

South East Queensland Water Corporation Limited



South East Queensland  
**WATER CORPORATION**  
LIMITED

**MANUAL OF  
OPERATIONAL PROCEDURES  
FOR FLOOD RELEASES  
FROM  
NORTH PINE DAM**

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South East Queensland Water Corporation Limited

## TABLE OF CONTENTS

<b>1. INTRODUCTION .....</b>	<b>5</b>
1.1 PREFACE.....	5
1.2 MEANING OF TERMS .....	6
1.3 PURPOSE OF MANUAL .....	6
1.4 LEGAL AUTHORITY.....	7
1.5 APPLICATION AND EFFECT.....	7
1.6 DATE OF EFFECT .....	7
1.7 OBSERVANCE OF MANUAL .....	7
1.8 PROVISION FOR VARIATIONS TO MANUAL .....	7
1.9 DISTRIBUTION OF MANUAL .....	7
1.10 AUTHORITY TO USE DISCRETION.....	7
<b>2. DIRECTION OF OPERATIONS .....</b>	<b>8</b>
2.1 STATUTORY OPERATION.....	8
2.1.1 <i>Designation of Senior Flood Operations Engineer</i> .....	8
2.1.2 <i>Designation of Flood Operations Engineers</i> .....	8
2.2 QUALIFICATIONS AND EXPERIENCE OF ENGINEERS .....	8
2.2.1 <i>Qualifications</i> .....	8
2.2.2 <i>Experience</i> .....	8
2.3 SCHEDULE OF AUTHORITIES .....	9
2.4 TRAINING .....	9
2.5 DAM OPERATION ARRANGEMENTS .....	9
2.6 RESPONSIBILITIES OF THE SENIOR FLOOD OPERATIONS ENGINEER.....	10
2.7 RESPONSIBILITIES OF THE FLOOD OPERATIONS ENGINEER .....	10
2.8 REASONABLE DISCRETION.....	10
2.9 REPORT .....	10
<b>3. FLOOD RELEASE OBJECTIVES .....</b>	<b>11</b>
3.1 GENERAL.....	11
3.2 STRUCTURAL SAFETY OF DAM .....	11
3.3 EXTREME FLOODS AND CLOSELY SPACED LARGE FLOODS .....	11
3.4 MAINTENANCE OF FULL SUPPLY LEVEL.....	12
3.5 DISRUPTION TO DOWNSTREAM AREAS.....	13
<b>4. FLOOD CLASSIFICATION.....</b>	<b>14</b>
<b>5. FLOOD MONITORING AND WARNING SYSTEM.....</b>	<b>15</b>
5.1 GENERAL.....	15
5.2 OPERATION .....	15
5.3 STORAGE OF DOCUMENTATION .....	16

## South East Queensland Water Corporation Limited

5.4	KEY REFERENCE LOCATIONS.....	16
5.5	REFERENCE GAUGE VALUES .....	16
<b>6.</b>	<b>COMMUNICATIONS .....</b>	<b>17</b>
6.1	COMMUNICATIONS BETWEEN STAFF .....	17
6.2	DISSEMINATION OF INFORMATION.....	17
6.3	NATURE OF INFORMATION.....	17
6.4	RELEASE OF INFORMATION TO THE PUBLIC.....	18
<b>7.</b>	<b>REVIEW.....</b>	<b>19</b>
7.1	INTRODUCTION.....	19
7.2	PERSONNEL TRAINING .....	19
7.3	MONITORING AND WARNING SYSTEM AND COMMUNICATION NETWORKS.....	19
7.4	OPERATIONAL REVIEW .....	20
7.5	FIVE YEARLY REVIEW .....	20
<b>8.</b>	<b>FLOOD RELEASE OPERATION .....</b>	<b>21</b>
8.1	INTRODUCTION.....	21
8.2	INITIAL ACTION.....	21
8.3	GATE OPERATION .....	22
8.4	OPERATING PROCEDURE.....	24
<b>9.</b>	<b>EMERGENCY.....</b>	<b>25</b>
9.1	INTRODUCTION.....	25
9.2	COMMUNICATIONS FAILURE.....	25
9.3	SPILLWAY GATE/GATES OUT OF SERVICE.....	25
9.4	EQUIPMENT FAILURE .....	25
<b>APPENDIX A.</b>	<b>EXTRACT FROM ACT .....</b>	<b>26</b>
<b>APPENDIX B.</b>	<b>AGENCIES HOLDING DOCUMENTS.....</b>	<b>28</b>
<b>APPENDIX C.</b>	<b>KEY REFERENCE LOCATIONS .....</b>	<b>29</b>
<b>APPENDIX D.</b>	<b>TABLES OF GATE SETTINGS.....</b>	<b>30</b>
<b>APPENDIX E.</b>	<b>AUXILIARY EQUIPMENT .....</b>	<b>56</b>
<b>APPENDIX F.</b>	<b>STORAGE AND INFLOW DETERMINATION .....</b>	<b>57</b>

South East Queensland Water Corporation Limited

## LIST OF TABLES

Table 3-1 – Critical Levels for North Pine Dam .....	11
Table 3-2 - North Pine Dam Estimated Peak Lake Levels .....	12
Table 4-1 - Flood Classification.....	14

## LIST OF FIGURES

Figure 8-1 - Section of North Pine Dam Spillway .....	21
Figure 8-2 - View of Spillway Looking Downstream .....	22
Figure 8-3 - Gate Operation Sequence .....	23

# 1. INTRODUCTION

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## 1.1 PREFACE

Given its size and location, it is imperative that North Pine Dam 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 that the South East Queensland Water Corporation's Technical Advisory Committee cause to be prepared a manual of operational procedures for the dam 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 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.

An expanded flood monitoring and warning radio telemetry network (ALERT) has been installed in the Pine River catchment. Additionally a computerised flood operational model, which allows for rainfall and river modelling in real time based on data from the ALERT network has been developed, implemented and fully commissioned. The small flood storage capacity of the dam and the relatively short response time between flood producing rains and the occurrence of flooding means that prescribed operating procedures must be followed. However the ALERT and flood modelling system allows earlier warning of an imminent flood event.

The operational effectiveness of the system has led to some flexibility in the operating procedures being identified. Some minor changes to the procedures have been incorporated in this current review as a consequence.

The review has not included a formal risk management assessment process. It is intended this shall form part of a broader assessment regarding dam and flood management and then be incorporated in this manual.

Flood studies undertaken since the last review in 2002 supported the basic procedures for operation of the dam and these have not been varied. Neither have the primary objectives of ensuring safety of the dam, its ability to deal with extreme and closely spaced floods, and protection of urban areas from those defined in the original manual.

Changes from the previous revision have mostly arisen from the refinement of gate opening and closing sequences based upon experience obtained during flood events whilst using the real time flood operations model. Other changes have been necessary to fit in with the new regulatory regime provided by the commencement of *Water Act 2000*.

A review of the hydrology for the North Pine Dam was carried out in June 2007 (SunWater 2007). The review has identified that the dam is incapable of passing the latest version of the Probable Maximum Flood without overtopping.

## 1.2 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 and Water;
"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;
"Dam"	means dam to which this Manual applies, that is North Pine Dam;
"Dam Supervisor"	means the senior on-site officer at North Pine Dam;
"EL"	means elevation in metres from Australian Height Datum;
"Flood Operations Engineer"	means the person designated at the time to direct the operations of North Pine Dam under the general direction of the Senior Flood Operations Engineer and in accordance with the procedures in this Manual;
"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 <sup>3</sup> /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 Releases from North Pine Dam"	means the current version of this Manual;
"PMF"	Means the Probable Maximum Flood and is the largest flood that could physically occur at the location of interest;
"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

## 1.3 PURPOSE OF MANUAL

The purpose of this Manual is to define standard procedures for the operation of North Pine Dam during flood periods.

## 1.4 LEGAL AUTHORITY

This manual has been prepared in accordance with the provisions of Part 6 Division 2 of the Act.

## 1.5 APPLICATION AND EFFECT

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

## 1.6 DATE OF EFFECT

The procedures in this Manual shall have effect on and from the date on which 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.

## 1.7 OBSERVANCE OF MANUAL

This Manual contains the operational procedures for North Pine Dam for the purposes of flood releases, and must be applied by the Headworks Operator for the operation of the dam.

## 1.8 PROVISION FOR VARIATIONS TO MANUAL

If the Corporation is of the opinion that the procedures in this Manual should be amended, altered or varied, it must submit for approval as soon as practical a request, which is in accordance with the flood mitigation provisions of the *Water Act 2000*, to the Chief Executive setting out the circumstances and the exact nature of the amendment, alteration or variation sought. The Chief Executive may require the Corporation amend the Manual by written notice.

## 1.9 DISTRIBUTION OF MANUAL

The Corporation must regard the manual as a Controlled Document and ensure that only controlled manuals are used in the direction of flood release 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 are approved.

Before using this Manual for the direction of flood releases, the Headworks Operator must ensure that it is the current version of the Controlled Document.

## 1.10 AUTHORITY TO USE DISCRETION

Where it is reasonable to expect that the safety of the dam will not be reduced, temporary deviations from the procedures detailed in this manual may be made in accordance with Section 2.8 of this Manual.

