2 Dams

2.1 Relevant agencies and legislation

2.1.1 Department of Environment and Resource Management

The Department of Environment and Resource Management (DERM) was established on 26 March 2009 when the Department of Natural Resources and Water and the Environmental Protection Agency were combined.

Before 21 February 2011, DERM's responsible Ministers were the Minister for Natural Resources, Mines and Energy and the Minister for Climate Change and Sustainability. In the lead up to, and during the 2010/2011 wet season, these offices were held by Stephen Robertson MP and Kate Jones MP. From 21 February 2011, DERM's responsible ministers were the Minister for Energy and Water Utilities and the Minister for Environment and Resource Management.[1] Following a further change in administrative arrangements, since 22 June 2011 DERM has three responsible Ministers. They are the Minister for Energy and Water Utilities, the Minister for Finance, Natural Resources and The Arts and the Minister for Environment.[2]

Legislation administered by DERM and relevant to the Commission's investigations includes that regulating water supply, dam safety, vegetation management and environmental protection. The following list of activities undertaken by DERM staff illustrates the importance of DERM to the management of flooding in Queensland:

- the regulation of dam safety
- the provision of technical advice in relation to the review of proposals, usually by local councils, for state and federal government funding for flood mitigation projects, and also about state planning policies and local government planning schemes[3]
- the publication of important technical documents relied upon by local councils in relation to flood management, for example, the *Queensland Urban Drainage Manual*[4]
- the provision of technical advice about state government water supply and flood mitigation projects[5]
- the undertaking of hydrological modelling about groundwater and surface water which is used in the allocation of water entitlements[6]
- the assessment of applications to remove vegetation, excavate or fill in a watercourse, lake or spring[7]
- rainfall and stream flow gauging, including flood gauging[8]
- flood mapping[9]
- the assessment of pollution caused by flooding (for example, hazardous waste overflow from mine dams and sewerage plants)[10]
- the production of seasonal climate outlook information.[11]

To date, the Commission's inquiries in connection with DERM have largely focussed upon its role in the regulation of large dams. For the purposes of its final report, the Commission expects to consider other aspects of DERM's responsibilities, particularly those touching upon land planning issues.

2.1.2 Queensland Water Commission

The Queensland Water Commission is a statutory body which was established by the Queensland Government in 2006 in response to the lengthy drought then being experienced. The main functions of the Water Commission, for the south-east Queensland region and other designated regions, are to:

- advise the Minister on matters relating to water supply and demand management
- advise the Minister on the delivery of desired level of service objectives for water supplied
- facilitate and implement regional water security programs
- ensure compliance with the programs and with water restrictions.[12]

The Water Commission is required to consider flood mitigation and dam safety in the preparation of assessments of water supply.[13]

A principal means through which the Water Commission has advised the government about water supply and demand management is the *South East Queensland Water Strategy*, which was released in July 2010. This strategy included a plan to carry out detailed investigations into increasing the full supply level of Wivenhoe Dam without raising the dam wall. Pursuant to this plan, on 10 January 2011, the Water Commission engaged Seqwater to conduct a flood hydrology impact study on the raising of Wivenhoe Dam's full supply level.[14]

Any increase in the full supply level of Wivenhoe Dam without changing the dimensions of the dam would reduce its flood mitigation capacity and have implications for dam safety.[15] Accordingly, although the Water Commission plays no role in the regulation of dam safety or in dam operations, even during flood events, this is an example of how its actions may potentially have an impact on flood mitigation and dam safety.

2.1.3 SEQ Water Grid Manager

In 2007, the Queensland Government commenced a major reform of south-east Queensland's urban water supply industry. The government's intention was to achieve a more equitable and sustainable distribution of water in the region.[16] Stage one of this reform restructured the bulk water supply and transport businesses, which were previously owned by 25 different entities serving 17 retail businesses. The second phase of the reform involved the establishment of three new retail businesses. The south-east Queensland water grid was created; it includes a network of treatment facilities and two-way pipes which allows for some movement of drinking water around south-east Queensland.[17]

The SEQ Water Grid Manager is a statutory authority established under the *South East Queensland Water (Restructuring) Act 2007*, the Act which introduced the reforms. Its functions are to purchase water services and sell water and to do 'anything else likely to complement or enhance' one of these functions, to the extent they are consistent with its operational and strategic plans. These plans must be submitted to the Water Grid Manager's responsible Ministers for approval each financial year.[18]

The Water Grid Manager holds various water entitlements which give it the right to be supplied water from dams owned by Seqwater. It purchases other water services from Seqwater, which also manufactures (recycles and desalinates) water, and from LinkWater, which transports water. The Water Grid Manager sells water to its customers: three council owned retail businesses,[19] Toowoomba Regional Council, CS Energy and Tarong Energy.

