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South East Queensland
WATER CORPORATION
LIMITED

# MANUAL

# OF

# OPERATIONAL PROCEDURES

# FOR FLOOD MITIGATION

# FOR

# WIVENHOE DAM

# AND SOMERSET DAM

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| Revision No. | Date | Amendment Details |
|---|---|---|
| 0 | 27 October 1968 | Original Issue |
| 1 | 6 October 1992 | Complete revision and re-issue |
| 2 | 13 November 1997 | Complete revision and re-issue |
| 3 | 24 August 1998 | Change to page 23 |
| 4 | 6 September 2002 | Complete revision and re-issue |
| 5 | 4 October 2004 | Complete revision |
| 6 | 20 December 2004 | Miscellaneous amendments and re-issue |
| 7 | 6 March 200 | Complete Revision |

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# 1 INTRODUCTION

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## 1.1 Preface

Given their size and location, it is imperative that Wivenhoe and Somerset Dams be operated during flood events in accordance with clearly defined procedures to minimise hazard to life and property.

Recognising this, the South East Queensland Water Board Act required a manual be prepared of operational procedures for the dams during floods. With changes to the controlling legislation, the manual became an approved flood mitigation manual under *Water Act 2000* (extract in Appendix A).

This Manual is the result of a review of the 2002 revision of the Manual. The South East Queensland Water Corporation is required to review, update the Manual if necessary, and submit it to the Chief Executive for approval prior to its expiry. Any amendments to the basic operating procedures need to be treated similarly.

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Prior to the 1998 version of the manual, an expanded flood monitoring and warning radio telemetry network (ALERT) was installed in the Brisbane River Catchment. Additionally, a computerised flood operational model that allows for rainfall and river modelling in real time based on data from the ALERT system was developed, implemented and fully commissioned. The accuracy and reliability of the system during a flood event has now been proven.

The primary objectives have not varied from those defined in the previous manual. These remain ensuring safety of the dams, their ability to deal with extreme and closely spaced floods, and protection of urban areas. The basic operational procedures have also essentially remained the same. Wivenhoe Dam and Somerset Dam are operated in conjunction so as to maximise the overall flood mitigation capabilities of the two dams. The procedures outlined in this Manual are based on the operation of the dams in tandem.

The changes to the 2002 version of the manual have arisen out of the spillway upgrade process for Wivenhoe Dam with the addition of the three bay right abutment fuse plug spillway. The changes enable Wivenhoe Dam to pass a 1:100,000 AEP flood event. The manual covers the provisions introduced to cover flood operations of the dams including the auxiliary spillway

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Meaning of Terms

In this Manual, save where a contrary definition appears -

"Act"
means the *Water Act 2000*;

"AEP"
means annual exceedance probability, the probability of a specified event being exceeded in any year.

"Agency"
includes a person, a local government and a department of state government within the meaning of the Acts Interpretation Act 1954;

"AHD"
means Australian Height Datum;

"Bureau of Meteorology"
means the Commonwealth Bureau of Meteorology;

"Chairperson"
means the Chairperson of the South East Queensland Water Corporation;

"Chief Executive"
means the Chief Executive or Director General of the Department of Natural Resources, Mines and Water;

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"Controlled Document"
means a document subject to managerial control over its contents, distribution and storage. It may have legal and contractual implications;

"Corporation"
means the South East Queensland Water Corporation;

"Dams"
means dams to which this Manual applies, that is Wivenhoe Dam and Somerset Dam;

"Dam Supervisor"
means the senior on-site officer at Wivenhoe or Somerset Dam as the case may be;

"EL"
means elevation in metres from Australian Height Datum;

"Flood Operations Engineer"
means the person designated at the time to direct the operations of Wivenhoe Dam and Somerset Dam under the general direction of the Senior Flood Operations Engineer and in accordance with the procedures in this Manual;

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"FSL" or "FULL SUPPLY LEVEL"
means the level of the water surface when the reservoir is at maximum operating level, excluding periods of flood discharge;

"Gauge"
when referred to in (m) means river level referenced to AHD, and
when referred to in ($m^3$/sec) means flow rate in cubic metres per second;

"Headworks Operator"
for the purposes of this manual the Headworks Operator is the South-East Queensland Water Corporation and any operator engaged by it, as the context permits

"Manual" or " Manual of Operational Procedures for Flood Mitigation for Wivenhoe Dam and Somerset Dam"
means the current version of this Manual;

"Power Station"
means the Wivenhoe pumped storage hydro-electric power station associated with Wivenhoe Dam and Split-Yard Creek Dam;

"Senior Flood Operations Engineer"
means the senior person designated at the time pursuant to Section 2.1 of this Manual under whose general direction the procedures in this Manual must be carried out;

"South East Queensland Water Corporation"
means South East Queensland Water Corporation Limited, Registered Public Company, ABN 14 008 729 766

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## 1.2 Purpose of Manual

The purpose of this Manual is to define procedures for the operation of Wivenhoe Dam and Somerset Dam to reduce, so far as practicable, the effects of flooding, by the proper control and regulation in time of headworks under the control of the Corporation, with due regard to the safety of the structures comprising those headworks.

For the purpose of this Manual, the Corporation adopts the policy that the community is to be protected to the maximum extent practical against flood hazards recognising the limitations on being able to:

- identify all potential flood hazards and their likelihood,
- remove or reduce community vulnerability to flood hazards,
- effectively respond to flooding, and
- provide resources in a cost effective manner.

## 1.3 Legal Authority

This manual has been prepared as a Flood Mitigation Manual in accordance with the provisions of Part 6 Division 2 of the Act.

## 1.4 Application and Effect

The procedures in this Manual apply to the operation of Wivenhoe Dam and Somerset Dam for the purpose of flood mitigation, and operation in accordance with the manual shall give the protection from liability provided by Section 500 of *Water Act 2000*.

## 1.5 Date of Effect

The procedures in this Manual shall have effect on and from the date on which this version of the Manual is approved by gazette notice.

The Manual shall remain in force for the period of approval as determined by the chief executive. This approval may be for a period of up to five years.

Before the approval of the Manual expires, the Corporation must review and if necessary update the Manual and submit a copy to the chief executive for approval.

## 1.6 Observance of Manual

This Manual contains the operational procedures for Wivenhoe Dam and Somerset Dam for the purposes of flood mitigation, and must be applied by the Headworks Operator for the operation of the dams.

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## 1.7 Provision for Variations to Manual

If the Corporation is of the opi nion that the pr ocedures in this Manual should be amended, altered or varied, it m ust submit for approval as soon as practical a request , w hich i s i n accordance wi th t he flood mitigation pr ovisions of the *Water Ac t 2000* , to t he Chief Executive setting out the circumstances and the exact nature of the amendment, alteration or variation sought. The Chief Exec utive may require the Corporation amend the Manual by written notice.

## 1.8 Distribution of Manual

The Corporation must re gard t he manual a s a Controlled Do cument and ensure that o nly controlled manuals are used in the direction of flood mitigation activities. Agencies having copies of Controlled Documents are listed in Appendix B. The Corporation must maintain a Register of Contact Persons for Controlled Documents and ensure that each issued document is updated whenever amendments or changes are approved.

Before using th is Manual for t he direction o f flood c ontrol, th e Hea dworks Operat or must ensure that it is the current version of the Controlled Document.

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# 2 DIRECTION OF OPERATIONS

## 2.1 Statutory Operation

Pursuant to the provisions of the Act, the Corporation is responsible for and has the duty for operation and maintenance of Wivenhoe Dam and Somerset Dam.

The Headworks Operator is responsible for operating and maintaining Wivenhoe and Somerset Dams in accordance with this Manual and whilst the South-East Queensland Water Corporation may contract with other parties for the purpose of discharging its responsibilities as Headworks Operator, the Corporation remains responsible to ensure that operators, employees, agents, and contractors comply with this manual in order to retain the protection from liability afforded by Section 500 of the Act. Operators, employees, agents, and contractors also must comply with this Manual to obtain the protection of Section 500 of the Act.

### 2.1.1 Designation of Senior Flood Operations Engineer

The Headworks Operator must ensure that the procedures set out in this Manual are carried out under the general direction of a suitably qualified and experienced person who shall be referred to hereafter as the Senior Flood Operations Engineer. Only a person authorised in the Schedule of Authorities can give the general direction for carrying out procedures set out in this Manual.

### 2.1.2 Designation of Flood Operations Engineer

The Headworks Operator must have available or on standby at all times a suitably qualified and experienced Flood Operations Engineer to direct the operation of the dams during floods in accordance with the general strategy determined by the Senior Flood Operations Engineer.

The Headworks Operator must ensure that flood control of the dams is under the direction of a Flood Operations Engineer at all times. Only a person authorised in the Schedule of Authorities can direct the flood operation of the dams.

The Headworks Operator must also employ an adequate number of suitably qualified and experienced persons to assist the Flood Operations Engineer in the operation of the dams during floods.

## 2.2 Qualifications and Experience of Engineers

### 2.2.1 Qualifications

All engineers referred to in Section 2.1 must meet all applicable requirements of registration or certification under any relevant State Act, and must hold appropriate engineering qualifications to the satisfaction of the Chief Executive.



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### 2.2.2 Experience

All engineers referred to in Section 2.1 must, to the satisfaction of the Chief Executive, have:

(1) Knowledge of design principles related to the structural, geotechnical and hydraulic design of large dams, and

(2) At least a total of five years of suitable experience and demonstrated expertise in at least two of the following areas:

(a) Investigation, design or construction of major dams;

(b) Operation and maintenance of major dams;

(c) Hydrology with particular reference to flooding, estimation of extreme storms, water management or meteorology;

(d) Applied hydrology with particular reference to flood forecasting and flood warning systems.

### 2.3 Schedule of Authorities

The Corporation must maintain a Schedule of Authorities containing a list of the Senior Flood Operations Engineers and Flood Operations Engineers approved to direct flood operations at the dams during floods. A copy of the Schedule of Authority must be provided to the chief executive by 1st September of each year.

The Headworks Operator shall, as the need arises, nominate suitably qualified and experienced engineers for registration in the Schedule of Authorities as Senior Flood Operations Engineers and Flood Operations Engineers. Each new nomination must include a copy of any certificate required under Section 2.2 and a validated statement of qualifications and experience.

The Headworks Operator must obtain the approval for all nominations from the Chief Executive prior to their inclusion in the Schedule of Authorities.

If, in the event of unforseen and emergency situations, no Senior Flood Operations Engineer or no Flood Operations Engineer is available from the Schedule of Authorities, the Headworks Operator must temporarily appoint a suitable person or persons and immediately seek ratification from the Chief Executive.

### 2.4 Training

The Headworks Operator must ensure that operational personnel required for flood control operations receive adequate training in the various activities involved in flood control operation.

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## 2.5 Dam Operation Arrangements

For the purposes of operation of the dams during times of flood, the Headworks Operator must ensure that:

(a) The operation be carried out under the general direction of the Senior Flood Operations Engineer, and

(b) In the direction of operations which may knowingly endanger life or property, the Senior Flood Operations Engineer must where practical liaise with the Chairperson of the Corporation and the Chief Executive or nominated delegate.

## 2.6 Responsibilities of the Senior Flood Operations Engineer

The Senior Flood Operations Engineer is responsible for the overall direction of flood operations.

Except insofar as reasonable discretion is provided for in Section 2.8 of this Manual, the Senior Flood Operations Engineer must ensure that the operational procedures for the dam shall be in accordance with this Manual.

## 2.7 Responsibilities of the Flood Operations Engineer

The Flood Operations Engineer must apply the operational procedures in accordance with this manual and the direction set for flood operations. In so doing, account must be taken of prevailing weather conditions, the probability of follow up storms and the ability of the dams to discharge excess flood waters in the period between rainfall events or in the period from the time of detection of conditions associated with the development storm cells, to the likely time of occurrence of the rainfall.

## 2.8 Reasonable Discretion

If in the opinion of the Senior Flood Operations Engineer, based on available information and professional experience, it is necessary to depart from the procedures set out in this manual, the Senior Flood Operations Engineer is authorised to adopt such other procedures as considered necessary to meet the situation, provided that the Senior Flood Operations Engineer observes the flood mitigation objectives set out in Section 3 of this Manual when exercising such reasonable discretion.

Before exercising discretion under this Section of the Manual with respect to flood mitigation operations, the Senior Flood Operations Engineer must consult with such of the following persons as are available at the time that the discretion has to be exercised:

the Chairperson of the Corporation, and
the Chief Executive or nominated delegate.

If not able to contact any of the above within a reasonable time, the Senior Flood Operations Engineer may proceed with such other procedures considered as necessary to meet the situation and report such action at the earliest opportunity to the above persons.

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## 2.9 Report

The Senior Flood Operations Engineer must prepare a report to the Headworks Operator after each event that requires flood operation of the dams and the report must contain details of the procedures used, the reasons therefore and other pertinent information. The Headworks Operator must forward the report to the Chief Executive together with any comments within six weeks of the completion of the event referred to.

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# 3 FLOOD MITIGATION OBJECTIVES

## 3.1 General

To meet the purpose of the flood operational procedures in this Manual, the following objectives, listed in descending order of importance, are as follows:

(a) Ensure the structural safety of the dams;

(b) Provide optimum protection of urbanised areas from inundation;

(c) Minimise disruption to rural life in the valleys of the Brisbane and Stanley Rivers;

(d) Minimise disruption and impact upon Wivenhoe Power Station;

(e) Minimise disruption to navigation in the Brisbane River.

## 3.2 Structural Safety of Dams

The structural safety of the dams must be the first consideration in the operation of the dams for the purpose of flood mitigation.

### 3.2.1 Wivenhoe Dam

The structural safety of Wivenhoe Dam is of paramount importance. Structural failure of Wivenhoe Dam would have catastrophic consequences.

Wivenhoe Dam is predominantly a central core rockfill dam. Such dams are not resistant to overtopping and are susceptible to breaching should such an event occur. Overtopping is considered a major threat to the security of Wivenhoe Dam. Works were undertaken between May 2004 and December 2005 to build an auxiliary spillway to cope with the 1: 100,000 AEP flood event without overtopping of the dam. The auxiliary spillway consists of a three bay fixed crest spillway that includes erodible fuse plug embankments that are designed to initiate at varying trigger levels.

The auxiliary spillway works in conjunction with the existing gated spillway. The design intent of the auxiliary spillway is to try and ensure that the existing spillway gates are fully opened by the time the first fuse plug bay is initiated. This is on the basis that the discharges through the existing spillway will result in less damage than allowing discharges through the auxiliary spillway.

The damage from the initiation of the fuse plug bays will be confined to the area immediately below the spillway return channel, with the routing effects of the reach to Savages Crossing reducing the peak in flooding further downstream in the Brisbane River.

### 3.2.2 Somerset Dam

The structural safety of Somerset Dam also is of paramount importance. Failure of Somerset Dam could have catastrophic consequences.

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Whilst Wivenhoe Dam has the capacity to mitigate the flood effects of such a failure in the absence of any other flooding, if the failure were to occur during major flooding, Wivenhoe Dam could be overtopped and destroyed also.

Somerset Dam is a mass concrete dam. Such dams can withstand limited overtopping without damage. Failure of such structures is rare but when they do occur, they occur suddenly without warning, creating very severe and destructive flood waves.

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### 3.2.3 Extreme Floods and Closely Spaced Large Floods

Techniques for estimating extreme floods indicate that floods are possible which would overtop both dams. In the case of Wivenhoe Dam such an overtopping would most likely result in the destruction of the dam itself. Such events however require several days of intense rainfall to produce the necessary runoff.

Historical records show that there is a significant probability of two or more flood producing storms occurring in the Brisbane River system within a short time of each other. In order to be prepared to meet such a situation, the stored floodwaters from one storm should be discharged from the dams after a flood as quickly as would be consistent with the other major operating principles. Typically the Senior Flood Operations Engineer should aim to empty stored floodwaters within seven days after the flood peak has passed through the lower reaches of the Brisbane River. In a very large flood, this time frame may not be achievable because of downstream flood conditions and it may be necessary to extend the emptying period by several days.

The discharges should be regulated so as to have little impact on the urban reaches of the Brisbane River taking into account inflows into the river downstream of the dams. However they may result in submergence of some bridges. The level of flooding as a result of emptying stored floodwaters after the peak has passed is to be less than the flood peak unless accelerated release is necessary to reduce the risk of overtopping.

## 3.3 Inundation of Urban Areas

The prime purpose of incorporating flood mitigation measures into Wivenhoe Dam and Somerset Dam is to reduce flooding in the urban areas on the flood plains below Wivenhoe Dam. The peak flows of floods emanating from the upper catchments of Brisbane and Stanley Rivers can be reduced by using the flood-gates to control releases from the dams, taking into account flooding derived from the lower Brisbane River catchments.

The auxiliary spillway constructed at Wivenhoe Dam incorporates fuse plugs. Triggering of a fuse plug will increase floods levels downstream. Where possible, gate operations at both Wivenhoe and Somerset dams should be formulated to prevent operation of the fuse plug. This is likely to be only possible when the forecast peak water level for Wivenhoe Dam just exceeds the trigger level for the fuse plug and sufficient time is available to alter releases.

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## 3.4 Disruption to Rural Areas

While the dams are being used for flood mitigation purposes, bridges and areas upstream of the dams may be temporarily inundated. Downstream of the dam, bridges and lower river

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terraces will be submerged. The operation of the dams should not prolong this inundation unnecessarily. The deck levels of bridges potentially inundated during flood events are shown on the Drawings in Appendix D.

### 3.5 Provision of Pumping Pool for Power Station

The power station is not affected by the reservoir level in Wivenhoe Dam during floods other than the impacts high tail water levels have on the efficiency of the power station. The power station does however require a pumping pool for operation. The loss of storage by dam failure would render the power station inoperative.

### 3.6 Disruption to Navigation

The disruption to navigation in the Brisbane River has been given the lower priority. The effect of flood flows upon navigation in the river varies widely.

Large ships can be manoeuvred in the river at considerable flood flows. On the other hand, barges and dredges are affected by low flows which lower salinity thus decreasing the density of the water which in turn causes craft to sit lower in the water, sometimes bottoming. The Moggill Ferry is also affected by low flood flows.

A short emptying period for the flood storage compartment of the dams is consistent with Objectives (c) and (e) of Section 3.1, which are closely related.



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## 4 FLOOD CLASSIFICATION

For the reference purposes of this Manual, five magnitudes of flooding are classified as follows:

Fresh
This causes only very low-level bridges to be submerged.

Minor Flooding
This causes inconvenience such as closing minor roads and the submergence of low-level bridges. Some urban properties are affected.

Moderate Flooding
This causes inundation of low-lying areas and may require the evacuation of some houses and/or business premises. Traffic bridges may be closed.

Major Flooding
This causes flooding of appreciable urban areas. Properties may become isolated. Major disruption occurs to traffic. Evacuation of many houses and business premises may be required.

Extreme Flooding
This causes flooding well in excess of floods in living memory and general evacuation of whole areas are likely to be required.

Usually a flood does not cause the same category of flooding along its entire length and the relevant agencies shall have regard to this when flooding is predicted.

