation of ultra violet light with depth.[83] Nevertheless Caldwell Connell had themselves calculated that there was a 28% increase in die-off times if account was taken for "the effect of light extinction within the top 7m".[84] Moreover Caldwell Connell have found that there is far less die-off at night because of the lack of sunlight.[85]

The Department of Mineral Resources suggested that if a submerged field was maintained then this might lead to an increase in the tainting of fish due to detergents and that the existing problem of the tainting of trevally and bream in the waters around Sydney had been ignored in the EIS's. Furthermore a

79 Caldwell Connell, Sydney Submarine Outfall Studies, p170.

80 ibid., p69.

81 ibid., p71.

82 ibid., p170.

83 S.P.C.C., Questions Relating to Proposed Malabar Outfall, M.W.S.&D.B., Sydney, June 1983.

84 Caldwell Connell, Sydney Submarine Outfall Studies, p174.

85 Caldwell Connell, Analysis of Oceanographic Data, p36.

submerged field would keep detergents under the surface and could lead to a decrease in the decay rate of biodegradable detergents, "hence ensuring a wider and more dilute distribution of the grease released during degradation of the detergents."

If the submerged field is of disputable and unpredictable benefit in terms of preventing sewage from coming into bathing waters and may even hinder the decomposition of sewage why did Caldwell Connell try so hard to achieve it? The answer seems to be that a submerged field would not be visible. Caldwell Connell say it is essential that the sewage discharges do not cause aesthetic nuisances and that this can be achieved firstly by dilution and secondly by maintaining a submerged field for as much of the year as possible.[86]

The SPCC has been particularly concerned about the visibility of surface sewage fields and they have emphasised it in meetings with the Board.[87] The SPCC wanted to know at what dilution would the surface field cease to be visible to a layperson from the shore, a boat and an aircraft and under what circumstances would surface slicks of floatable material become visible.[88] They were concerned that in experiments carried out at the Board's Paddington Laboratory that effluent/sea water mixtures at dilutions of up to 150:1 didn't have the same appearance as seawater alone and also that field studies in California had found `visible' slicks of floatable material above diffusers off Los Angeles even though the effluent discharging from those outfalls were less concentrated than what would be discharged at Malabar.[89]

Caldwell Connell assured the SPCC that the Malabar sewage field would generally not be visible from the shore, boat or air and that on the rare occasion when there was a malfunction, illegal or uncontrolled discharged or a rare combination of climatic conditions such as no current, wind or waves, only a person with keen eyesight would be able to see it.

Brooks and Harremoes, the experts brought in to assess the submarine outfall designs (more about them next chapter), also reassured the SPCC that submarine ocean outfalls would effect a vast improvement to water quality along the coast. They said that the sewage field would only be visible when it came to the surface but it would not be aesthetically offensive. They did warn that "excellent removal or source control of oil and grease and other floatables" was essential to minimise visibility.[90] This was because whether or not a submerged field can be achieved it would be likely that oil and grease would still go to the surface and form a slick. This is why the Board has been so tough on grease discharge into the sewers by householders, commercial premises and industry.

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86 Caldwell Connell, Sydney Submarine Outfall Studies, p167.

87 Caldwell Connell, Analysis of Oceanographic Data, p9.

88 S.P.C.C., Questions Relating to Proposed Malabar Outfall.

89 ibid.

90 M.W.S.&D.B., 'Technical Report in support of Application for Approval under Section 19 for the Malabar Extended Ocean Outfall' presented at Clean Waters Advisory Committee meeting, 8th September, 1983, p25.

PATHOGENIC ORGANISMS - DO THEY DIE OFF?

Caldwell Connell stated in their 1976 report that reduction of organisms such as bacteria and viruses would occur mainly because of the dilution, but they would also die in the hostile seawater environment, be consumed by protozoans and other small animals and be reduced due to sedimentation, adsorption, normal biological mortality and sunlight.[91] In a later report the Water Board state that die-off rates have a significant effect on concentrations at shore.[92] However, in their report Caldwell Connell only consider the die-off rates of faecal coliform because the SPCC WP-1 guidelines are in terms of concentrations of faecal coliforms in bathing waters.

The experts brought to Sydney to evaluate the submarine outfalls were uncertain whether even the existing WP-1 guidelines would be met in the winter despite the looser standards prescribed for winter. Both men believed that coliform requirements would be met in the summer period "provided the sewage field is kept submerged by the density stratification in the ocean for well over 90 percent of the time". They referred to Caldwell Connell's prediction that this would happen 96% of the time but were not prepared to back that prediction up.

> With the data presented, we are unable to judge whether the consultants' predictions of frequency of shoreline impact are conservative or not. To demonstrate compliance with the 90% requirement, more careful attention to infrequent events is required.[93]

But in winter, Brooks in particular, believed that when the sewage field surfaced faecal coliform counts on shore would exceed 400/100ml (the SPCC summer 90 percentile standard) and probably 2000/100ml (the SPCC winter 90 percentile standard). Moreover, they both thought it was possible that unusual situations such as following storms or during transition seasons could cause high readings of feacal coliforms (>400/100ml) for more than 10% of the time during the summer bathing season.[94]

Brooks felt that disinfection on an intermittent basis might be required, judging by his experience of other outfalls which also required intermittent disinfection. When the Clean Waters Advisory Committee considered the approval of the Malabar submarine ocean outfall in September 1983 the possible need for disinfection by chlorination of the sewage was discussed. The problem with chlorination was said to be that it took some time to become effective in bathing waters and that it might be "intrinsically undesirable in terms of acute environmental toxicity and production of persistent organochlorine compounds." The Committee decided that chlorination should only be used as a last resort.[95]

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[91] Caldwell Connell, Sydney Submarine Outfall Studies, pp10-12.

[92] M.W.S.&D.B., 'Technical Report in support of Application', p19.

[93] ibid., pp25-6.

[94] ibid., p27.

[95] Clean Waters Advisory Committee meeting, 8th September, 1983.

It should be noted in this regard that chlorination had long been considered a poor option for dealing with bacteria and viruses in sewage. In 1977 a Water Board report stated that

> the proposition that chlorination of primary treatment can effectively control bacterial pollution is not supportable. The fact is recognised in the Board's policy of not chlorinating primary effluent.[96]

In addition, a 1979 SPCC report had concluded that there were few, if any, benefits arising from chlorination and that those were "outweighed by many disadvantages". The report stated that underchlorination would not reduce pathogen numbers by more than a factor of ten and that chloramines produced through underchlorination were toxic compounds which were hazardous to many fish. Overchlorination could also result in fish kills. Even with optimum amounts of chlorine, toxic chlorinated compounds besides chloramines could be formed. Chlorinated compounds could bioaccumulate, especially in shellfish. Moreover, chlorination could interfere with the natural purification processes.[97]

At the time of writing their report Caldwell Connell were well aware of the inadequacies of faecal coliforms as a measure of health risk. They admitted that there was very little evidence that related "faecal coliform concentration to the incidence of water borne disease"[98] and recognised that a specific faecal coliform limit did not define the line between a safe and hazardous water. However they defended the use of faecal coliforms as an indicator of pollution of sewage origin because it was not 'practicable' to routinely monitor pathogenic organisms directly.[99]

Caldwell Connell, however, used faecal coliform, in their study, not as an indicator of the presence of sewage, which was what it was supposed to be used for, but as the focus of their study into the die-off rates of pathogenic organisms in the ocean. They did this "as a matter of convenience,"[100] although they admitted that different organisms, including those of sewage origin, could be expected to have different die-off rates. Another implicitly stated reason was that the submarine outfalls had to conform with WP-1 guidelines and these were in terms of faecal coliform.

However their use of faecal coliform in die-off experiments was ironic. Their findings that faecal coliform die off fairly rapidly tells us little about the fate of other organisms which can be health threatening. Their experiments serve only to discredit faecal coliforms as an indicator of sewage since they die-off so quickly. Low faecal coliform concentrations do not mean the water is not polluted. The Water Board found that ninety percent of faecal coliform die off in 1 to 7 hours during the daytime.[101] Low concentrations in bathing waters mean

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96 MWS&DB, North Head WPCP and Ocean Outfall Re-evaluation of Treatment and Disposal Options, Sept 1977, p5-3.

97 S.P.C.C., Health Aspects of Faecal Contamination, Botany Bay Study 4, Sydney 1979, p14.

98 Caldwell Connell, Sydney Submarine Outfall Studies, p34.

99 ibid., p12.

100 ibid., p149.

101 Malabar & Bondi W.P.C.P. Submarine Ocean Outfall Technical Data, Data Pack Item 6(4), September 1981.

only that sewage pollution that might be present has been in the sea for more than an hour.

