[redacted]

6th April 2011

Commissioner
Queensland Floods Commission of Inquiry
PO Box 1738
Brisbane QLD 4001

Dear Commissioner Holmes

Enclosed please find a copy of the report on Flooding in Flat Rock Creek, referenced in a submission to your Commission made by G McMahon

QUEENSLAND WATER RESOURCES COMMISSION
TOWN WATER SUPPLY AND SEWERAGE BRANCH

REPORT

on

HISTORY AND CAUSES OF FLOODING IN FLAT ROCK CREEK

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Prepared for:

DEPARTMENT of LOCAL GOVERNMENT

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REPORT

ON

HISTORY AND CAUSES

OF FLOODING

IN

FLAT ROCK CREEK

INDEX

INDEX (CONTINUED)

REPORT ON HISTORY AND CAUSES

OF FLOODING IN FLAT ROCK CREEK

1. INTRODUCTION

This report is the result of a request, from the Department of Local Government, for comments on a letter written to the Minister for Local Government by a resident of the Flat Rock Creek catchment area, Mr. [redacted]

Mr. [redacted], in his letter dated 7th April, 1981, raised several matters - flooding, pollution, health matters and civil aviation problems. This report deals with the flooding aspects only, though it is clear that other concerns of Mr. [redacted] are related to the flooding problem.

The report's findings are based on documents obtained from and/or personal interviews held with the following persons and organizations:

a. [redacted] (resident);
b. [redacted] (resident);
c. [redacted] (resident);
d. [redacted] (resident);
e. [redacted] (Consulting Engineers);
f. Gold Coast City Council;
g. Blain, Bremner and Williams Pty. Ltd. (Consulting Engineers);
h. Department of Harbours and Marine;
i. Queensland Water Resources Commission;
j. Department of Local Government;
k. Department of Main Roads;
l. Titles Office;
m. The National Trust of Queensland; and
n. Australian Government Department of Housing and Construction (War Service Homes Section).

2. AIM

The aim of this report is twofold:

a. To summarize the history of flooding in the Flat Rock Creek catchment; and

b. To define the causes of past flooding and the causes of future flooding in the catchment.

3. DISCUSSION

3.1 GENERAL

3.1.1 Need for This Report

3.1.1.1 Outline

There is a need for a comprehensive overview of the events and decisions that form the background to Mr. [redacted] complaints to the Minister, for the following reasons:

a. Similar complaints will almost assuredly be made again on this matter in the future;

b. It is possible that future complaints may be of a more serious nature than past and present complaints;

c. To date the matter has been handled in a somewhat piecemeal and unco-ordinated fashion by separate organizations primarily interested in their own particular responsibilities; and

d. Much of the documentary material describing what has happened and why is, to varying extents, misleading, contradictory, superseded, and/or uninformed.

3.1.1.2 Nature of This Report

This report offers a qualitative rather than a quantitative overview of the history and causes of the flooding matters raised by Mr. [redacted]

3.1.1.3 Qualifications and Context

The accuracy of this report has been restricted by several factors. Reference to parts of this report, without reference to the qualifications contained herein, may act to use this report out of context. These qualifications are as follows:

a. Missing Records

Technical information on engineering works carried out in the catchment over the period 1967 to 1973 is not complete, because some of the participants, namely [redacted]., Blain Bremner and Williams Pty. Ltd., the Gold Caost City Council and the Main Roads Department, are unable to locate some of their records from that period.

b. Quantitative Analysis Not Undertaken

This report does not benefit from a full set of independent quantitative checks of calculations done at various times by the participants in the debate on flooding in Flat Rock Creek. The report relies largely on calculations done by others, some simple quantitative checks and some judgements as to the assumptions upon which calculations by others were made. Because of the complicated nature of the basic flooding problem, a quantitative analysis of the primary issues that bear on this problem was judged to be too complex and too expensive an assignment for the immediate purposes of this report.

4. DESCRIPTION OF CATCHMENT

The flooding problem in Flat Rock Creek occurs in that reach of the Creek flanked by the Currumbin Bird Sanctuary. This reach consists of two ponds or lakes, the upper ("upstream" or "western") pond and the lower ("downstream", "eastern" or "Sanctuary") pond, which are separated by the Pacific Highway. The lower pond is separated from the Pacific Ocean by Teemangum Street and Currumbin Beach. Figure 1 is a plan of the area.

The upper pond has always flowed into the lower pond through culverts under the Pacific Highway, though in times of flood the waters have, on some occasions and for different reasons, flowed over the roadway surface.

The lower pond, before 1967, was tidally connected to the sea, though the crossing of the beach was non-navigable. The tidal connection usually existed only at high tide, and may have been broken altogether after a long dry spell during which there was no flood of sufficient size to sweep out the beach sand formation and re-establish the tidal connection. The tidal flow passed under Teemangum Street through a low timber bridge. Plans of the bridge could not be found and estimates of its span vary from 20 ft. to 50 ft. Since 1969[1], a low weir has separated the pond from the ocean, the opening under Teemangum Street has been changed in height, shape and size, and the Teemangum Street kerb levels have been raised. A 54"ϕ pipe outlet structure from the lower pond to the ocean was also constructed about 1967.

The upper pond, before 1967, was also tidally connected through the lower pond. Subsequent to 1969[1], the tidal connection was broken, but the upper pond still flowed into the lower pond under the Gold Coast Highway. From 1967 to 1973, this connection was through 3 No. 2700 x 1500 RCBC's[2] (a total cross-sectional area of 12.15 m^2) at an approximate invert level of 0.6 m AHD[3]. After 1973, the connection consisted of 4 No. 1200 RCPs (a total