## **2. DIRECTION OF OPERATIONS**

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### **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 North Pine Dam.

The Headworks Operator is responsible for operating and maintaining North Pine Dam 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 Engineers**

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 dam 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 dam 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 dam.

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 dam 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.

### **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 1<sup>st</sup> October of each year.

The Headworks Operator must, 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 unforeseen 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 suitable 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.

### 2.5 DAM OPERATION ARRANGEMENTS

For the purposes of operation of the dam 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 dam 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 of 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 release 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 release 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.

## **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 dam and the report must contain details of the procedures used, the reasons therefore and other pertinent information. The Headworks Operator shall forward a copy of the report to the Chief Executive within six weeks of the event referred to.

### 3. FLOOD RELEASE OBJECTIVES

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#### 3.1 GENERAL

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

- (a) Ensure the structural safety of the dam;
- (b) Minimise disruption to urban and rural life in the valleys of the North Pine River and its major tributaries; and
- (c) Retain storage at the full supply level.

#### 3.2 STRUCTURAL SAFETY OF DAM

The structural safety of North Pine Dam must be the first consideration in flood release operations. Failure could have catastrophic consequences due to the magnitude of flood damage that would be caused downstream, and also due to the loss of a water supply source.

The most likely cause of damage is overtopping. North Pine Dam consists of a mass concrete section, and earthen embankment sections. Concrete sections can withstand limited overtopping without damage. Failure of such sections is rare but when they do occur, they occur suddenly without warning, creating very severe and destructive flood waves. Embankment sections on the other hand will washout rapidly if overtopped and cause failure of the dam, resulting in severe flooding downstream. The prevention of overtopping is thus of paramount importance.

The safety of the dam therefore depends primarily on the proper operation of the spillway gates, which are used to control maximum flood levels. Such operation in turn relies on the proper functioning of the mechanical hoist mechanisms and their electric power supply and controls. This equipment is located just above full supply level and can become inundated. Once inundated, the electric winches will not work and backup systems which themselves may not be able to respond quickly enough to handle large flows will be needed to adjust gate positions.

The critical levels for the operation of the dam and the consequence of their exceedance are as follows:

**Table 3-1 – Critical Levels for North Pine Dam**

Description	AHD(m)	Possible Consequence
Embankment Crest	43.28	Breach of embankment by erosion
Radial Gate Switch Gear	41.66	Electric motors submerged, backup opening system required
Above Full Supply Level at Start of Storm	39.60	Reduced capacity to handle large floods

#### 3.3 EXTREME FLOODS AND CLOSELY SPACED LARGE FLOODS

The spillway of North Pine Dam has adequate capacity with gates operating correctly to handle current maximum estimates of runoff from precipitation. Techniques for estimating extreme

floods have in the past had a tendency to increase flood magnitudes as more has become known about possible flooding. There is still a very remote possibility that floods are possible which would overtop the dam. Such events however require intense rainfall to produce the necessary runoff. Pre-release of storage at flood producing levels could reduce the risk of overtopping but this may result in discharges exceeding inflows. Such a measure should be taken only after careful consideration of the reliability of precipitation forecasts and of perceived antecedent conditions.

Anticipated reservoir levels for various magnitude inflows under normal gate operations and with one gate inoperable in the closed position are as follows:

**Table 3-2 - North Pine Dam Estimated Peak Lake Levels**

Average Recurrence Interval of Inflows (Years)	Normal Gate Operations (m AHD)	One Gate Inoperable (m AHD)
2	39.92	39.96
5	40.01	40.07
10	40.07	40.14
20	40.17	40.24
50	40.28	40.38
100	40.39	40.50
200	40.51	40.64
500	40.67	40.84
1 000	40.85	41.03
10 000	41.14	41.38
100 000	41.71	42.44
1 000 000	42.95	43.62*
PMF	43.47*	43.89*

Source: SunWater (2007), "North Pine Dam Design Flood Hydrology", Report No:G-81802-09-01-03, June 2007

Notes:

1. Crest of embankment is EL 43.28.
2. \* Indicates overtopping of the embankment.
3. MFL determined assuming broad crested weir flow over embankments

Historical records show that there is a significant probability of two or more flood producing storms occurring in the Brisbane area within a short time of each other.

In order to be prepared to meet such a situation the stored flood waters from one storm should be discharged from the dam after a flood as quickly as would be consistent with the other major operating principles.

### 3.4 MAINTENANCE OF FULL SUPPLY LEVEL

North Pine Dam provides water for the cities of Brisbane and Redcliffe and for the Shires of Caboolture and Pine Rivers. For this reason the storage level after a flood release must be near full supply level. Failure to achieve this objective may place the water supply to these areas at unnecessary risk.

### **3.5 DISRUPTION TO DOWNSTREAM AREAS**

Under normal flood situations, community disruption will be limited to inundation of bridges and low-lying paddocks.

In the case of major floods, several houses immediately downstream of the dam may be subject to partial inundation.

In the case of dam break, floods can be generated which are well in excess of natural floods. Dam break floods or the detection of situations that may result in dam break shall be grounds for the emergency evacuation of threatened areas by the appropriate counter disaster agencies.

## 4. FLOOD CLASSIFICATION

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

**Table 4-1 - Flood Classification**

Flood Classification	Event Description
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 must 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.)

## **5. FLOOD MONITORING AND WARNING SYSTEM**

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### **5.1 GENERAL**

A real time flood monitoring and warning system is established in the Pine River catchment. This system is an event reporting radio telemetry system, (ALERT), used to collect, transmit and receive rainfall and streamflow information. The system consists of field stations which automatically record rainfall and/or river heights at selected locations in the catchments.

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 real time flood operations 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.

A log of the performance of the system (ALERT and RTFM) shall 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 faults.

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 LOCATIONS**

Key field 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 alter these locations or vary flood classification levels, agreement must first be obtained between the Corporation, Headworks Operator 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 C.

Gauge boards which can be read manually must be maintained as part of the ALERT stations installed at any key reference location. The Corporation must have procedures to ensure such gauge boards are read in the event of failure of a field station to operate.

### **5.5 REFERENCE GAUGE VALUES**

Other agencies such as the Bureau of Meteorology, the Pine Rivers Shire 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 Corporations field stations is shared with such agencies.



## **6. COMMUNICATIONS**

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### **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 North Pine Dam.

The Headworks Operator is responsible for ensuring that adequate communication exists at all times between the Flood Operations Engineer and site staff at North Pine Dam. 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**

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. These agencies shall include agencies holding Controlled Documents (Appendix B). For this purpose, the Corporation must maintain a Register of Contact Persons for Information, their means of contact and the type of information 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 Flood Operations Engineer must supply information (refer Section 6.3) to each of these contact persons during dam releases.

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 dam is likely until flood release operations are completed.

Some agencies have responsibilities for formal flood predictions, the interpretation of flood information and advice to the public. The Corporation, Headworks Operator, Senior Flood Operations Engineer and Flood Operations Engineer must liaise and consult with those agencies with a view to ensuring all information relative to the flood event is consistent, and used and disseminated in accordance with agreed responsibilities.

### **6.3 NATURE OF INFORMATION**

When, in the opinion of the Flood Operations Engineer, a flood situation is imminent and gate operations are likely, the Flood Operations Engineer must advise those listed in the Register of Contact Persons for Information of:

- (a) the current and proposed releases from the dam; and
- (b) the estimated flow rates and water heights at the key reference locations listed below:
  - Grant Street at Whiteside
  - Railway Bridge on North Pine River at Wyllie Park, Petrie

- Railway Bridge on South Pine River at Bald Hills

This information is to be updated at intervals as better and more accurate information becomes available.

#### **6.4 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 dam to the public and the media.

The Bureau of Meteorology has responsibility for issuing severe weather 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.

## **7. REVIEW**

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### **7.1 INTRODUCTION**

This review of the Manual has addressed the mechanisms of delegation and control of the dam in periods of operation of the dam for flood releases. The dam may overtop in the eventuality that the flood-gate control systems fail to operate or partially malfunction during the passage of a major flood or combination of floods.

Procedures and systems have been developed since the last revision that should enable lower risk operation of the dam for flood release 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 of this Manual.

### **7.2 PERSONNEL TRAINING**

The Headworks Operator must prepare a report by 1st October 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 and Water.

### **7.3 MONITORING AND WARNING SYSTEM AND COMMUNICATION NETWORKS**

The Headworks Operator must prepare a report 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.

The Corporation must review the report, and taking into account its own log of the performance of the field equipment, take any action considered necessary for the proper functioning and improvement of the system. A copy of this report must be forwarded to the Chief Executive of the Department of Natural Resources and Water.

#### **7.4 OPERATIONAL REVIEW**

After each significant flood event, the Corporation must review the effectiveness of the operational procedures contained in this manual. The Headworks Operator is required to prepare a report for submission to the Corporation within six weeks of any flood event that requires mobilisation of the Flood Control Centre.