(The classifications of minor, moderate and major flooding are based on the Bureau of Meteorology Standard Flood Classifications for Australia)

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# 5 FLOOD MONITORING AND WARNING SYSTEM

## 5.1 General

A real time flood monitoring and warning system is established in the Brisbane Valley. This system is based upon an event reporting protocol. A radio telemetry system (ALERT) is used to collect, transmit and receive rainfall and streamflow information. The system consists of more than 50 field stations that automatically record rainfall and/or river heights at selected locations in the Stanley and Brisbane River catchments. Some of the field stations are owned by the Corporation with the remainder belonging to other agencies.

The rainfall and river height data is transmitted by radio telemetry, via repeater stations, to base stations at the head office of the Headworks Operator (and the Corporation). There the data is processed in real time by computer programs to assess what is occurring in the catchments in terms of flood flows and what could occur if weather conditions continued, or changed.

Other agencies with their own base stations can, and do, receive data transmissions direct, and so collect and are able to process rainfall and streamflow information appropriate to their needs.

The real time flood model (RTFM) is a suite of hydrologic and hydraulic computer programs that utilise the real time ALERT data to assist in the operation of the dams during flood events.

## 5.2 Operation

The Headworks Operator is responsible for operating the computer model provided by the Corporation for flood monitoring and forecasting during flood events to optimise flood gate operations and minimise the impacts of flooding.

It is the responsibility of the Corporation to maintain and keep calibrated its own equipment; and to enter into such arrangements with other agencies or to provide such further equipment as the Corporation deems necessary for the Headworks Operator to properly operate the computer model for flood monitoring and forecasting.

A system such as this is expected to improve over time due to:

- improved operation and reliability with experience,
- improved calibration as further data becomes available,
- software upgrades, and
- the number, type and locations of sensors being varied.

A regular process of internal audit and management review must be maintained to achieve this.

A log of the performance of all field equipment necessary to properly operate the computer model must be kept by the Corporation. The log is to also include all revised field calibrations and changes to the number, type and locations of gauges. Entries onto the log are to be notified to the Headworks Operator without delay in writing.

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A log of the performance of the system (ALERT and RTFM) must be kept by the Senior Flood Operations Engineer. Any faults to the computer hardware or software, and any faults to field equipment which the Corporation has not advised the Headworks Operator of, are to be notified to the Corporation without delay in writing. The Corporation must promptly attend to the matters under its control and refer other matters to the appropriate agencies.

Whenever the Senior Flood Operations Engineer considers that the performance and functionality of the system can be improved, by whatever means, a recommendation must be made to the Headworks Operator accordingly. The Headworks Operator must promptly consider, act on, or refer such recommendations to the Corporation as it considers appropriate.

### 5.3 Storage of Documentation

The performance of any flood monitoring and warning system is reliant on accurate historical data over a long period of time. The Senior Flood Operations Engineer must ensure that all available data and other documentation is appropriately collected and catalogued as approved by the Corporation, for future use.

### 5.4 Key Reference Gauges

Key field station locations have been identified for reference purposes when flood information is exchanged between authorities or given to the public. Should it be deemed desirable to relocate field stations from these locations, or vary flood classification levels, agreement must first be obtained between the Corporation, Headworks Operator, Bureau of Meteorology and the Local Governments within whose boundaries the locations are situated. The locations and gauge readings at which the various classifications of flooding occur are contained in Appendix D.

Gauge boards that can be read manually must be maintained as part of the equipment of each key field station. The Corporation must have procedures to ensure such gauge boards are read in the event of failure of field stations to operate.

### 5.5 Reference Gauge Values

Other agencies such as the Bureau of Meteorology, Ipswich City Council and the Brisbane City Council have direct access to the information from field stations for flood assessment purposes. The consultation between agencies is a very important part of the assessment and prediction of flood flows and heights.

The Corporation must ensure that information relative to the calibration of the Corporation's field stations is shared with such agencies.

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# 6 COMMUNICATIONS

## 6.1 Communications between Staff

The Corporation is responsible for providing and maintaining equipment to allow adequate channels of communication to exist at all times between the Flood Operations Engineer and site staff at Wivenhoe and Somerset Dams.

The Headworks Operator is responsible for ensuring that adequate communication exists at all times between the Flood Operations Engineer and site staff at Wivenhoe and Somerset Dams. Where equipment deficiencies are detected during normal operations, such deficiencies are to be reported within one week to the Corporation for timely corrective action.

## 6.2 Dissemination of Information

Other agencies have responsibilities for formal flood predictions, the interpretation of flood information and advice to the public. Adequate and timely information is to be supplied to agencies responsible for the operation of facilities affected by flooding and for providing warnings and information to the public. Agency information requirements are generally as shown in Table 6.1.

The Flood Operations Engineer must supply information to each of these agencies during dam releases. For this purpose, the Corporation must maintain a Register of Contact Persons for Information, their means of contact including back up systems, and the specific information, including the timing, to be supplied to each. The Corporation must ensure that each agency receives a copy of the updated Register of Contact Persons for Information whenever amendments are made, but at least every 6 months.

The Corporation, Headworks Operator, Senior Flood Operations Engineer and Flood Operations Engineer must liaise and consult with the agencies with a view to ensuring all information relative to the flood event is consistent, and used and disseminated in accordance with agreed responsibilities.

All enquiries other than provided for in the Register of Contact Persons for Information, either to the Headworks Operator, the Senior Flood Operations Engineer, the Flood Operations Engineer or dam site staff must be referred to the Corporation. The Corporation must provide a mechanism to receive these enquiries from the time it is advised that releases from the dams are likely until flood release operations are completed.



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**TABLE 6.1 - AGENCY INFORMATION REQUIREMENTS**

| Agency Act | ivity | Information Requirement from SEQWC Flood Centre | Trigger |
|---|---|---|---|
| | | | |
| Bureau of Meteorology | Issue of flood warnings for Brisbane River basin | Actual and projected discharges from Wivenhoe Dam<br><br>Actual and projected discharges from Somerset Dam | Initial gate operations and thereafter at intervals to suit forecasting requirements. |
| Natural Resources and Mines | Review of flood operations and discretionary powers. | Actual and predicted lake levels and discharges | |
| Kilcoy Shire Council | Flood level information upstream of Somerset Dam | Actual and predicted lake levels, Somerset Dam | Somerset Dam water level predicted to exceed EL 102 |
| Esk Shire Council | Flood Level information upstream and downstream of Wivenhoe Dam | Actual and predicted lake levels and discharges, Wivenhoe Dam | Initial Wivenhoe Dam gate operation. |
| Ipswich City Council | Flood level information for Ipswich City area | Nil (information obtained from BoM) | |
| Brisbane City Council | Flood level information for Brisbane City area | Nil (information obtained from BoM) | |

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### 6.3 Release of Information to the Public

The Corporation is responsible for the issue of information regarding storage conditions and current and proposed releases from the dams to the public and the media.

The Bureau of Meteorology has responsibility for issuing flood warnings.

The Emergency Services Response Authorities, under the Disaster Management Act 2003, have responsibility for the preparation of a local counter disaster plan hence the interpretation of flood forecast information for inclusion in their local flood warnings prepared under the flood sub plan of the counter disaster plan.



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# 7 REVIEW

## 7.1 Introduction

This review of the Manual has addressed the mechanisms of delegation and control of the dams in periods of operation of the dams for flood mitigation. It is known overtopping of the dams can result should floods occur which are derived from lesser rainfall than the probable maximum precipitation storm or from the combination of two lesser storms in close proximity. The dams may also overtop in the eventuality that the flood-gate control systems or fuse plugs fail to operate as planned or partially malfunction during the passage of a major flood or combination of floods.

Procedures and systems have been developed that should enable lower risk operation of the dams for flood mitigation purposes. This technology is intended to provide longer warning times and the capability of examining options to optimise the safety of the dams and minimise the hazard potential and risk to the community.

With the passage of time neither the technical assumptions nor the physical conditions on which this Manual is based may remain unchanged. It is also recognised that the relevance of the Manual may change with changing circumstances.

It is important, therefore, that the Manual contain operational procedures which in themselves cause the Manual's procedures, and the assumptions and conditions upon which they are based, to be checked and reviewed regularly.

The checking and reviewing process must involve the Headworks Operator and all associated operations personnel in order that changes of personnel do not result in a diminished understanding of the basic principles upon which the operational procedures are based.

Variations to the Manual may be made in accordance with provisions in Section 1.8.

## 7.2 Personnel Training

The Headworks Operator must report to the Corporation by 30th September each year on the training and state of preparedness of operations personnel. A copy of this report must be forwarded to the Chief Executive of the Department of Natural Resources, Mines and Water within 14 days of it being received by the Corporation.

## 7.3 Monitoring and Warning System and Communication Networks

The Headworks Operator must provide a report to the Corporation by the 1st May and 1st November of each year; and after each flood event. The report must assess in terms of hardware, software and personnel, the :

- adequacy of the communication and data gathering facilities,
- reliability of the system over the previous period,
- reliability of the system under prolonged flood conditions,
- accuracy of forecasting flood flows and heights, and
- the overall state of preparedness of the system.

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The Corpo ration must review the rep ort, an d t aking i nto account it s own lo g o f th e performance o f t he field equipment, ta ke any action considered nec essary for the p roper functioning and improvement of the system. . A copy of this report must be forwarded to the Chief Executive of the Department of Natural Resources, Mines and Water within 14 days of it being received by the Corporation.

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### 7.4 Operational Review

After eac h si gnificant f lood event, the Cor poration must revi ew the e ffectiveness of t he operational procedures contained i n t his m anual. The H eadworks O perator i s required t o prepare a re port for subm ission to the Corporation within six weeks of any flood eve nt that requires mobilisation of the Fl ood Con trol Centre. A copy of t his report must be forwarded to the Chief Executive of the Department of Natural Resources, Mines and Water within 14 days of it being received by the Corporation.

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### 7.5 Five Yearly Review

Prior to the expiry of the approval period, the Corporation must review the Manual pursuant to S ection 6 Division 2 of the Act. The re view is t o take i nto a ccount t he c ontinued suitability of the communication network, and the flood monitoring and warning system as well as hyd rological and hydr aulic e ngineering assessments of t he operationa l proc edures. The h ydrologic investigations perfo rmed for the pur pose of this manual are discussed in Appendix I.

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# 8 WIVENHOE DAM OPERATIONAL PROCEDURES

## 8.1 Introduction

Wivenhoe Dam is capable of being operated in a number of ways to reduce flooding in the Brisbane River downstream of the dam, depending on the part of the catchment in which the flood originates and depending also on the magnitude of the flood. Maximum overall flood mitigation effect will be achieved by operating Wivenhoe Dam in conjunction with Somerset Dam.

A general plan and cross-section of Wivenhoe Dam, and relevant elevations are included in Appendix J. Storage and discharge data are included in Appendix E.

The reservoir volume above FSL of EL 67.0 is available as temporary flood storage. How much of the available flood storage compartment is utilised, will depend on the initial reservoir level below FSL, the magnitude of the flood being regulated and the procedures adopted. Spiltyard Creek Dam is part of the overall Wivenhoe Area Project and it forms the upper pumped storage of the peak power generation scheme. Splityard Creek Dam impounds a volume of 28 700 ML at its normal full supply level (EL 166.5). The contents of Splityard Creek Dam can be emptied into Lake Wivenhoe within 12 hours by releasing water through the power station conduits. This volume of water can affect the level in Wivenhoe Dam by up to 300mm when Wivenhoe Dam is close to FSL. Operation of the power station and therefore also release of water from Splityard Creek Dam to Lake Wivenhoe is outside the control of the Corporation. The operational level of Splityard Creek Dam should be considered when assessing the various trigger levels of Wivenhoe Dam.

The Corporation has acquired land above FSL to a level of EL 75.0 to provide temporary flood storage. Reasonable care must be exercised to confine the flood rises to below this level. This requirement should be ignored in the case of extreme floods that threaten the safety of the dams.

## 8.2 Auxiliary Spillway

The auxiliary spillway for Wivenhoe Dam constructed in 2004/05 as part of an upgrade to improve flood adequacy consists of a three bay fuse plug spillway located on the right abutment of the main embankment. In association with other works carried out at the dam, the dam crest flood is now assessed as having an annual exceedance probability (AEP) of approximately 1 in 100,000. Another one bay fuse plug spillway may be constructed at Saddle Dam Two in the future to provide full protection against the Probable Maxmimum Flood.

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Pertinent information about the auxiliary spillway, including the initiation level for the specific bays is given in Table 8.1.

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**TABLE 8.1 -RIGHT BANK FUSE PLUG DETAILS**

| Auxiliary Spillway Component | Spillway Crest Control Type | Spillway Crest Width (m) | Spillway Crest Level (m AHD) | Fuse Plug Pilot Channel Invert Level (m AHD) | Lake Level corresponding to Fuse Plug Pilot Channel Invert Level* (m AHD) |
|---|---|---|---|---|---|
| Central fuse plug bay | Ogee | 34 | 67 | 75.7 | 75.7 |
| Right hand side fuse plug bay | Ogee | 64.5 | 67 | 76.2 | 76.23+ |
| Left hand side fuse plug bay | Ogee | 65.5 | 67 | 76.7 | 76.78++ |

* Lake Water Level is as per that measured at the Headwater Gauge.
Initiation of Fuse Plug is expected to occur when the Lake Water Level exceeds the Lake Level at Fuse Plug Pilot Channel by 0.10 - 0.15 m

\+ Includes 0.03m of drawdown from the Fuse Plug Pilot Channel Invert to the Lake Water Level

++ Includes 0.08m of drawdown from the Fuse Plug Pilot Channel Invert to the Lake Water Level

## 8.3 Initial Flood Control Action

When indications are received of an imminent flood, the flood control operation of the dam must commence with the storing of all inflow of the Brisbane River in Wivenhoe Dam, whilst an assessment is made of the origin and magnitude of the flood. The spillway gates are not to be opened for flood control purposes prior to the reservoir level exceeding EL 67.25.

## 8.4 Regulator and Gate Operation Sequences

Rapid opening of outlets (spillway gates and regulators) can cause hydraulic surges and other effects in the Brisbane River that can endanger life and property and may sometimes have other adverse effects. Under normal gate operations, the gates and regulators are therefore to be operated one at a time at intervals that will minimise adverse impacts on the river system.

Rapid closure of the gates can affect river-bank stability. Rapid closure of more than one gate at a time should only be used when time is critical and there is a requirement to correct a malfunction to preserve storage or to reduce downstream flooding rapidly. For flood operations where time is not critical, longer closure intervals should be used. The minimum closure intervals specified below are based on the recession limb of natural flood hydrographs such as the January 1974 flood.

During the initial opening or final closure sequences of gate operations it is permissible to replace the discharge through a gate by the immediate opening of a regulator valve (or the reverse operation). This allows for greater control of low flows and enables a smooth transition and closure as slow as possible to prevent the stranding of fish downstream of Wivenhoe Dam.

Except as provided for in Procedure 4 of Section 8.4 where it is necessary to prevent operation of a fuse plug or to have the gates clear of the spillway flow prior to the fuse plug operating and as indicated above, the gate opening and closing intervals as shown in Table 8.2 are the most rapid permitted for flood mitigation purposes.



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**TABLE 8.2 - MINIMUM INTERVALS FOR NORMAL GATE OPERATIONS**

| | |
|---|---|
| 500 mm Incremental gate openings | 10 minutes |
| 500 mm Incremental gate closures | 20 minutes |
| Full regulator opening or closures | 30 minutes |

The flip bucket spillway is designed to control the discharge from the reservoir and to dissipate the energy of the discharge. The flip throws the discharge clear of the concrete structures into a plunge pool where the energy is dissipated by turbulence. Under non-symmetric flow conditions, or when gates 1 and 5 are not operating, the discharge jet may impinge on the walls of the plunge pool, which has been excavated into erodible sandstone rock, and cause non-predictable erosion. Upstream migration of this erosion is to be avoided. The wing walls adjacent to the flip bucket deflect the discharge away from the walls of the plunge pool when gates 1 and 5 are operated.

Therefore in operating the spillway, the principles to be observed are, in order of priority:

(i) The discharge jet into the plunge pool is not to impinge on the right or left walls of the plunge pool.

(ii) The flow in the spillway is to be symmetrical.

Under normal operation, only one gate is to be opened at any one time and the sequences given in Table 8.3 are to be adopted:



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## TABLE 8.3 – RADIAL GATE OPENING SEQUENCES[1]

| Approximate Discharge Range | Gate opening sequence[2] | Comments |
|---|---|---|
| (a) Up to 330 $m^3$/sec | Open Gate 3 up to 3.5 metres | Gates 1, 2, 4 & 5 remain closed |
| (b) 330 $m^3$/sec to 575 $m^3$/sec | Gate 3 at 3.5 metres<br>Open Gates 2 & 4 alternately to 0.5 metre<br>Open Gate 3 to 4.0 metre<br>Open Gates 2 & 4 alternately to 1.0 metre | Gates 1 & 5 remain closed unless discharge from Gates 2 & 4 impinges on side wall of plunge pool proceed to (c) |
| (c) 575 $m^3$/sec to 1160 $m^3$/sec | Gate 3 kept at 4.0 metres<br>Open Gates 1 & 5 alternately one increment followed by Gates 2 & 4 alternately one increment<br>Repeat Step until at the end of the sequence Gates 1 & 5 are open 1.5 metres and Gates 2 & 4 are open 2.5 metres | Flow in spillway to be as symmetrical as possible<br>Gates 2 & 4 are to have openings not more than 1.0 metre more than Gates 1 & 5 |
| (d) 1 160 $m^3$/sec to 1385 $m^3$/sec | Open Gate 3 to 4.0 metres<br>Open Gates 1 & 5 alternately to 2.0 metres followed by opening Gates 2 & 4 alternately to 3.0 metres | Flow in spillway to be as symmetrical as possible<br>Gates 2 & 4 are to have openings not more than 1.0 metre more than Gates 1 & 5 |
| (e) 1 385 $m^3$/sec to 2290 $m^3$/sec | Open ALL gates to 5.0 metre openings | Flow in spillway to be as symmetrical as possible<br>Gates 2 & 4 are to have openings not less than Gates 1 & 5 or not more than 1.0 metre more than Gates 1 & 5<br>Gate 3 is to have an opening not less than Gates 2 & 4 or not more than 1.0 metre more than Gates 2 & 4. |
| (f) Greate r than 2290 $m^3$/sec | Open ALL gates incrementally in the sequence 3, 2, 4, 1, 5[3] | Flow in spillway to be as symmetrical as possible<br>Gate 3 to have the largest opening<br>Gates 2 & 4 are to have openings greater than Gates 1 & 5 |

1 Gates are numbered 1 to 5 from the left bank looking downstream.
2 Gate movements are to normally occur in 500 mm increments.
3 When the accelerated opening rate applies, gate-opening increments of 1.0 metres may be used.

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Gate operating procedures in the event of equipment failure are contained in Appendix G. If one or more gates are inoperable during the course of the flood event, the gate openings of the remaining gates are to be adjusted to compensate. These adjustments should ensure that:

a) the impact of the flow on the sidewalls of the plunge pool should be minimised, and
b) the flow in the spillway is as symmetrical as practicable.