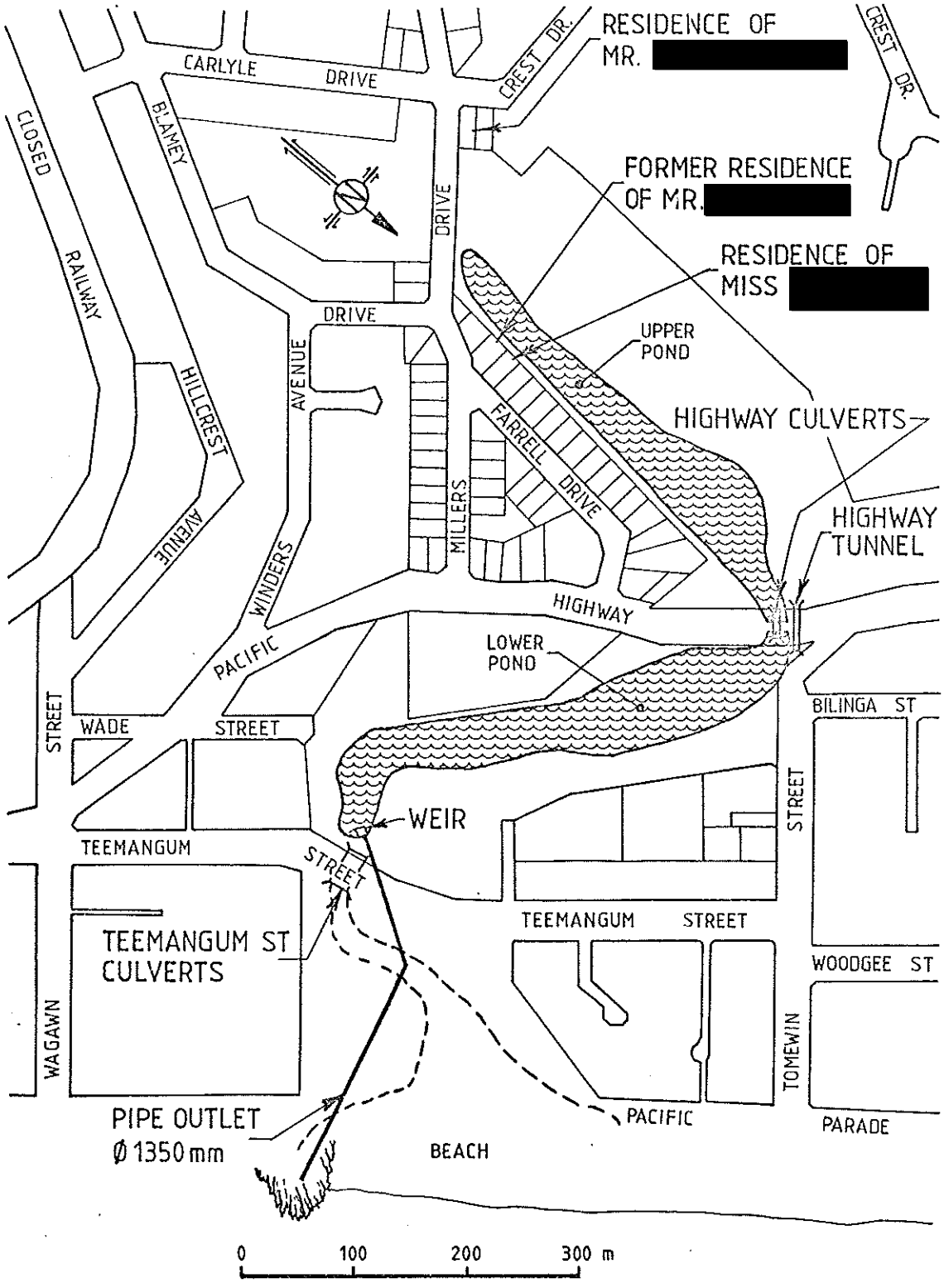

FIGURE 1: FLAT ROCK CREEK LOWER CATCHMENT

cross-sectional area of 3.39 m^2) at an invert level of 0.9 m AHD, and a tunnel, the mini-railway section of the tunnel being 2400 x 2400 (a cross-sectional area of 5.76 m^2) at 1.9 m AHD, and the pedestrian section of the tunnel being 1700 x 2100 m (a cross-sectional area of 3.57 m^2) at 2.2 m AHD[4].

5. PUBLIC RECORD OF EVENTS

5.1 March 1967

Gold Coast City Council began design and construction of a small concrete weir structure between the lower pond and the ocean, with a 54"ϕ pipe outlet from the weir to an outfall on a rock outcrop at the beach. These structures were based on a Master Drainage Plan prepared for Council by [redacted] Consulting Engineers and dated March 1967[5]. The creek was apparently closed off from tidal intrusion in May 1969[1].

5.2 May 1969 to October 1972

A number of significant events occurred in the catchment over this period:

a. Changes in the environment of the ponds accompanied the closing off of the ponds from tidal intrusion, for example:

   (1) a fishkill and resultant stench within a month of the date of closing off the ponds from the ocean[6];

   (2) extensive growth of weeds (salvinia auriculata)[7]; and

   (3) build up of the sand formation across the old tidal outlet, which trapped salt water from wave action at high tide between the beach and Teemangum Street - this trapped sea water went stagnant[8];

b. The level of the weir was raised above that level studied in the report of [redacted] and above the level reviewed by various government departments[9]. It is presumed that this work was done with the knowledge and consent of the Gold Coast City Council;

c. Gold Coast City Council reconstructed Teemangum Street, raising that part of it that crossed the line of Flat Rock Creek from RL 9.15 to RL 10.42, and eliminating the culvert across Flat Rock Creek that had been under the old roadway. That length of the new roadway that crossed the line of Flat Rock Creek was also superelevated[10];

d. The Currumbin Bird Sanctuary carried out various works[11] in the area of the ponds, including:

   (1) construction of fences across and through the ponds;

   (2) dredging of the ponds and raising of the ground levels about the ponds; and

   (3) construction of a revetment wall forming the boundary of the lower pond, the top RL of this wall being set higher than that allowed for in flood studies;

e. The Gold Coast City Council issued advice to house builders and approved plans for home constructions on areas adjoining the ponds, after reference to the report on flooding in Flat Rock Creek by [redacted] dated 1967[12]; and

f. Flooding occurred in the Creek in April 1972. Following complaints, the water level in the lower pond was lowered to RL 5.28 ft., which was closer to, but not as low as, the level studied by [redacted] namely 5.0 ft. RL[9].

5.3 October 1972

A significant rainfall event in the catchment caused extensive flooding of houses in the area. The aftermath of this flooding included the following events:

a. GCCC used machinery to remove portion of the superelevated section of Teemangum Street the day after flooding first occurred. This allowed the floodwaters to recede by over one foot in depth, but the flood waters remained in the houses for a further period in excess of 48 hours[8, 13];

b. GCCC, acting on advice from [redacted], stated that the rainfall event was greater than the expected 1 in 100 year rainfall and was certainly greater than the 1 in 50 year event allowed for in the design of the drainage system[8].

c. GCCC denied liability for the flooding in the area, acting on advice from their insurers[15];

d. GCCC settled out of court legal proceedings initiated by one of the residents having land adjoining the upper pond[8, 15]. The resident states that he received his claim in full; and

e. The flooding problem and possible solutions were re-studied by [redacted][4, 16]; and

f. 10 No. 48" x 18" (1200 x 450) RCBCs were installed under Teemangum Street[17], and the superelevated grading of the roadway removed.