#### **7.5 FIVE YEARLY REVIEW**

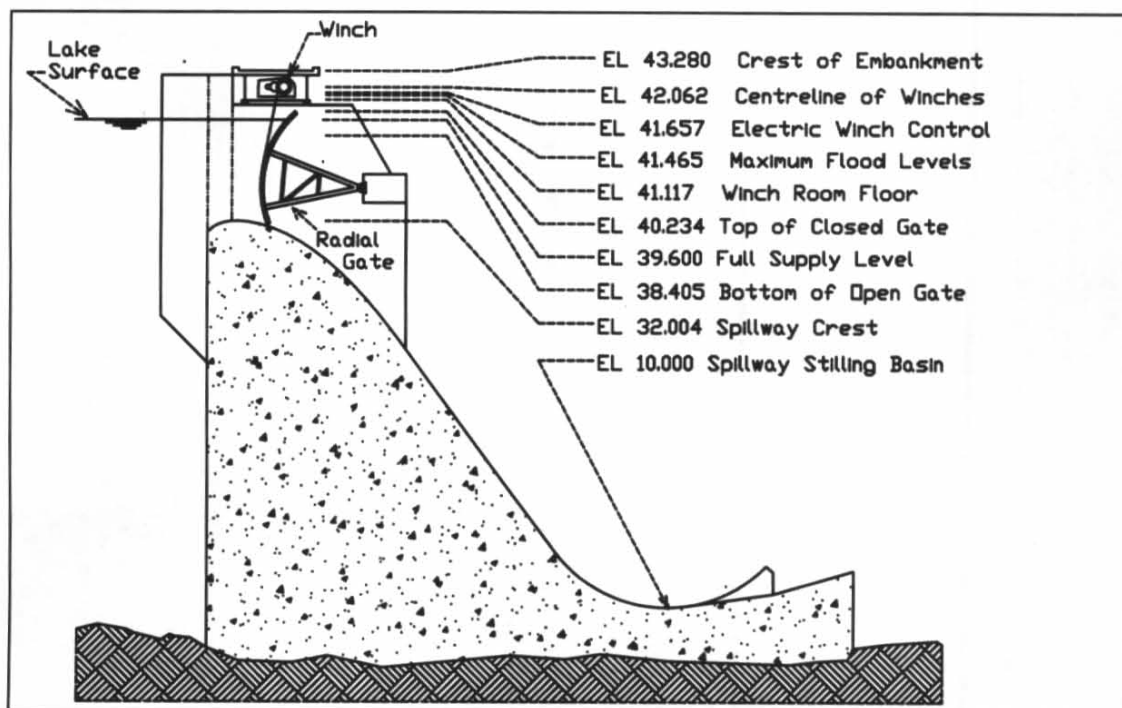
Prior to the expiry of the approval period, the Corporation must review the Manual pursuant to Section 6 Division 2 of the Act. The review is to take into account the continued suitability of the communication network, and the flood monitoring and warning system as well as hydrological and hydraulic engineering assessments of the operational procedures.

## 8. FLOOD RELEASE OPERATION

### 8.1 INTRODUCTION

North Pine dam is a water supply dam with only a small flood storage compartment above full supply level. It effectively has no provision for flood mitigation. The peak inflow from critical storms may occur approximately two to four hours after the commencement of heavy rain. Because of this, operation of the dam during flood periods is restricted to satisfying the flood release objectives and the rapid response of the catchment to flood rains. Once the dam is full, floods will pass through the reservoir with little mitigation.

Figure 8-1 - Section of North Pine Dam Spillway

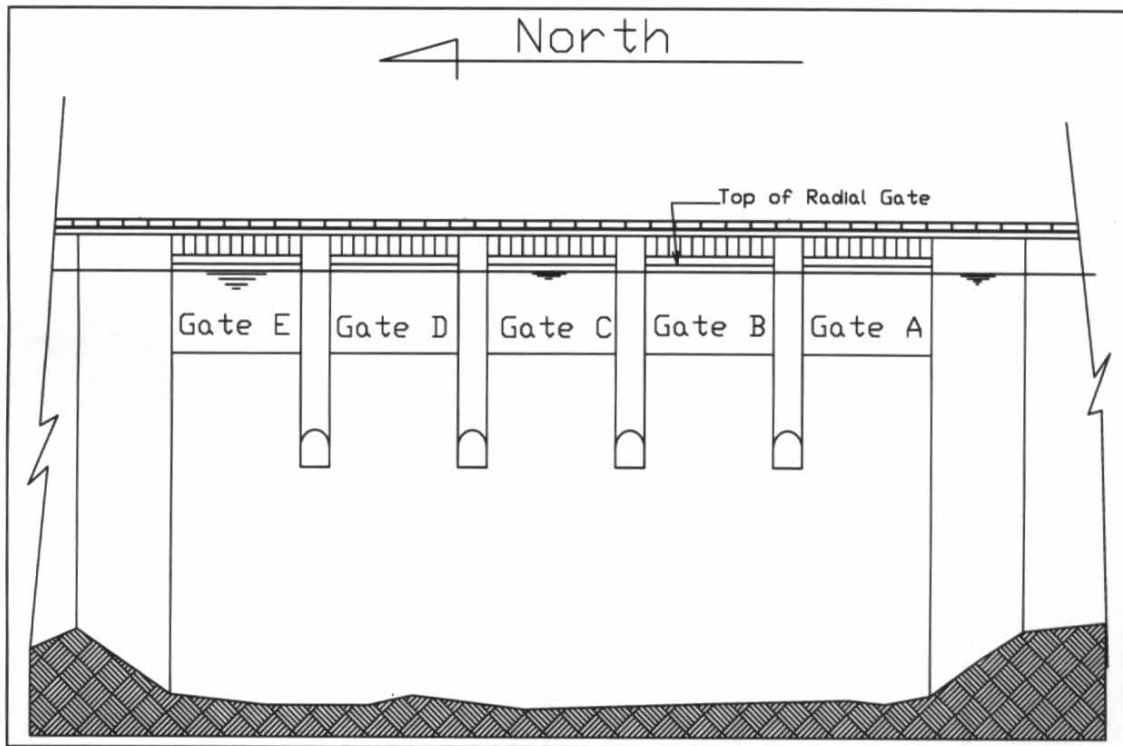


### 8.2 INITIAL ACTION

With the onset of heavy rain, initial runoff is to be stored until the lake level exceeds FSL by 50mm, whereafter the spillway gates must be used to control lake level in accordance with the procedures laid out herein. This action is to keep Young's Crossing open for as long as possible.

The Dam Supervisor must ensure that the gates on the road approaches to the Grant Street causeway are also closed before flood releases occur.

Figure 8-2 - View of Spillway Looking Downstream



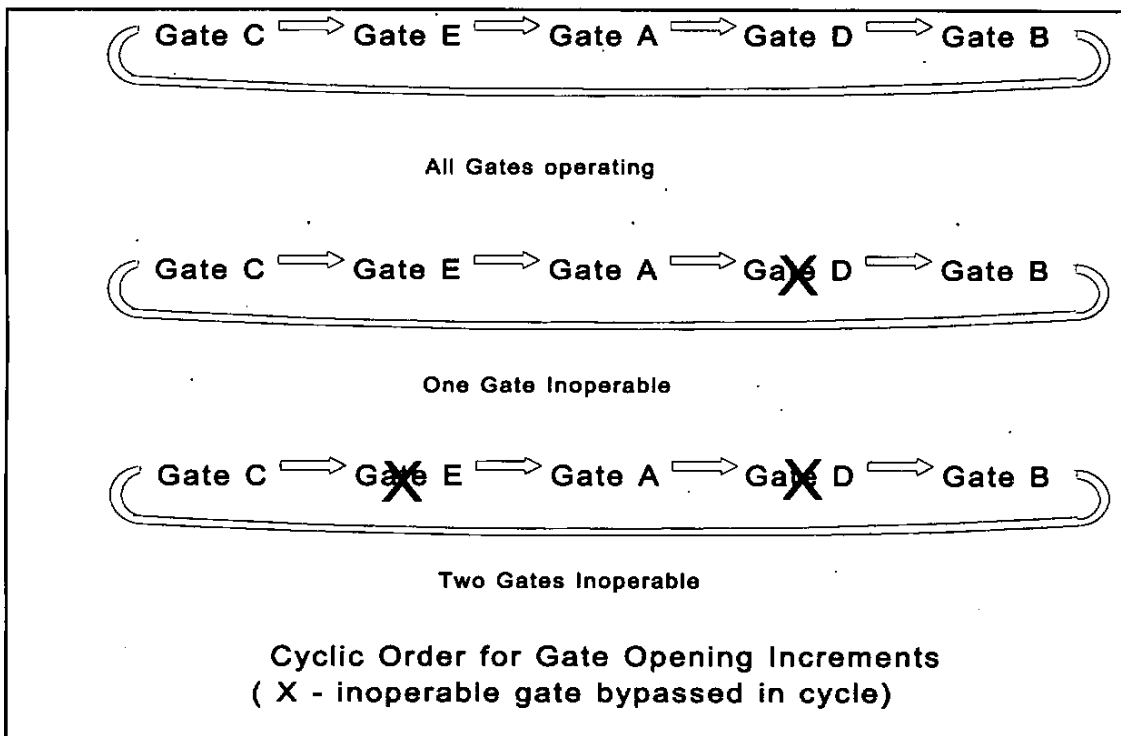
### 8.3 GATE OPERATION

To minimise potential damage to the dissipator and the river-bed and banks downstream, the gates must be opened incrementally in accordance with the cyclic sequences shown in Figure 8.3. There is to be no more than one increment between any two operable spillway gates.