Viruses, Caldwell Connell said, were difficult and costly to test for and could not be carried out without specialist assistance[102] so they were not investigated at all and the possibility of viruses surviving long was dismissed with a statement that "viruses can only multiply in living host cells" and their numbers "diminish rapidly through treatment, dilution and natural die-off."[103]

Such conclusions don't seem to be supported in the scientific literature. Primary treatment does not remove any viruses[104] and viruses can survive if they are associated with solid material. This association protects them from inactivation and also provides a transport mechanism for them.[105] A recent U.S. Office of Technology Assessment report points to "a growing body of evidence" that human pathogens may persist in the marine environment for periods of many months and longer "in a nonculturable, but virulent form".[106] Viable human pathogenic viruses have been discovered in water, crabs and bottom sediments of an old sludge dump site[107] that had been disused for 17 months and an outbreak of cholera along the Gulf coast of Texas has been traced back to agents which survived in the coastal waters for at least five years.[108]

Some viruses and parasites are very resistant to environmental degradation or destruction. Sometimes the colder temperature towards the bottom of the sea can help them survive whilst inhibiting their growth.[109] As well as being protected by sludge or suspended sewage particles, viruses and bacteria can also be protected in grease balls as discussed earlier in this chapter. Because some of these viruses are inactivated they cannot be cultured in the laboratory and they cannot be detected with traditional tests yet they can be reactivated in a human host.[110]

Although these are recent findings, Caldwell Connell don't seem to have conducted any literature search in this area despite their own admitted lack of expertise with viruses, nor have they made any efforts to back up their assumptions about viruses being shortlived. Moreover, they do not supply any evidence that the die-off will be greater with the new ocean outfalls than it was with the existing ocean outfalls. The extra distance the sewage has to travel only adds a few hours, if that, to the travel time of the sewage field and if that field is submerged the reduced exposure to sunlight could well counteract this small advantage. It seems their primary concern is not with ensuring that the submarine outfalls pose no health threat to bathers but rather with whether the

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102 Caldwell Connell, Sydney Submarine Outfall Studies, p149.

103 ibid., p12.

104 Otis J. Sproul, 'Removal of Viruses by Treatment Processes' in Gerald Berg et al (eds), Viruses in Water, American Public Health Association, 1976, p175.

105 Lewis, 'Fate Of Human Enteroviruses in Sewage', p226.

106 U.S. Office of Technology, Wastes in Marine Environments, p135.

107 Sagar Goyal et al, 'Human Pathogenic Viruses at Sewage Sludge Disposal Sites in the Middle Atlantic Region', Applied Environmental Microbiology, Oct 1984, pp758-763.

108 Office of Technology, Wastes in Marine Environments, p135.

109 ibid., p135.

110 ibid., p138.

new outfalls will comply with WP-1 guidelines, which set standards in terms of faecal coliform.

The attitude which the authorities have towards health risks has always differed from that of bathers and surfers who know by first hand and second hand experience that swimming in sewage polluted water is not a healthy occupation. The SPCC and the Water Board do not want to know about this because a solution could be expensive and 'inpracticable' so despite the on-going debate and widespread interest there has still been very little investigation into the health dangers of bathing in contaminated sea-water in Australia.[111]

The difficulty in determining what the health effects are of swimming in polluted water include the problems that the symptoms of the disease might not occur till some time after exposure, many diseases which could be transmitted in this way were neither fatal nor notifiable and many of those disease are transmitted in other ways.[112] Nevertheless the SPCC still held the view at the end of 1979 that coastal waters could be presumed to be bacteriologically safe for swimming if aesthetic criteria were met and they claimed that this view was endorsed by the NSW Health Commission.[113]

This view was based on a 1959 study undertaken in the U.K which is still referred to in Britain, Australia and New Zealand as the classic paper on the subject[114] despite the continuing debate amongst experts, new research and developments in the field of virology and the various papers reaching contrary conclusions being published since that date. This report emphasised diseases such as typhoid and paratyphoid fevers which have been traditionally associated with sewage and relatively minor diseases, such as viral gastro-enteritis, which do not require the health authorities to be notified were ignored.[115]

The UK study was based on five years of investigation of 43 U.K beaches. It concluded that there was only a "negligible risk to health" of bathing in sewage polluted sea water even when beaches were "aesthetically very unsatisfactory" and that a serious risk would only exist if the water was so fouled as to be revolting to the senses. It insisted that pathogenic bacteria which were isolated from sewage contaminated sea water was more important as an indicator of the disease in the population than as evidence of a health risk in the waters.[116]

Moore believed that bathing was "an unnatural activity in man" and he ascribed the prevalence of upper respiratory infections in bathers to the mechanical effect of bacteria being forced up the nose and into the middle ear when diving or to close personal contact with fellow bathers in overcrowded swimming pools. He dismissed without further investigation the idea that such infections arose from

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111 Paul Ryan, Submarine Ocean Outfall Sewers, typescript, undated, p13.

112 S.P.C.C., Health Aspects of Faecal Contamination, p17.

113 S.P.C.C., Monitoring of Ocean Beaches for Sewage Pollution, internal report, 13th November 1979.

114 for example N.A.Smith & W.J.Speir, 'Ocean Discharge of Sewage is a Treatment Option', in 1985 Australasian Conference on Coastal and Ocean Engineering, p36; Observer, 7th August 1988; N.R.Achuthan et al, 'Development of a Beach Pollution Index for Sydney Coastal Beaches', Water, September 1985, p15.

115 Dave Wheeler, 'Sea Fever: UK's Polluted Beaches', Science for People 52, undated, p9.

116 Paul Ryan, Submarine Ocean Outfall Sewers, p14.

the ingestion or inhalation of pathogens from contaminated waters. For this reason his working group did not concern itself with upper respiratory infections but confined their investigations to "diseases the causal agents of which are known to be present in sewage" particularly paratyphoid or typhoid fever and poliomyelitis."[117]

Moore's criteria for attributing paratyphoid or typhoid fever to bathing in sewage-polluted seawater were

1. The patient must have bathed in seawater known to have been contaminated at the time with enteric organisms of the same type as caused the illness.

2. The case must not be otherwise explicable, for example, if there were other cases in the same neighbourhood.

3. The case was stronger if it was known that the patient swallowed a good deal of sea-water, for example, through being a poor swimmer or having fallen out of a boat into deep water.

4. The case was stronger if the bathing waters in question had been heavily polluted, or if it was known that the patient had had direct contact with unmacerated faecal matter while bathing on the day of presumed infection.

5. Credibility was lost if a single bathing episode, say 10 to 11 days before the onset of illness could not be pointed to.[118]

The criteria therefore included various assumptions by Moore about what he expected his conclusions would be. The most obvious being that he was more likely to believe a case was caused by bathing in sewage polluted water if the bather came in contact with faeces. He then concluded from his study that the negligible risk of contracting disease was probably from chance contact with intact aggregates of faecal matter from an infected person.[119] Cases that occurred when the beaches weren't grossly polluted were not attributed to bathing and not surprisingly he concluded that disease would not be contracted unless the bathing waters were grossly polluted.

Moore used a different methodology to study the incidence of poliomyelitis. He focused on children and asked local medical officers to pick a suitable healthy child to be compared to each child that was diagnosed to have poliomyelitis. The bathing records of each child in the previous three weeks to the onset of illness were recorded and a comparison made. The results are shown in Table 8.6.

It was concluded that since the bathing histories of children with poliomyelitis were similar to the bathing histories of healthy children then "the history of bathing is probably irrelevant".[120]

117 B.Moore, 'The Risk of Infection Through Bathing in Sewage-Polluted Water', in E.A.Pearson, Waste Disposal in the Marine Environment, Pergamon Press, 1959, p32.

118 ibid., p35.

119 Paul Ryan, Submarine Ocean Outfall Sewers, p14.

120 Moore, 'The Risk of Infection Through Bathing in Sewage-Polluted Water', p37.

Moore's results show that bathing is not the main way to catch poliomyelitis but small incidences due to bathing would not show up using this method. Overall Moore's study proved nothing about the health risks of swimming in sewage polluted water other than those related to poliomyelitis, paratyphoid and typhoid fever. Even then the evidence is far from convincing, yet this study has continued to be referred to for decades.

TABLE 8.6

Quarter of year	Patients			Controls		
	Bathed	Did not bathe	Total	Bathed	Did not bathe	Total
2nd	3	4	7	4	3	7
3rd	40	61	101	38	63	101
4th	2	40	42	2	40	42
All Quarters	45	105	150	44	106	150

Bathing History of 150 poliomyelitis pathients aged 0-15 years and of paired controls of the same age and sex, three weeks before the onset of symptoms in the patients.

SOURCE: B. Moore, 'The Risk of Infection Through Bathing in Sewage-Polluted Water', in E.A.Pearson, Waste Disposal in the Marine Environment, Pergamon Press, 1959, p37.