5.4 1973

In this year the Main Roads Department upgraded the section of Pacific Highway that crossed the line of Flat Rock Creek, raising the level of the roadway surface and changing the culvert structures under the roadway[4]. Salient aspects of this development in the catchment are as follows:

a. The new culverts under the Highway were designed by Blain Bremner and Williams, Consulting Engineers (hence termed BBW). The firm is unable to locate their design calculations on these culverts but state that they were based on [redacted] 1967 report;

b. MRD is unable to locate, on their files for this job, the Form 14 used to describe the basis of design of the culverts on Flat Rock Creek.

c. During construction of these culverts the GCCC became concerned as to their size and capacity and the effect they would have on flood levels[18]. A meeting with MRD officers resolved to have [redacted] check the design. [redacted] checked the design and found that the water level in the upper pond, caused by the October 1972 storm, would have been 9.95 ft. SD[19]. This level was determined by GCCC to be acceptable[19]; and

d. MRD constructed the culverts as designed[4].

5.5 1974 to 1976

Two more severe storms occurred in the Gold Coast area during this period, namely the March 1974 and March 1976 storms. The latter caused flood levels of about 10 ft. SD at the Gold Coast Highway in the Flat Rock Creek catchment. The storms were analysed by [redacted], who reported they were of the same order of magnitude as the October 1972 storm[20]. The events that followed from these developments included the following:

a. The GCCC[18], [redacted], and the residents[8] of Flat Rock Creek realized that the October 1972 storm was not a 1 in 100 year event as had been previously argued;

b. CMP, in August 1976, reported[20] to GCCC that flood damage was occurring in the catchment with the existing preferred flood level in the upper pond of 9.95 ft. SD. [redacted] also stated:

(1) that works to improve the culverts at Teemangum Street would be more effective in improving the flood levels in the upper pond than works to improve the culverts at the Gold Coast Highway; and

(2) significant improvements could be obtained by further reducing the permanent pond water level in the lower pond;

c. GCCC commissioned [redacted] to derive a solution that would reduce flood levels in the upper pond for the October 1972 storm to RL 9.4 ft. SD;

d. [redacted] carried out such an analysis and found that:

(1) significant improvements in flood levels in the upper pond were NOT obtained when the permanent water level of the lower pond was lowered;

(2) significant improvements could be obtained by increasing the number and size of culverts at Teemangum Street, and by reducing their ILs;

(3) 10 No. 48" x 18" (1200 x 450) RCBCs at an IL of RL 5.5 ft. was the best arrangement of additional culvert capacity for Teemangum Street;

(4) the additional culvert capacity would reduce flood levels in the upper pond for the October 1972 storm to RL 9.0 ft. SD; and

(5) this solution required that the free open outlet to the ocean be maintained at all times; and

e. GCCC constructed culverts under Teemangum Street as recommended by [redacted].

5.6 1977 and 1978

No further works have been done to improve the flood levels of Flat Rock Creek since the GCCC constructed the wide low battery of culverts under Teemangum Street just described. With this work GCCC were of the opinion that the flood level in the upper pond was 9.0 ft. SD for the 50 year storm[21]. This meant a freeboard of 1 ft. above the 1 in 50 flood level existed for most properties adjacent to the upper pond - an acceptable degree of protection in many flooding situations. However, a number of disclosures brought the matter of flooding in the catchment back into question:

a. [redacted] discovered an error in their calculations, which changed the calculated flood level in the upper pond, for the October 1972 storm, from 9.0 ft. to 9.83 ft. SD[23]. Thus the freeboard protection was reduced from 1 foot to 2 inches;

b. GCCC came to realize that the October 1972 storm was probably NOT as severe as the 1 in 50 yr. event[24]. Thus the 2 inch freeboard protection provided in the upper pond was not protection against the 1 in 50 yr. storm, but was instead the protection against possibly only the 1 in 20 yr. storm. A 2 inch freeboard protection against a 1 in 20 year flood is not an acceptable degree of protection by present engineering practice;

c. [redacted] identified the solution to the flooding situation as being to increase the culvert capacity under the Gold Coast Highway[23];

d. GCCC[25] wrote to MRD requesting them to re-examine the culverts on Flat Rock Creek, and providing them with information MRD[26] requested on the flooding problem and associated matters; and

e. MRD have not as yet complied with GCCC's request.

5.7 1979 to Present

No change.

6. CAUSES OF FLOODING

The October 1972 Flood

6.1 The Causes of Flooding

There were several factors that contributed to the flooding in the upper pond on Flat Rock Creek in October 1972. These included:

a. Failure of the GCCC to make proper allowance for significant flooding events in the development of their master drainage plan for Flat Rock Creek;

b. Errors in the calculations and assumptions contained in [redacted] March 1967 report, together with some shortcomings in the scope of the report;

c. Failure of GCCC to administer its responsibilities in the catchment in line with the recommendations of [redacted] March 1967 report, and other advice provided to Council;

d. Works carried out by the Currumbin Bird Sanctuary;

e. Works carried out by GCCC; and

f. Effects of sand, silt, vegetation, and debris in reducing the effective capacity of drainage structures in the Creek.

6.2 Provision for Major Floods

The terms of reference that GCCC drew up for the master drainage plan study of the Flat Rock Creek catchment did not include consideration of the effects of major flooding events[27]. Such consideration was warranted, as the Council proposed to close the Creek to tidal intrusion. Council's action to raise Teemangum Street and do away with the existing bridge along Teemangum Street reflect the failure of Council to plan for or investigate the impact the works they proposed were going to have on flood levels in the catchment. Other examples, of where Council's attitude towards and attention to the prospects of damage from major floods appear to be less than desirable, include:

a. GCCC's letter 28032 dated 9th October, 1967 to Department of Local Government, acknowledging that, with the 1 x 54" outlet, the 1 in 50 yr. flood level in the pond would be increased above 9.5 ft. SD, but expressing the opinion that flooding above this level was not considered critical. This opinion was contradictory to the report by CMP of floor levels of existing buildings that were below 10.0 ft. SD[28];

b. Council appears to have allowed the raising of the weir in Flat Rock Creek by 1.0 ft., which is twice the freeboard protection afforded properties adjacent to the ponds; and

c. Council appears to have allowed filling of the flood plain upstream of the weir, to the level of a raised revetment wall, without quantitative checks of its impact on flood levels.