The operating rule involves assigning gate positions to corresponding lake levels in the reservoir, as detailed in Appendix D.

As the lake level rises, the gates are to be opened in cyclic sequence to positions assigned for the current lake level. A gate opening increment is required for each water level rise of 15 mm, except for the initial two increments that involve water level rises of 50 mm.

Figure 8-3 - Gate Operation Sequence



As the lake level falls, the gates are to be closed in the reverse of the order shown in Figure 8.3. During small, long duration flood events, extra gate openings may be used on the falling limb of the storage levels to minimise the duration of gate operation. Such openings should not result in discharges that are higher than the peak discharge encountered on the rising limb of the flood event. Gate opening sequences should be in accordance with Figure 8.3 and minimum gate opening and closing intervals should be observed at all times during this operation.

Where one or more gates are inoperable, the same sequencing applies except that the inoperable gates must be ignored in the cycle and their increments passed on to the next gate in the sequence. The cumulative number of increments taken by all gates at any particular lake level thus remains unaltered save that the total number of available gate increments has been reduced by inoperable gates. The process is illustrated in Figure 8.3 where inoperable gates have been crossed out.

Appendix D contains tables of gate position settings against lake levels for the situations where all gates are operating and where one gate is inoperable.

The minimum time interval between increments of gates in the spillway must be determined by prevailing circumstances. Short time intervals between successive increments of the gates can cause surging of the river downstream of the dam. This is undesirable as it may damage banks or put at risk near-stream population and property. The adoption of long periods between increments could result in excessive maximum flood levels within the dam. The higher maximum flood levels are associated with higher probabilities of damage or failure of the dam.

It is therefore necessary to consider two situations for the operation of the gates:

1. Gradually varying lake levels where long intervals between gate increments are sufficient to control the lake level; and

2. Rapidly varying lake levels where high inflows are causing the lake level to rise rapidly.

In the case of gradually varying lake levels, the minimum time interval between successive operations of any spillway gate must be determined by the lake level as shown below:

Lake Level	Opening Interval	Closing Interval
Below EL 39.9 m	15 min	15 min
EL 39.9 to 40.5 m	10 min	10 min
Above EL 40.5 m	5 min	5 min

## 8.4 OPERATING PROCEDURE

Spillway gates are to be opened to successive settings in the order specified in Appendix D subject to the provisions of Section 8.3 above.

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

If the actual gate settings fall more than three settings below the cumulative number of minimum settings of Table D.1, then successive gate operations are to be carried out as rapidly as possible until the minimum settings are achieved.

As soon as the lake level begins to fall, the gates are to be closed in the order specified in Appendix D. At no time are the gate settings to be less than those specified in Appendix D. As noted in Section 8.3 for small floods of long duration, additional gate openings may be used to reduce the duration of gate operation. Such openings should not result in discharges that are higher than the peak discharge encountered on the rising limb of the flood event. Gate opening sequences should be in accordance with Figure 8.3 and minimum gate opening and closing intervals should be observed at all times during this operation.

To prevent the stranding of fish downstream of North Pine Dam after flood events final closure should be as slow as practicable and whenever practicable, closure should be on a weekend so that volunteer rescuers can be mobilised.

The last gate closing is to take place when the lake level falls to EL 39.550.



## **9. EMERGENCY**

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### **9.1 INTRODUCTION**

While every care has been exercised in the design and construction of the dam, there still remains a low risk that the dam 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 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;
- ⇒ Damage to the dam by earthquake;
- ⇒ Damage to the dam as an act of war or terrorism; and
- ⇒ Other rarer mechanisms.

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

### **9.2 COMMUNICATIONS FAILURE**

In the event of normal communications being lost between the Flood Operations Engineer and North Pine dam, the Dam Supervisor is to adopt the procedure set out in Section 8.3 above.

### **9.3 SPILLWAY GATE/GATES OUT OF SERVICE**

In the event of one or more spillway gates being out of service, the remaining operable gates are to be opened in the cyclic order as shown in Figure 8.3.

The provisions of Section 8.3 are to be applied in this case also.

### **9.4 EQUIPMENT FAILURE**

In the event of an electrical failure of the gate lifting machinery, the gates are to be operated using the auxiliary compressed air drive mechanism.

Further details of the auxiliary equipment are contained in Appendix E.

## **APPENDIX A. EXTRACT FROM ACT**

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### **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) If the owner complies with the chief executive's request, the chief executive must, by gazette notice, approve the manual as amended.

(4) The approval of the manual as amended may 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.

(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-

- (a) review, and if necessary, update the manual; and
- (b) give a copy of it to the chief executive under section 497.

**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.

## **APPENDIX B. AGENCIES HOLDING DOCUMENTS**

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### **AGENCIES HOLDING CONTROLLED DOCUMENTS**

**OF**

### **MANUAL OF OPERATIONAL PROCEDURES**

**FOR**

### **FLOOD RELEASES FROM NORTH PINE DAM**

<b>Role</b>	<b>Organisation</b>
Dam Owner	South East Queensland Water Corporation
Emergency Services	Department of Emergency Services, Disaster Operations Brisbane City Counter Disaster Committee Pine Rivers Shire Counter Disaster Committee
Severe Weather Warning Authority	Bureau of Meteorology
Primary Response Authorities	Brisbane City Council Pine Rivers Shire Council
Regulator	Department of Natural Resources and Water
Headworks Operator	SunWater

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

## APPENDIX C. KEY REFERENCE LOCATIONS

### PINE RIVERS SHIRE

Gauge	FLOOD CLASSIFICATION			
	Minor	Moderate	Major	1974 Flood
Grant Street, Whiteside	any release from dam			
Railway Bridge, Wyllie Park, Petrie	4.0	5.0	6.0	5.1
Railway Bridge, South Pine River, Bald Hills		3.5	6.0	5.18

Note: Values are in metres AHD

Dam Supervisor to close gates on road approaches to the Grant Street causeway before releases occur (Section 8.2 refers).

## **APPENDIX D. TABLES OF GATE SETTINGS**

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### **Object of Tables**

To provide the target gate settings for any particular lake level in situations when all gates are operational or when one gate is inoperable.

### **Method of Use:**

For rising lake level:

As the lake surface reaches each level shown in the left column, one gate has to be opened to the next setting. This continues until the limit of movement of the gates (setting 23) is reached.

For falling lake level:

As the lake surface falls below each level shown in the left column, one gate has to be closed to the next setting.

### **Cautionary Notes:**

1. The discharges shown in the right hand columns of Tables E are estimates only and may be revised when actual measurements can be taken.
2. The actual openings of the gates are set by electro-mechanical controls. As no direct measurement of gate position is available and these settings could drift with time, the actual openings may vary slightly from those originally determined. The discharges indicated are estimated on the basis of the design openings.

South East Queensland Water Corporation Limited

Table D.0 - Design Spillway Gate Settings

Gate Setting	Gate Opening (m)	Top of Gate (EL)	Gate Setting	Gate Opening (m)	Top of Gate (EL)
1	0.152	40.362	13	3.810	41.885
2	0.457	40.547	14	4.115	41.940
3	0.762	40.720	15	4.420	41.984
4	1.067	40.886	16	4.724	42.016
5	1.372	41.041	17	5.029	42.037
6	1.676	41.185	18	5.334	42.047
7	1.981	41.316	19	5.639	42.047
8	2.286	41.349	20	5.944	42.047
9	2.591	41.549	21	6.248	42.047
10	2.896	41.650	22	6.553	42.047
11	3.200	41.740	23	6.858	42.047
12	3.505	41.817			

Table D.1 - Minimum Gate Settings for North Pine Dam

All Gates Operational						
Level (m AHD)	Gate A	Gate B	Gate C	Gate D	Gate E	Discharge (m <sup>3</sup> /sec)
39.600	closed	closed	closed	closed	closed	0
39.650	closed	closed	1	closed	closed	16
39.700	closed	closed	1	closed	1	32
39.715	1	closed	1	closed	1	48
39.730	1	closed	1	1	1	64
39.745	1	1	1	1	1	80
39.760	1	1	2	1	1	104
39.775	1	1	2	1	2	129
39.790	2	1	2	1	2	153
39.805	2	1	2	2	2	177
39.820	2	2	2	2	2	201
39.835	2	2	3	2	2	228
39.850	2	2	3	2	3	254
39.865	3	2	3	2	3	281
39.880	3	2	3	3	3	307
39.895	3	3	3	3	3	334
39.910	3	3	4	3	3	362
39.925	3	3	4	3	4	390
39.940	4	3	4	3	4	417
39.955	4	3	4	4	4	445
39.970	4	4	4	4	4	473
39.985	4	4	5	4	4	500
40.000	4	4	5	4	5	527
40.015	5	4	5	4	5	554
40.030	5	4	5	5	5	581
40.045	5	5	5	5	5	608
40.060	5	5	6	5	5	636
40.075	5	5	6	5	6	664
40.090	6	5	6	5	6	692
40.105	6	5	6	6	6	720
40.120	6	6	6	6	6	748
40.135	6	6	7	6	6	776
40.150	6	6	7	6	7	804
40.165	7	6	7	6	7	832