In general, gate closing is to occur in the reverse order. The final gate closure should occur when the lake level has returned to Full Supply Level.

### 8.5 Flood Control Procedures

When the preliminary estimation of the degree of expected flooding has been made, the operating procedures set out hereunder shall be used at Wivenhoe Dam in line with the Flood Mitigation Objectives.

When considering the discharge to be made from both Wivenhoe Dam and Somerset Dam under particular procedures, the total discharge for each dam from all sources is to be considered when determining the appropriate openings for gates, valves and sluices.

The flood control procedures to be adopted commence with Procedure 1 and extend through to Procedure 4 as the magnitude of the flood as predicted by the real time flood model increases. Table 8.5 summarises the application for each procedure for the initial filling of Wivenhoe Dam. Once Wivenhoe Dam has peaked and the drainage phase has commenced the indicative limits will not apply.

***Procedure 1***

*Under Procedure 1, water is to be released from Wivenhoe Dam with care being taken not to prematurely submerge the downstream bridges. The limiting condition for Procedure 1 is the submergence of Mt Crosby Weir Bridge that occurs at approximately 1,900 $m^3$/sec.*

*The procedure adopted primarily depends on the level in Wivenhoe Dam and the discharge emanating from Lockyer Creek.*

*For situations where flood rains are occurring on the catchment upstream of Wivenhoe Dam and only minor rainfall is occurring downstream of the dam, releases are to be regulated to limit, as much as appropriate in the circumstances, downstream flooding. Except in the drainage phase releases are not to exceed the values given in Table 8.4:-*

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*TABLE 8.4 – WIVENHOE DAM, PROCEDURE 1 MAXIMUM RELEASE RATES*

| *Lake Level in Wivenhoe Dam* | *Maximum Release Rate ($m^3$/sec)* |
|---|---|
| *67.00 - 67.25* | *0* |
| *67.25 - 67.50* | *110* |
| *67.50 - 67.75* | *380* |
| *67.75 - 68.00* | *500* |
| *68.00 - 68.25* | *900* |
| *68.25 - 68.50* | *1900* |

*The following subsets of Procedure 1 were originally developed by the Brisbane City Council to cater for limiting the submergence of the various low-level downstream bridges. The procedures require a great deal of control over releases and knowledge of discharges from Lockyer Creek.*

*In general, the releases from Wivenhoe Dam are controlled such that the combined flow from Lockyer Creek and Wivenhoe Dam is less than the limiting values to delay the submergence of particular bridges.*

## *Procedure 1A* Savages Crossing & Colleges Crossing

*For: Lake level between 67.25 and 67.5 m AHD [Maximum Release 110 $m^3$/sec]*

*Endeavour to maintain Twin Bridges trafficable by limiting releases at Wivenhoe Dam to a maximum of 50 $m^3$/sec and by reducing this rate of release if run-off from Lockyer Creek is likely to cause the bridges to be overtopped. The bridges become untrafficable at a flow of about 55 $m^3$/sec.*

*Once Twin Bridges are overtopped by run-off from Lockyer Creek, release to be directed towards maintaining College's Crossing trafficable by adjusting the rate of release so that the combined flow rate at College's Crossing is less than 175 $m^3$/sec.*

## *Procedure 1B* Noogoorah Bridge (Burtons Bridge)

*For: Lake level between 67.50 and 67.75 m AHD [Maximum Release 380 $m^3$/sec]*

*Initially endeavour to maintain College's Crossing trafficable. This becomes untrafficable at a flow of about 175 $m^3$/sec. No consideration to be given to keeping Twin Bridges trafficable.*

*Once College's Crossing is flooded by the run-off from Lockyer Creek and the downstream section of the Brisbane River, releases to be set to achieve a combined flow of about 380 $m^3$/sec at the Noogoorah Bridge Crossing. This bridge becomes untrafficable at a flow of about 430 $m^3$/sec.*

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*Procedure 1C* *Kholo Bridge*

*For: Lake level between 67.75 and 68.00 m AHD [Maximum Release 500 $m^3$/sec]*

*Initially endeavour to maintain Noogoorah Bridge trafficable. No consideration to be given to keeping College's Crossing trafficable.*

*Once Noogoorah Bridge is flooded by the run-off from Lockyer Creek and the downstream section of the Brisbane River, releases to be set to keep Kholo Bridge trafficable. This bridge becomes untrafficable at a flow rate of about 550 $m^3$/sec.*

*Procedure 1D* *Mt Crosby Weir Bridge*

*For: Lake level between 68.00 and 68.25 m AHD [Maximum Release 900 $m^3$/sec]*

*Initially endeavour to maintain Kholo Bridge trafficable. No consideration to be given to keeping Noogoorah Bridge trafficable.*

*Once Kholo Bridge is flooded by the run-off from Lockyer Creek and the downstream section of the Brisbane River, releases to be set to keep Mt Crosby Bridge trafficable. This bridge becomes untrafficable at a flow of 1,900 $m^3$/sec.*

*Procedure 1E* *Mt Crosby Weir Bridge*

*For: Lake level between 68.25 and 68.50 m AHD [Maximum Release 1,900 $m^3$/sec]*

*Similar to Procedure 1D, but with an upper release limit of 1,900 $m^3$/sec.*

***If the level reaches EL 68.5 m AHD in Wivenhoe Dam, operations switch to Procedure 2 or 3 as appropriate.***

*Procedure 2 may be bypassed if it is clear from the flood modelling that Procedure 3 will be activated.*

## *Procedure 2*

*Under Procedure 2, water is to be released from Wivenhoe Dam with care being taken not to submerge Fernvale Bridge and Mt Crosby Weir Bridge prematurely. Typically releases will take place on the rising limb of the flow from Lockyer Creek. If this flow is sufficient to submerge Mt Crosby Weir bridge (1,900 $m^3$/sec), releases are to be increased such that the combined flow from Lockyer Creek and Wivenhoe Dam releases does not exceed either:-*

*(i) 3,500 $m^3$/sec at Lowood or*
*(ii) the greater of the peak flow of Lockyer Creek or the predicted peak flood flow of the Bremer River.*

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*Should the Mt Crosby Weir Bridge be flooded by flows from catchments downstream of Wivenhoe Dam, the upper limit of the combined Lockyer Creek flow and releases from Wivenhoe Dam shall, subject to (i) and (ii) above, not exceed 3,500 $m^3$/sec at Lowood.*

*The gate opening constraints are to be overridden when the gates will be overtopped during normal operation.*

## *Procedure 3*

*Under Procedure 3, water is to be released from Wivenhoe Dam such that the combined Lockyer Creek flood flow and Wivenhoe Dam release is not to exceed 3,500 $m^3$/sec at Lowood. The releases are to be regulated such that the total regulated flow at Moggill gauge downstream of the Bremer River junction does not exceed 4,000 $m^3$/sec [which is the upper limit for non-damaging flows for the urban reaches of the Brisbane River].*

*The gate opening constraints are to be overridden when the gates will be overtopped during normal operation.*

## *Procedure 4*

*This procedure normally comes into effect when the water level in Wivenhoe Dam reaches EL 74. However the Senior Flood Operations Engineer may seek to invoke the discretionary powers of Section 2.8 if earlier commencement is able to prevent triggering of a fuse plug.*

*Under Procedure 4 the release rate is increased as the safety of the dam becomes the priority. Opening of the gates is to occur until the storage level of Wivenhoe Dam begins to fall.*

*If required, the minimum time interval between gate openings can be reduced or successive gate openings of the same gate may be used in this procedure as considered appropriate. In addition to dam safety issues, the impact of rapidly increasing discharge from Wivenhoe Dam on downstream reaches should be considered in determining these intervals*

*Sub-procedures 4A, and 4B have been developed for use depending on the expected peak water level in the dam.*

### *Procedure 4A*

*Procedure 4A applies while all indications of the peak flood level in Wivenhoe Dam are that it will be insufficient to trigger operation of the first bay of the fuse plug by reaching EL 75.5.*

*Gate openings are to occur at the minimum intervals and sequences as specified in Section 8.3. Opening of the gates is to continue until the storage level of Wivenhoe Dam begins to fall.*

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*The gate opening constraints are to be overridden when the gates will be overtopped during normal operation.*

## *Procedure 4B*

*Procedure 4B applies once indications are the peak flood level in Wivenhoe Dam will exceed EL75.5 using the minimum gate opening intervals for normal operation as specified in Section 8.3 i.e. it is expected that the fuse plug will be triggered under normal operation.*

*In this procedure the minimum time interval between gate openings is able to be reduced and successive gate openings of the same gate may be made.*

*If the real time flood model using a 1 metre in 10 minute gate opening procedure, predicts a peak water level in Wivenhoe Dam of less than EL 75.5, the gates may be raised at a rate to maximise flood storage capacity but to prevent the first fuse plug from initiating.*

*Otherwise the gates are to be raised at a rate to ensure they are out of the water before the initiation of the first fuse plug (if possible). Where practicable, the gates are to be in the fully open position before the dam water level reaches EL 75.7 m AHD.*

*In addition to dam safety issues, the impact of rapidly increasing discharge from Wivenhoe Dam on downstream reaches should be considered in determining these intervals.*

*The effect of varying the operational procedures at Somerset Dam in keeping the peak flood level at Wivenhoe Dam below EL 75.7 may also be investigated using the real time flood model.*

*The gate opening constraints are to be overridden when the gates will be overtopped during normal operation.*

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**Deleted:** *Procedure 4C*¶
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*Procedure 4C applies only during the construction phase of the right bank auxiliary spillway.*¶
¶
*Opening of the gates is to occur until the storage level of Wivenhoe Dam begins to fall.* ¶
*The minimum time interval between gate openings can be reduced or successive gate openings of the same gate may be used in this procedure as considered appropriate for ensuring the safety of the dam. In addition to dam safety issues, the impact of rapidly increasing discharge from Wivenhoe Dam on downstream reaches should be considered in determining these intervals.*¶
¶
*The gate opening constraints are to be overridden when the gates will be overtopped during normal operation.*¶

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## TABLE 8.5 WIVENHOE DAM – NORMAL RELEASE OPERATING PROCEDURES: INITIAL FILLING

| Procedure | Reservoir Level | Applicable Limits | | |
|---|---|---|---|---|
| 0 | EL < 67.25 | $Q_{Wivenhoe}$ = 0 $m^3$/sec ... i.e No Releases | | |
| 1A | 67.25 < EL < 67.50 | $Q_{Wivenhoe}$ < 110 $m^3$/sec Q | $_{Colleges\ Crossing}$ < 175 $m^3$/sec with care taken not to submerge Twin Bridges prematurely | |
| 1B | 67.25 < EL < 67.50 | $Q_{Wivenhoe}$ < 380 $m^3$/sec Q | $_{Burtons/Noogoorah}$ < 430 $m^3$/sec with care taken not to submerge Colleges Crossing prematurely | |
| 1C | 67.75 < EL < 68.00 | $Q_{Wivenhoe}$ < 500 $m^3$/sec Q | $_{Kholo}$ < 550 $m^3$/sec with care taken not to submerge Burtons/Noogoorah prematurely | |
| 1D | 68.00 < EL < 68.25 | $Q_{Wivenhoe}$ < 900 $m^3$/sec Q | $_{MtCrosby}$ < 1900$m^3$/sec with care taken not to submerge Kholo prematurely | |
| 1E | 68.25 < EL < 68.50 | $Q_{Wivenhoe}$ < 1500 $m^3$/sec Q | $_{MtCrosby}$ < 1900$m^3$/sec with care taken not to submerge Kholo prematurely | |
| 2 | 68.50 < EL < 74.00 | $Q_{Lowood}$ < 3500 $m^3$/sec Q | $_{Lowood}$ < peak of Lockyer and $Q_{Lowood}$ < peak of Bremer | Gates are NOT to be overtopped |
| 3 | 68.50 < EL < 74.00 | $Q_{Lowood}$ < 3500 $m^3$/sec Q | $_{Moggill}$ < 4000 $m^3$/sec | |
| 4 | EL > 74.00[4] | Gates are to be opened until reservoir level begins to fall | | |

4 Once water level exceeds EL 74.0, operating procedures are dependant on the predicted peak water level.

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## 8.6 Closing Procedures

If at the time the lake level in Wivenhoe Dam begins to fall, the combined flow at Lowood is in excess of 3500 $m^3$/sec, then the combined flow at Lowood is to be reduced to 3500 $m^3$/sec as quickly as practicable having regard to Section 3, and is to remain at this rate until final gate closure procedures can commence.

Gate closing procedures should be initiated having regard to the following requirements:

a) Early release of stored water to regain flood-mitigating ability for any subsequent flood inflows as described in Section 3.2.3.

b) The total discharge from Wivenhoe Dam from all sources is to be considered when considering appropriate closing procedures. This includes any discharge from triggered fuse plugs.

c) Gate operation procedures as described in Section 8.4.

d) Establishment of storage at FSL at completion of flood events.

e) Downstream impact of the discharges. To prevent the stranding of fish downstream of the dam, closures below flows of 275 $m^3$/sec should be undertaken as slow as practicable and if possible such closures should occur during daylight hours on a weekday so that personnel are available for fish rescue.

If the flood storage compartments of Wivenhoe Dam and Somerset Dam can be emptied within the prescribed time of seven days, the release from Wivenhoe Dam should be limited to between 1900 $m^3$/sec and 3500 $m^3$/sec. In such circumstances, the release from the dam should be less than the peak flow into the lake. Where possible, total releases during closure should not produce greater flood levels downstream than occurred during the flood event.

## 8.7 Modification to Flood Operating Procedures if a Fuse Plug triggers prematurely

Where the operation of a fuse plug spillway bay has been triggered prior to its design initiation level being reached, the flood operation procedures are to be modified such that:

- the discharge from the triggered fuse plug is to be taken into account when determining total flood releases from the dam;
- the gates are to be operated, to the extent possible, so that the same discharge restrictions apply as would have if the fuse plug embankment was intact.

## 8.8 Modification to Flood Operating Procedures if a subsequent flood event occurs prior to the reconstruction of Triggered Fuse Plugs



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Where the operation of any or all of the fuse plug spillway bays has been triggered and a flood event occurs before the fuse plug can be reinstated, the flood operation procedures are to be modified such that:

- the discharge from the triggered fuse plug is to be taken into account when determining total flood releases from the dam;
- the gates are to be operated, to the extent possible, so that the same discharge restrictions apply as would have if the fuse plug embankment was intact.

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**<#>Auxiliary Spillway Area¶**
¶
The embankment forming the temporary road diversion that acts as a coffer dam is to be retained in place until the construction of the fuse plug has proceeded past EL 74, and then its removal is only to proceed once the written approval of a Senior Flood Operations Engineer has been obtained.¶
¶
**<#>Gated Spillway Area¶**
¶
The following provisions will apply for works undertaken within the gated spillway:¶
¶
<#>The opening of spillway gates to discharge floodwaters is at the sole discretion of the Senior Flood Operations Engineer;¶
¶
<#>There is to be no obstruction of any spillway bay without the written approval of the Senior Flood Operations Engineer;¶
¶
<#>All gates are to be capable of being operated at short notice during a flood if required. To ensure this capability is maintained Table 8.6 specifies limitations that apply to the number of bays in which works may be occurring at any time. This table also nominates a target notice period to be provided by the Senior Flood Operations Engineer for the removal of construction material from the spillway bays prior to their use for releases. However the Senior Flood Operations Engineer is not constrained to provide this length of notice before operating any particular gate if its earlier operation is considered nec ... [2]

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# 9 SOMERSET DAM OPERATIONAL PROCEDURES

## 9.1 Introduction

Somerset Dam is capable of being operated in a number of ways to regulate Stanley River floods. Somerset Dam and Wivenhoe Dam are meant to be operated in conjunction to optimise the flood mitigation capacity downstream of Wivenhoe Dam.

A general plan and cross-section of Somerset Dam, and relevant dam operating levels are included in Appendix J.

The discharge capacities for various storage levels of Somerset Dam are listed in Appendix F.

## 9.2 Initial Flood Control Action

Upon indications being received of a significant inflow, the flood control operation of the dam shall commence with the raising of any closed gates and the closure of all low level regulators and sluices, whilst an assessment is made of the origin and magnitude of the flood.

## 9.3 Regulator and Gate Operation Procedures

The following minimum intervals must be observed whilst opening and closing regulators, sluices and crest gates at Somerset Dam for flood mitigation purposes:

**TABLE 9.1- MINIMUM INTERVALS, NORMAL OPERATION, SOMERSET DAM**

| | OPENING | CLOSING |
|---|---|---|
| Regulators | 30 minutes | 60 minutes |
| Sluice Gates | 120 minutes | 180 minutes |
| Crest Gates | Gates are normally open | |

During the initial opening or final closure sequences of gate operations it is permissible to replace the discharge through a sluice gate by the immediate opening of one or more regulator valves (or the reverse operation). This allows for greater control of low flows and enables a smooth transition on opening and closing sequences.



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## 9.4 Flood Control Procedure

It is esse ntial that the operating procedures adopted shou ld not endanger the safety of Wivenhoe Dam downstream. Within this constraint, the Se nior F lood Operations Engineer must adopt a procedure for the operation of Somerset Dam such that:

a) the structural safety of Somerset Dam is not endangered;

b) the Upper Brisbane River flood flow plus Somerset Dam releases does not cause Wivenhoe Dam to be overtopped.

The normal operating procedure to be used for Somerset Dam is as follows.

The crest gates are raised to enable uncontrolled discharge. The low level regulators and sluices are to be kept closed until either:

(i) the lake level in Wivenhoe Dam begins to drop or

(ii) the level in Somerset Dam exceeds EL 102.25.

In the case of (i) above the opening of the regulators and sluices is not to increase the inflow to Wivenhoe Dam above the peak inflow from the Brisbane River just passed or, if possible, not to cause the Wivenhoe Dam lake level to exceed EL 74.

In the case of (ii) above, the Senior Flood Operations Engineer must direct the operation of the low-level regulators and sluices to ensure the safety of Somerset Dam. If the water level and predicted inflows are such that the safety of Somerset Dam is not an overriding concern, operations are to target a correlation of water levels in Somerset Dam and Wivenhoe Dam as set out in Table 9.2 such that the relative flood storage between the flood level in Wivenhoe Dam and EL 80 is the same as the relative flood storage between the flood level in Somerset Dam and EL 107.46, the non-spillway crest level in Somerset Dam.

**TABLE 9.2 – Water Level Correlation Targets**

| Somerset Lake Level M AHD | Wivenhoe Lake Level m AHD |
|---|---|
| 102.5<br>103.5<br>104.5<br>105.5 | 72.073.675.276.878.580.<br>0 |



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| | |
|---|---|
| 106.5<br>107.46 | |

The constraints applicable to case (i) operation above do not apply to case (ii) operation.

If the flood event emanates from the Stanley River catchment only, without significant runoff in the Upper Brisbane River catchment, the operation of Somerset Dam will proceed on the basis that Wivenhoe Dam has peaked as per (i) above.