6.3 [redacted] March 1967 Report

a. The errors contained in this report, and/or the calculations and assumptions upon which it is based, include:

(1) The calculation of impervious area is slightly in error,

which results in an underestimation of peak flows for the assumed 1 in 50 yr. storm of 4%, and for the assumed 1 in 10 yr. storm of 5%[29];

(2) The upper and lower ponds appear to have been treated as a single pond or as a single unit rather than as two ponds acting as an interdependent system connected via a culvert[30]. This assumption would create errors in two calculations:

(i) calculating the storage vs. depth of water curve and thus the attenuation effects of the ponds on the flows along the Creek; and

(ii) calculating the hydraulic gradient, and thus the relative flood levels, through the two ponds;

(3) Some comparisons of 1981 RLs and the RLs assumed for the upper pond by [redacted] in 1967 suggest these assumptions may have been in error, though exact statements on this matter are impossible due to reported filling of the floodplain in this area since 1967 by the Bird Sanctuary management;

(4) The choice of storm duration for the 1 in 50 year flood analysed was made on the basis of the comparison of flood effects from different storm durations for the 1 in 5 yr. rainfall event, rather than from a similar study of a series of 1 in 50 year rainfall events[32];

(5) Though the report, in the hydrology section of the report, provides information which calculates peak flow (for a 1 in 50 yr., 23 minute storm) of over 1100 cusecs, it is probable that the highest flow actually analysed for flood levels in the report was about 620 cusecs; and

(6) Zero loss of capacity was assumed for culverts and pipes due to siltation and debris;

b. Areas of [redacted] report that might be criticised for a lack of depth or lack of scope in the calculations that were conducted, include:

(1) The catchment, as it existed in 1966 before any of the proposed works were undertaken, was not analysed in the report. Thus the understanding of the catchment flooding problem gained from the calculation actually carried out and reported on would not be as good as it might have been if an attempt to match the results of the calculation techniques used, with measurements of historic flood and tidal flows, had been made. Especially, critical components of the catchment, such as the ponds, the culverts under the Pacific Highway and Teemangum Street, and the beach dunes would have been better understood, and the effects of proposals to vary the environment of the catchment would have been more accurately comprehended, if an analysis of the catchment as it existed in 1967 had been conducted;

(2) No sensitivity analysis was reported for important design parameters of the 1 in 50 year event. Examples of parameters that might have been so tested, with good cause, include:

(i) Peak flows (for all analyses, but in particular for steady state analyses);
(ii) Temporal patterns;
(iii) Storm Durations (in particular for runoff routing and detention basin analyses);
(iv) Friction factors; and
(v) Loss of capacity in hydraulic structures;

(3) Following on from (2), the freeboard of 6 inches recommended by the report was probably an arbitrary choice, rather than a judgement based either on estimates of the effects of any errors in the analysis on flood levels, or on any other estimates;

(4) Detailed survey information related to the critical features of the catchment was not obtained. For example, the construction of the stage storage curves for the ponds was probably based on assumptions as to levels rather than measured levels[33];

c. An error in the report which did not, it is argued, contribute significantly to flooding in the October 1972 storm, concerns the estimates the report contains of the 1 in 50 rainfall intensities. The report used rainfall intensity data based on Brisbane rainfall records. While it has been demonstrated, since 1967, that these estimates underestimate the real 1 in 50 year rainfall intensities for the South Coast, the 1967 CMP report did investigate a storm of approximately the same severity (within 10%) as the worst period of the October 1972 storm[34]. The difference between the calculated and actual storms is within the safety factor that normal practice might apply in using transposed rainfall data. Sensitivity analysis of storm durations and use of a non-uniform rainfall temporal pattern would also, most probably have overcome the 10% difference; and

d. Finally, all the attention that [redacted] paid to the 1 in 50 yr. event was outside the terms of reference given this firm by GCCC. The shortcomings that might exist in the report with respect to the 1 in 50 yr. event are not as great as they might have been if [redacted] had kept their investigation to the terms of reference. How receptive GCCC might have been to expanding the terms of reference, in response to any requests from [redacted] that might have been made to do so, would only be known by the participants.

6.4 GCCC's Administration of Development in the Flood Plain

This area of criticism of actions by GCCC is best described by reference to the circumstances of one of the residents, Miss [redacted] Miss [redacted] was eligible for a war service home, and the War Service Homes Section of the Commonwealth Government, in 1970/71, managed the construction of Miss [redacted] home. The site is situated at the junction of Millers Drive and Farrell Drive, and backs on to the upstream section of the upper pond. Miss [redacted] owned the property prior to 1967, but the house was not built until after 1970.

a. The War Service Homes Section (now, of the Department of Housing and Construction) wrote to Council in 1970, seeking approval to build, and specifically requesting information with respect to flooding;

b. GCCC replied to the War Service Homes section, in a letter[35], dated 10th November, 1970, stating:

(1) Flood level was 9.5 ft.; and
(2) Minimum floor level was 10.0 ft;

c. This advice was incorrect, because of the following:

(1) [redacted] 1967 report stated that 9.5 ft. was the flood level for the LOWER pond. However, section 5.6 of the same report, dealing with the recommended and adopted works proposals, states:

> *"The hydraulic gradient through the lake at design flood (1 in 50 years) will be about 0.20 ft. from the outlet weir to Millers Drive and this must be added to the tabulated levels to determine flood levels at the upstream end of the lake."* (Underlining added);

(2) On the basis of this remark the advice GCCC should have given was:

(i) Flood level = 9.5 + 0.2 = 9.7 ft.; and
(ii) Min Floor Level = 10.0 + 0.2 = 10.2 ft.;

(3) GCCC, following advice from the Department of Local Government[36] that the flood level in the lower pond with a 1/54" outlet pipe was 9.7 ft. and not 9.5 ft. (a difference of 0.2 ft.) agreed there was a discrepancy but stated that the new level was 9.6 ft., not 9.7 ft., and stated that[37] -

"attention to this will be given in Building Permit Conditions";

(4) On this basis, the advice GCCC should have given to the War Service Homes section was:

(i) Flood Level = 9.7 + 0.2 = 9.9 ft.;
(ii) Min. Floor Level = 10.2 + 0.2 = 10.4 ft.;

(5) The weir in Flat Rock Creek had been raised from the level of 5.0 ft., allowed for in the calculations for [redacted] 1967 report, to a level of 6.0 ft., a difference of 1.0 ft.;

(6) On this basis, in the absence of a fresh analysis of the new situation, the advice GCCC should have given in 1970 for the benefit of Miss [redacted] was -

(i) Flood level = 9.9 + 1.0 = 10.9 ft.;
(ii) Min. Floor Level = 10.4 + 1.0 = 11.4 ft.;

d. The maximum flood height recorded in the October 1972 storm was 11.3 ft.[38], which is just below the level that GCCC should have advised as being the minimum floor level for Miss [redacted] home;

e. Miss [redacted] home was constructed 0.25 ft. above the minimum floor level given to War Service Homes section by GCCC. If that advice had been 11.4 ft., instead of 10.0 ft., Miss [redacted] would have been relatively flood free in October 1972, instead of receiving over 1 ft. of water through her house for three days;

f. Miss [redacted] states she did not receive compensation from Council for damages she suffered as a result of flooding in Flat Rock Creek in October 1972. This resident states she did not initiate legal proceedings against Council because she did not have the funds and was "heartbroken" by what had happened to her new home and her possessions;

g. This resident's case has been the subject of letters to the local newspapers by other residents; and

h. She also states that a horizontal thin brown mark, still visible in 1981 on the internal walls of the house, was the water mark left by three days' inundation of the house in October 1972.

Note: This resident's house is still subject to flooding today, probably for the 1 in 20 year storm.

The point to the circumstances of this resident is that, quite apart from any technical matters that contributed to flooding in this catchment, the flooding in this resident's house was due to administrative errors.

6.5 Works By the Currumbin Bird Sanctuary

Works probably aggravating the flooding problems in Flat Rock Creek carried out, after 1967 and before October 1972, by the Bird Sanctuary management include:

a. Construction of a concrete revetment wall on the boundary of the lower pond, which was raised above the height for which flooding was investigated, subtracting from the detention storage characteristics of the pond;

b. Filling of land to RL 9.0 on the eastern side of the lower pond, subtracting from the detention storage characteristics of the pond;

c. Allegations by residents claiming that the flood plain adjoining the upper pond was filled, subtracting from the detention storage characteristics of the pond;

d. Construction of fences across the Creek in the upper pond and upstream of the upper pond, trapping debris and vegetation which acted to impede the flow; and

e. Sand bag retaining walls, placed on the upstream side of the culverts under the Gold Coast Highway, are alleged by residents to have been put there by the Bird Sanctuary management[39].

6.6 Works by GCCC

Works by GCCC which contributed to the flooding in the area of the ponds in October 1972 include:

a. The weir and outlet structure which cut off the ponds from tidal intrusion;

b. The removal of the bridge under Teemangum Street;

c. The raising of Teemangum Street, from 9.15 ft. to 10.42 ft. SD, and the superelevation of the cross-sections of the road length crossing the Creek; and

d. The 54"ϕ outlet from the lower pond crosses the line of Flat Rock Creek in the section of creek between Teemangum Street and the beach; the level of the obvert of this pipe is about 600 mm or 2 ft. above the bed level of the Creek at this point[40].

6.7 Sand Silt Vegetation and Debris

Photographs in the local newspaper indicate that significant amounts of debris and vegetation are contained in the flood flows down Flat Rock creek. While the vegetation may well come from the upper, undeveloped areas of the catchment, it is also true that, since tidal intrusion of the ponds has been prevented, extensive weed growth has occurred in the ponds themselves. Infestations[41] of large leafed plants and *salvinia auriculata* have at times completely covered the surface area of the ponds. While this growth may have significance for health reasons, bringing insects, rats etc. to the area, it also is significant from a flooding standpoint, when these weeds impede flow at the entrances to culverts and pipes and through fences and gates. Silt and sand accumulations, on the beach and at the outlet to or within culverts and pipes, also impede the rate of flow of water over or through critical portions of the flood flow paths for Flat Rock Creek.

The March 1976 Flood

6.8 Aftermath of the October 1972 Storm

Further analysis of the catchment was carried out, immediately after the October 1972 flood, and during the time that MRD were raising and upgrading the Pacific Highway, with the provision of a new culvert arrangement under the Highway. The analyses conducted, however, were distracted to a significant extent by the belief that the October 1972 storm was a 1 in 100 year event[42]. On the basis of the facts known at that time, that belief, though convenient in the circumstances, was not supported by those circumstances. In the end, culvert capacity was provided under Teemangum Street but at a level that preserved the effect of the weir in preventing salt water intrusion into the ponds.

6.9 Causes of Flooding

The flood levels in March 1976, that matched the levels recorded in October 1972, were the result of the following factors:

a. [redacted] it appears, failed to detect the more significant errors in the calculations that formed the basis of their 1967 report. In particular, [redacted] it appears, did not realize the fundamental analytical error they were making in their treatment of the ponds and the new MRD culverts connecting them;

b. Works by MRD;

c. Additional works by the Bird Sanctuary; and

d. The causes of the October 1972 storm.

6.10 Checks by [redacted] 1972 to 1975

Some judgements are offered about the checks done by [redacted] after the October 1972 storm -

a. The calculations do not appear to have been based on a proper treatment of the two ponds as a coupled system, but may have been changed in some calculations from treatment of a single pond to treatment of two independent basins[43];

b. The calculations of the capacity of the culverts under the Pacific Highway for MRD were probably based on formulae assuming upstream control of flow through the culverts rather than the downstream control probably in effect throughout the high point of the flooding; and

c. The calculations of outflows from the lower basin also seem to have been made on assumptions that ignore tide levels, surge levels and wave set up effects.

6.11 Works by MRD

These works on the Pacific Highway route were designed by Blain Bremner and Williams, Consulting Engineers, who assert (their records cannot now be found) that the design was based on [redacted] 1967 report. The works were further checked by [redacted] themselves after the October 1972 storm, at the instigation of GCCC and with the agreement of MRD. The design, by normal MRD procedure, would also have been reviewed by MRD. Though the errors in the calculations were not detected by any of the participants, suspicion of the design might have been aroused by the following factors:

a. The culverts, being replaced, were 3/9' x 5' RCBCs at (probable) RL of 2.0 ft. AHD. The new tunnel and culverts in combination had the same cross-sectional area, but the culverts were smaller in individual size and thereby more vulnerable to debris problems, and both the culverts and tunnel had higher ILs, thereby necessarily increasing flood levels upstream of the Highway; and

b. The works constructed downstream of the Highway, in as much as they cut off the lower pond from tidal intrusion, must have raised tailwater levels downstream of the Highway.