The British reliance on this report has enabled British authorities to avoid treatment altogether at many of their ocean outfalls and British beaches are notorious for their pollution. European Common Market Directives from the 1970s that beaches meet a standard of not exceeding 2000 faecal coliform per 100 ml of water could not be met by many British beaches and so they bypassed the requirement by only designating 27 beaches out of over 600 as bathing beaches. This compared to France which designated 1,500 and Italy with 3,000. British authorities accomplished this by making the criterion for a designated beach 1000 bathers/kilometre during their wet dreary summer of 1979. This enabled many of their major seaside resorts, such as Blackpool, which have long lengths of beach, to be missed out.[121] After heavy criticism for this, Britain increased its number of designated beaches to 391 in 1986.[122]

In contrast, epidemiological studies in the U.S. since the early 1950s have considered minor diseases and have demonstrated "significant risks of bathing associated disease, particularly gastro-enteritis, in recreational waters even mildly contaminated with sewage."[123] Apart from stomach illness, ear, eye, nose and throat infections, hepatitis and cystitis have all been linked with swimming in sewage polluted waters.[124]

A 1975 British study which also considered more minor illnesses also showed no differences between swimmers and non-swimmers and Britain has maintained

121 Fred Pearce, 'The Unspeakable Beaches of Britain', New Scientist, 16th July 1981, pp139-143; Anon, 'Ministers call for survey of beach sewage', New Scientist, 25th July 1985, p21; Graham Ridout, 'Sewage: Why are we Getting a Raw Deal', Windsurf Magazine, March 1987.

122 Observer, 7th August 1988.

123 Wheeler, 'Sea Fever', p9.

124 Observer, 7th August 1988.

that since there is no epidemiological evidence of any significant health threat they would not set standards. They did, however, recognise that in other countries immersion or swimming times might be longer and the risks higher. The U.S. Environmental Protection Authority has also noted a "paucity of valid epidemiological data" but in contrast to British Authorities has not taken this to mean that there are no problems.[125]

A 1979 SPCC report concluded that although studies had not been done in NSW, increased illness amongst swimmers had not been observed and experience confirmed overseas findings that there was a "low probability of persons becoming infected" after bathing in sewage polluted waters. For this reason, public health could adequately be protected if aesthetic considerations were met; in other words, no undisintegrated faecal matter or other materials "clearly of sewage origin" should be allowed into bathing areas and also no "noticeable" turbidity or discolouration of bathing water attributable to sewage and no "perceptible smell". There was no evidence in the Australian context, the report went on, to support a numerical standard. [126] There is no evidence because the proper epidemiological studies have not been done in Australia.

However in 1980 a US EPA spokesman claimed that

> surveys of 30,000 bathers and non-bathers contacted on beaches in New York and Boston revealed statistically significant increases in cases of vomiting, diarrhoea, nausea, fever and stomach aches among swimmers who had bathed in polluted waters....The results show a strong link between bacteria counts in the water at the time of bathing and subsequent health of the swimmers.[127]

He went on to suggest that 4% of swimmers would get severe cases of fever and stomach upset if they swam in waters less polluted that 2000 faecal coliform/100 ml and that if there were an epidemic in the population this risk to swimmers of getting other diseases would be greater.[128]

A later US report from the Office of Technology Assessment found that sewage polluted bathing waters were responsible for relatively high rates of gastro-intestinal disease and that the outbreaks of water-borne diseases, particularly viral diseases including hepatitis, had been steadily increasing in the past decades.[129]

In 1982 a group of staff and students from the NSW Institute of Technology found in a study they were undertaking that large amounts of bacteria were breeding off Sydney's beaches whether or not the sewage workers were on strike. Jerry Jackson, the environmental engineer in charge of the project said that there was no difference in levels of disease-causing micro-organisms in the sea whether or not the sewage underwent primary treatment or was discharged raw, since primary treatment only removed large particles. The dangers to health

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125 S.P.C.C., Health Aspects of Faecal Contamination, pp16-23.
126 ibid., pp66-7,75.
127 Pearce, 'The Unspeakable Beaches of Britain', p143.
128 ibid., p143.
129 US Technology Assessmen Office, Wastes in Marine Environments, p137.

depended on the general health of the community and what diseases were spreading through the sewage.[130]

In 1987 a leaked confidential Department of Health Report was passed on to Tracks magazine and the Sydney Morning Herald. The report said

> Salmonella serotypes continue to be recovered from water samples from beaches in the Waverley and Randwick municipalities. In the last 3 years Salmonella Paratyphi B has been isolated on 2 previous occasions. However, on 6 out of 9 sampling occasions between 20 October and 15 December, 1986, S. Paratyphi B was positively identified in water samples from Maroubra, Coogee, Malabar and McMahon's Pool. [131]

According to Professor Clem Boughton, head of the Infectious Diseases Department at Prince Henry Hospital, Salmonella serotypes could cause diseases similar to Gastro-enteritis and Salmonella Paratyphi B could cause paratyphoid fever. He said that other infectious diseases such as polio and hepatitis A, particularly, but also hepatitis B, typhoid, rotavirus and other enteroviruses were likely to be in beach waters, given the presence of salmonella.[132] Dr Nancy Millis of the School of Microbiology at Melbourne University warned in the 1970s that the presence of even one salmonella in a sample indicated a definite health risk. The numbers of salmonella organisms necessary to cause disease differed according to the strain of salmonella and susceptibility of individual people.[133]

The leaked report showed results of a much longer study undertaken by the NSW Department of Health. A paper published in 1988 summarises data collected by the Department between October 1983 and April 1987. Salmonella was detected in 183 out of 1058 (17%) samples tested at Eastern suburbs swimming spots and beaches (including Malabar which is closed for swimming) over the three and a half years.[134] Unfortunately there is no breakdown of percentages over time or individual beaches and the data for the Northern beaches covers several miles of beaches including those that are often not affected by sewage pollution.

The Department study also monitored the beach for faecal coliform, faecal streptococci and P.aeruginosa. These results are summarised in table 8.7. The Department's bacteriological standard for bathing waters differs significantly from that of the SPCC. It is as follows:

> Water should be considered to be unsuitable for bathing where the faecal coliform count, calculated as the geometric mean of the number of organisms in 3 water samples taken at the one time from the area

130 Southern Courier, 19th March 1982.

131 Department of Health, `Public Health Report', January- February 1987.

132 Eastern Herald, 2nd April 1987.

133 Peter Russ & Lindsay Tanner, The Politics of Pollution, Visa, 1978, p81.

134 A.G.Bernard, The Bacteriological Quality of Sydney's Tidal Bathing Waters', in Proceedings of Water Quality & Management for Recreation & Tourism, International Confernece, IAWPRC &I AWWA, July 1988, p50.

being examined, exceeds 300 organisms per 100 mL, with an upper limit of 2,000 organisms per 100 mL (in any one sample). [135]

Using this standard, as can be seen in table 8.7, the Eastern suburbs beaches were found to be unsatisfactory for between 29 and 83% of the time. This is in marked contrast to the results of the Water Boards self monitoring which, using geometric means over 30 day periods that had to be less than 200 faecal coliforms per 100 ml, and could only exceed 1000 per 100 ml in more than 10% of samples for summer (and looser standards for winter) managed to balance out high readings with low readings and show much better results. (see figure 8.10)

Table 8.7

DEPT OF HEALTH BACTERIOLOGICAL SURVEY OF BEACHES 1983-1987

BATHING AREAS	Percentage of Samples Unsatis-factory [a]		F.coliform Maximum organisms/100ml		F.Coliform Median orgs/100m.	
	dry [b]	wet [c]	dry [b]	wet [c]	dry [b]	wet [c]
Bondi, Bronte, Clovelly	31	38	7500	4500	59	160
Coogee, Tamarama	29	53	9300	10000	91	230
Malabar, Maroubra, Little Bay	57	83	26000	46000	440	2700
Mahon Pool	30	60	11000	14000	71	100
Sydney Harbour	36	62	30000	20000	100	710
Northern Surfing Beaches	14	71	3900	10000	99	650
Botany Bay	0	50	370	20000	2	320

[a] Unsatisfactory samples = those where faecal coliform geometric mean of three samples is greater than 300 per 100ml

[b] dry weather - no rainfall within 24 hours prior to sampling

[c] wet weather - rainfall within 24 hours prior to sampling

INFO FROM: A.G.Bernard, 'The Bacteriological Quality of Sydney's Tidal Bathing Waters' in Water Quality & Management for Recreation & Tourism, Proceedings of an International Conference, IAWPRC & AWWA, Brisbane 1988.

The median Health Dept results also correlate much better with the Water Department results (table 8.8). Clearly the use of a geometric mean (the multiplication of all sample results and the calculation of the appropriate root of that product) is preferred by the SPCC and the Water Board because it tends to be less distorted by high readings and because the use of such a mean over a month long period enables a large proportion of samples to be unsatisfactory and yet yield a satisfactory geometric mean. Nevertheless this use of statistics is inappropriate in a situation where health threats are being monitored. If 30-50% of the time the beaches are unsuitable for swimming then a mean that shows that the averaged beach conditions are safe, is meaningless and serves only to cover up the health risk.

135 ibid., p46.