The Somerset Dam gates and valves may also be temporarily closed if such action is able to prevent a fuse plug from initiating. Such closure is not to threaten the safety of the dam



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# 10 EMERGENCY FLOOD OPERATIONS

## 10.1 Introduction

While every care has been exercised in the design and construction of the dams, there still remains a low risk that the dams may develop an emergency condition either through flood events or other causes. Experience elsewhere in the world suggests that vigilance is required to recognise emergency flood conditions such as:

- Occurrence of a much larger flood than the discharge capacity of the dam;
- Occurrence of a series of large storms in a short period;
- Failure of one or more gates during a flood.
- Development of a piping failure through the embankment of Wivenhoe Dam;
- Damage to the dams by earthquake;
- Damage to the dams as an act of war or terrorism;
- Other uncommon mechanisms.

Responses to these and other conditions are included in separate Emergency Action Plans.

## 10.2 Overtopping of Dams

Whatever the circumstances, every endeavour must be made to prevent overtopping of Wivenhoe Dam by the progressive opening of operative spillway gates. The probability of overtopping of Wivenhoe Dam will be significantly reduced following the completion of the auxiliary spillway.

In the event that the probability of overtopping of Wivenhoe Dam is unacceptably high, then as an absolute last resort the saddle dams may be breached. Such actions must only be initiated with the agreement of the Chief Executive.

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Somerset Dam should, if possible, not be overtopped by flood water but, if Wivenhoe Dam is threatened by overtopping, the release of water from Somerset Dam is to be reduced, for example by the use of its spillway gates, even at the risk of overtopping Somerset Dam in order to prevent, if possible, the overtopping of Wivenhoe Dam.

## 10.3 Communications Failure

In the event of normal communications being lost between the Flood Operations Engineer and either Wivenhoe Dam or Somerset Dam, the dam supervisor at that dam is to maintain contact with the dam supervisor at the other dam, to receive instructions through the remaining communications link.

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In the event of normal communications being lost between the Flood Operations Engineer and both Wivenhoe Dam and Somerset Dam, the dam supervisors at each dam are to adopt the procedures set out below during flood events, and are to maintain contact with each other, where possible.

If all communications are lost between the Flood Operations Engineer, Wivenhoe Dam and Somerset Dam, the officers in charge at each dam are to adopt the procedures set out below.

### 10.3.1 Wivenhoe Dam Emergency Procedure

In the event of total communication failure, the minimum gate openings related to lake levels up to EL 74 are set out in the Table 10.1 are to be maintained for both opening and closing operations. Once the lake level exceeds EL 74 the gates are to be raised at the rate of 1 metre per 10 minutes till the water level peaks or the gates are fully open.

**Table 10.1 Minimum Gate Openings Wivenhoe Dam**

| Lake Level m AHD | Gate 3 Opening (m) | Gates 2 & 4 Opening (m) | Gates 1 & 5 Opening (m) | Total Discharge $m^3$/sec |
|---|---|---|---|---|
| 67.0 | | - | - | 0 |
| 67.5 | 0.5 | - | - | 50 |
| 68.0 | 1.5 | - | - | 155 |
| 68.5 | 2.5 | - | - | 260 |
| 69.0 | 3.5 | 0.5 | - | 470 |
| 69.5 | 4.0 | 1.0 | - | 640 |
| 70.0 | 4.0 | 1.5 | 0.5 | 875 |
| 70.5 | 4.0 | 2.0 | 1.0 | 1115 |
| 71.0 | 4.0 | 2.5 | 1.5 | 1365 |
| 71.5 | 4.5 | 2.5 | 2.0 | 1560 |
| 72.0 | 4.5 | 3.0 | 2.5 | 1820 |
| 72.5 | 5.0 | 4.0 | 3.0 | 2250 |
| 73.0 | 5.0 | 5.0 | 5.0 | 2960 |
| 73.5 | 6.5 | 6.5 | 6.5 | 3850 |
| 74.0 | 8.0 | 8.0 | 8.0 | 4750 |



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| >74.0 | Gates are to be raised at the rate of 1 metre per 10 minutes till the water level peaks or gates are fully open | |
| 75.7 | Gates are to be fully open before the first fuse plug triggers at this level. | |

If one or more gates become inoperable, then by reference to Table E-2 the gate openings of operable gates are to be increased in order that the discharges for the lake levels shown in Table 10.1 are achieved.

If, because of compliance with the provisions of Section 8.3 and the high inflow rate, the minimum gate openings cannot be maintained, the time intervals between successive openings shown in Table 8.2 are to be halved.

If the actual gate openings fall more than three settings below the cumulative number of minimum settings of Table 10.1, then successive gate operations are to be carried out as rapidly as possible until the minimum settings are achieved. Under these circumstances, it may be necessary to operate more than one gate at any one time.

### 10.3.2 Somerset Dam Emergency Procedure

In the event of total communication failure, the spillway gates are to be kept raised to allow uncontrolled discharge. The regulators and sluices are to be kept closed until either:

(i) the level in Wivenhoe Dam begins to drop or

(ii) the level in Somerset Dam exceeds EL 102.25.

The level in Wivenhoe Dam can be determined locally by the Dam Supervisor at Somerset Dam from the tailwater gauge located just downstream of Somerset Dam.

In the case of (i) above, the opening of the regulators and sluices is not to increase the level in Wivenhoe Dam above the peak level already attained. Section 9.3 on regulator and gate operation interval is to be observed.

In the case of (ii) above, the regulators and sluices are to be operated such that the relative flood storage between the flood level in Wivenhoe Dam and EL 80 is the same as the relative flood storage between the flood level in Somerset Dam and the non-spillway crest level in Somerset Dam (EL 107.46). Table 10.2 gives

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the water level correlations. The low level outlets in Somerset Dam are not to be opened if the water level in Wivenhoe Dam exceeds the level set out below for given water levels in Somerset Dam.

**TABLE 10.2 – Water Level Correlation Targets**

| Somerset Lake Level m AHD | Wivenhoe Lake Level m AHD |
|---|---|
| 102.5<br>103.5<br>104.5<br>105.5<br>106.5<br>107.46 | 72.073.675.276.878.580.0 |

The constraints applicable to case (i) operation above do not apply to case (ii) operation.

## 10.4 Equipment Failure

In the event of equipment failure the action to be taken is indicated in Appendix G for Wivenhoe Dam and Appendix H for Somerset Dam.

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# APPENDIX A EXTRACT FROM WATER ACT 2000

**Division 2 – Flood Mitigation**

**Owners of certain dams must prepare flood mitigation manual**

496.(1) A regulation may nominate an owner of a dam as an owner who must prepare a manual (a "flood mitigation manual") of operational procedures for flood mitigation for the dam.

(2) The regulation must nominate the time by which the owner must comply with section 497(1).

**Approving flood mitigation manual**

497.(1) The owner must give the chief executive a copy of the flood mitigation manual for the chief executive's approval.

(2) The chief executive may, by gazette notice, approve the manual.

(3) The approval may be for a period of not more than 5 years.

(4) The chief executive may get advice from an advisory council before approving the manual.

**Amending flood mitigation manual**

498.(1) The chief executive may require the owner, by notice, to amend the flood mitigation manual.

(2) The owner must comply with the chief executive's request under subsection (1).

(3) The chief executive must, by gazette notice, approve the manual as amended.

(4) The approval of the manual as amended must be for-

(a) the balance of the period of the approval for the manual before amendment; or

(b) a period of not more than 5 years from the day the manual as amended was approved.



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(5) The chief executive may get advice from an advisory council before approving the manual as amended.

**Regular reviews of flood mitigation manual**

499. Before the approval for the flood mitigation manual expires, the owner must-
review, and if necessary, update the manual; and
give a copy of it to the chief executive under section 497.

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**Protection from liability for complying with flood mitigation manual**

500.(1) The chief executive or a member of the council does not incur civil liability for an act done, or omission made, honestly and without negligence under this division.

(2) An owner who observes the operational procedures in a flood mitigation manual approved by the chief executive does not incur civil liability for an act done, or omission made, honestly and without negligence in observing the procedures.

(3) If subsection (1) or (2) prevents civil liability attaching to a person, the liability attaches instead to the State.

(4) In this section-

"owner" includes-

a) a director of the owner or operator of the dam; or

b) an employee of the owner or operator of the dam; or

c) an agent of the owner or operator of the dam



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# APPENDIX B AGENCIES HOLDING DOCUMENTS

## AGENCIES HOLDING CONTROLLED DOCUMENTS OF MANUAL OF OPERATIONAL PROCEDURES FOR FLOOD MITIGATION FOR WIVENHOE DAM AND SOMERSET DAM

| | |
|---|---|
| Dam Owner | South East Queensland Water Corporation |
| Emergency Services | Department of Emergency Services, Disaster Management Service<br><br>Brisbane City Counter Disaster Committee<br><br>Esk Shire Counter Disaster Committee<br><br>Ipswich City Counter Disaster Committee<br><br>Kilcoy Shire Counter Disaster Committee |
| Severe Weather Warning Authority | Bureau of Meteorology |
| Primary Response Authorities | Brisbane City Council<br><br>Esk Shire Council<br><br>Ipswich City Council<br><br>Kilcoy Shire Council |
| | |



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| | |
|---|---|
| Regulator of Dam Safety | Department of Natural Resources, and Mines and Water |
| Dams Operator | SunWater |

The Corporation must keep a register of contact persons of holders of controlled documents (Section 1.9 refers).

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# APPENDIX C BRIDGE DECK LEVELS

Roads Upstream of Somerset Dam



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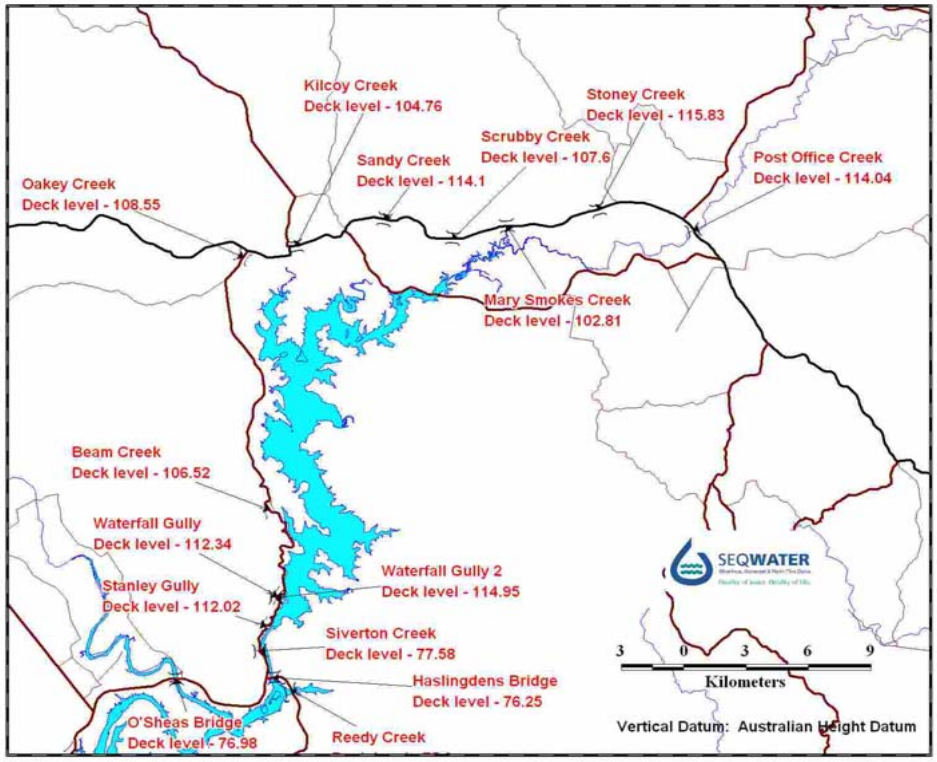


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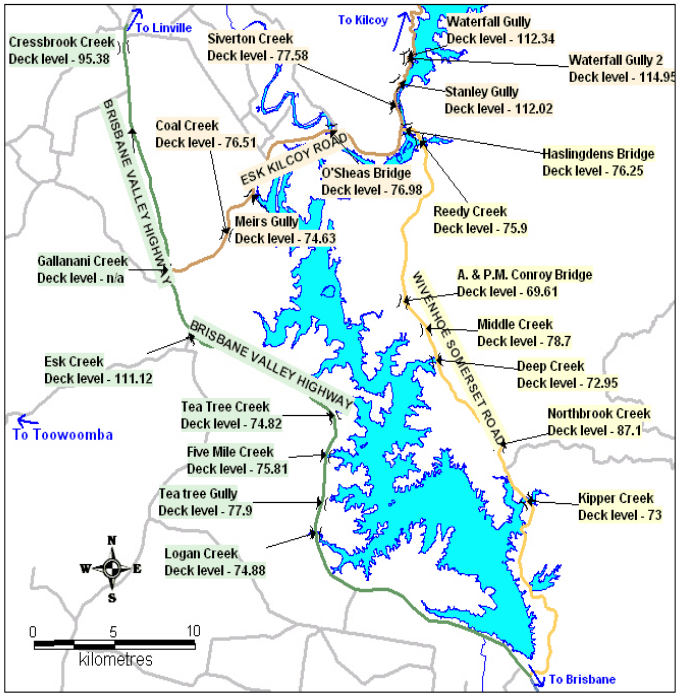
Roads Surrounding Wivenhoe Dam

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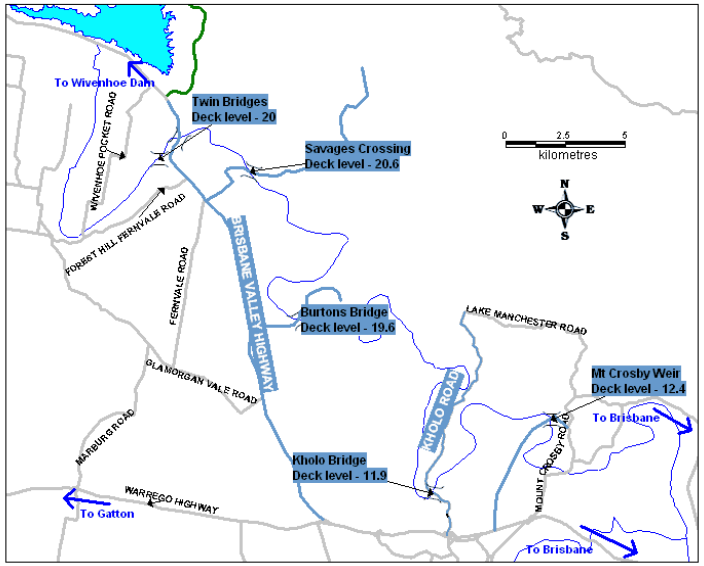
Bridges Downstream of Wivenhoe Dam

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APPENDIX D GAUGES AND BRIDGES

## Table D.1. KEY REFERENCE GAUGES

| Location G | Z | 1974 Gauge Height | Minor Mode | | rate | | Major | |
|---|---|---|---|---|---|---|---|---|
| | | | Gauge Height | Flow | Gauge Height | Flow | Gauge Height | Flow |
| | | | m m | $^3$/s m | | m$^3$/s m | | m$^3$/s |
| Stanley R at Somerset Dam* | 0.00 AHD | - | 103.0 | | 105.0 | | 106.0 | |
| Brisbane R at Lowood | 23.68 AHD | 22.02 | 8.0 15. | 1000 | 0 | 3300 | 20.0 | 6000 |
| Brisbane R at Lowood* | 22.74 SD | - | 8.6 15. | | 9 | | 21.2 | |
| Brisbane R at Savages Crossing* | 18.43 AHD | 23.79 | 9.0 16. | | 0 | | 21.0 | |
| Brisbane R at Mt Crosby* | 0.00 AHD | 26.74 | 11.0 | | 13.0 | | 21.0 | |
| Bremer R at Ipswich* | 0.00 AHD | 20.70 | 7.0 | | 9.0 | | 11.7 | |
| Brisbane R at Moggill* | 0.00 AHD | 19.95 | 10.0 13. | 4000 | 0 15 | 5000 | .5 | 6500 |
| Brisbane R at Jindalee Br* | 0.00 AHD | 14.10 | 6.0 8. | | 0 10 | | .0 | |
| Brisbane R at City Gauge* | 0.00 AHD | 5.45 | 1.7 | | 2.6 | | 3.5 | |

* Indicates an automatic gauge
Flows are approximate only and gauge heights are tide dependent in the lower reaches.
A complete list of the latest river heights can be found at http://www.bom.gov.au



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**Table D.2. SUBMERGENCE FLOWS FOR BRIDGES**

| AMTD | Bridge Name | Location | Estimated Submergence Flow $m^3/sec$ |
|---|---|---|---|
| 140 | Twin Bridges | Wivenhoe Pocket Road, Fernvale | 50 |
| 132 | Savage's Crossing | Banks Creek Road, Fernvale | 130 |
| 87 | College's Crossing | Mt Crosby Rd, Karana Downs | 175-200* |
| 120 | Burton's Bridge | E Summerville Road, Borallon | 430 |
| 100 | Kholo Bridge | Kholo Rd, Ipswich | 550 |
| 91 | Mt.Crosby Weir Bridge | Allawah Rd, Mt Crosby | 1900 |
| 136 | Fernvale Bridge | Brisbane Valley Hwy, Fernvale | 2000 |

* Affected by tides.