6.12 Works by the Bird Sanctuary

Residents have claimed that the management of the Bird Sanctuary continued filling of the floodplain with material dredged up in deepening the ponds[45]. Claims regarding the construction of sand bag weirs were repeated in the period between the October 1972 and March 1976 storms. The important works, additional to the type of works complained of by residents prior to the October 1972 storm, that aggravated the flooding in Flat Rock Creek, concern the tunnel constructed under the Pacific Highway by MRD in 1973 -

a. This tunnel provides approximately 75% of the cross-sectional area of all drainage structures under the Pacific Highway;

b. The tunnel is used by the Sanctuary to allow customers to walk or travel by mini-train to and from the Sanctuary areas west of the Highway;

c. To facilitate this traffic, and apparently unmindful of the effect on flood levels, the Sanctuary has constructed on the floor of the tunnel a 0.3 m (1.0 ft.) high footpath and a mini-railway track. These works have acted to raise the invert level at which flood waters will begin to drain from the upper pond, and have decreased the conveyance efficiency of the tunnel as a drainage structure through increased roughness; and

d. Further, the Sanctuary has placed a wire gate on the entrances to the tunnel to control animal movements at night. This gate, when closed, acts as a trap for debris and weeds which blanket the gate, thereby reducing the flow into and out of the tunnel. This factor acts to increase the levels in the upper pond.

6.13 Aftermath of the March 1976 Storm

Further analysis of the flooding problem in the Creek was carried out by [redacted] which brought further insight to the situation, but failed to recognize some critical aspects of what had to be done to solve the problem completely.-

a. Severity of Historic Storms

With four storms (April 1972, October 1972, March 1974 and March 1976) causing flood damage in four years, it became fairly clear that the October 1972 storm was not a 1 in 100 year storm, nor even a 1 in 50 year storm. A report done by [redacted] for GCCC on Coolangatta Creek indicates that the October 1972 storm may have only been a 1 in 20 year storm for the design storm duration. It was realized, as a result, that the drainage designs meant to handle the October 1972 storm were, in fact, dealing with a flood well below the severity of the 1 in 50 year flood; and

b. Redesign

Efforts by [redacted] to improve the drainage design in 1976 again, it appears, failed to detect the error that had been made in the treatment of the ponds. As a result, conclusions reached were:

(1) that relatively minor gains were to be made in reducing flood levels by increasing the culvert capacity under the Highway;

(2) that reduced flood levels would be gained by increasing the number of culverts under Teemangum Street and by placing these culverts at a lower invert level;

(3) that marginal gains would be made if a retention basin in the upper catchment, behind an old railway embankment, was constructed (Previous designs had included assumptions that both this railway detention basin be built and also that the catchment be fully developed. As the latter assumption was not yet reality and was therefore a conservative assumption, GCCC had felt justified in not constructing this railway pond up to that time);

(4) that the flood levels in the Creek were very sensitive to obstruction of the culverts; and

(5) that weed growth had obstructed the culverts in the past.

The Highway Culverts

6.14 Detection of Error

In 1977, while [redacted] were investigating a proposal to place a permanent weir structure in the upper pond, the error in [redacted] previous analytical

treatment of the ponds appears to have been detected[48]. A paper presented to a national symposium on hydrology[49] in 1978 by a member of [redacted] staff refers specifically to [redacted] experience in Flat Rock Creek, and demonstrates an error in the flood levels caused in the upper pond for the October 1972 storm, by the incorrect treatment of the ponds, of 0.51 m or 1.7 ft.

6.15 Mitigation of Flooding

[redacted] thereupon realized that the culvert capacity under the Pacific Highway was an important factor to the solution of the flooding problem. They communicated this to GCCC who requested MRD to investigate the problem, offering MRD a possible solution worked out by [redacted] MRD were not convinced by the arguments of GCCC and requested additional information. This was provided along with a repeated request to MRD to increase the culvert capacity under the Highway[50].

6.16 Current Status

This last letter from GCCC was dated March 1978. The files at MRD indicate no action has been taken by MRD to consider the matter[51].

Special Matters

6.17 Ownership of the Upper Pond

Whereas the lower pond is situated within a reserve or Council held land (zoned PUBLIC OPEN SPACE), the upper pond is within and part of freehold land, the title being held by the National Trust of Queensland (and zoned PRIVATE OPEN SPACE). Whatever differences this may make in a legal sense when it comes to what the National Trust can or cannot do to that portion of its land that forms the bed, banks and floodplain of Flat Rock Creek, in a practical sense it appears that the activities of the Bird Sanctuary management in the upper pond have been subject to less control by Council than in the lower pond.

6.18 Sand Bag Weirs

Allegations as to the construction of such weirs at and upstream of the Pacific Highway culverts have been made by residents, and have been referred to in letters written by MRD and GCCC. When QWRC surveyors visited the site as part of this investigation, they found sand bags in the culverts under the Highway. Whichever organization is constructing these sand bag weirs and/or leaving them in such a position is putting residents upstream of the Highway at unnecessary risk of flooding.

Present Causes of Flooding

6.19 Summary

Causes of any future flooding will be any or all of the following:

a. The culverts under the Pacific Highway are too high and too small;

b. The sand formation on the beach is too high, which is a probable result, in part, of cutting off Flat Rock Creek from tidal intrusion;

c. The earth mound between the lower pond and the beach is too high;

d. The culverts under Teemangum Street are too high and too small;

e. Structures are too small in individual sizes, or otherwise are not designed to cope with the debris load expected for flooding in Flat Rock Creek;

f. The activities of the Bird Sanctuary management in developing the Sanctuary do not have the benefit of quantitative guidelines and restrictions on what can be achieved without further aggravation of the flooding problem;

g. The freeboard allowed above the design flood levels for the Creek does not reflect the true sensitivity of the resultant levels to the inevitable errors in the engineering assumptions and analytical techniques that derived these design flood levels; and

h. The tailwater effects of high tides and/or surges during flooding[52].