Figure 8.10 RESULTS OF WATER BOARD BEACH MONITORING FOR BACTERIAL INDICATORS OF SEWAGE POLLUTION

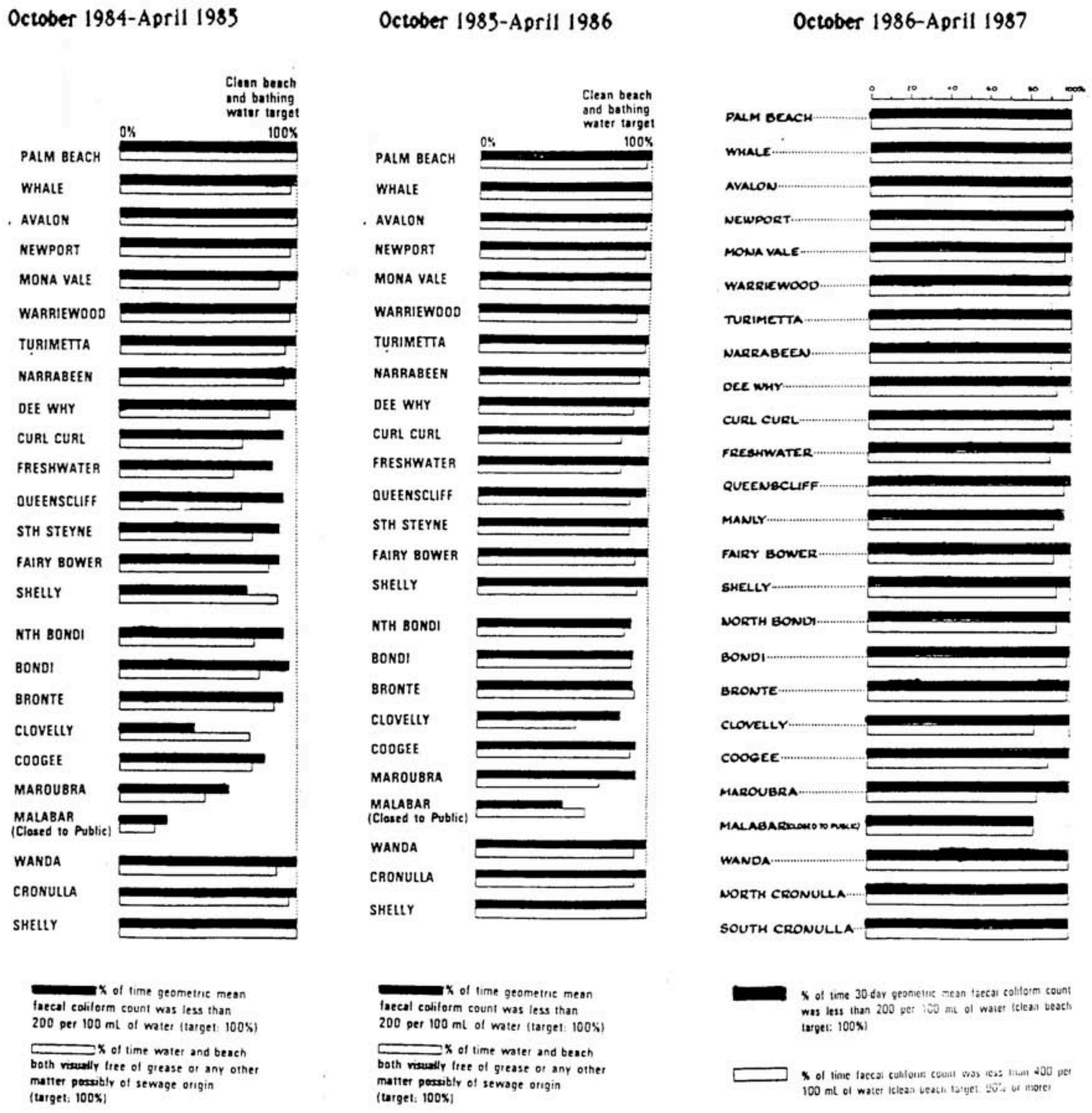


Table 8.8 shows the results of recent monitoring of beaches in the Waverley Municipal area conducted by the Health Department for the Council. The Table shows the geometric mean of 5 samples in 30 days (in the way the SPCC requires) and also the average of the same 5 samples to show how the geometric mean tends to be much lower. The results are also shown visually in figures 8.11 & 8.12 with the Health Department 300 faecal organisms/100 ml level shown.

These beaches were unsatisfactory in terms of both SPCC guidelines and Health Department guidelines according to the Health Department readings and yet the Water Board claimed that the "geometric mean coliform level during the same period complied with SPCC guidelines. The beaches were not closed during this period and the Board only issued warnings on two occasions, once for Bronte and

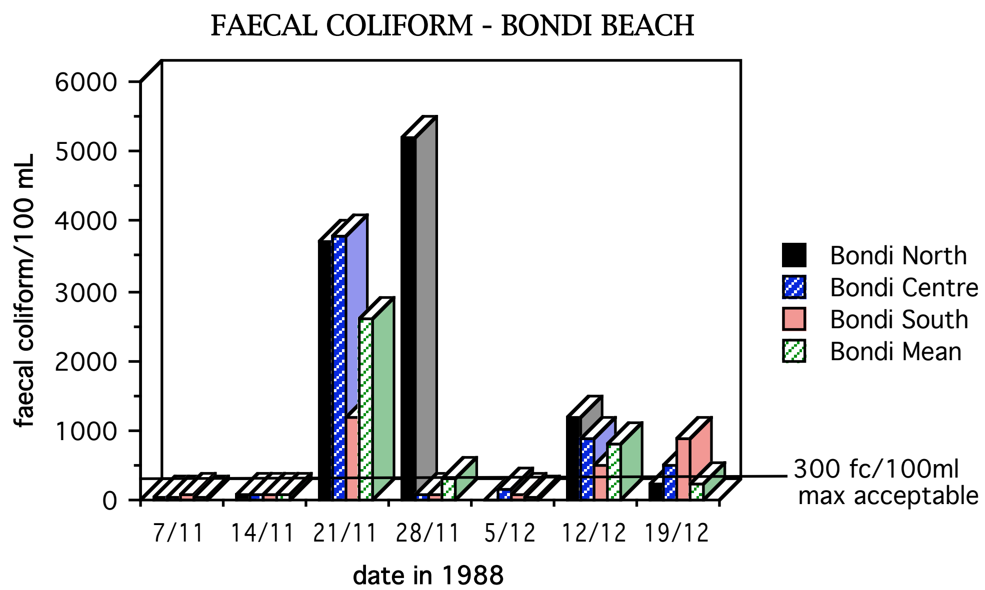
TABLE 8.8

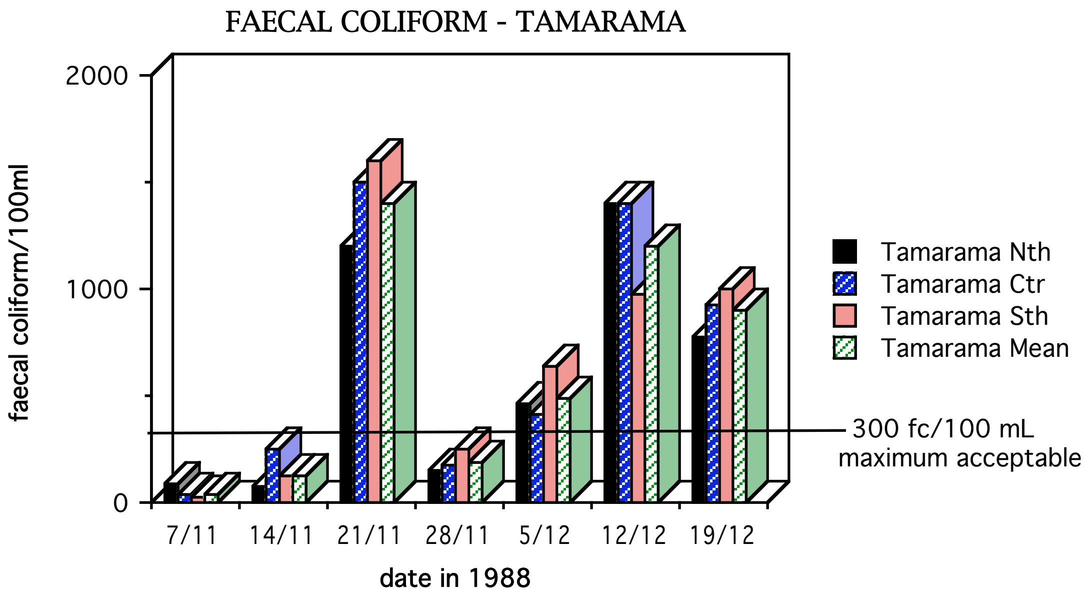
FAECAL COLIFORM LEVELS AT BONDI AND TAMATARAMA- NOV & DEC 1988					
LOCATION	BEACH	WIND	FAECAL COLIFORM/ 100ML	GEOMETRIC MEAN OF 5 SAMPLES IN 30 DAYS	AVERAGE OF 5 SAMPLES IN 30 DAYS
BONDI NORTH	19/12/88	NIL	230		
	12/12/88	S-E	1200	881	2068
	5/12/88	NIL	10		
	28/11/88	S-E	5200		
	21/11/88	NIL	3700	244	1810
	14/11/88	N-E	90		
	7/11/88	E	50		
BONDI CENTRE	19/12/88	NIL	510		
	12/12/88	S-E	890	460	1086
	5/12/88	NIL	150		
	28/11/88	S-E	80		
	21/11/88	NIL	3800	161	828
	14/11/88	N-E	80		
	7/11/88	E	30		
BONDI SOUTH	19/12/88	NIL	870		
	12/12/88	S-E	510	320	548
	5/12/88	NIL	90		
	28/11/88	S-E	70		
	21/11/88	NIL	1200	133	302
	14/11/88	N-E	80		
	7/11/88	E	70		
TAMARAMA NORTH	19/12/88	NIL	780		
	12/12/88	S-E	1400	618	1894
	5/12/88	NIL	460		
	28/11/88	S-E	150		
	21/11/88	NIL	1200	220	394
	14/11/88	N-E	70		
	7/11/88	E	90		
TAMARAMA CENTRE	19/12/88	NIL	920		
	12/12/88	S-E	1400	671	798
	5/12/88	NIL	410		
	28/11/88	S-E	170		
	21/11/88	NIL	1500	253	474
	14/11/88	N-E	250		
	7/11/88	E	40		
TAMARAMA SOUTH	19/12/88	NIL	1000		
	12/12/88	S-E	980	758	880
	5/12/88	NIL	640		
	28/11/88	S-E	250		
	21/11/88	NIL	1600	228	526
	14/11/88	N-E	120		
	7/11/88	E	20		