South East Queensland Water Corporation Limited

**Table D.1 - Minimum Gate Settings for North Pine Dam**

<b>All Gates Operational</b>						
40.180	7	6	7	7	7	860
40.195	7	7	7	7	7	888
40.210	7	7	8	7	7	916
40.225	7	7	8	7	8	943
40.240	8	7	8	7	8	970
40.255	8	7	8	8	8	998
40.270	8	8	8	8	8	1025
40.285	8	8	9	8	8	1052
40.300	8	8	9	8	9	1079
40.315	9	8	9	8	9	1106
40.330	9	8	9	9	9	1133
40.345	9	9	9	9	9	1160
40.360	9	9	10	9	9	1187
40.375	9	9	10	9	10	1213
40.390	10	9	10	9	10	1240
40.405	10	9	10	10	10	1266
40.420	10	10	10	10	10	1293
40.435	10	10	11	10	10	1320
40.450	10	10	11	10	11	1347
40.465	11	10	11	10	11	1374
40.480	11	10	11	11	11	1401
40.495	11	11	11	11	11	1428
40.510	11	11	12	11	11	1455
40.525	11	11	12	11	12	1482
40.540	12	11	12	11	12	1510
40.555	12	11	12	12	12	1537
40.570	12	12	12	12	12	1564
40.585	12	12	13	12	12	1593
40.600	12	12	13	12	13	1621
40.615	13	12	13	12	13	1650
40.630	13	12	13	13	13	1678
40.645	13	13	13	13	13	1707
40.660	13	13	14	13	13	1736
40.675	13	13	14	13	14	1765
40.690	14	13	14	13	14	1794
40.705	14	13	14	14	14	1823

## South East Queensland Water Corporation Limited

<b>Table D.1 - Minimum Gate Settings for North Pine Dam</b>						
<b>All Gates Operational</b>						
40.720	14	14	14	14	14	1852
40.735	14	14	15	14	14	1883
40.750	14	14	15	14	15	1914
40.765	15	14	15	14	15	1946
40.780	15	14	15	15	15	1978
40.795	15	15	15	15	15	2009
40.810	15	15	16	15	15	2044
40.825	15	15	16	15	16	2079
40.840	16	15	16	15	16	2114
40.855	16	15	16	16	16	2148
40.870	16	16	16	16	16	2183
40.885	16	16	17	16	16	2222
40.900	16	16	17	16	17	2260
40.915	17	16	17	16	17	2299
40.930	17	16	17	17	17	2337
40.945	17	17	17	17	17	2376
40.960	17	17	18	17	17	2415
40.975	17	17	18	17	18	2453
40.990	18	17	18	17	18	2491
41.005	18	17	18	18	18	2530
41.020	18	18	18	18	18	2568
41.035	18	18	19	18	18	2601
41.050	18	18	19	18	19	2635
41.065	19	18	19	18	19	2668
41.080	19	18	19	19	19	2701
41.095	19	19	19	19	19	2734
41.110	19	19	20	19	19	2773
41.125	19	19	20	19	20	2806
41.140	20	19	20	19	20	2842
41.155	20	19	20	20	20	2878
41.170	20	20	20	20	20	2913
41.185	20	20	21	20	20	3026
41.200	20	20	21	20	21	3142
41.215	21	20	21	20	21	3260
41.230	21	20	21	21	21	3382
41.245	21	21	21	21	21	3506

South East Queensland Water Corporation Limited

<b>Table D.1 - Minimum Gate Settings for North Pine Dam</b>						
<b>All Gates Operational</b>						
41.260	21	21	22	21	21	3515
41.275	21	21	22	21	22	3524
41.290	22	21	22	21	22	3532
41.305	22	21	22	22	22	3541
41.320	22	22	22	22	22	3550
41.335	22	22	23	22	22	3559
41.350	22	22	23	22	23	3567
41.365	23	22	23	22	23	3576
41.380	23	22	23	23	23	3585
41.395	23	23	23	23	23	3594

Table D.2 - Minimum Gate Settings for North Pine Dam						
Gate A Stuck or Inoperable						
Level (m AHD)	Gate A	Gate B	Gate C	Gate D	Gate E	Discharge (m <sup>3</sup> /sec)
39.600	closed	closed	closed	closed	closed	0
39.650	closed	closed	1	closed	closed	16
39.700	closed	closed	1	closed	1	32
39.715	closed	closed	1	1	1	48
39.730	closed	1	1	1	1	64
39.745	closed	1	2	1	1	88
39.760	closed	1	2	1	2	112
39.775	closed	1	2	2	2	137
39.790	closed	2	2	2	2	161
39.805	closed	2	3	2	2	187
39.820	closed	2	3	2	3	213
39.835	closed	2	3	3	3	240
39.850	closed	3	3	3	3	266
39.865	closed	3	4	3	3	294
39.880	closed	3	4	3	4	322
39.895	closed	3	4	4	4	349
39.910	closed	4	4	4	4	377
39.925	closed	4	5	4	4	404
39.940	closed	4	5	4	5	430
39.955	closed	4	5	5	5	457
39.970	closed	5	5	5	5	484
39.985	closed	5	6	5	5	512
40.000	closed	5	6	5	6	539
40.015	closed	5	6	6	6	567
40.030	closed	6	6	6	6	595
40.045	closed	6	7	6	6	623
40.060	closed	6	7	6	7	650
40.075	closed	6	7	7	7	678
40.090	closed	7	7	7	7	706
40.105	closed	7	8	7	7	732
40.120	closed	7	8	7	8	759
40.135	closed	7	8	8	8	786
40.150	closed	8	8	8	8	812
40.165	closed	8	9	8	8	839

<b>Table D.2 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate A Stuck or Inoperable</b>						
40.180	closed	8	9	8	9	866
40.195	closed	8	9	9	9	893
40.210	closed	9	9	9	9	920
40.225	closed	9	10	9	9	946
40.240	closed	9	10	9	10	972
40.255	closed	9	10	10	10	998
40.270	closed	10	10	10	10	1024
40.285	closed	10	11	10	10	1050
40.300	closed	10	11	10	11	1077
40.315	closed	10	11	11	11	1103
40.330	closed	11	11	11	11	1130
40.345	closed	11	12	11	11	1156
40.360	closed	11	12	11	12	1183
40.375	closed	11	12	12	12	1210
40.390	closed	12	12	12	12	1237
40.405	closed	12	13	12	12	1264
40.420	closed	12	13	12	13	1292
40.435	closed	12	13	13	13	1320
40.450	closed	13	13	13	13	1348
40.465	closed	13	14	13	13	1377
40.480	closed	13	14	13	14	1405
40.495	closed	13	14	14	14	1433
40.510	closed	14	14	14	14	1462
40.525	closed	14	15	14	14	1492
40.540	closed	14	15	14	15	1523
40.555	closed	14	15	15	15	1554
40.570	closed	15	15	15	15	1585
40.585	closed	15	16	15	15	1619
40.600	closed	15	16	15	16	1653
40.615	closed	15	16	16	16	1687
40.630	closed	16	16	16	16	1721
40.645	closed	16	17	16	16	1759
40.660	closed	16	17	16	17	1797
40.675	closed	16	17	17	17	1834
40.690	closed	17	17	17	17	1872
40.705	closed	17	18	17	17	1911

South East Queensland Water Corporation Limited

<b>Table D.2 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate A Stuck or Inoperable</b>						
40.720	closed	17	18	17	18	1949
40.735	closed	17	18	18	18	1988
40.750	closed	18	18	18	18	2026
40.765	closed	18	19	18	18	2060
40.780	closed	18	19	18	19	2094
40.795	closed	18	19	19	19	2127
40.810	closed	19	19	19	19	2161
40.825	closed	19	20	19	19	2277
40.840	closed	19	20	19	20	2395
40.855	closed	19	20	20	20	2516
40.870	closed	20	20	20	20	2639
40.885	closed	20	21	20	20	2645
40.900	closed	20	21	20	21	2650
40.915	closed	20	21	21	21	2655
40.930	closed	21	21	21	21	2660
40.945	closed	21	22	21	21	2667
40.960	closed	21	22	21	22	2674
40.975	closed	21	22	22	22	2680
40.990	closed	22	22	22	22	2687
41.005	closed	22	23	22	22	2694
41.020	closed	22	23	22	23	2701
41.035	closed	22	23	23	23	2708
41.050	closed	23	23	23	23	2715
41.065	closed	23	23	23	23	2722
41.080	closed	23	23	23	23	2729
41.095	closed	23	23	23	23	2736
41.110	closed	23	23	23	23	2742
41.125	closed	23	23	23	23	2749
41.140	closed	23	23	23	23	2756
41.155	closed	23	23	23	23	2763
41.170	closed	23	23	23	23	2770
41.185	closed	23	23	23	23	2777
41.200	closed	23	23	23	23	2784
41.215	closed	23	23	23	23	2791
41.230	closed	23	23	23	23	2798
41.245	closed	23	23	23	23	2805