6.20 Liability

It is clear that most of the causes of flooding in the Creek are the results of works undertaken by bodies or persons other than the residents. A quotation from [redacted] supports this view:

> *"Whether the augmentation should keep flood levels down below RL 10.0 or not is a matter of economics and politics... The only feature which makes Flat Rock Creek different to most other areas is that here by deliberate action works have been done which could have caused flooding which otherwise may not have occurred"*[53].

Quantitative Definition of Causes of Flooding

6.21 General

This report provides only a qualitative description of the factors causing flooding in Flat Rock Creek. The solution to these problems requires a detailed quantitative analysis of the catchment, its drainage structures, and its outfall to the sea.

6.22 Tidal Barrage

The earth mound and culverts between the lower pond and the beach act as a tidal barrage. The power to investigate and alter or remove such existing structures would appear to lie with the Commissioner for Water Resources via Section 7 of the Water Act.

REPORT BY [redacted]
G. McMAHON

ENDORSED BY [redacted]
W.A.L. WEBBER,
CHIEF DESIGNING ENGINEER.

DATE: 27TH JANUARY, 1982.

FOOTNOTES

1. The actual date at which the lower pond was cut off from tidal intrusion appears to be 8th May, 1969, going on the text of correspondence on GCCC file 28032 (DLG letter dated 28th July, 1969).

2. Shown on MRD Drawing 138243 prepared by Blain Bremner and Williams Pty. Ltd.

3. Estimated from MRD Drawing 138243, by assuming a depth of 1.0 ft. from SL of pre-1973 roadway to obvert level of culverts.

4. Taken from MRD Drawings 138242, 138243, 138244, 138246, 138248, 138249, 138250, 138251, 138253, 138260 and 138261, and checked by surveys conducted by QWRC in August 1981.

5. Reference B.

6. GCCC file 28032 (DLG correspondence dated 28th July, 1969).

7. GCCC file 28032 (Currumbin Bird Sanctuary correspondence dated 8th May, 1970).

8. Information provided by residents.

9. GCCC file 28032 (internal correspondence dated 24th April, 1972), information provided by residents, and Reference J.

10. GCCC file 28032 (correspondence and petitions from residents dated 10th April, 1972 and 11th February, 1976) and GCCC Drawings M5576 and L5549.

11. GCCC file 28032 (various correspondence - internal report dated 9th February, 1968, Works Agenda before Council 4th July, 1969, Currumbin Bird Sanctuary letters dated 25th August, 1969 and 25th September, 1969) and information provided by residents.

12. Reference E is an example.

13. GCCC file 28032 (internal correspondence dated 3rd November, 1972).

14. Reference G.

15. GCCC file 28032 (internal correspondence dated 3rd December, 1973 and letters to residents dated 8th May, 1973).

16. Reference H.

17. Reference N and GCCC Drawing L-6228.

18. GCCC file 28032 (File Note by Deputy Chief Engineer undated, and Works Agenda Before Council 30th September, 1977).

19. Reference I.

20. Reference J.

21. Reference L.

22. References R and S.

23. Reference O.

24. Reference K, Figure 6.

25. References R and U.

26. Reference T.

27. Paragraph 3.3 of Reference B indicates the brief given to [redacted] by GCCC required studies only of the 1 in 5 year and 1 in 10 year floods. See

also the text of Reference A.

28. Paragraph 3.3 (sub-paragraphs 3 and 4) of Reference B.

29. The assumptions in paragraph 3.2 of Reference B, namely of 20 - 22 perch blocks, of 200 sq. yds. of impervious area per allotment, and of 800 sq. yds. of impervious area per acre on roads, footpaths, etc., lead to a total impervious area per acre of:

$$200\frac{(4840 - 800)}{(20 * 30.25)} + 800 = 2136 \text{ sq. yds. or } 44\%.$$

30. Figure 7 of Reference B shows a line that is meant to represent the combined storage of the two ponds.

31. Figure 8 of Reference B.

32. Paragraph 3.6 of Reference B.

33. Paragraph 2 and Figure 8 of Reference B.

34. The DLG rainfall intensity charts for Brisbane used by [redacted] in Reference B give (by extrapolation) a rainfall intensity, for the 1 in 50 year, 98 minute storm of approximately 2.5 ins/hr. Figure 1 of Reference F indicates the worst period of the October 1972 storm was 2.7 ins/hr. for a 120 minute duration. The rainfall charts used, only gave rainfall intensities for storms of less than 2 hrs. duration. If [redacted] had investigated 1 in 50 yr. storms of longer or shorter duration and imposed a non-uniform temporal pattern to the corresponding rainfall intensities, it is probable that flows so derived would have had a similar calculated effect on the upper pond as did the historical October 1972 storm.

35. Reference E.

36. See QWRC (Town Water Supply and Sewerage Division) file 1999 Pr Preliminary Batch 1 Series 1 folio 25 dated 26th July, 1967. The review of Reference B by officers of the DLG discovered that [redacted] assumed the 54"ϕ pipe outlet would flow full from the beginning of runoff. This assumption, DLG calculations suggest, was *"not completely correct"* and caused an error in the 1 in 50 year flood level of 0.2 ft.

37. Reference D.

38. Reference N.

39. See also paragraph 6.18 of this report.

40. Reference B, figure 9 illustrates this fact (see chainage 700 approx.).

41. GCCC file 28032 (Currumbin Bird Sanctuary letter dated 8th May, 1970).

42. Reference F.

43. This inference is taken from, among other things, the discussion in paragraph 6.14 and in footnotes 48 and 49.

44. References I and S.

45. GCCC file 28032 (internal correspondence dated 29th March, 1973).

46. Reference K.

47. References J and L.

48. Reference O.

49. An extract from Reference X explains the probable source of error in the treatment of the ponds:

"3 COUPLED RETARDING BASINS

In flat country where retarding basins are close together, the water level in one basin may affect the discharge from the basin immediately upstream from it. When this occurs it is no longer correct to route the rainfall excess through each basin consecutively, as is typically done in the Laurenson Model. Rather, the governing 5 differential equations of the interacting elements of the system become coupled and it is necessary to solve the resulting set of simultaneous differential equations together.