INFO FROM NSW Department of Health Analysis of Tests Taken by Waverley Municipal Council.

once for Tamarama and Bronte.[136] On the day on which Health Department and Water Board readings coincided, November 28th the findings of the Water Board were substantially lower. For example the Health Department found 310 faecal coliform/100 ml at Bondi whereas the Board found 60-80 faecal coliform/100 ml at Bondi.[137]

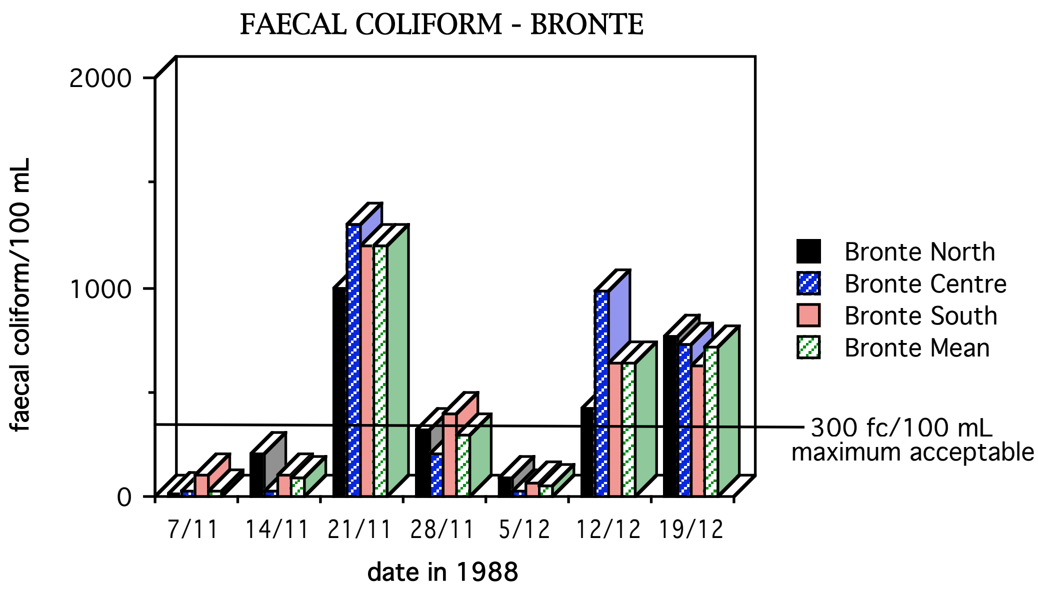
Figure 8.11

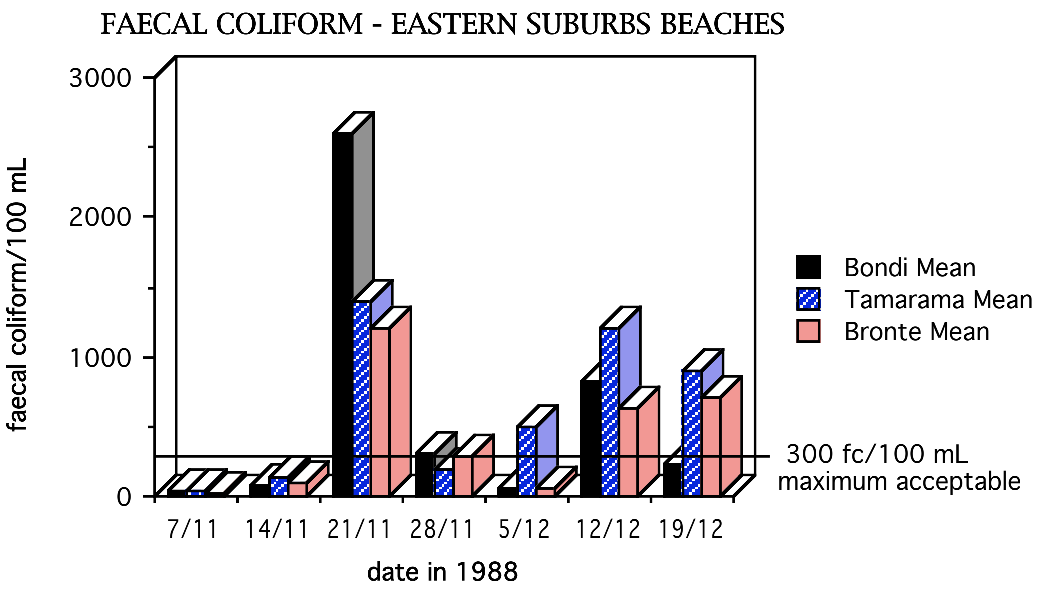




136 Eastern Herald, 12th January 1989.
137 ibid.

Figure 8.12





OUTFALLS - ARE WE FOLLOWING THE U.S. EXAMPLE OR NOT?

In a submission on the Environmental Impact Statements for the submarine ocean outfalls, the firm Commonwealth Industrial Gases (CIG), which was proposing an alternative form of treatment, had argued that with the exception of Sydney and Geelong (another Caldwell Connell job), all of the other major population centres in Australia where effluent was discharged to coastal waters either achieved or were committed to achieving secondary effluent standards and had listed them all in a table.[138] (see table 8.9)

138 Commonwealth Industrial Gases, Oxygen Technology for Sewage Treatment and Disposal: Fast Economic Alternatives to the Proposed Deepwater Submarine Outfalls for Sydney, C.I.G., March 1980, pp18-9.

Table 8.9

Summary of Treatment Standards on Australia's Coasts

	AUTHORITY	PRESENT DEGREE OF TREATMENT	RECEIVING WATERS	LONG TERM POLICY	DEGREE OF IMPLEMENTATION
NEW SOUTH WALES					
Sydney	MWS & DB	RAW SCREENED OR PRIMARY	Pacific Ocean	UNDECIDED	Impact Statement
Newcastle	HDWB	RAW SCREENED OR PRIMARY	Pacific Ocean	SECONDARY	Commenced
Wollongong	MWS & DB	PRIMARY/SECONDARY	Pacific Ocean	SECONDARY	Part Completed
Other	LOCAL COUNCILS/PWD	SECONDARY	Pacific Ocean	SECONDARY	Mostly Completed
VICTORIA					
Melbourne	MMBW	SECONDARY	Bass Strait/Pt. Phillip Bay	SECONDARY	Completed
Geelong	GW & ST	RAW SCREENED	Bass Strait		
QUEENSLAND					
Brisbane	B.C.C.	PRIMARY/SECONDARY	Moreton Bay	SECONDARY	Under Construction
Gold Coast	G.C.C.C.	SECONDARY	Pacific Ocean	SECONDARY	Under Construction
Cairns	C.C.C.	SECONDARY	Pacific Ocean	SECONDARY	Completed
Townsville	T.C.C.	SECONDARY	Pacific Ocean	SECONDARY	Completed
Rockhampton	R.C.C.	SECONDARY	Pacific Ocean	SECONDARY	Completed
Mackay	M.C.C.	SECONDARY	Pacific Ocean	SECONDARY	Completed
SOUTH AUSTRALIA					
Adelaide	E & WS	SECONDARY	Great Australian Bight	SECONDARY	Completed
WESTERN AUSTRALIA					
Perth	MWSS & DB	PRIMARY/SECONDARY	Cockburn Sound	SECONDARY	Part Completed
TASMANIA	VARIOUS COUNCILS	PRIMARY/SECONDARY	Estuaries/Bass Strait	SECONDARY	Part Completed
NORTHERN TERRITORY					
Darwin	D.C.C.	SECONDARY	Timor Sea	SECONDARY	Completed

SOURCE: CIG, Oxygen Technology For Sewage Treatment and Disposal, Submission to SPCC, March 1980, p19.