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# APPENDIX E WIVENHOE DAM TECHNICAL DATA

## TABLE E1 STORAGE AND UNCONTROLLED GATE DISCHARGES

| Lake level M AHD | Storage Capacity $10^6$ $m^3$ | *** Flood Capacity $10^6$ $m^3$ | ** Net Inflow per 1mm rise per hour $m^3$/sec | * Discharge per Regulator $m^3$/sec | * Discharge per Spillway Bay $m^3$/sec | Maximum Available Discharge $m^3$/sec |
|---|---|---|---|---|---|---|
| 57.0 | 414 | - | 11.10 | 24.9 | 0 | 50 |
| 57.5 | 453 | - | 12.04 | 25.2 | 4 | 69 |
| 58.0 | 466 | - | 12.97 | 25.4 | 15 | 128 |
| 58.5 | 494 | - | 13.90 | 25.7 | 32 | 211 |
| 59.0 | 523 | - | 14.84 | 25.9 | 53 | 316 |
| 59.5 | 553 | - | 15.77 | 26.2 | 77 | 439 |
| 60.0 | 584 | - | 16.71 | 26.4 | 105 | 579 |
| 60.5 | 616 | - | 17.64 | 26.6 | 136 | 735 |
| 61.0 | 649 | - | 18.58 | 26.9 | 170 | 905 |
| 61.5 | 683 | - | 19.51 | 27.1 | 207 | 1 090 |
| 62.0 | 719 | - | 20.45 | 27.3 | 246 | 1 290 |
| 62.5 | 756 | - | 21.38 | 27.5 | 288 | 1 495 |
| 63.0 | 795 | - | 22.32 | 27.8 | 333 | 1 720 |
| 63.5 | 835 | - | 23.25 | 28.0 | 379 | 1 950 |
| 64.0 | 877 | - | 24.19 | 28.2 | 428 | 2 195 |
| 64.5 | 920 | - | 25.12 | 28.4 | 479 | 2 450 |
| 65.0 | 965 | - | 26.06 | 28.7 | 532 | 2 720 |
| 65.5 | 1 012 | - | 26.99 | 28.9 | 587 | 2 995 |
| 66.0 | 1 061 | - | 27.92 | 29.1 | 645 | 3 280 |
| 66.5 | 1 112 | - | 28.86 | 29.3 | 704 | 3 580 |
| 67.0 | 1 165 | 0 | 29.79 | 29.5 | 765 | 3 885 |
| 67.5 | 1 220 | 56 | 30.73 | 29.7 | 828 | 4 200 |
| 68.0 | 1 276 | 112 | 31.66 | 29.9 | 893 | 4 525 |
| 68.5 | 1 334 | 171 | 32.60 | 30.1 | 959 | 4 860 |
| 69.0 | 1 393 | 230 | 33.53 | 30.3 | 1 028 | 5 200 |
| 69.5 | 1 454 | 290 | 34.47 | 30.5 | 1 098 | 5 550 |
| 70.0 | 1 517 | 350 | 35.40 | 30.7 | 1 170 | 5 910 |
| 70.5 | 1 581 | 418 | 36.33 | 30.9 | 1 244 | 6 280 |
| 71.0 | 1 647 | 485 | 37.27 | 31.1 | 1 319 | 6 660 |
| 71.5 | 1 714 | 550 | 38.20 | 31.3 | 1 396 | 7 040 |
| 72.0 | 1 783 | 615 | 39.14 | 31.5 | 1 474 | 7 430 |
| 72.5 | 1 854 | 683 | 40.07 | 31.7 | 1 554 | 7 840 |
| 73.0 | 1 926 | 750 | 41.01 | 31.9 | 1 636 | 8 240 |
| 73.5 | 2 000 | 830 | 41.94 | 32.1 | 1 719 | 8 660 |
| 74.0 | 2 076 | 910 | 42.87 | 32.3 | 1 804 | 9 080 |
| 74.5 | 2 153 | 995 | 43.81 | 32.5 | 1 890 | 9 520 |
| 75.0 | 2 232 | 1 080 | 44.74 | 32.7 | 1 978 | 9 960 |
| 75.5 | 2 313 | 1 160 | 45.68 | 32.9 | 2 067 | 10 400 |



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|---|---|---|---|---|---|---|
| 76.0 **** | 2 395 | 1 240 | 46.61 | 33.1 | 2 158 | 10 860 |
| 76.5 | 2 480 | 1 258 | 47.55 | 33.3 | 2 250 | 11 320 |
| 77.0 | 2 566 | 1 420 | 48.48 | 33.4 | 2 343 | 11 780 |
| 77.5 | 2 655 | 1 500 | 49.41 | 36.6 | 2 438 | 12 260 |
| 78.0 | 2 746 | 1 580 | 50.35 | 33.8 | 2 535 | 12 740 |
| 78.5 | 2 839 | 1 680 | 51.28 | 34.0 | 2 632 | 13 230 |
| 79.0 | 2 934 | 1 780 | 51.28 | 34.2 | 2 731 | 13 730 |
| 79.5 | 3 032 | 1 867 | 52.22 | 34.4 | 2 832 | 14 230 |
| 80.0 | 3 132 | 1 966 | 52.22 | 34.5 | 2 891 | 14 455 |

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* This is the maximum discharge of an individual spillway bay or regulator. Total discharge is calculated by adding the contributions of each gate or regulator. There are two (2) regulators to five (5) spillway bays.

** This assumes that all gates and sluices are closed. Discharges through the spillway have to be added to the above figures to calculate the actual inflow into the reservoir.

*** The temporary storage above normal Full Supply Level of EL 67.0.

**** The first fuse plug is designed to trigger at EL75.7. Above this level, fuse plug flows from Table E.3 need to be added to give the full outflow.

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## TABLE E2 CONTROLLED GATE DISCHARGES

Wivenhoe Dam Gate Opening (m of Tangential Travel)

| Water EL (m AHD) | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 1 | 0.5 | 1 | 1.0 | 11. | 5 | 12.0 | 12.5 | 1 | 3.0 | 13.5 | 14.0 | 14.5 | 15.0 | 15 | .5 | 16 | .0 | 16 | .5 | 17 | .0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 67.0 | 0 | 49 | 98 | 146 | 19 | 4 | 24 | 0 | 28 | 5 | 32 | 9 | 37 | 2 | 41 | 3 | 45 | 3 | 49 | 2 | 53 | 0 | 56 | 7 | 60 | 3 | 63 | 9 | 67 | 5 | 70 | 9 | 74 | 4 | 765 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 67.2 | 0 | 49 | 99 | 148 | 19 | 6 | 24 | 3 | 28 | 8 | 33 | 3 | 37 | 6 | 41 | 8 | 45 | 8 | 49 | 8 | 53 | 7 | 57 | 4 | 61 | 1 | 64 | 8 | 68 | 4 | 72 | 0 | 75 | 5 | 790 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 67.4 | 0 | 50 | 100 | 1 | 49 | 1 | 98 | 2 | 45 | 2 | 91 | 3 | 36 | 3 | 80 | 4 | 22 | 4 | 64 | 5 | 04 | 5 | 43 | 5 | 82 | 6 | 19 | 6 | 57 | 6 | 93 | 7 | 30 | 7 | 66 | 802 | 815 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 67.6 | 0 | 50 | 101 | 1 | 51 | 2 | 00 | 2 | 48 | 2 | 94 | 3 | 40 | 3 | 84 | 4 | 27 | 4 | 69 | 5 | 10 | 5 | 50 | 5 | 89 | 6 | 27 | 6 | 65 | 7 | 02 | 7 | 40 | 7 | 77 | 814 | 841 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 67.8 | 0 | 51 | 102 | 1 | 52 | 2 | 02 | 2 | 50 | 2 | 97 | 3 | 43 | 3 | 88 | 4 | 32 | 4 | 74 | 5 | 15 | 5 | 56 | 5 | 96 | 6 | 35 | 6 | 73 | 7 | 12 | 7 | 50 | 7 | 87 | 825 | 863 | 867 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 68.0 | 0 | 51 | 103 | 1 | 54 | 2 | 04 | 2 | 53 | 3 | 00 | 3 | 47 | 3 | 92 | 4 | 36 | 4 | 79 | 5 | 21 | 5 | 62 | 6 | 03 | 6 | 42 | 6 | 82 | 7 | 21 | 7 | 59 | 7 | 98 | 837 | 876 | 893 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 68.2 | 0 | 52 | 104 | 1 | 55 | 2 | 06 | 2 | 55 | 3 | 03 | 3 | 50 | 3 | 96 | 4 | 41 | 4 | 84 | 5 | 27 | 5 | 69 | 6 | 10 | 6 | 50 | 6 | 90 | 7 | 29 | 7 | 69 | 8 | 08 | 848 | 888 | 919 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 68.4 | 0 | 52 | 105 | 1 | 56 | 2 | 07 | 2 | 57 | 3 | 06 | 3 | 54 | 4 | 00 | 4 | 45 | 4 | 89 | 5 | 32 | 5 | 75 | 6 | 16 | 6 | 57 | 6 | 98 | 7 | 38 | 7 | 78 | 8 | 18 | 859 | 899 | 940 | 946 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 68.6 | 0 | 53 | 105 | 1 | 58 | 2 | 09 | 2 | 60 | 3 | 09 | 3 | 57 | 4 | 04 | 4 | 50 | 4 | 94 | 5 | 38 | 5 | 81 | 6 | 23 | 6 | 65 | 7 | 06 | 7 | 47 | 7 | 88 | 8 | 29 | 870 | 911 | 953 | 973 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 68.8 | 0 | 53 | 106 | 1 | 59 | 2 | 11 | 2 | 62 | 3 | 12 | 3 | 60 | 4 | 08 | 4 | 54 | 4 | 99 | 5 | 43 | 5 | 87 | 6 | 30 | 6 | 72 | 7 | 14 | 7 | 55 | 7 | 97 | 8 | 38 | 880 | 923 | 965 | 1000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 69.0 | 0 | 54 | 107 | 1 | 60 | 2 | 13 | 2 | 64 | 3 | 15 | 3 | 64 | 4 | 12 | 4 | 58 | 5 | 04 | 5 | 49 | 5 | 93 | 6 | 36 | 6 | 79 | 7 | 22 | 7 | 64 | 8 | 06 | 8 | 48 | 891 | 934 | 977 | 1022 | 1028 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 69.2 | 0 | 54 | 108 | 1 | 62 | 2 | 15 | 2 | 67 | 3 | 17 | 3 | 67 | 4 | 15 | 4 | 63 | 5 | 09 | 5 | 54 | 5 | 99 | 6 | 43 | 6 | 86 | 7 | 29 | 7 | 72 | 8 | 15 | 8 | 58 | 901 | 945 | 989 | 1035 | 1056 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 69.4 | 0 | 54 | 109 | 1 | 63 | 2 | 17 | 2 | 69 | 3 | 20 | 3 | 70 | 4 | 19 | 4 | 67 | 5 | 14 | 5 | 60 | 6 | 05 | 6 | 49 | 6 | 93 | 7 | 37 | 7 | 80 | 8 | 24 | 8 | 68 | 912 | 956 | 1001 | 1047 | 1084 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 69.6 | 0 | 55 | 110 | 1 | 64 | 2 | 18 | 2 | 71 | 3 | 23 | 3 | 73 | 4 | 23 | 4 | 71 | 5 | 18 | 5 | 65 | 6 | 11 | 6 | 56 | 7 | 00 | 7 | 44 | 7 | 89 | 8 | 33 | 8 | 77 | 922 | 967 | 1013 | 1060 | 1107 | 1112 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 69.8 | 0 | 55 | 111 | 1 | 66 | 2 | 20 | 2 | 73 | 3 | 26 | 3 | 77 | 4 | 27 | 4 | 75 | 5 | 23 | 5 | 70 | 6 | 16 | 6 | 62 | 7 | 07 | 7 | 52 | 7 | 97 | 8 | 42 | 8 | 87 | 932 | 978 | 1025 | 1072 | 1121 | 1141 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 70.0 | 0 | 56 | 112 | 1 | 67 | 2 | 22 | 2 | 76 | 3 | 28 | 3 | 80 | 4 | 30 | 4 | 79 | 5 | 28 | 5 | 75 | 6 | 22 | 6 | 68 | 7 | 14 | 7 | 59 | 8 | 05 | 8 | 50 | 8 | 96 | 942 | 989 | 1036 | 1085 | 1134 | 1170 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 70.2 | 0 | 56 | 112 | 1 | 68 | 2 | 24 | 2 | 78 | 3 | 31 | 3 | 83 | 4 | 34 | 4 | 84 | 5 | 32 | 5 | 80 | 6 | 28 | 6 | 74 | 7 | 21 | 7 | 67 | 8 | 13 | 8 | 59 | 9 | 05 | 952 | 1000 | 1048 | 1097 | 1147 | 1198 | 1199 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 70.4 | 0 | 56 | 113 | 1 | 70 | 2 | 25 | 2 | 80 | 3 | 34 | 3 | 86 | 4 | 37 | 4 | 88 | 5 | 37 | 5 | 86 | 6 | 33 | 6 | 80 | 7 | 27 | 7 | 74 | 8 | 21 | 8 | 67 | 9 | 14 | 962 | 1010 | 1059 | 1109 | 1160 | 1212 | 1229 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

UNCONTROLLED DISCHARGE

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 70.6 | 0 | 57 | 114 1 | 71 2 | 27 2 | 82 3 | 36 3 | 89 4 | 41 4 | 92 5 | 42 5 | 91 6 | 39 6 | 87 7 | 34 7 | 81 8 | 28 8 | 76 9 | 23 | 972 | 1020 | 1070 | 1121 | 1173 | 1226 | 1258 | | | | | |
| 70.8 | 0 | 57 | 115 1 | 72 2 | 29 2 | 84 3 | 39 3 | 92 4 | 45 4 | 96 5 | 46 5 | 96 6 | 44 6 | 93 7 | 41 7 | 88 8 | 36 8 | 84 9 | 32 | 981 | 1031 | 1081 | 1133 | 1185 | 1239 | 1289 | | | | | |
| 71.0 | 0 | 58 | 116 1 | 73 2 | 30 2 | 86 3 | 41 3 | 95 4 | 48 5 | 00 5 | 51 6 | 01 6 | 50 6 | 99 7 | 47 7 | 95 8 | 44 8 | 92 9 | 41 | 991 | 1041 | 1092 | 1144 | 1198 | 1252 | 1309 | 1319 | | | | |
| 71.2 | 0 | 58 | 117 1 | 75 2 | 32 2 | 89 3 | 44 3 | 98 4 | 52 5 | 04 5 | 55 6 | 05 6 | 55 7 | 05 7 | 54 8 | 02 8 | 51 9 | 00 9 | 50 | 1000 | 1051 | 1103 | 1156 | 1210 | 1266 | 1323 | 1349 | | | | |
| 71.4 | 0 | 58 | 117 1 | 76 2 | 34 2 | 91 3 | 47 4 | 01 4 | 55 5 | 08 5 | 59 6 | 10 6 | 61 7 | 10 7 | 60 8 | 09 8 | 59 9 | 08 9 | 59 | 1009 | 1061 | 1114 | 1167 | 1222 | 1279 | 1337 | 1380 | | | | |
| 71.6 | 0 | 59 | 118 1 | 77 2 | 35 2 | 93 3 | 49 4 | 04 4 | 58 5 | 12 5 | 64 6 | 15 6 | 66 7 | 16 7 | 66 8 | 16 8 | 66 9 | 16 9 | 67 | 1019 | 1071 | 1124 | 1179 | 1234 | 1292 | 1350 | 1410 | 1411 | | | |
| 71.8 | 0 | 59 | 119 1 | 78 2 | 37 2 | 95 3 | 52 4 | 07 4 | 62 5 | 15 5 | 68 6 | 20 6 | 71 7 | 22 7 | 73 8 | 23 8 | 74 9 | 24 9 | 76 | 1028 | 1081 | 1135 | 1190 | 1246 | 1304 | 1364 | 1425 | 1443 | | | |
| 72.0 | 0 | 60 | 120 1 | 80 2 | 39 2 | 97 3 | 54 4 | 10 4 | 65 5 | 19 5 | 72 6 | 25 6 | 76 7 | 28 7 | 79 8 | 30 8 | 81 9 | 32 9 | 84 | 1037 | 1091 | 1145 | 1201 | 1258 | 1317 | 1377 | 1439 | 1474 | | | |
| 72.2 | 0 | 60 | 121 1 | 81 2 | 40 2 | 99 3 | 57 4 | 13 4 | 69 5 | 23 5 | 77 6 | 29 6 | 82 7 | 33 7 | 85 8 | 37 8 | 88 9 | 40 9 | 93 | 1046 | 1100 | 1156 | 1212 | 1270 | 1330 | 1391 | 1454 | 1506 | | | |
| 72.4 | 0 | 60 | 121 1 | 82 2 | 42 3 | 01 3 | 59 4 | 16 4 | 72 5 | 27 5 | 81 6 | 34 6 | 87 7 | 39 7 | 91 8 | 43 8 | 95 9 | 48 1 | 001 | 1055 | 1110 | 1166 | 1223 | 1282 | 1342 | 1404 | 1468 | 1533 | 1538 | | |
| 72.6 | 0 | 61 | 122 1 | 83 2 | 43 3 | 03 3 | 61 4 | 19 4 | 75 5 | 31 5 | 85 6 | 39 6 | 92 7 | 45 7 | 97 8 | 50 9 | 03 9 | 56 1 | 009 | 1064 | 1119 | 1176 | 1234 | 1293 | 1354 | 1417 | 1482 | 1548 | 1570 | | |
| 72.8 | 0 | 61 | 123 1 | 84 2 | 45 3 | 05 3 | 64 4 | 22 4 | 78 5 | 34 5 | 89 6 | 43 6 | 97 7 | 50 8 | 03 8 | 56 9 | 10 9 | 63 1 | 018 | 1073 | 1129 | 1186 | 1245 | 1305 | 1367 | 1430 | 1496 | 1563 | 1603 | | |



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**TABLE E2 CONTROLLED GATE DISCHARGES (continued)**

Wivenhoe Dam Gate Opening (m of Tangential Travel)