Two recent studies made by the authors' firm involved the analysis of coupled retarding basin systems on the Gold Coast of Queensland. The following method of analysis was developed. For each retarding basin, i, the usual continuity equation holds:

$$\frac{dS_i}{dt} = I_i - O_i \qquad (1)$$

where S_i is the volume of water stored in basin at time t (m^3),

I_i is the inflow at time t (m^3/s),

and O_i is the outflow at time t (m^3/s).

The volume of water stored in basin i can be expressed as a function of water level, y_i

$$S_i = f_i\{y_i\} \qquad (2)$$

where $f_i\{y_i\}$ is the Storage-Stage function.

The inflow and outflow can be similarly expressed in terms of water levels:

$$I_i = g_{i-1}\{y_{i-1}, y_i\} + D_i \qquad (3)$$

$$O_i = g_i\{y_i, y_{i+1}\} \qquad (4)$$

Where $g_i\{\ \}$ is the discharge function for basin i, which depends on the water levels in basins i and i+1 respectively, and D_i is the direct catchment runoff into basin i.

Substituting equations (2), (3) and (4) into (1) leads to the following system of coupled differential equations:

$$\frac{df_i\{y_i\}}{dt} = g_{i-1}\{y_{i-1}, y_i\} - g_i\{y_i, y_{i+1}\} + D_i \qquad (5)$$

The resulting system of non-linear differential equations was solved by a standard digital computer sub-routing. The storage and discharge functions are input to this model as vectors and matrices respectively. Table III shows examples of them.

TABLE III

STAGE - STORAGE VECTOR & COUPLED STAGE - DISCHARGE MATRIX, FLAT ROCK CREEK, UPPER BASIN.

STAGE - STORAGE

Headwater Level (m)	Storage (x 1000 m^3)
610	0
1.58	11.3
2.32	34.0
2.85	56.6
3.12	79.1
3.31	102.0
3.58	118.0

STAGE - DISCHARGE (m^3/s).

Head Water Level \ Tailwater Level	0.61	0.91	1.22	1.52	1.83	2.13	2.44	2.74
1.52	0	0	0	0	-7.9	-15.7	-22.6	-28.5
1.83	7.9	7.9	7.9	7.9	0	-7.9	-15.7	-22.6
2.13	15.7	15.7	15.7	15.7	14.5	0	-7.9	-15.7
2.44	22.6	22.6	22.6	22.6	22.6	14.3	0	-7.9
2.74	28.5	28.5	28.5	28.5	28.5	24.0	17.6	0
3.05	34.3	34.3	34.3	34.3	34.3	33.1	25.8	20.0
3.35	40.5	40.5	40.5	40.5	40.5	37.0	33.0	28.0

The storage-stage vector and stage-discharge matrix are defined at equal increments of storage and stage respectively to allow for the easy linear interpolation of intermediate values. From the discharge matrix it is seen that the discharge from this basin is only affected

by downstream water levels when the tailwater level is greater than 1.52 m. This reflects the presence of an overflow weir with its crest at this level. Whenever the tailwater level is higher than the headwater level, if such a situation exists, the flow will be from the downstream basin into the upstream one. Hence the negative signs in the discharge matrix.

The Flat Rock Creek drainage system at Currumbin on the Gold Coast consists of two coupled retarding basins. Table IV shows the peak heights in these basins when they are analysed as an independent pair and as a coupled system.

TABLE IV

PEAK WATER LEVELS (m) IN FLAT ROCK CREEK RETARDING BASINS (OCTOBER, 1972, STORM)

BASIN	INDEPENDENT BASINS	COUPLED SYSTEMS
Upstream	2.29	2.80
Downstream	2.57	2.49

When correctly analysed as a coupled system, the peak water level in the upstream basin is 0.5 m higher, a significant amount in terms of upstream flooding because of the flat nature of the immediate catchment and proximity of houses around the upper basin. The peak level in the lower basin drops because of the extra volume stored in the upper basin. This coupled model has also been applied to the Coolangatta drainage system, which consists of 9 retarding basins (or effective retarding basins) in series, all of which are coupled because of the short drainage length involved (5 km) and the flat nature of the catchment. Tidal influences downstream of the last basin affect water levels in the first basin of the series. The model successfully handled these tidal influences as well as the coupled nature of the nine basins."

50. References R, S, T, and U.

51. This advice was provided orally by officers from MRD.

52. GCCC file 28032 includes an internal memo dated 24th April, 1972 that offers the opinion that high tide conditions possibly reduced the capacity of the outlet structure during the 2nd/3rd April, 1972 flood. These tidal and surge effects appear not to have been considered in analyses of the flooding in Flat Rock Creek carried out to date.

53. Reference F.

REFERENCES

A. GCCC letter (Drainage Folio 449696) dated 18th November, 1966.

B. GCCC Report - Master Drainage Plan for Flat Rock Creek Catchment, Currumbin by CMP March 1967.

C. DLG letter 1999 dated 22nd August, 1967.

D. GCCC letter 28032 dated 9th October, 1967.

E. GCCC letter 12-1960(2) dated 10th November, 1970.

F. [redacted] letter 72-351 dated 14th November, 1972.

G. Report - Flat Rock Creek - Currumbin Drainage by CMP November 1972.

H. [redacted] letter 72-351 dated 9th January, 1973.

I. [redacted] letter 73-357 dated 16th November, 1973.

J. Report for GCCC - Flat Rock Creek Catchment by [redacted] August 1976.

K. Report for GCCC - Master Drainage Study for the Coolangatta Creek Catchment by [redacted] August 1976.

L. Supplementary Report for GCCC - Flat Rock Creek Catchment by [redacted] November 1976.

M. GCCC letter 28032 dated 15th December, 1976.

N. GCCC letter 28032 dated 17th March, 1977.

O. [redacted] letter 76-1097 dated 1st August, 1977.

P. GCCC letter 28032 dated 7th September, 1977.

Q. [redacted] letter 76-1097 dated 12th September, 1977.

R. GCCC letter 28032 dated 8th November, 1977.

S. Report - Highway Culvert Capacity Flat Rock Creek, Currumbin by GCCC November, 1977.

T. MRD letter 169/11B/61; 169/11B/702.9 undated, received 19th January, 1978.

U. GCCC letter 28032 dated 23rd March, 1978.

V. Bird Sanctuary letter (to GCCC) dated 23rd March, 1978.

W. National Trust of Queensland letter (to A. Sutherland) dated 12th May, 1981.

X. Aspects of the Analysis and Design of Retarding Basins by C.S. Joy and M.P. Woodhouse, Hydrology Symposium, Canberra 1978.