South East Queensland Water Corporation Limited

<b>Table D.2 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate A Stuck or Inoperable</b>						
41.260	closed	23	23	23	23	2812
41.275	closed	23	23	23	23	2819
41.290	closed	23	23	23	23	2826
41.305	closed	23	23	23	23	2833
41.320	closed	23	23	23	23	2840
41.335	closed	23	23	23	23	2847
41.350	closed	23	23	23	23	2854
41.365	closed	23	23	23	23	2861
41.380	closed	23	23	23	23	2868
41.395	closed	23	23	23	23	2875

Table D.3 - Minimum Gate Settings for North Pine Dam						
Gate B Stuck or Inoperable						
Level (m AHD)	Gate A	Gate B	Gate C	Gate D	Gate E	Discharge (m <sup>3</sup> /sec)
39.600	closed	closed	closed	closed	closed	0
39.650	closed	closed	1	closed	closed	16
39.700	closed	closed	1	closed	1	32
39.715	1	closed	1	closed	1	48
39.730	1	closed	1	1	1	64
39.745	1	closed	2	1	1	88
39.760	1	closed	2	1	2	112
39.775	2	closed	2	1	2	137
39.790	2	closed	2	2	2	161
39.805	2	closed	3	2	2	187
39.820	2	closed	3	2	3	213
39.835	3	closed	3	2	3	240
39.850	3	closed	3	3	3	266
39.865	3	closed	4	3	3	294
39.880	3	closed	4	3	4	322
39.895	4	closed	4	3	4	349
39.910	4	closed	4	4	4	377
39.925	4	closed	5	4	4	404
39.940	4	closed	5	4	5	430
39.955	5	closed	5	4	5	457
39.970	5	closed	5	5	5	484
39.985	5	closed	6	5	5	512
40.000	5	closed	6	5	6	539
40.015	6	closed	6	5	6	567
40.030	6	closed	6	6	6	595
40.045	6	closed	7	6	6	623
40.060	6	closed	7	6	7	650
40.075	7	closed	7	6	7	678
40.090	7	closed	7	7	7	706
40.105	7	closed	8	7	7	732
40.120	7	closed	8	7	8	759
40.135	8	closed	8	7	8	786
40.150	8	closed	8	8	8	812
40.165	8	closed	9	8	8	839
40.180	8	closed	9	8	9	866



<b>Table D.3 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate B Stuck or Inoperable</b>						
40.195	9	closed	9	8	9	893
40.210	9	closed	9	9	9	920
40.225	9	closed	10	9	9	946
40.240	9	closed	10	9	10	972
40.255	10	closed	10	9	10	998
40.270	10	closed	10	10	10	1024
40.285	10	closed	11	10	10	1050
40.300	10	closed	11	10	11	1077
40.315	11	closed	11	10	11	1103
40.330	11	closed	11	11	11	1130
40.345	11	closed	12	11	11	1156
40.360	11	closed	12	11	12	1183
40.375	12	closed	12	11	12	1210
40.390	12	closed	12	12	12	1237
40.405	12	closed	13	12	12	1264
40.420	12	closed	13	12	13	1292
40.435	13	closed	13	12	13	1320
40.450	13	closed	13	13	13	1348
40.465	13	closed	14	13	13	1377
40.480	13	closed	14	13	14	1405
40.495	14	closed	14	13	14	1433
40.510	14	closed	14	14	14	1462
40.525	14	closed	15	14	14	1492
40.540	14	closed	15	14	15	1523
40.555	15	closed	15	14	15	1554
40.570	15	closed	15	15	15	1585
40.585	15	closed	16	15	15	1619
40.600	15	closed	16	15	16	1653
40.615	16	closed	16	15	16	1687
40.630	16	closed	16	16	16	1721
40.645	16	closed	17	16	16	1759
40.660	16	closed	17	16	17	1797
40.675	17	closed	17	16	17	1834
40.690	17	closed	17	17	17	1872
40.705	17	closed	18	17	17	1911
40.720	17	closed	18	17	18	1949

<b>Table D.3 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate B Stuck or Inoperable</b>						
40.735	18	closed	18	17	18	1988
40.750	18	closed	18	18	18	2026
40.765	18	closed	19	18	18	2060
40.780	18	closed	19	18	19	2094
40.795	19	closed	19	18	19	2127
40.810	19	closed	19	19	19	2161
40.825	19	closed	20	19	19	2277
40.840	19	closed	20	19	20	2395
40.855	20	closed	20	19	20	2516
40.870	20	closed	20	20	20	2639
40.885	20	closed	21	20	20	2645
40.900	20	closed	21	20	21	2650
40.915	21	closed	21	20	21	2655
40.930	21	closed	21	21	21	2660
40.945	21	closed	22	21	21	2667
40.960	21	closed	22	21	22	2674
40.975	22	closed	22	21	22	2680
40.990	22	closed	22	22	22	2687
41.005	22	closed	23	22	22	2694
41.020	22	closed	23	22	23	2701
41.035	23	closed	23	22	23	2708
41.050	23	closed	23	23	23	2715
41.065	23	closed	23	23	23	2722
41.080	23	closed	23	23	23	2729
41.095	23	closed	23	23	23	2736
41.110	23	closed	23	23	23	2742
41.125	23	closed	23	23	23	2749
41.140	23	closed	23	23	23	2756
41.155	23	closed	23	23	23	2763
41.170	23	closed	23	23	23	2770
41.185	23	closed	23	23	23	2777
41.200	23	closed	23	23	23	2784
41.215	23	closed	23	23	23	2791
41.230	23	closed	23	23	23	2798
41.245	23	closed	23	23	23	2805
41.260	23	closed	23	23	23	2812

South East Queensland Water Corporation Limited

<b>Table D.3 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate B Stuck or Inoperable</b>						
41.275	23	closed	23	23	23	2819
41.290	23	closed	23	23	23	2826
41.305	23	closed	23	23	23	2833
41.320	23	closed	23	23	23	2840
41.335	23	closed	23	23	23	2847
41.350	23	closed	23	23	23	2854
41.365	23	closed	23	23	23	2861
41.380	23	closed	23	23	23	2868
41.395	23	closed	23	23	23	2875

Table D.4 - Minimum Gate Settings for North Pine Dam						
Gate C Stuck or Inoperable						
Level (m AHD)	Gate A	Gate B	Gate C	Gate D	Gate E	Discharge (m <sup>3</sup> /sec)
39.600	closed	closed	closed	closed	closed	0
39.650	closed	closed	closed	closed	1	16
39.700	1	closed	closed	closed	1	32
39.715	1	closed	closed	1	1	48
39.730	1	1	closed	1	1	64
39.745	1	1	closed	1	2	88
39.760	2	1	closed	1	2	112
39.775	2	1	closed	2	2	137
39.790	2	2	closed	2	2	161
39.805	2	2	closed	2	3	187
39.820	3	2	closed	2	3	213
39.835	3	2	closed	3	3	240
39.850	3	3	closed	3	3	266
39.865	3	3	closed	3	4	294
39.880	4	3	closed	3	4	322
39.895	4	3	closed	4	4	349
39.910	4	4	closed	4	4	377
39.925	4	4	closed	4	5	404
39.940	5	4	closed	4	5	430
39.955	5	4	closed	5	5	457
39.970	5	5	closed	5	5	484
39.985	5	5	closed	5	6	512
40.000	6	5	closed	5	6	539
40.015	6	5	closed	6	6	567
40.030	6	6	closed	6	6	595
40.045	6	6	closed	6	7	623
40.060	7	6	closed	6	7	650
40.075	7	6	closed	7	7	678
40.090	7	7	closed	7	7	706
40.105	7	7	closed	7	8	732
40.120	8	7	closed	7	8	759
40.135	8	7	closed	8	8	786

<b>Table D.4 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate C Stuck or Inoperable</b>						
40.150	8	8	closed	8	8	812
40.165	8	8	closed	8	9	839
40.180	9	8	closed	8	9	866
40.195	9	8	closed	9	9	893
40.210	9	9	closed	9	9	920
40.225	9	9	closed	9	10	946
40.240	10	9	closed	9	10	972
40.255	10	9	closed	10	10	998
40.270	10	10	closed	10	10	1024
40.285	10	10	closed	10	11	1050
40.300	11	10	closed	10	11	1077
40.315	11	10	closed	11	11	1103
40.330	11	11	closed	11	11	1130
40.345	11	11	closed	11	12	1156
40.360	12	11	closed	11	12	1183
40.375	12	11	closed	12	12	1210
40.390	12	12	closed	12	12	1237
40.405	12	12	closed	12	13	1264
40.420	13	12	closed	12	13	1292
40.435	13	12	closed	13	13	1320
40.450	13	13	closed	13	13	1348
40.465	13	13	closed	13	14	1377
40.480	14	13	closed	13	14	1405
40.495	14	13	closed	14	14	1433
40.510	14	14	closed	14	14	1462
40.525	14	14	closed	14	15	1492
40.540	15	14	closed	14	15	1523
40.555	15	14	closed	15	15	1554
40.570	15	15	closed	15	15	1585
40.585	15	15	closed	15	16	1619
40.600	16	15	closed	15	16	1653
40.615	16	15	closed	16	16	1687
40.630	16	16	closed	16	16	1721
40.645	16	16	closed	16	17	1759
40.660	17	16	closed	16	17	1797