| Water EL (m AHD) | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 10.5 | 11.0 | 11.5 | 12.0 | 12.5 | 13.0 | 13.5 | 14.0 | 14.5 | 15.0 | 15.5 | 16.0 | 16.5 | 17.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 73.0 | 0 | 62 | 124 | 185 2 | 47 3 | 07 | 366 4 | 25 482 | | 538 593 648 | | | 702 7 | 56 8 | 09 | 863 | 917 | 971 | 1026 | 1081 | 1138 | 1196 | 1255 | 1316 | 1379 | 1443 | 1509 | 1577 | 1636 | | | | | | | |
| 73.2 | 2 | 62 | 124 | 187 2 | 48 3 | 09 | 369 4 | 27 485 | | 542 597 653 | | | 707 7 | 61 8 | 15 | 869 | 924 | 978 | 1034 | 1090 | 1147 | 1206 | 1266 | 1327 | 1391 | 1456 | 1523 | 1592 | 1663 1 | 69 | | UNCONTROLLED | | | |
| 73.4 | 6 | 62 | 125 | 188 2 | 50 3 | 11 | 371 4 | 30 488 | | 545 602 657 | | | 712 7 | 67 8 | 21 | 876 | 931 | 986 | 1042 | 1099 | 1156 | 1216 | 1276 | 1339 | 1403 | 1469 | 1536 | 1606 | 1678 1 | 02 | | DISCHARGE | | | |
| 73.6 | 11 | 64 | 126 | 189 2 | 51 3 | 13 | 373 4 | 33 491 | | 549 606 662 | | | 717 7 | 72 8 | 27 | 882 | 937 | 993 | 1050 | 1107 | 1166 | 1225 | 1287 | 1350 | 1414 | 1481 | 1550 | 1620 | 1693 1 | 36 | | | | | |
| 73.8 | 17 | 69 | 127 | 190 2 | 53 3 | 15 | 376 4 | 36 495 | | 553 610 666 | | | 722 7 | 78 8 | 33 | 888 | 944 | 1001 | 1058 | 1116 | 1175 | 1235 | 1297 | 1361 | 1426 | 1494 | 1563 | 1635 | 1708 1 | 70 | | | | | |
| 74.0 | 23 | 74 | 129 | 191 2 | 54 3 | 17 | 378 4 | 38 498 | | 556 614 671 | | | 727 7 | 83 8 | 39 | 895 | 951 | 1008 | 1065 | 1124 | 1184 | 1245 | 1307 | 1372 | 1438 | 1506 | 1576 | 1648 | 1723 18 | 00 18 | 04 | | | | |
| 74.2 | 31 | 80 | 133 | 192 2 | 56 3 | 19 | 380 4 | 41 501 | | 560 618 675 | | | 732 7 | 88 8 | 45 | 901 | 958 | 1015 | 1073 | 1132 | 1192 | 1254 | 1317 | 1382 | 1449 | 1518 | 1589 | 1662 | 1738 18 | 15 18 | 38 | | | | |
| 74.4 | 39 | 87 | 139 | 195 2 | 57 3 | 21 | 383 4 | 44 504 | | 563 622 679 | | | 737 7 | 93 8 | 50 | 907 | 964 | 1022 | 1081 | 1140 | 1201 | 1264 | 1327 | 1393 | 1461 | 1530 | 1602 | 1676 | 1752 18 | 31 18 | 73 | | | | |
| 74.6 | 47 | 94 | 145 | 200 2 | 59 3 | 22 | 385 4 | 47 507 | | 567 626 684 | | | 741 7 | 99 8 | 56 | 913 | 971 | 1029 | 1089 | 1149 | 1210 | 1273 | 1337 | 1404 | 1472 | 1542 | 1615 | 1690 | 1767 18 | 46 19 | 08 | | | | |
| 74.8 | 56 | 103 | 153 | 206 2 | 62 3 | 24 | 387 4 | 49 510 | | 570 629 688 | | | 746 8 | 04 8 | 62 | 919 | 978 | 1036 | 1096 | 1157 | 1219 | 1282 | 1347 | 1414 | 1483 | 1554 | 1628 | 1703 1 | 781 18 | 61 19 | 43 | | | | |
| 7 5.0 | 66 | 112 | 161 | 213 2 | 67 3 | 26 | 390 4 | 52 513 | | 574 633 692 | | | 751 8 | 09 8 | 67 | 926 | 984 | 1044 | 1104 | 1165 | 1227 | 1291 | 1357 | 1425 | 1494 | 1566 | 1640 | 1717 | 1795 18 | 76 19 | 60 | 1978 | | | |
| 75.2 | 76 | 121 | 169 | 220 2 | 74 3 | 30 | 392 4 | 55 516 | | 577 637 697 | | | 756 8 | 14 8 | 73 | 932 | 991 | 1051 | 1111 | 1173 | 1236 | 1301 | 1367 | 1435 | 1506 | 1578 | 1653 | 1730 1 | 809 18 | 91 19 | 76 | 2013 | | | |
| 75.4 | 87 | 131 | 178 | 229 2 | 81 3 | 36 | 394 4 | 57 519 | | 581 641 701 | | | 760 8 | 19 8 | 78 | 938 | 997 | 1057 | 1119 | 1181 | 1245 | 1310 | 1377 | 1446 | 1517 | 1590 | 1665 | 1743 1 | 823 19 | 06 19 | 92 | 2049 | | | |
| 75.6 | 98 | 141 | 188 | 237 2 | 89 3 | 43 | 399 4 | 60 522 | | 584 645 705 | | | 765 8 | 24 8 | 84 | 944 | 1004 | 1064 | 1126 | 1189 | 1253 | 1319 | 1386 | 1456 | 1527 | 1601 | 1678 | 1756 1 | 837 19 | 21 20 | 07 | 2085 | | | |
| 75.8 | 109 1 | 52 | 198 | 247 2 | 98 3 | 50 | 405 4 | 63 525 | | 587 649 709 | | | 769 8 | 29 8 | 89 | 949 | 1010 | 1071 | 1133 | 1197 | 1261 | 1328 | 1396 | 1466 | 1538 | 1613 | 1690 | 1769 185 | 1 1 | 936 2 | 023 | 2112 | 2121 | | |
| | | OVERTOPPING of GATE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 76.0 | 121 1 | 64 | 209 | 257 3 | 07 3 | 59 | 412 4 | 68 578 | | 591 652 713 | | | 774 8 | 34 8 | 95 | 955 | 1016 | 1078 | 1141 | 1205 | 1270 | 1337 | 1405 | 1476 | 1549 | 1624 | 1702 | 1782 186 | 5 1 | 950 2 | 038 | 2129 | 2158 | | |
| 76.2 | 133 1 | 75 | 220 | 268 3 | 17 3 | 68 | 421 4 | 75 532 | | 594 656 718 | | | 779 8 | 39 9 | 00 | 961 | 1023 | 1085 | 1148 | 1212 | 1278 | 1346 | 1415 | 1486 | 1560 | 1636 | 1714 | 1795 187 | 8 1 | 965 2 | 053 | 2145 | 2194 | | |
| 76.4 | 146 1 | 87 | 232 | 279 3 | 27 3 | 78 | 429 4 | 83 539 | | 597 660 722 | | | 783 8 | 44 9 | 06 | 967 | 1029 | 1092 | 1155 | 1220 | 1286 | 1354 | 1424 | 1496 | 1570 | 1647 | 1726 | 1808 189 | 2 1 | 979 2 | 069 | 2161 | 2231 | | |
| 76.6 | 159 2 | 00 | 244 | 290 3 | 38 3 | 88 | 439 4 | 92 546 | | 603 664 726 | | | 788 8 | 49 9 | 11 | 973 | 1035 | 1098 | 1162 | 1228 | 1295 | 1363 | 1434 | 1506 | 1581 | 1658 | 1738 | 1820 190 | 5 1 | 993 2 | 084 | 2177 | 2268 | | |
| 76.8 | 173 | 213 | 257 | 302 | 350 | 399 | 449 | 501 | 554 | 610 | 668 | 730 | 792 | 854 | 916 | 978 | 1041 | 1105 | 1170 | 1235 | 1303 | 1372 | 1443 | 1516 | 1591 | 1669 | 1750 | 1833 | 1919 | 2007 | 2099 | 2193 | 2289 | 2306 | |
| | | | OVERTOPPING of GATE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 77.0 | 186 2 | 26 | 270 | 315 3 | 62 4 | 10 | 460 5 | 11 564 | | 618 674 734 | | | 797 8 | 59 9 | 21 | 984 | 1047 | 1112 | 1177 | 1243 | 1311 | 1380 | 1452 | 1526 | 1602 | 1680 | 1762 | 1845 193 | 2 2 | 021 2 | 113 | 2208 | 2306 2 | 343 | |
| 77.2 | 200 2 | 40 | 283 | 328 3 | 74 4 | 22 | 471 5 | 22 574 | | 627 682 739 | | | 801 8 | 64 9 | 27 | 990 | 1054 | 1118 | 1184 | 1250 | 1319 | 1389 | 1461 | 1536 | 1612 | 1691 | 1773 | 1858 194 | 5 2 | 035 2 | 128 | 2224 | 2322 2 | 381 | |
| 77.4 | 215 2 | 54 | 297 | 341 3 | 87 4 | 35 | 483 5 | 33 584 | | 637 691 747 | | | 806 8 | 69 9 | 32 | 996 | 1060 | 1125 | 1191 | 1258 | 1327 | 1398 | 1470 | 1545 | 1622 | 1702 | 1785 | 1870 195 | 8 2 | 049 2 | 143 | 2239 | 2339 2 | 419 | |
| 77.6 | 230 2 | 69 | 311 | 355 4 | 00 4 | 47 | 496 5 | 45 595 | | 647 700 756 | | | 813 8 | 73 9 | 37 | 1001 | 1066 | 1131 | 1198 | 1265 | 1335 | 1406 | 1479 | 1555 | 1633 | 1713 | 1796 | 1882 197 | 1 2 | 063 2 | 157 | 2255 | 2355 2 | 457 | |
| 77.8 | 245 2 | 83 | 325 | 369 4 | 14 4 | 61 | 508 5 | 57 607 | | 658 711 765 | | | 821 8 | 80 9 | 42 | 1007 | 1072 | 1138 | 1205 | 1273 | 1343 | 1414 | 1488 | 1564 | 1643 | 1724 | 1808 | 1894 198 | 4 2 | 076 2 | 172 | 2270 | 2371 2 | 475 | 2496 |
| 78.0 | 260 2 | 99 | 340 | 383 4 | 28 4 | 74 | 522 5 | 70 619 | | 670 722 775 | | | 831 8 | 88 9 | 48 | 1012 | 1078 | 1144 | 1211 | 1280 | 1351 | 1423 | 1497 | 1574 | 1653 | 1735 | 1819 | 1907 199 | 7 2 | 090 2 | 186 | 2285 | 2387 2 | 492 | 2535 |



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**TABLE E2 CONTROLLED GATE DISCHARGES (continued)**

Wivenhoe Dam Gate Opening (m of Tangential Travel)

| Water El (m AHD) | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 | 9.0 | 9.5 | 10.0 | 10.5 | 11.0 | 11.5 | 12.0 | 12.5 | 13.0 | 13.5 | 14.0 | 14.5 | 15.0 | 15.5 | 16.0 | 16.5 | 17.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | OVERTOPPING of GATE | | | | | | | | | | | | | | | | | | | | | | | | | |
| 79.0 | 342 | 379 | 419 | 460 | 504 | 548 | 594 | 640 | 688 | 736 | 786 | 837 | 889 | 943 | 999 | 1057 | 1117 | 1180 | 1246 | 1316 | 1389 | 1464 | 1541 | 1620 | 1703 | 1787 | 1875 | 1966 | 2060 | 2156 | 2257 | 2360 | 2466 | 2575 | 2687 |
| | | | | | | | | | | | | | | | | | OVERTOPPING of GATE | | | | | | | | | | | | | | | | | | | |
| 80.0 | 431 | 466 | 505 | 545 | 587 | 630 | 675 | 720 | 766 | 813 | 861 | 910 | 961 | 1013 | 1068 | 1124 | 1182 | 1243 | 1306 | 1372 | 1441 | 1513 | 1589 | 1668 | 1751 | 1838 | 1929 | 2023 | 2121 | 2221 | 2325 | 2432 | 2542 | 2655 | 2772 |

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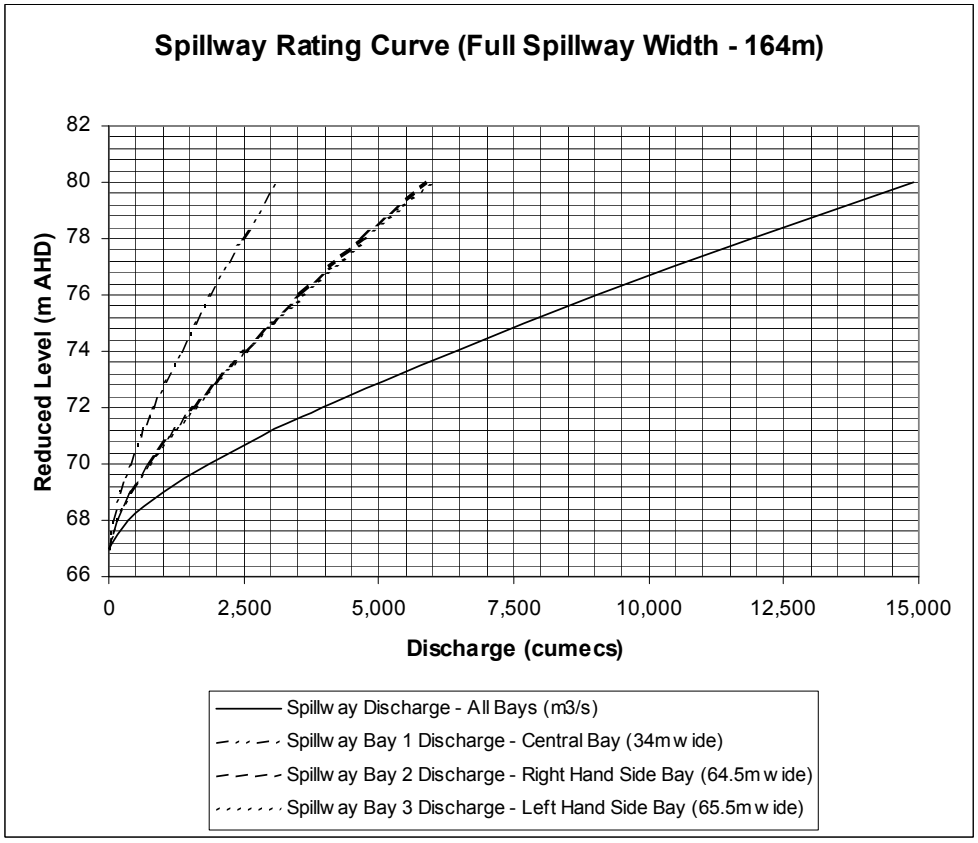
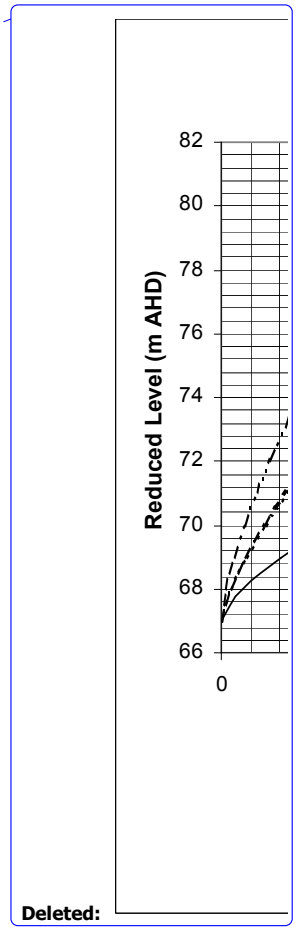
## TABLE E.3 – WIVENHOE DAM AUXILIARY SPILLWAY RATING TABLE

| Storage Level (m AHD) | Spillway Discharge - All Bays (m3/s) | Discharge Central Bay (34m wide) | Discharge Right Side Bay (64.5m wide) | Discharge Left Side Bay (65.5m wide) |
|---|---|---|---|---|
| 67 0 | | 0 | 0 | 0 |
| 68 361 | | 75 | 142 | 144 |
| 69 1,020 | | 212 | 401 | 408 |
| 70 1,858 | | 385 | 731 | 742 |
| 71 2,847 | | 590 | 1,120 | 1,137 |
| 72 3,961 | | 821 | 1,558 | 1,582 |
| 74 6,409 | | 1,329 | 2,521 | 2,560 |
| 76 9,033 | | 1,873 | 3,553 | 3,608 |
| 78 11,907 | | 2,468 | 4,683 | 4,755 |
| 80 14,913 | | 3,092 | 5,865 | 5,956 |

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# APPENDIX F SOMERSET DAM TECHNICAL DATA

Table F-l STORAGE AND DISCHARGE FOR SOMERSET DAM

| Lake level M AHD | Reservoir Capacity $10^6$ $m^3$ | Temporary Flood Storage $10^6$ $m^3$ | Net Inflow per 1mm rise per hour $m^3$/sec | * Discharge per Regulator $m^3$/sec | * Discharge per Sluice $m^3$/sec | * Discharge per Spillway Bay $m^3$/sec | Maximum Available Discharge $m^3$/sec |
|---|---|---|---|---|---|---|---|
| 90.0 | 120.3 | - | 5.29 | 57 | 163 | - | 1 529 |
| 90.5 | 129.5 | - | 5.50 | 58 | 165 | - | 1 550 |
| 91.0 | 139.3 | - | 4.88 | 58 | 167 | - | 1 572 |
| 91.5 | 149.6 | - | 5.28 | 59 | 170 | - | 1 593 |
| 92.0 | 160.5 | - | 5.68 | 60 | 172 | - | 1 614 |
| 92.5 | 172.0 | - | 6.09 | 60 | 174 | - | 1 635 |
| 93.0 | 184.1 | - | 6.79 | 61 | 176 | - | 1 655 |
| 93.5 | 196.7 | - | 7.10 | 62 | 179 | - | 1 676 |
| 94.0 | 210.0 | - | 7.43 | 62 | 181 | - | 1 695 |
| 94.5 | 224.0 | - | 7.78 | 63 | 183 | - | 1 715 |
| 95.0 | 238.5 | - | 8.15 | 64 | 185 | - | 1 735 |
| 95.5 | 253.6 | - | 8.54 | 64 | 187 | - | 1 754 |
| 96.0 | 269.3 | - | 8.95 | 65 | 189 | - | 1 773 |
| 96.5 | 285.6 | - | 9.37 | 66 | 191 | - | 1 792 |
| 97.0 | 302.7 | - | 9.81 | 66 | 193 | - | 1 810 |
| 97.5 | 320.7 | - | 10.28 | 67 | 195 | - | 1 829 |
| 98.0 | 339.5 | - | 10.76 | 67 | 197 | - | 1 847 |
| 98.5 | 359.2 | - | 11.25 | 68 | 199 | - | 1 865 |
| 99.0 | 379.8 | 0.0 | 11.77 | 69 | 201 | - | 1 883 |
| 99.5 | 401.4 | 21.5 | 12.31 | 69 | 203 | - | 1 901 |
| 100.0 | 428.9 | 49.0 | 13.28 | 70 | 205 | - | 1 918 |
| 100.5 | 447.5 | 67.6 | 13.83 | 70 | 207 | 0 | 1 937 |
| 101.0 | 472.2 | 92.3 | 14.39 | 71 | 209 | 4 | 1 989 |
| 101.5 | 498.0 | 118.1 | 14.95 | 72 | 211 | 13 | 2 076 |
| 102.0 | 524.9 | 145.1 | 15.53 | 72 | 212 | 25 | 2 189 |
| 102.5 | 553.1 | 173.3 | 16.11 | 73 | 214 | 40 | 2 325 |
| 103.0 | 582.6 | 202.7 | 16.70 | 73 | 216 | 58 | 2 482 |
| 103.5 | 613.2 | 233.4 | 17.30 | 74 | 218 | 78 | 2 659 |
| 104.0 | 645.1 | 265.3 | 17.90 | 74 | 220 | 100 | 2 854 |
| 104.5 | 678.3 | 298.4 | 18.52 | 75 | 221 | 125 | 3 067 |
| 105.0 | 712.7 | 332.8 | 19.14 | 75 | 223 | 151 | 3 296 |
| 105.5 | 748.3 | 368.4 | 19.78 | 76 | 225 | 180 | 3 542 |
| 106.0 | 785.2 | 405.4 | 20.42 | 76 | 226 | 211 | 3 803 |
| 106.5 | 823.4 | 443.6 | 21.07 | 77 | 228 | 243 | 4 079 |
| 107.0 | 863.1 | 483.2 | 21.73 | 78 | 230 | 278 | 4 370 |
| 107.5 | 904.0 | 524.2 | 22.39 | 78 | 232 | 314 | 4 675 |

* This is the maximum discharge of an individual gate or regulator. Total discharge is calculated by adding the contributions of each gate or regulator.

Regulator - Discharge regulator valve of which there are four (4).
Sluice - Sluice gate of which there are eight (8).
Spillway - Overflow section of dam controlled by eight (8) radial gates.
Temporary Flood- The temporary storage above the normal full supply level of El 99 m (AHD) Storage



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# APPENDIX G WIVENHOE DAM GATE OPERATION CONSIDERATIONS

Full size plans of Wivenhoe Dam, and Operations and Maintenance Manuals for Wivenhoe Dam are held by the Corporation and the Headworks Operator and are available at the site. Operations and Maintenance Manuals relevant to the flood operation of the gates are:

(a) "Master Manual and Drawings."

(b) "Radial and Penstock Gate Hoists and Drawings."

## G.1. SPILLWAY OPERATION PRINCIPLES

The radial gates are sequentially numbered from 1 to 5 from left to right looking in the downstream direction. Appendix I shows the general arrangement of the spillway area.