The Water Grid Manager plays no role in dam operations, including during flood events. However, following October 2010 flood releases from the Wivenhoe and Somerset dams, a draft *Protocol for the Communication of Flooding Information for the Brisbane River Catchment – including Flood Water Releases from Wivenhoe and Somerset Dams* was created. Pursuant to the draft communications protocol, during the January 2011 flood events, the Water Grid Manager supplied information about floodwater releases to the Directors-General of the Department of the Premier and Cabinet and DERM and to relevant local councils. The Water Grid Manager also published media releases about dam operations and other flood related topics. For further discussion of the draft communications protocol see, *2.6.10 Communications*.

2.1.4 Queensland Bulk Water Supply Authority trading as Seqwater

The Queensland Bulk Water Supply Authority, which trades as Seqwater, is a statutory authority responsible for bulk water supply to south-east Queensland. It was established on 16 November 2007 under the *South East Queensland Water (Restructuring) Act 2007*.

Seqwater was previously known as the Brisbane Area Water Board (from about 1990 to 1993), the South East Queensland Water Board and the South East Queensland Water Corporation trading as SEQ Water.[20] Changes in Seqwater's roles and responsibilities during the past two decades have mirrored significant legislative and policy changes.

Seqwater owns, operates and manages 26 dams and 47 weirs across south-east Queensland. Dams owned by Seqwater include Wivenhoe, Somerset, North Pine, Hinze and Baroon Pocket dams. Seqwater also owns 46 water treatment plants.[21] On 1 July 2011, Seqwater became the owner of the Western Corridor Recycled Water Scheme and the Gold Coast desalination plant.[22]

2.1.5 SunWater Limited

SunWater Limited is a government owned corporation which is a bulk water infrastructure developer, owner and manager. Burnett Water Pty Ltd, the owner of Paradise Dam, is a wholly owned subsidiary of SunWater. The Minister for Energy and Water Utilities and the Minister for Finance, Natural Resources and The Arts are SunWater's shareholding ministers.

SunWater is a registered large service provider for water supply and services under the *Water Supply (Safety and Reliability) Act 2008* (the Water Supply Act). SunWater owns and operates 23 referable dams, including 18 major dams, 60 weirs and barrages, 77 major pump stations, 2920 kilometres of pipelines and channels and 690 kilometres of drainage works.[23]

Before July 2008, SunWater owned a number of water supply schemes and large dams in south-east Queensland, including Atkinson Dam, Bill Gunn Dam, Clarendon Dam, Maroon Dam and Moogerah Dam. These were sold to Seqwater in connection with the state government's reform of the water supply sector discussed above.

SunWater currently manages the following dams pursuant to facility management contracts with their owners: Glenlyon Dam for the Borders River Commission, Ross River Dam for the Townsville City Council and Scrivener Dam in the Australian Capital Territory.[24]

Until 1 July 2011 and under contract, SunWater operated the flood operations centre for Wivenhoe, Somerset and North Pine dams on Seqwater's behalf. The manner in which this service was provided is discussed below at *2.3.1 Arrangements for flood operations* and *2.6 Decision-making and conditions at the flood operations centre*.

2.1.6 Relationships between DERM and the water agencies

The Minister for Energy and Water Utilities and the Minister for Finance, Natural Resources and The Arts are portfolio Ministers for the Queensland Water Commission, the Water Grid Manager, Seqwater and SunWater (the water agencies). Until 21 February 2011, the water agencies were within the portfolio of the Minister for Natural Resources, Mines and Energy. (The water agencies' relationships with their other responsible Ministers have not been relevant to the Commission's inquiries.)

The Ministers hold various powers relevant to the business of the water agencies.
For example:

- Under section 38(1) of the *Water Act 2000,* the Minister may prepare a water resource plan for any part of Queensland to advance the sustainable management of water.
- Under section 61 of the *South East Queensland Water (Restructuring) Act 2007*, the Minister may give a written direction to the boards of the Water Grid Manager or Seqwater if satisfied that, because of exceptional circumstances, it is necessary to give the direction in the public interest. (The section does not provide limitations on the subject matter or scope of such directions. Nor does it provide any guidance as to what might constitute 'exceptional circumstances'.)

- The Water Commission is not ordinarily subject to direction by the state, but the Minister holds a reserve power to give written directions as to the Water Commission's performance of its non-advisory functions, if satisfied that because of exceptional circumstances it is necessary to do so in the public interest.[25] (Again, the term 'exceptional circumstances' is not explained.)

The Water Act, the Water Supply Act and the *South East Queensland Water (Restructuring) Act 2007* contain many provisions allowing for the making of regulations and statutory instruments with consequences for the business of the water agencies. Proposed regulations, or amendments to regulations, are considered by the Executive Council. The Minister for Energy and Water Utilities is responsible for taking the revision of some regulations and statutory instruments to the Executive Council.[26] If the Executive Council agrees with the Minister's proposal, it advises the Governor of Queensland accordingly. If the Governor approves the draft regulations or statutory instrument and signs the relevant Executive Council minute, the regulations or statutory instrument come into effect.