<b>Table D.4 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate C Stuck or Inoperable</b>						
40.675	17	16	closed	17	17	1834
40.690	17	17	closed	17	17	1872
40.705	17	17	closed	17	18	1911
40.720	18	17	closed	17	18	1949
40.735	18	17	closed	18	18	1988
40.750	18	18	closed	18	18	2026
40.765	18	18	closed	18	19	2060
40.780	19	18	closed	18	19	2094
40.795	19	18	closed	19	19	2127
40.810	19	19	closed	19	19	2161
40.825	19	19	closed	19	20	2277
40.840	20	19	closed	19	20	2395
40.855	20	19	closed	20	20	2516
40.870	20	20	closed	20	20	2639
40.885	20	20	closed	20	21	2645
40.900	21	20	closed	20	21	2650
40.915	21	20	closed	21	21	2655
40.930	21	21	closed	21	21	2660
40.945	21	21	closed	21	22	2667
40.960	22	21	closed	21	22	2674
40.975	22	21	closed	22	22	2680
40.990	22	22	closed	22	22	2687
41.005	22	22	closed	22	23	2694
41.020	23	22	closed	22	23	2701
41.035	23	22	closed	23	23	2708
41.050	23	23	closed	23	23	2715
41.065	23	23	closed	23	23	2722
41.080	23	23	closed	23	23	2729
41.095	23	23	closed	23	23	2736
41.110	23	23	closed	23	23	2742
41.125	23	23	closed	23	23	2749
41.140	23	23	closed	23	23	2756
41.155	23	23	closed	23	23	2763
41.170	23	23	closed	23	23	2770
41.185	23	23	closed	23	23	2777

South East Queensland Water Corporation Limited

<b>Table D.4 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate C Stuck or Inoperable</b>						
41.200	23	23	closed	23	23	2784
41.215	23	23	closed	23	23	2791
41.230	23	23	closed	23	23	2798
41.245	23	23	closed	23	23	2805
41.260	23	23	closed	23	23	2812
41.275	23	23	closed	23	23	2819
41.290	23	23	closed	23	23	2826
41.305	23	23	closed	23	23	2833
41.320	23	23	closed	23	23	2840
41.335	23	23	closed	23	23	2847
41.350	23	23	closed	23	23	2854
41.365	23	23	closed	23	23	2861
41.380	23	23	closed	23	23	2868
41.395	23	23	closed	23	23	2875

South East Queensland Water Corporation Limited

Table D.5 - Minimum Gate Settings for North Pine Dam						
Gate D Stuck or Inoperable						
Level (m AHD)	Gate A	Gate B	Gate C	Gate D	Gate E	Discharge (m <sup>3</sup> /sec)
39.600	closed	closed	closed	closed	closed	0
39.650	closed	closed	1	closed	closed	16
39.700	closed	closed	1	closed	1	32
39.715	1	closed	1	closed	1	48
39.730	1	1	1	closed	1	64
39.745	1	1	2	closed	1	88
39.760	1	1	2	closed	2	112
39.775	2	1	2	closed	2	137
39.790	2	2	2	closed	2	161
39.805	2	2	3	closed	2	187
39.820	2	2	3	closed	3	213
39.835	3	2	3	closed	3	240
39.850	3	3	3	closed	3	266
39.865	3	3	4	closed	3	294
39.880	3	3	4	closed	4	322
39.895	4	3	4	closed	4	349
39.910	4	4	4	closed	4	377
39.925	4	4	5	closed	4	404
39.940	4	4	5	closed	5	430
39.955	5	4	5	closed	5	457
39.970	5	5	5	closed	5	484
39.985	5	5	6	closed	5	512
40.000	5	5	6	closed	6	539
40.015	6	5	6	closed	6	567
40.030	6	6	6	closed	6	595
40.045	6	6	7	closed	6	623
40.060	6	6	7	closed	7	650
40.075	7	6	7	closed	7	678
40.090	7	7	7	closed	7	706
40.105	7	7	8	closed	7	732
40.120	7	7	8	closed	8	759
40.135	8	7	8	closed	8	786



<b>Table D.5 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate D Stuck or Inoperable</b>						
40.150	8	8	8	closed	8	812
40.165	8	8	9	closed	8	839
40.180	8	8	9	closed	9	866
40.195	9	8	9	closed	9	893
40.210	9	9	9	closed	9	920
40.225	9	9	10	closed	9	946
40.240	9	9	10	closed	10	972
40.255	10	9	10	closed	10	998
40.270	10	10	10	closed	10	1024
40.285	10	10	11	closed	10	1050
40.300	10	10	11	closed	11	1077
40.315	11	10	11	closed	11	1103
40.330	11	11	11	closed	11	1130
40.345	11	11	12	closed	11	1156
40.360	11	11	12	closed	12	1183
40.375	12	11	12	closed	12	1210
40.390	12	12	12	closed	12	1237
40.405	12	12	13	closed	12	1264
40.420	12	12	13	closed	13	1292
40.435	13	12	13	closed	13	1320
40.450	13	13	13	closed	13	1348
40.465	13	13	14	closed	13	1377
40.480	13	13	14	closed	14	1405
40.495	14	13	14	closed	14	1433
40.510	14	14	14	closed	14	1462
40.525	14	14	15	closed	14	1492
40.540	14	14	15	closed	15	1523
40.555	15	14	15	closed	15	1554
40.570	15	15	15	closed	15	1585
40.585	15	15	16	closed	15	1619
40.600	15	15	16	closed	16	1653
40.615	16	15	16	closed	16	1687
40.630	16	16	16	closed	16	1721
40.645	16	16	17	closed	16	1759
40.660	16	16	17	closed	17	1797

<b>Table D.5 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate D Stuck or Inoperable</b>						
40.675	17	16	17	closed	17	1834
40.690	17	17	17	closed	17	1872
40.705	17	17	18	closed	17	1911
40.720	17	17	18	closed	18	1949
40.735	18	17	18	closed	18	1988
40.750	18	18	18	closed	18	2026
40.765	18	18	19	closed	18	2060
40.780	18	18	19	closed	19	2094
40.795	19	18	19	closed	19	2127
40.810	19	19	19	closed	19	2161
40.825	19	19	20	closed	19	2277
40.840	19	19	20	closed	20	2395
40.855	20	19	20	closed	20	2516
40.870	20	20	20	closed	20	2639
40.885	20	20	21	closed	20	2645
40.900	20	20	21	closed	21	2650
40.915	21	20	21	closed	21	2655
40.930	21	21	21	closed	21	2660
40.945	21	21	22	closed	21	2667
40.960	21	21	22	closed	22	2674
40.975	22	21	22	closed	22	2680
40.990	22	22	22	closed	22	2687
41.005	22	22	23	closed	22	2694
41.020	22	22	23	closed	23	2701
41.035	23	22	23	closed	23	2708
41.050	23	23	23	closed	23	2715
41.065	23	23	23	closed	23	2722
41.080	23	23	23	closed	23	2729
41.095	23	23	23	closed	23	2736
41.110	23	23	23	closed	23	2742
41.125	23	23	23	closed	23	2749
41.140	23	23	23	closed	23	2756
41.155	23	23	23	closed	23	2763
41.170	23	23	23	closed	23	2770
41.185	23	23	23	closed	23	2777

<b>Table D.5 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate D Stuck or Inoperable</b>						
41.200	23	23	23	closed	23	2784
41.215	23	23	23	closed	23	2791
41.230	23	23	23	closed	23	2798
41.245	23	23	23	closed	23	2805
41.260	23	23	23	closed	23	2812
41.275	23	23	23	closed	23	2819
41.290	23	23	23	closed	23	2826
41.305	23	23	23	closed	23	2833
41.320	23	23	23	closed	23	2840
41.335	23	23	23	closed	23	2847
41.350	23	23	23	closed	23	2854
41.365	23	23	23	closed	23	2861
41.380	23	23	23	closed	23	2868
41.395	23	23	23	closed	23	2875