The flip bucket spillway is designed to control the discharge from the reservoir and to dissipate the energy of the discharge. The flip throws the discharge clear of the concrete structures into a plunge pool where the energy is dissipated by turbulence. Under non-symmetric flow conditions, or when gates 1 and 5 are not operating, the discharge jet may impinge on the walls of the plunge pool, which has been excavated into erodible sandstone rock, and cause non-predictable erosion. Upstream migration of this erosion is to be avoided. The wing walls adjacent to the flip bucket deflect the discharge away from the walls of the plunge pool when gates 1 and 5 are operated.

Therefore in operating the spillway, the principles to be observed are, in order of priority:

(i) The discharge jet into the plunge pool is not to impinge on the right or left walls of the plunge pool.

(ii) The flow in the spillway is to be symmetrical.

The main purpose of gating the spillway is to exercise maximum control over the flow in the Brisbane River insofar as river flows in excess of 4 000 $m^3$/sec cause damage to urban areas downstream. The gates also allow the routing of much larger floods with substantial flood mitigation being achieved.

## G.2. RADIAL GATE OPERATING PRINCIPLE

Each radial gate consists of a cylindrical upstream skinplate segment that is attached to the radial arms. The cylindrical axis is horizontal. Each gate rotates about two spherical trunnion bearings that are on this axis.

The position of the gate is controlled by hydraulically driven winches that are located on the piers beside the gates. Wire ropes are attached to the downstream face of the skin plate through a pulley system. The hydraulic motors work off a common pressure manifold and under perfectly matched conditions, will give an equal lifting force to each side of the gate. This system does not sense rope travel and will take up slack rope. It cannot prevent or correct skewing of the skin plate segment between the piers. If skewing occurs, skids will come into contact with the side seal plates to limit movement.



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It is not possible to operate a winch independently of the other winch attached to the gate.

When the hydraulic motors are not energised, the gates are held in position by spring loaded friction brakes on the winches. There are two brake bands per winch and each band is capable of supporting half the weight of the gate. One winch can support the total weight of a gate on both its brake bands but not on one.

## G.3. RADIAL GATES OPERATING LIMITATIONS

### G.3.1. Opening and Closing Rate

The aperture opening rate of each gate is limited to 500 mm/minute.

Aperture movement is limited by a programmable timer that stops gate movement after a set period of time.

### G.3.2. Alternate Consecutive Operation

To maintain symmetry of discharge in the spillway, either gates 1 and 5 or gates 2 and 4 are to be operated in alternate consecutive increments. The power for gate operation comes from two independent electric hydraulic pumps, each of which is capable of operating one gate at a time.

The normal hydraulic pressure source for each gate is as follows:

| GATES | POWER SOURCE |
|---|---|
| Radial Gates 1 & 2, and Penstock Gate Hoist | Electric hydraulic pump 1 |
| Radial Gates 3, 4 & 5 | Electric hydraulic pump 2 |

In the event that an electric hydraulic pump fails, hydraulic pressure can be redirected from the other power source, but concurrent operation of more than one gate from a single power source is not possible.



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G.3.3. Overt opping

While the radi al gates have been designed t o withstand overtopping, it should be avoided if possible. T he res ervoir level s and the structural state of the radial gates when in the closed position are as follows:

| Reservoir Level m AHD | Condition | Radial Gate Stress Condition with Gate Closed |
|---|---|---|
| 73 | Top of closed gate | Normal |
| 77 | Design Flood Level | 33% Overstress |
| 80 | Crest Level | Critical |

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Once overtopped, t he gates beco me i noperable w hen the lifting tackle is fouled by debris from the overflow. The gates remain structurally secure until the reservoir level exceeds EL 77. The ability to control floods however may be lost.

G.3.4. Gat e Dropping

Under no circumstances are the gates to be dropped. The lower skin plate sections are overstressed if a freefall of 60 mm is arrested by the seal plate on the spillway.

If a gate becomes stuck in an open position, it is to be freed by applying positive lifting forces. Under no circumstances are the winches to be unloaded and the direct weight of the gates used to yield the obstruction.

G.3.5. Operation in High Wind

Other than in periods of mitigation of medium and major floods, the gates are not to be raised or lo wered when clear of water, during periods of high winds. The gates can however, be held on the brakes in any position in the presence of high wind.

The term "high wind" means any wind that causes twisting or movement of the gate. While a pre cise figure cannot be p laced on these velocit ies, further experience ov er time may allow a figure to be determined.

This limitation is required to prevent the gate from twisting from skew on one side to skew on the othe r side. While the gate is being raised or l owered, skewing canno t be prevented b y the hyd raulic lifting system and any im pact forces encountered may damage the gate.

G.3.6. Mai ntenance

No more th an one gate is to be in operable at any one ti me for maintenance. Th e maintenance is to be sch eduled so that the spillway bay can be cleared of obstructions in a reasonable time to allow its use in the event of major flooding.



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## G.4. BULKHEAD GATE OPERATING LIMITATIONS

The bulkhead gate can be used to control discharge in an emergency situation where a radial gate is inoperable. It is transported to, and lowered upstream of the inoperable radial gate by means of the gantry crane. The following conditions apply:

(a) The bulkhead gate can always be lowered with any type of underflow; and

(b) It is not possible to raise the bulkhead gate once it has been lowered past certain levels depending on upstream conditions without there being a pool of water between it and the radial gate. (Department of Primary Industries Wivenhoe Dam Design Report, September 1995 refers).

It is thus possible to preserve storage by effectively closing the spillway even with one radial gate inoperable. It will not be possible to raise the bulkhead gate until the radial gate behind has been repaired and is again storing water between the bulkhead gate and itself.

The bulkhead gate is not to be used for flood regulation until the reservoir level is falling and not likely to rise within the period needed to repair the inoperable radial gate.

### G.4.1. Opening and Closing Rates

The spillway gantry crane is to be used to raise and lower the bulkhead gate. The crane operates at two speeds, 1.5 and 3.0 m/min. When within the bulkhead gate guides, the bulkhead gate is to be moved only at 1.5 m/min.

### G.4.2. Overtopping

In the event that the bulkhead gate is overtopped (reservoir level exceeds EL 69 when bulkhead gate is closed), it cannot be removed unless a pool of water fills the space between it and the radial gate behind. The closed bulkhead becomes critically stressed when the reservoir level overtops it to EL 71.4.

It is not possible to engage the lifting tackle while overtopping is occurring. While there is any risk that the bulkhead gate may be overtopped, the lifting gear is to be left engaged so that the gate can be raised once the downstream radial gate becomes operable.

### G.4.3. Discharge Regulation

In the event that a radial gate is inoperable in a partially open position, the bulkhead gate can be used for flow regulation provided that the lower lip of the radial gate is clear of the underflow jet.

Where a pool exists between the bulkhead gate and a radial gate under flow conditions, the bulkhead gate will be subjected to additional pull-down and possibly subjected to vortex-induced vibrations. When this condition occurs, the bulkhead gate is to be lowered to dewater the pool. The bulkhead gate can then be adjusted to regulate the flow provided the underflow jet remains below the lower lip of the radial gate.



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## G.5. RADIAL GATE OPERATING PROCEDURES



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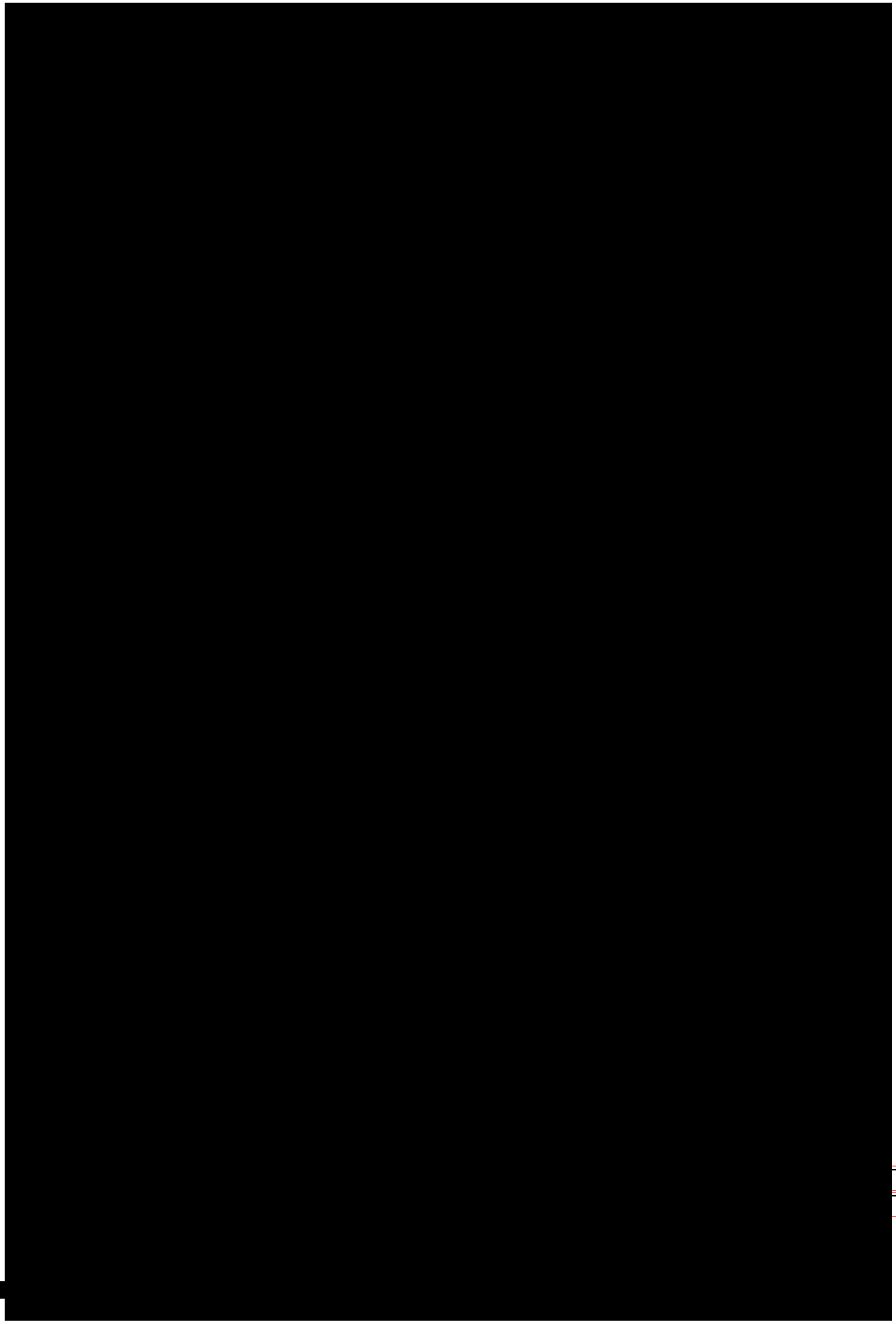



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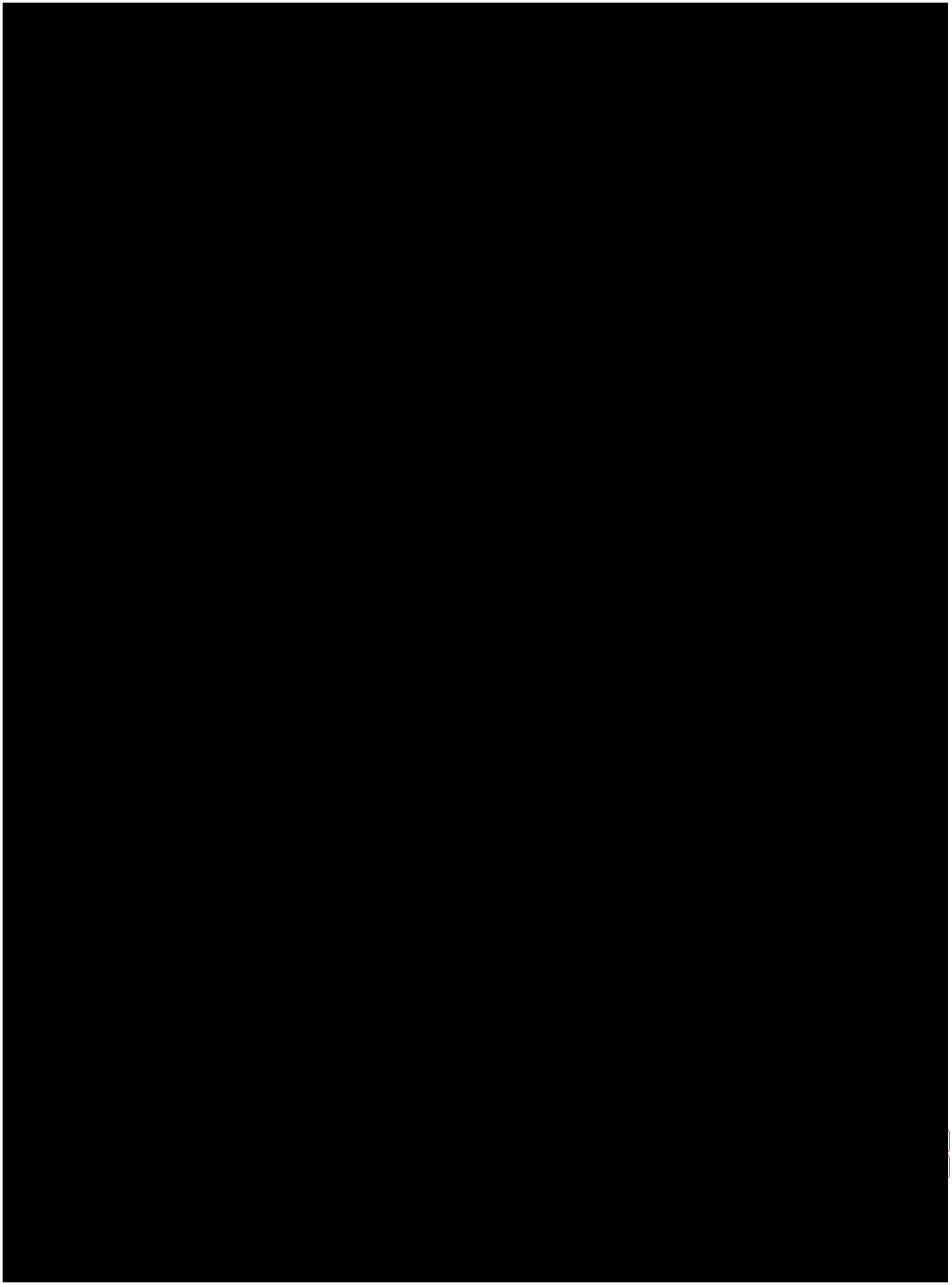