The CIG proposal also highlighted US legislation which had in 1972 required all publicly owned treatment works to achieve secondary treatment by July 1 1977. Despite Caldwell Connell's argument that submarine outfalls facilitated a form of secondary treatment that took place in the ocean, the United States legislation was quite clear that such a concept was not acceptable. Secondary treatment was defined in terms of four pre-discharge effluent parameters - biochemical oxygen demand, suspended solids, pH and faecal coliform bacteria.[139]

Following the enactment of this legislation in the United States, several municipalities, mainly from the West Coast of the US had complained that secondary treatment was not necessary "to protect the marine environment or to assure the attainment and maintenance of water quality in ocean waters." They argued that pollution parameters that were important for freshwater ecosystems were not significant in ocean waters where there was plenty of oxygen, and where wastes would be rapidly assimilated and dispersed.[140]

Because of the testimony of these municipal authorities, the Act was amended with the addition of a section 301(h) which allowed for a municipal marine discharger to present its case to the Federal Environmental Protection Agency (EPA) and obtain a waiver to the requirement for secondary treatment if it is demonstrated to the satisfaction of the EPA administrator that the receiving waters would not be impaired because of that waiver and the discharge of toxic pollutants would not be increased.[141]

CIG argued that such waivers were difficult to get and that the intention of the US legislation was obviously to maintain secondary standards for ocean outfalls.[142] The Board in response, contended that its ocean outfall proposals would meet the requirements for a waiver, whereas CIG's proposal would not.[143]

In fact the Water Board proposals would have failed to obtain a waiver on at least two major points. Firstly, section 301(h) applicants had to demonstrate that they would provide a minimum of full primary treatment and that an applicant providing only primary treatment would bear a particularly heavy burden in demonstrating to the EPA that the treatment provided would be adequate. The EPA believed that primary treatment, which removed up to 40% of suspended solids, plus floatables and grease, was an absolute minimum level of treatment for adequate protection of water quality. In fact, the State of California required 75% removal of suspended solids as well as floatables and grease.[144]

For the North Head proposal where something less than primary treatment was being planned, (i.e. high rate primary treatment) it was predicted in the EIS that 18% of suspended solids would be removed.[145] At Bondi, where the sludge was

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139 Environmental Protection Agency, 'Modification of Secondary Treatment Requirements for Discharges into Marine Waters', Federal Register 4(117), 15 June 1979, p34784.

140 ibid., p34784.

141 ibid., p34784.

142 C.I.G., Oxygen Technology for Sewage Treatment and Disposal, p23.

143 Chief Engineer, Investigation, M.W.S.&D.B., internal report, 29th April, 1980.

144 E.P.A., 'Modification of Secondary Treatment Requirements', pp34796-7.

145 Caldwell Connell, Environmental Impact Statement North Head, p44.

added back into the effluent before discharge the suspended solids removal was 11% with an predicted ultimate performance of 18% in the year 2025.[146]

The second reason why the Board's proposals would fail to get permission in the United States was because they planned to discharge the sludge with the effluent into the sea. In the US the disposal of sludge, digested or not, into the ocean was illegal and there were to be no waivers on this account. The EPA explained that the Congress had specifically prohibited the discharge of untreated sewage and,

> Since sewage sludge is, basically the material which is removed from raw sewage during the treatment process, allowing a POTW [Publicly Owned Treatment Works] to discharge both treated effluent and sewage sludge, or sewage sludge alone, would be equivalent to allowing it to discharge untreated sewage.[147]

Another requirement for a waiver in the US was that the discharger be able to prove that a balanced, indigenous marine population would be maintained at the site of discharge. This required a comparison of the ecological characteristics between sites of no pollution and those with current or planned discharge. Variation beyond what was found naturally between habitats would be unacceptable. The bioaccumulation of toxic materials was one of the several aspects which the legislation was concerned with.[148]

Finally, the regulations for obtaining a waiver in the US specifically called for the applicable standards to be met under assumed worst case conditions which might include low current velocities in the ocean and maximum waste flow and the worst possible ambient density stratification. The reasoning behind this was that the initial dilution achieved at a discharge site was likely to be highly variable and

> measuring compliance with water quality standards on the basis of average initial dilution would mean that those standards might be exceeded 50% of the time. Furthermore, this formulation would be inconsistent with Congress' intent that water uses and marine life be protected under "assumed worst conditions".[149]

Caldwell Connell and the Water Board often cited the outfall at Hyperion, California as the model for the Sydney outfalls, because of similarities in its design. Caldwell Connell told the SPCC that the Hyperion outfall met the required health standards (<20% of samples exceeded 100 total coliforms/100ml) in 1981 and only 3.5% exceeded the 100 coliform/100 ml standards in summer and 2.0% in winter with occasional chlorination of the effluent. The standards were also met at Whites Point and at Orange County except on rainy days when stormwater runoff discharged into the ocean.[150]

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146 M.W.S.&D.B., Environmental Impact Statement Bondi Water Pollution Control Plant, M.W.S.&D.B., p7.

147 E.P.A., 'Modification of Secondary Treatment Requirements', p34797.

148 ibid., p34788.

149 ibid., p34800.

150 S.P.C.C., Questions Relating to Proposed Malabar Outfall.

However there were important differences between the proposed Malabar outfall and those which existed in California. The Malabar outfall was closer to shore (thus providing less time for bacteria, particularly coliforms, in a surface field to die off before hitting the beach) but also deeper. The effluent going through the Hyperion outfall was better quality because part of it was secondary treated and the rest given full primary treatment. All California outfalls "have, or soon will have effluents with suspended solids and BOD concentrations only about half of the values at Malabar, and oil and grease concentrations only one-third." [151]

Moreover, the success of the Hyperion outfall is disputed. Reports have been reaching Australia, via surfing magazines, that the El Segundo/El Porto area, where the Hyperion outfall is sited, has been nicknamed "El Stinko" by surfers and residents because of the continuous stench in the area which intensifies during onshore winds and during storms. As a result of complaints and Federal legislation (local groups were able to get Los Angeles section 301(h) waiver rescinded after a successful federal suit) the State authorities have ordered the local council, Los Angeles City Council, to give all their sewage secondary treatment before discharge to ocean. It is estimated that this would cost $528 million.[152] In 1987 Los Angeles had still not improved the quality of sewage treatment and was fined $625,000. It must institute full secondary treatment by 1998.[153]

Similarly Caldwell Connell used the Hyperion outfall to justify their conclusions that the disposal of digested sludge to sea through the Sydney outfalls would be safe and innocuous. They argued that sludge had been discharged through the Hyperion outfall for seventeen years and a 1973 study had shown that although there were some localized effects there was "no scientific basis for concluding that the marine disposal of digested sludge had been harmful to the marine biology."[154]

In fact the Hyperion sludge line is 11km from shore (rather than the 2.2 to 3.8 km proposed for Sydney) and it discharges off the edge of a natural canyon in the ocean floor (no such features off Sydney's coast).[155] More significantly, studies have found that the sludge discharged there is not as harmless as Caldwell Connell would have liked to have believed and fish disease attributed to pollution has been discovered in the vicinity of the outfall.[156] Los Angeles City Council was ordered to stop dumping sludge through its Hyperion Outfall by the end of 1987.[157]

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151 M.W.S.&D.B., 'Technical Report in support of Application for Approval', pp27-8.

152 for example Mike Balzer, 'Taking the Stink Out of El Stinko', Surfing , June 1986, p36.

153 Michael Moreau, Santa Monica Bay: Spills of Indifference', Surfer, December 1987, p36; Mike Balzer, 'Brown Water', Surfing, August 1987, p52.

154 Caldwell Connel, Sydney Submarine Outfall Studies, p153.

155 Willard Bascom, 'The Effects of Sludge Disposal in Santa Monica Bay' in Virginia Tippie & Dana Kester, Impact of Marine Pollution on Society, Praeger, Mass., 1982, p223.

156 ibid.

157 Mike Balzer, 'Brown Water', p52.

ENGINEERING THE FACTS

The work of the Water Board and their consultants, Caldwell Connell Engineers, clearly displays a use of science in engineering which clearly contrasts with the traditional view of engineering as being simply the application of science to real problems.

The relationship between science and technology is a complex one which has been much debated. In 1974 Edwin Layton put forward the proposition that technology should be considered as knowledge in its own right.[158] Layton points out that technological knowledge is different from scientific knowledge because although science purports to understand nature and the universe, engineering knowledge is developed to "provide a rational basis for design".[159] Henry Skolimowski had made a similar distinction earlier. He said that "in science we investigate the reality that is given; in technology we create a reality according to our designs."[160]

It is this different approach that seems to give engineers much more freedom than scientists to manipulate their data to fit their goals. The social construction of engineering knowledge is much more obvious and crude than the construction of scientific knowledge. As one engineering writer has pointed out, engineers are less concerned about accuracy than scientists are and require only that their theories be adequate for their purposes.[161] The "norms" of science; the need to back up every assumption with evidence, the testing of hypotheses and the testing of other scientists work, do not apply in engineering. The only test for technology is whether it "works" and the meaning of "works" is also socially negotiated.