South East Queensland Water Corporation Limited

Table D.6 - Minimum Gate Settings for North Pine Dam						
Gate E Stuck or Inoperable						
Level (m AHD)	Gate A	Gate B	Gate C	Gate D	Gate E	Discharge (m <sup>3</sup> /sec)
39.600	closed	closed	closed	closed	closed	0
39.650	closed	closed	1	closed	closed	16
39.700	1	closed	1	closed	closed	32
39.715	1	closed	1	1	closed	48
39.730	1	1	1	1	closed	64
39.745	1	1	2	1	closed	88
39.760	2	1	2	1	closed	112
39.775	2	1	2	2	closed	137
39.790	2	2	2	2	closed	161
39.805	2	2	3	2	closed	187
39.820	3	2	3	2	closed	213
39.835	3	2	3	3	closed	240
39.850	3	3	3	3	closed	266
39.865	3	3	4	3	closed	294
39.880	4	3	4	3	closed	322
39.895	4	3	4	4	closed	349
39.910	4	4	4	4	closed	377
39.925	4	4	5	4	closed	404
39.940	5	4	5	4	closed	430
39.955	5	4	5	5	closed	457
39.970	5	5	5	5	closed	484
39.985	5	5	6	5	closed	512
40.000	6	5	6	5	closed	539
40.015	6	5	6	6	closed	567
40.030	6	6	6	6	closed	595
40.045	6	6	7	6	closed	623
40.060	7	6	7	6	closed	650
40.075	7	6	7	7	closed	678
40.090	7	7	7	7	closed	706
40.105	7	7	8	7	closed	732
40.120	8	7	8	7	closed	759
40.135	8	7	8	8	closed	786
40.150	8	8	8	8	closed	812

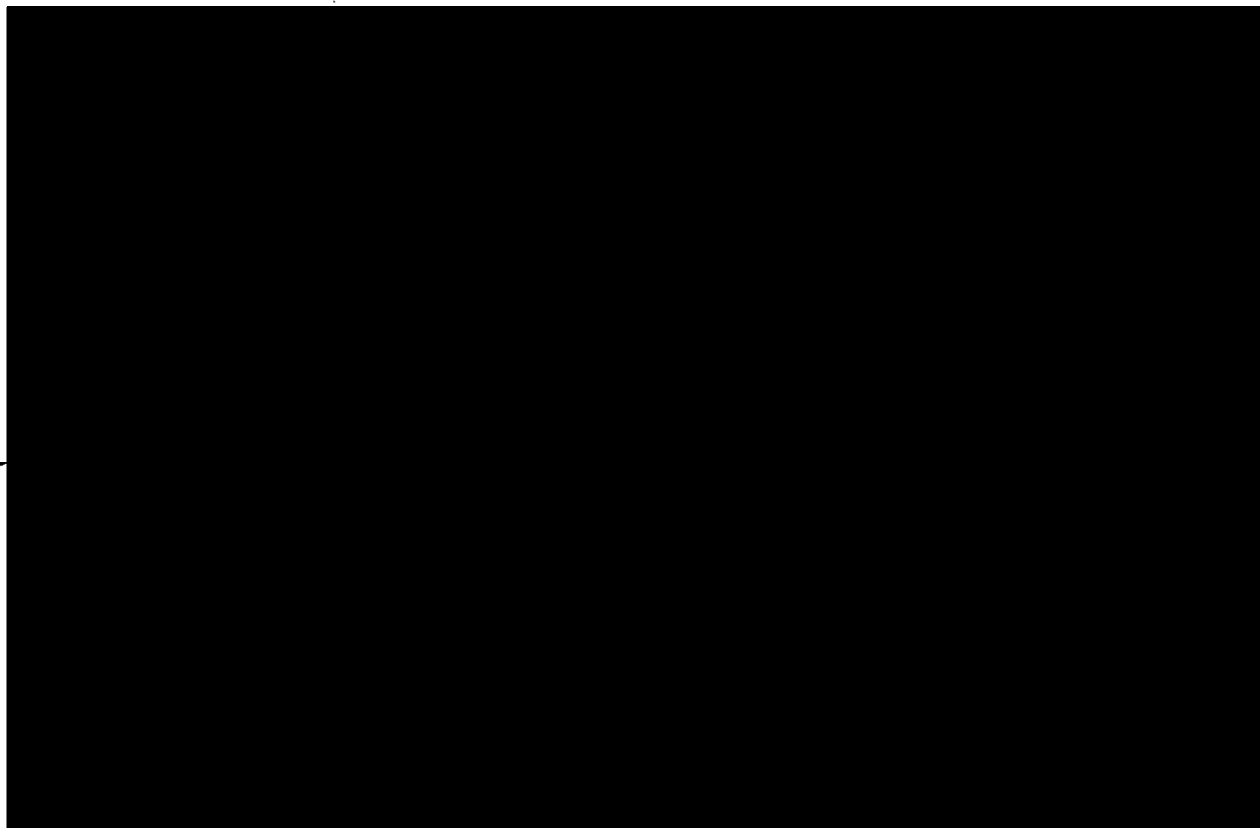
<b>Gate E Stuck or Inoperable</b>						
40.165	8	8	9	8	closed	839
40.180	9	8	9	8	closed	866
40.195	9	8	9	9	closed	893
40.210	9	9	9	9	closed	920
40.225	9	9	10	9	closed	946
40.240	10	9	10	9	closed	972
40.255	10	9	10	10	closed	998
40.270	10	10	10	10	closed	1024
40.285	10	10	11	10	closed	1050
40.300	11	10	11	10	closed	1077
40.315	11	10	11	11	closed	1103
40.330	11	11	11	11	closed	1130
40.345	11	11	12	11	closed	1156
40.360	12	11	12	11	closed	1183
40.375	12	11	12	12	closed	1210
40.390	12	12	12	12	closed	1237
40.405	12	12	13	12	closed	1264
40.420	13	12	13	12	closed	1292
40.435	13	12	13	13	closed	1320
40.450	13	13	13	13	closed	1348
40.465	13	13	14	13	closed	1377
40.480	14	13	14	13	closed	1405
40.495	14	13	14	14	closed	1433
40.510	14	14	14	14	closed	1462
40.525	14	14	15	14	closed	1492
40.540	15	14	15	14	closed	1523
40.555	15	14	15	15	closed	1554
40.570	15	15	15	15	closed	1585
40.585	15	15	16	15	closed	1619
40.600	16	15	16	15	closed	1653
40.615	16	15	16	16	closed	1687
40.630	16	16	16	16	closed	1721
40.645	16	16	17	16	closed	1759
40.660	17	16	17	16	closed	1797
40.675	17	16	17	17	closed	1834
40.690	17	17	17	17	closed	1872

<b>Table D.6 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate E Stuck or Inoperable</b>						
40.705	17	17	18	17	closed	1911
40.720	18	17	18	17	closed	1949
40.735	18	17	18	18	closed	1988
40.750	18	18	18	18	closed	2026
40.765	18	18	19	18	closed	2060
40.780	19	18	19	18	closed	2094
40.795	19	18	19	19	closed	2127
40.810	19	19	19	19	closed	2161
40.825	19	19	20	19	closed	2277
40.840	20	19	20	19	closed	2395
40.855	20	19	20	20	closed	2516
40.870	20	20	20	20	closed	2639
40.885	20	20	21	20	closed	2645
40.900	21	20	21	20	closed	2650
40.915	21	20	21	21	closed	2655
40.930	21	21	21	21	closed	2660
40.945	21	21	22	21	closed	2667
40.960	22	21	22	21	closed	2674
40.975	22	21	22	22	closed	2680
40.990	22	22	22	22	closed	2687
41.005	22	22	23	22	closed	2694
41.020	23	22	23	22	closed	2701
41.035	23	22	23	23	closed	2708
41.050	23	23	23	23	closed	2715
41.065	23	23	23	23	closed	2722
41.080	23	23	23	23	closed	2729
41.095	23	23	23	23	closed	2736
41.110	23	23	23	23	closed	2742
41.125	23	23	23	23	closed	2749
41.140	23	23	23	23	closed	2756
41.155	23	23	23	23	closed	2763
41.170	23	23	23	23	closed	2770
41.185	23	23	23	23	closed	2777
41.200	23	23	23	23	closed	2784
41.215	23	23	23	23	closed	2791
41.230	23	23	23	23	closed	2798

South East Queensland Water Corporation Limited

<b>Table D.6 - Minimum Gate Settings for North Pine Dam</b>						
<b>Gate E Stuck or Inoperable</b>						
41.245	23	23	23	23	closed	2805
41.260	23	23	23	23	closed	2812
41.275	23	23	23	23	closed	2819
41.290	23	23	23	23	closed	2826
41.305	23	23	23	23	closed	2833
41.320	23	23	23	23	closed	2840
41.335	23	23	23	23	closed	2847
41.350	23	23	23	23	closed	2854
41.365	23	23	23	23	closed	2861
41.380	23	23	23	23	closed	2868
41.395	23	23	23	23	closed	2875

## APPENDIX E. AUXILIARY EQUIPMENT





## APPENDIX F. STORAGE AND INFLOW DETERMINATION

Lake Level EL (m)	Storage 10 <sup>6</sup> m <sup>3</sup>	Inflow Rate m <sup>3</sup> /s
39.0	187	5.8
39.2	191	5.9
39.4	196	6.0
39.6	200	6.1
39.8	205	6.2
40.0	209	6.3
40.2	214	6.4
40.4	218	6.5
40.6	223	6.6
40.8	228	6.8
41.0	233	6.9
41.2	238	7.0
41.4	243	7.1
41.6	248	7.2
41.8	253	7.3
42.0	258	7.4
42.2	264	7.5
42.4	270	7.7
42.6	275	7.8
42.8	281	7.9
43.0	287	8.1
43.2	292	8.2
43.3	295	8.3

This is the net inflow that causes the reservoir to rise 1 mm in one hour with the spillway gates functioning normally.