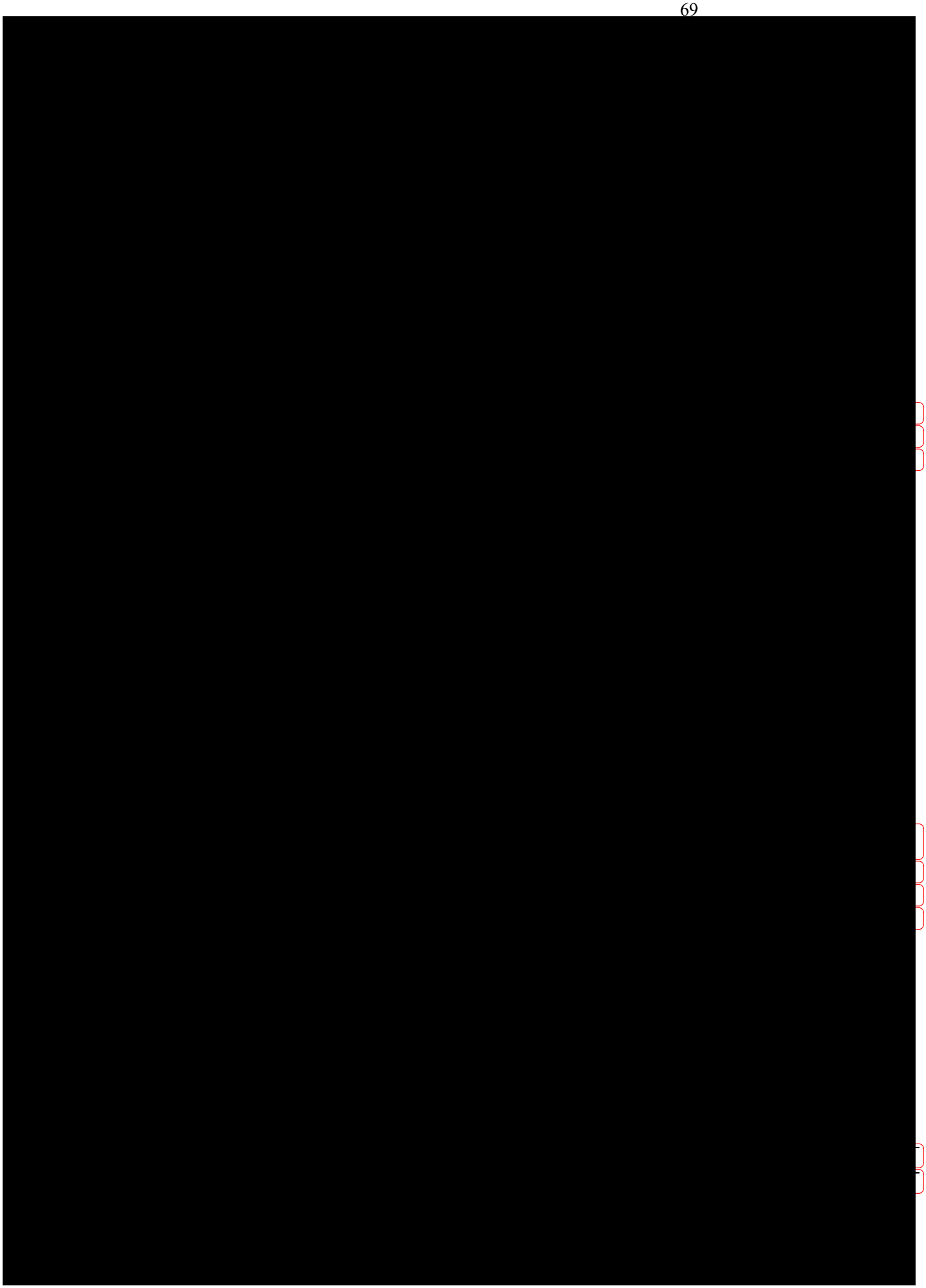

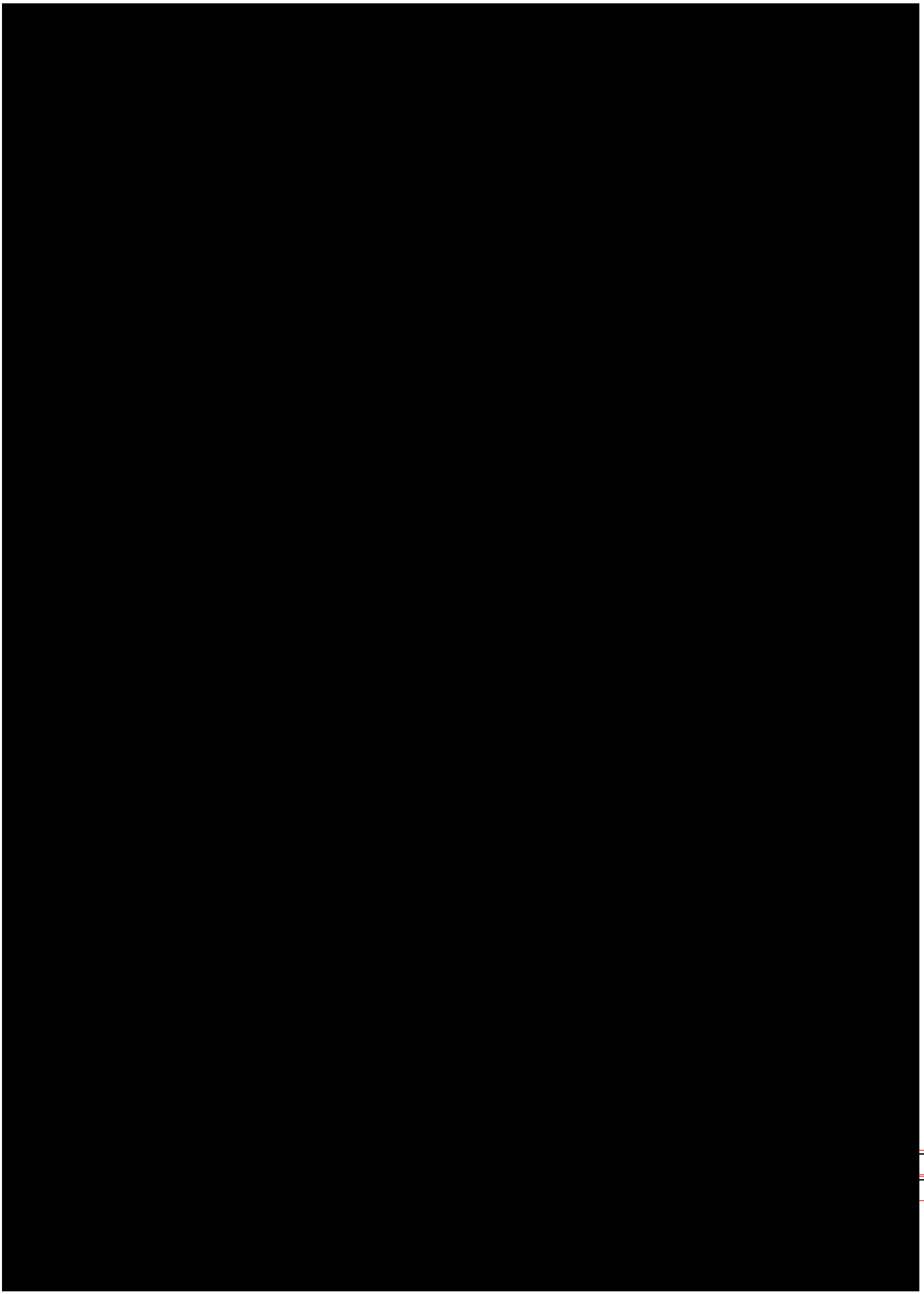



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[a] Dam Crest Flood
[b] Overtops dam wall
[c] Increases due to changes to Procedure 4.

## I.6. SOMERSET DAM FLOODS

Somerset Dam floods were estimated using the rainfalls and runoff routing model already discussed. Inflows to Somerset Dam, assuming the dam to be in existence and full, were calculated, as well as flow at the site without the dam in the catchment. The forty-eight hour PMP storm event was found to be critical, though the long duration PMP's produced very large flood volumes. Table I-6 lists results for the forty-eight hour duration storms.

**Table I-6**
**Somerset Dam Floods**
**(for two-day storm duration)+**

| AEP % | Peak Inflow ($m^3$/sec) | Peak Outflow ($m^3$/sec) | Flood Volume (ML) | Peak Lake Level (m AHD) |
|---|---|---|---|---|
| 1 | 3,500 | 1,700 | 421,000 | 103.5 |
| 0.1 | 4,500 | 2,600 | 690,000 | 104.5 |
| 0.01 | 6,800 | 4,700 | 1,042,000 | 107.5 |
| 0.001 | 9,200 | 6,300 | 1,412,000 | 109.3 |
| PMF* | 16,000 | 9,600 | 1,952,800 | 112.0 |

+ - NB. This duration does NOT give the maximum Peak Inflow for a given AEP
* - Overtopped, estimated flow based on no dam failure

## I.7 FLOOD CONTROL OPERATION MODEL

Floods in the Brisbane River catchment above Wivenhoe Dam can originate in either the Stanley River or upper Brisbane River catchment or both. Both of the dams are capable of being operated in a number of ways, each of which will reduce the flow downstream. However, in order to achieve maximum reduction of flooding downstream of Wivenhoe Dam, it was necessary to review the operations at Somerset and Wivenhoe Dams using a flood operations simulation model.

The most recent flood studies have reviewed the basic hydrologic algorithms in the operational models used in the earlier study and modified them to incorporate additional features relating to gate openings and closings. The revised design flood hydrology and operational model algorithms were then used to re-examine the original five possible operational procedures for each of Somerset Dam and Wivenhoe Dam, giving twenty-five possible combinations to be re-considered. The procedures previously developed for Wivenhoe Dam were designed so that initial release operations did not adversely affect later operations in the event of later rainfall causing the magnitude of the flood to exceed the original estimate.

The procedures previously developed were also designed to restrict flooding in the lower catchment to the lowest level of the following categories where practicable:

(i) low level bridges submerged, Fernvale bridge open;



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(ii) all bridges except Mt. Crosby Weir and to Fernvale bridges submerged;

(iii) all bridges submerged, no damage to urban areas;

(iv) damage to urban areas due to peak flow from downstream catchment, no releases from Wivenhoe Dam contributing to peak flow;

(v) extensive damage to urban areas due to combined Wivenhoe Dam releases and downstream flow, Wivenhoe Dam release component of peak flow minimum practicable.

The previous flood studies recommended that one procedure be selected for the operation at Somerset Dam. This procedure had two advantages over the other procedures tested. Firstly, it was feasible for all magnitudes of Stanley River floods tested and, secondly, it was the simplest procedure to carry out. The re-analysis confirmed this conclusion.

The previous flood studies concluded that procedures for Wivenhoe Dam be reduced to four by combining two procedures into one. The resulting four procedures formed a hierarchy and the procedure to be adopted advances to the next procedure as the flood magnitude increases. The re-analysis confirmed this conclusion.

A Real Time Flood Operations Model for Somerset and Wivenhoe has been developed as part of the "Brisbane River and Pine River Flood Studies". This model incorporates the revised operational algorithms.

* Assume no failure of Wivenhoe Dam or Somerset Dam



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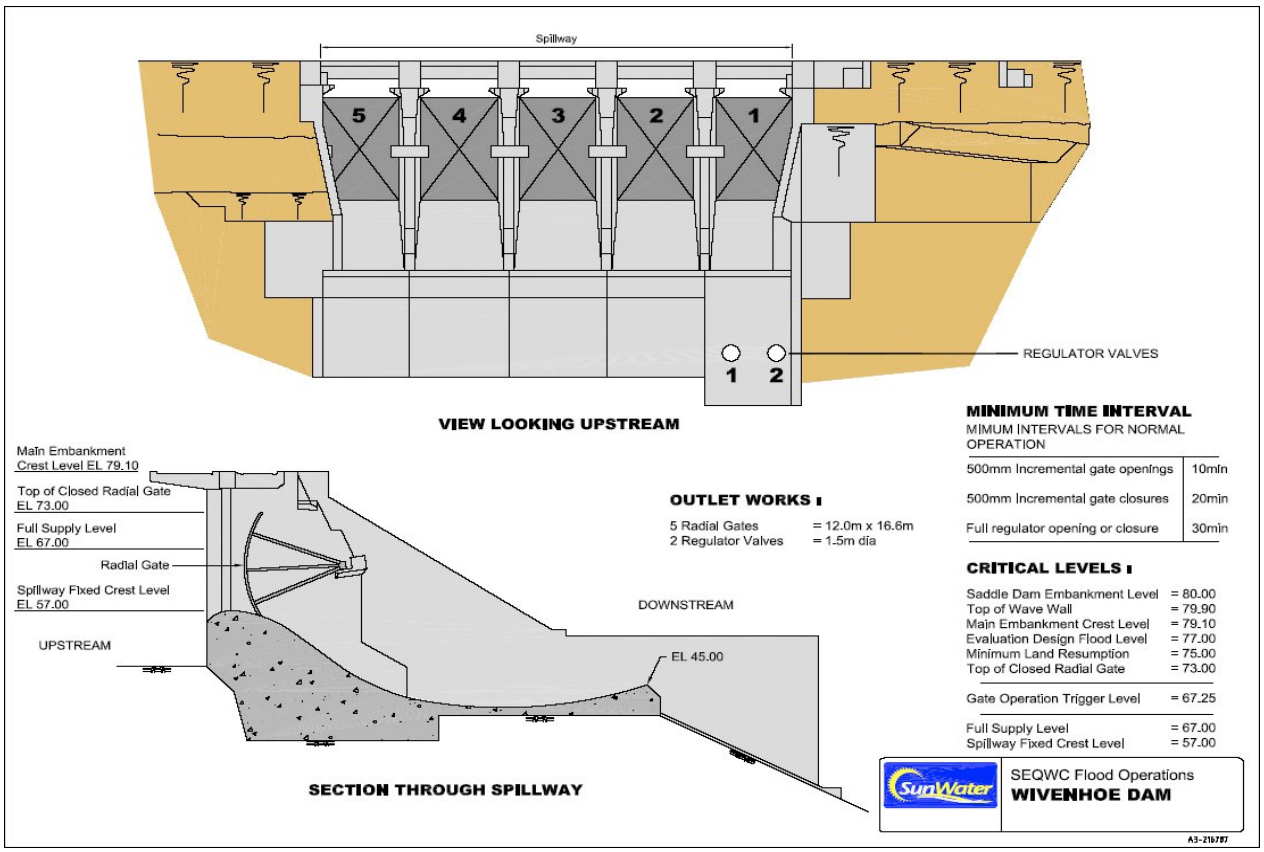
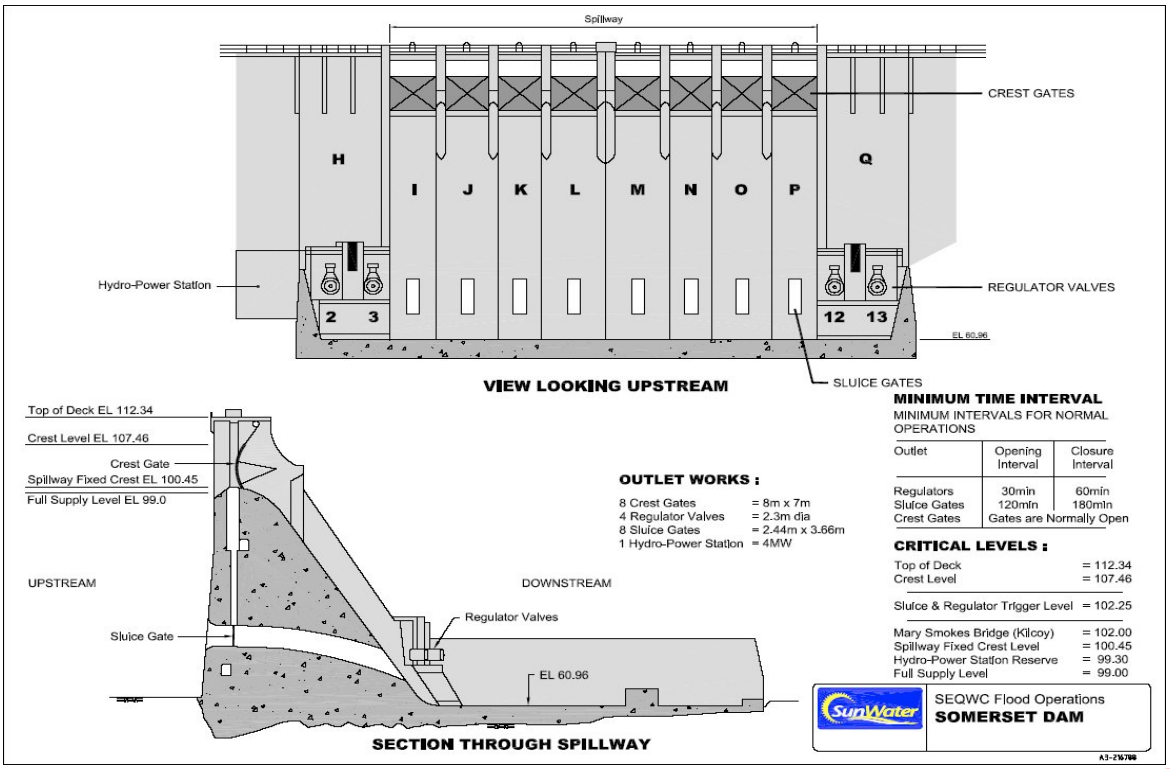
# APPENDIX J DRAWINGS



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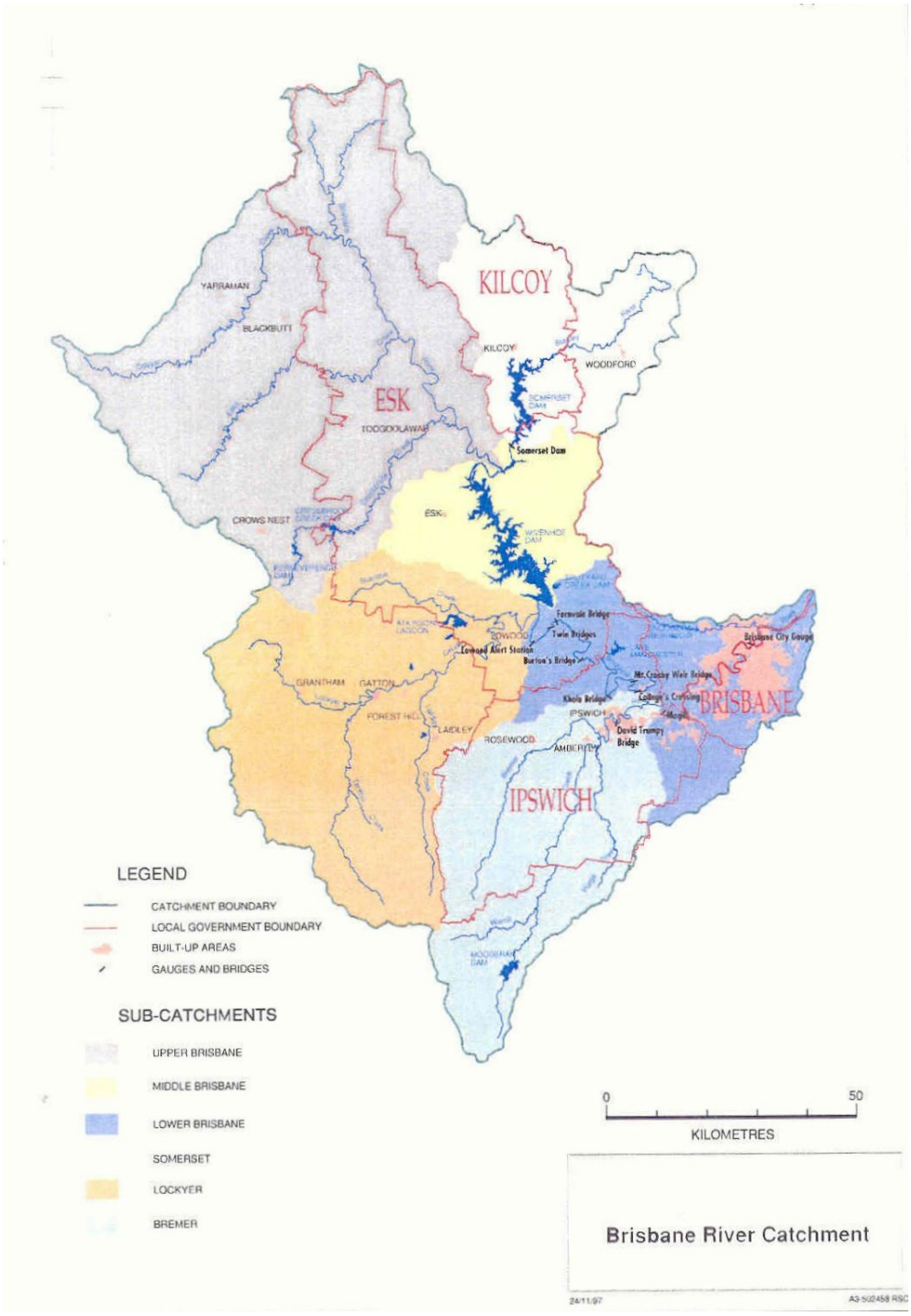
# APPENDIX K BRISBANE RIVER CATCHMENT



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**Additional Provisions during Construction Works 2004/05**

**Auxiliary Spillway Area**

The embankment forming the temporary road diversion that acts as a coffer dam is to be retained in place until the construction of the fuse plug has proceeded past EL 74, and then its removal is only to proceed once the written approval of a Senior Flood Operations Engineer has been obtained.

**Gated Spillway Area**

The following provisions will apply for works undertaken within the gated spillway:

The opening of spillway gates to discharge floodwaters is at the sole discretion of the Senior Flood Operations Engineer;

There is to be no obstruction of any spillway bay without the written approval of the Senior Flood Operations Engineer;

All gates are to be capable of being operated at short notice during a flood if required. To ensure this capability is maintained Table 8.6 specifies limitations that apply to the number of bays in which works may be occurring

at any time. This table also nominates a target notice period to be provided by the Senior Flood Operations Engineer for the removal of construction material from the spillway bays prior to their use for releases. However the Senior Flood Operations Engineer is not constrained to provide this length of notice before operating any particular gate if its earlier operation is considered necessary.

**Table 8.6 – Gated Spillway Area Works Restrictions**

| Dam Level | Season | Maximum number of bays that may be occupied at any time | Comments |
|---|---|---|---|
| Below EL 64.0 | Winter (May to September) | 3 | 12 hours notice to clear spillway |
| Below EL 64.0 | Summer (October to April) | 2 | 12 hours notice to clear spillway |
| Above EL 64.0 | Winter (May to September) | 2 | 12 hours notice to clear spillway |
| Above EL 64.0 | Summer (October to April) | 2 | 12 hours notice to clear spillway |
| Above EL 66.0 | Flood Season (January to April) | 1 | Preferably not gate 1 or 5, 6 hours notice to clear spillway |

A maximum of one gate may be treated as inoperable and remain closed if a flood will severely damage works if it is opened, and the expected flood magnitude can be catered for with 4 gates. The other gates are to be operated in accordance with the existing flood operational procedures but to compensate for the loss of flow in the closed gate. As the flood rises to the top of the closed gate at an EL 73 m AHD, the gate is incrementally raised to prevent it from being overtopped. It is noted that a large flood is required for the lake level to reach EL 73 m AHD.

The Corporation must prepare a Standing Operating Procedure for the conduct of works in the gated spillway whereby the above provisions are met such the capacity to achieve the dam's operational objectives is maintained.