In engineering, knowledge serves not only as a basis for design but also as a tool of legitimation and justification. The 1976 Caldwell Connell feasibility study, which followed the decision to build the submarine ocean outfall, served both these purposes. It provided the data necessary for the design of the outfalls but also played a role in advocating those outfalls as an environmentally sound solution to the problems of ocean pollution. The study seemed on the face of it to be a comprehensive, well documented scientific study and in areas where information was needed for the purposes of design, it was.

However, the parts of the study which were aimed at proving that the performance of the outfalls would be environmentally beneficial were poorly documented and contained little relevant data. The key assumptions upon which the conclusions about environmental performance depended were unsupported. In particular, the claimed performance of the submarine outfalls depended heavily on at least three key assumptions; firstly the assumption that sludge would not accumulate in the sediments, secondly the assumption that the

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[158] Edwin Layton, 'Technology as Knowledge', Technology and Culture 15(1), 1974, pp31-41.

[159] ibid., p40.

[160] Henry Skolimowski, 'The Structure of Thinking in Technology', Technology and Culture 7(3), 1966, p374.

[161] G.F.C.Rogers, The Nature of Engineering: A Philosophy of Technology, MacMillan 1983, p54.

submerged field would not come on shore and thirdly the assumption that water-borne pathogenic organisms would die-off rapidly in the ocean. None of these assumptions were investigated.

This report and those that followed it were clearly attempts to construct and shape knowledge for political and social ends. The scientific experiments and computer modelling gave the veneer of a scientific approach but did not address the key questions. Yet the scientific packaging was necessary to give the report the aura of objectivity and truth which are usually associated with scientific reports.

The report was not unique in its use of and emphasis on scientific trappings as part of the presentation of a case. It follows in a long tradition of engineering reports, from the nineteenth century onwards, which have sought to present and define knowledge that accords with the political and social goals of the engineers themselves and their employers.

In the nineteenth century, however, the lack of consensus amongst engineers meant that various engineers used various "scientific findings" to support various systems and their subsequent knowledge claims were seen to be a resource for combatants rather than any statement of truth. Since the formation of a sewerage treatment paradigm, the engineers have got their act together and are careful not contradict each other. Rather they support each other's knowledge claims and these are presented to the public as factual, truthful, objective findings about reality.

Apart from the role of justification and advocacy, a science-like approach is also used by engineers generally to enhance their prestige and standing in the community. Practicing engineers and professional engineering societies have always seen an emphasis on science as a means of gaining status. Engineers came to define themselves by their ability to apply scientific laws to achieve their ends.

> The cement binding the engineer to his profession was scientific knowledge. All the themes leading towards a closer identification of the engineer with his [sic] profession rested on the assumption that the engineer was an applied scientist.[162]

Engineering educators increasingly emphasised and added to the scientific content of the education of university trained engineers in the nineteenth century as a way of improving their status and thereby "capitalize on the growing respectability of science". Scientific education carried a certain amount of prestige because of "a small but prominent and growing profession, that of the scientific researcher"[163] and this prestige had its effect on engineering education. The educators in early engineering schools, operating within

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[162] Edwin Layton, The Revolt of the Engineers, Press of Case Western Reserve University, 1971, p58.

[163] Randall Collins, The Credential Society: An Historical Sociology of Education and Stratification, Academic Press, 1979, p124.

universities, were highly conscious of their second-class status and even the newly esteemed scientists looked down upon them.[164]

The scientific approach has, of course, yielded solutions to engineering problems which the old trial and error methods never could but the need to teach science in engineering schools has been grossly inflated by the needs of the engineering profession for esoteric knowledge and of engineering educators for academic respectability.[165] And in many cases complex abstract methods have replaced simple empirical methods without any gain in the final engineering product.

This phenomenon was observed in a case study of American highway research by Bruce Seely. An increased scientisation of engineering had resulted from an effort to reap the higher status accorded to scientists after World War I. As part of this trend the Bureau of Public Roads concentrated on getting "precise quantitative data and the expression of results in mathematical terms". They also attempted to replace the knowledge they had gained through experience, observation and empirical methods with a more theoretical understanding of road construction. Seely concluded from his study that the embracing of scientific methodology and attitudes actually hindered the development of practical solutions.[166]

The new science of submarine outfalls seems to fit this pattern. The attempts to model real life situations mathematically tend to oversimplify the very complex action of the ocean and the heterogeneous nature of the sewage discharged into it. The preference for computer modelling over empirical experiments is marked in all of Caldwell Connell's studies, although very little evidence for the veracity of such models is given in their reports. Yet while computer modelling may seem to offer little gain over empirical methods in terms of power to predict the impact of the outfalls, it does have other advantages. Not only do the engineers and the study gain from the prestige associated with complex analytical methods (the engineers must have much esoteric knowledge and expertise and the study must be comprehensive, objective and true) but also the interpretation of results and assumptions inherent in such modelling and simulation exercises are less obvious and accessible to the lay reader than empirical tests such as drogue and dye experiments. These, as can be seen in this and previous chapters, are more obvious attempts to shape knowledge by specifically arranging experiments to give the required evidence and carefully minimising factors which may be known to be significant.

Michael Mulkay has pointed out the many flaws in arguments which treat the success of science in manipulating and controlling nature as proof of the validity of scientific conclusions[167] and a similar claim could be made about technological knowledge. The engineering knowledge of submarine outfalls and their predicted performance can be tested once they are built by how well they work. Yet the

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164 David Noble, America By Design: Science, Technology and the Rise of Corporate Capitalism, New York, Alfred A Knopf, 1977, p26.

165 ibid.

166 Bruce Seely, 'The Scientific Mystique in Engineering: Highway Research at the Bureau of Public Roads, 1918 -1940', Technology and Culture 25(4), 1984, pp 798-831.

167 Michael Mulkay, 'Knowledge and Utility: Implications for the Sociology of Knowledge', Social Studies of Science 9, 1979, p68.

definition of "working" is a negotiated one in terms of both the parameters which are defined to be important and the measures of those parameters which define success.

When the outfalls are built and operating, and if the engineers succeed in making the sewage field less visible, there may be no obvious signs of their impact. In the past, obvious signs of pollution have been denied, evidence of ill-health has been disputed, fish survey results have been labelled insignificant. The only measurable parameters which are officially endorsed are the limits on concentrations of restricted substances at the boundary of the initial dilution zone and concentrations of faecal coliform in bathing waters.

It is debatable whether the concentrations of restricted substances at the boundary of the initial dilution zone provide a satisfactory criterion of performance. Moreover these concentrations are not measured directly. Rather concentrations in the effluent are measured. This is not a simple matter of dipping a test tube into the flow. The Board is careful to get a composite sample which they say is representative of the flow which will vary at various places in the cross-section of the pipeline, with heavier material being towards the bottom etc. (Clearly there is ample opportunity here for sampling procedures that minimise the peaks of toxic metal concentration especially since the Board does not really want to know but is only satisfying SPCC requirements in taking the measurements.) The contents of this composite sample is then multiplied by an assumed dilution factor and it is this final manipulated result which can be compared to SPCC WP-1 criteria which are themselves negotiated.

Similarly, the concentration of faecal coliform is agreed by almost everyone to be an unsatisfactory indicator of bacteria and viruses in sewage and a dubious indicator of the presence of sewage because of short die-off rates. Moreover the monitoring process is manipulated to ensure that a large number of unsatisfactory readings are hidden within a mean figure. Evidence of this manipulation process is given in a recent Water Board report which observes that the chance of the worst 10% of samples being significantly over limits is increased if samples are taken less often.

> If a 6-daily strategy were adopted there would be a 35% chance that the measured 90 percentile from one season's monitoring would exceed the present value of 1000 cfu/100ml - i.e. we would be incorrectly deducing that the new outfalls had worsened the situation... For a 3-daily and daily sampling this chance reduces to 15 and 5% respectively.[168]

The report therefore recommends that sampling for the first year after the outfalls are commissioned should be at least once every 3 days with the possibility of reducing to 6 daily "if levels prove to be less than expected."[169]

There are numerous other examples where the monitoring programme for the new submarine ocean outfalls, which is supposed to assess their performance, is

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168 Sydney Water Board, Sydney Deepwater Outfalls, Environmental Monitoring Programme: Pilot Study, vol 3, March 1988, p17.

169 ibid., p18.

being manipulated in advance. During pre-commissioning beaches will be monitored at several locations, purportedly to establish the influence of alternate sources of pollution, and then after commissioning only one location[170], chosen by the Board on the basis of their pre-commissioning results, will be monitored on seven selected beaches (Avalon, Turimetta, Dee Why, Freshwater, Bondi, Malabar, Cronulla), not including Maroubra, Queenscliffe or Clovelly which are some of the most polluted at present.[171] Since 25 beaches are monitored routinely by the Board[172] it is hard to understand this selectivity.

These beaches will be monitored for faecal coliform and faecal streptococci, neither of which are pathogenic although faecal Streptococci bacteria survive longer in seawater than coliforms. Although the Board admitted that human viruses were generally more infectious and survived longer in the environment than most bacteria, they argued that they are hard to detect and may not supply "significant additional information". Salmonella will not be monitored, although it is tested for by the Department of Health, because the Board claim that it does not survive outside the body and is only found in sewage if there are carriers in the population, because salmonella can result from pollution by animals and birds and because it is unlikely that people would become infected by it from swimming. [173]

Similarly, as was discussed in chapter 7, the fish which are going to be monitored are fish which have not given too much trouble in terms of accumulation of organochlorines and heavy metals, unlike, for example, the Red Morwong, the Blackfish or the Blue Groper.[174] In fact the first volume of the Water Board's pilot study (preceding the full monitoring programme) indicated that the bioaccumulation studies were only going to be undertaken at Bondi and North Head[175], although I was told that it was later decided that Malabar would also be monitored and a later volume of the pilot study also indicated this.[176]

The use, in the earlier Caldwell Connell reports, of sediment samples obtained with a Shipek Grab Sampler, which was questioned by the SPCC does not seem to be improved upon much in recent investigations. In the pilot study, two sediment samples were collected using a Smith-McIntyre grab and no restricted substances were detected in either sample. The Board did admit, however that "this may have been due to "washing" of the sample during retrieval".[177] Moreover, sediments will be sampled in the initial dilution zone, close to the submarine diffusers (thereby assuming no travel of the sediments) and the control sites (off Long Reef and Port Hacking) will be easily within the 14 km that the Board previously argued the sludge particles would travel. Initial

170 ibid., pp16-18.

171 ibid., p9.

172 Sydney Water Board, Annual Report, Year ended 30 June 1988, p34.

173 Sydney Water Board, Pilot Study, vol 3, pp7-9.

174 ibid., vol 11, p16.

175 ibid., vol 1, tables 8a &b.

176 ibid., vol 11, figure 10.

177 ibid., vol 11, p12.

sampling will be reviewed after six months and the sampling strategy modified if necessary.[178]

Another important difference between the construction of scientific knowledge and the construction of technological knowledge lies in the difference of approach. Technologists assume that nature can be modified and manipulated.[179] Not only do they seek to dominate nature but they are also insensitive to the complexities and delicate balances that ecosystems rely on. Engineers see oceans in terms of their assimilative capacities. They assume that matter and energy move in linear pathways unlike "the ecologists notion of keeping matter and energy within as tight as possible circles or cycles."[180]

Sewerage engineers think primarily in terms of oxygen demand, suspended solids and faecal coliform, as they have done for years but these are crude measures of the impact of sewage on an ecosystem which is more complex than we can know and has evolved subtle balances over millions of years. Engineers are used to avoiding major easily detectable impacts, yet more subtle impacts on ecosystems can be just as devastating in the long term.[181] In particular, engineers have not been concerned about the eventual fate of the sewage discharged. They seem to consider that if they can prove that the sewage will not build up or form a nuisance near the outfalls and nearby beaches then it doesn't matter where it goes to.

Engineers do call on the work of people in other fields of expertise but they do this selectively and according to what will be useful or will support their goals. This is clearly shown in the area of health risks arising from swimming in sewage polluted waters and the continued reference by engineers in the SPCC and the Water Board to the findings of a 1959 report despite all the research and evidence that has been done since that time. They are similarly selective about citing overseas experience of environmental impacts associated with engineering projects similar to their own. Nor are engineers the only ones to shape knowledge to suit their purposes. Moore's study also clearly shows how medical knowledge can be shaped to suit social and political ends and shows the folly of relying on one study to ascertain health risks unless that study suits your purposes.

And whilst engineers must necessarily draw upon the knowledge of other professions, particularly scientists and medical experts, they are not willing to take criticism from those whose areas of expertise they encroach on. There is no reason for them to since the knowledge they desire is just enough to be able to construct lasting, low maintenance structures and convince others that they are adequate. The knowledge of others who do not share their paradigm is not only seen as superfluous but also counterproductive.

For example, Mullins, as a marine chemist, found the engineering simplifications of the behaviour of the ocean as one homogeneous mass and the interaction of a changeable sewage effluent with it, to be almost incomprehensible. Moreover his priorities were quite different from those of the sewerage engineers. He wanted

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178 ibid., vol 11, pp17-18.

179 Rogers, The Nature of Engineering, p30.

180 Jorling,'The Southern California Bight', p252.

181 ibid., pp252-5.

to see the marine life protected and the sewage recycled.[182] His criticisms were described by the Water Board as "unsubstantial and irresponsible" and a board spokesman asserted that Mullins had not understood the Board's "extensive" EIS's.[183]

What Mullins failed to understand, from the Board's point of view, was the extent to which political ends and cost considerations shaped the choice of submarine outfalls and the way the scientific data had to fit in with that. It was irresponsible not to consider such things. What was called for was "unemotional consideration of the subject by those qualified and experienced in this field."[184] Clearly only engineers, who were willing to consider political and economical aspects of the situation, were properly qualified to comment.

Brain, who as an engineer should have known better, took the request to assess the Caldwell Connell study seriously. He later admitted that he had misunderstood the situation; that the SPCC had made a policy decision in favour of the submarine outfalls and that he was supposed to support the report. He had not and he was very unpopular because of it. He claimed that he had been "crucified" and that he was pushed into other work. It was the end of his career in the SPCC.[185]

CONCLUSIONS - AND ARE THEY NEGOTIABLE?

The advantages which submarine ocean outfalls are supposed to have over shoreline discharges are firstly the greater dilution and dispersion they will effect, secondly the ability to keep the sewage field submerged because of the depth at which the sewage is released and thirdly the greater die-off of water borne disease-causing organisms due to the greater distance they have to travel before reaching shore.

The faith in dilution has its roots in the faith of early American engineers in the almost infinite ability of running water in rivers to purify effluent. Yet dilution is not the only mechanism that operates in ocean waters and various materials in the sewage tend to accumulate and agglomerate rather than disperse in the ocean or are bio-accumulated in the marine food chain. Moreover a narrow emphasis on dilution ignores the effect that continual discharge may eventually have on a finite body of water. There is evidence that sewage and sludge disposal to sea are causing a build up of pathogenic microorganisms and toxins in various parts of the world.

Similarly the role of the submerged field and die-off factors are open to question. Even if a submerged field can be maintained most of the time in summer, as Caldwell Connell hope it will, the bacterial die-off rate will be reduced and the submerged field may still come in shore. Faecal coliforms may die-off quickly but bacteria and viruses can live for months.

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[182] T. Mullins, 'Submarine Sewerage Out-Fall', Communique 2, August 1981.

[183] Southern News, 21st July 1981.

[184] Sydney Morning Herald, 8th June 1970.

[185] Robert Brain, personal communication, July 1987.

Engineering knowledge is not about truth nor does it describe reality, past, present or future. It is a special blend of know-how, ideology and representation aimed at achieving ends. It mimics science, takes on the trappings of science, utilises science selectively, but also ends up being a parody of science. This tendency is heightened in public sector technology where the evaluation of a technology is endlessly manipulable and the criteria for performance socially negotiated.

In the case of sewerage technology and, in particular, the submarine ocean outfalls, the only means of evaluation is through legislated standards and guidelines. Yet the standards and guidelines reflect the same engineering knowledge that the technology is based upon with the same inconsistencies and the same selective use of scientific findings. These standards are also subject to social construction and manipulation. The WP-1 guidelines were put together in 1974, upon request from the Water Board. Many of the provisions within them are open to interpretation and the numeric standards they contain are based on principles that were at the time and are increasingly questioned.

In particular, the bacterial standards are based on measures of faecal coliform, which bear little behavioural relation to pathogens and the levels of restricted substances are based on concepts of a zone of sacrifice and the efficacy of dilution for dealing with toxics. It has been argued, moreover that the focus by sewerage authorities and regulatory agencies on faecal coliforms "is a public relations exercise aimed at distracting attention from the very serious, long-term water pollution problems which are not being tackled." Other indicators of water quality such as levels of heavy metals in fish are not publicised and "the public is mistakenly led to believe that 'all is well' if most beaches are given the all clear in terms of faecal pollution.[186]

The proposed monitoring programme for the new ocean outfalls is being worked out on the basis of a pilot study which allows the Water Board to choose and shape its methods, criteria and locations for monitoring in advance and because the monitoring programme have a pre-commissioning stage, this process will be refined as results come in. This provides for ample opportunity to shape the results and ensure that the Board only discovers what it wants to discover.

The Water Board and Caldwell Connell Engineers have spent over a decade putting together a knowledge base that supports their submarine ocean outfalls, presently being constructed. This was not only to convince the community and their politicians that the outfalls would "work" but also to convince the SPCC as regulatory authority so that approval would be granted. The next chapter will consider, the social context of their work, the debates over their knowledge claims and the preparations being made to ensure that the submarine ocean outfalls are defined as "working" after they are commissioned.

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186 Russ & Tanner, The Politics of Pollution, pp79-80.