The legislation requires that the water agencies report regularly to the Ministers about many matters. Representatives of the water agencies meet with the Ministers regularly, and the Ministers also require briefings on particular issues. For example, on 16 January 2011, in response to a request from the Minister's office, Seqwater provided a briefing note to the Minister about the January 2011 flood event and Wivenhoe Dam operations.

It is clear from considering the legislative scheme provided by the three Acts that Parliament intended that the Minister would be responsible for setting policy frameworks, supervising the water agencies and exercising certain emergency powers if necessary in the public interest. It is of course the case under our system of government that Ministers are responsible to Parliament for the administration of their portfolios.

Many of the powers under the Water Act, *South East Queensland Water (Restructuring) Act 2007* and Water Supply Act are held by the Director-General of DERM. For example:

- The chief executive (the Director-General) may prepare a resource operations plan to implement a water resource plan.[27] The chief executive may grant resource operations licences, distribution operations licences and water allocations.[28]
- The Director-General may apply safety conditions to an existing referable dam.[29]
- If the Director-General is satisfied or reasonably believes there is danger of the failure of a dam, the failure is likely to pose a risk to safety or health of the public or individual and immediate action is necessary to prevent or minimise the impact of the failure, the Director-General may take reasonable steps to prevent or minimise the impact of the failure.[30]

For the most part, this legislative scheme provides that the Director-General has responsibility for the setting of operational rules, the assessment of applications and enforcement activities. As is usually the case, many of the Director-General's powers have been delegated to other officers within the department.

As the chief executive, the Director-General retains responsibility for any decisions made under delegation and, of course, for all of DERM's operations. The Director-General bears responsibility for ensuring that the Ministers are provided with appropriate advice by DERM officers about policy matters requiring the Ministers' attention, including matters which must be taken to the Executive Council.

The Director-General is very often responsible for contacting the water agencies on the Ministers' behalf, although the Commission notes that the ministerial staff of the current Minister for Energy and Water Utilities have made inquiries of the water agencies on his behalf.

2.1.7 Local councils

Some local councils own and operate referable dams. For example, Wide Bay Water Corporation, which owns and operates Lenthalls and Cassava dams, is wholly owned by the Fraser Coast Regional Council. Councils which own referable dams are subject to the same regulatory scheme as other dam owners.

Local councils which do not own referable dams have no part in their regulation or operation, whether for water supply or flood mitigation purposes. By way of example, the Brisbane City Council, Ipswich City Council and Somerset Regional Council play no role in relation to the operation of Somerset and Wivenhoe dams. Likewise, the Brisbane City Council and Moreton Bay Regional Council are not involved in North Pine Dam operations. However, local councils are responsible for communicating information about flooding, including flooding related

to dam releases, to local residents. The role of local councils in communicating information about flooding is discussed in chapter *4 Forecasts, warnings and information.*

2.2 Dam history, functions and capacities

2.2.1 Referable dams

The Commission's investigations have so far only involved referable dams.

The Water Supply Act sets out a regulatory framework for the provision of water and sewerage services. It also provides for the regulation of referable dams. Referable dams are those which are assessed as posing a risk to the safety of two or more people should they fail. There are presently 106 referable dams in Queensland.[31]

Dams containing hazardous contaminants (for example, tailings waste produced by mines) are not referable dams. Dams of this type posing a significant or high hazard are regulated separately under the *Environmental Protection Act 1994*.

The Water Supply Act is administered by DERM, and the department's Director-General is the regulator under the Act.[32] Staff within DERM's Office of the Water Supply Regulator are delegated the dam-related powers of the Director-General under the Water Supply Act.[33] Peter Allen, the Director, Dam Safety, Water Supply (the Dam Safety Regulator) is stationed within the Office of the Water Supply Regulator.

The Water Supply Act provides that failure impact assessments must be undertaken by registered professional engineers on dams or proposed dams which exceed certain dimensions. The Act also allows for the imposition of safety conditions on existing referable dams. Safety conditions are imposed upon new referable dams pursuant to development permits issued under the *Sustainable Planning Act 2009*. The Water Supply Act provides the regulator with emergency powers in the event that there is a danger of failure of a dam.

2.2.2 Flood mitigation manuals

Chapter 4, Part 2 of the Water Supply Act deals with the preparation and approval of manuals of operational procedures for flood mitigation for dams. Prior to the enactment of the Water Supply Act, identical provisions were located in the Water Act.

The Water Supply Act provides that a regulation may nominate that an owner of a dam must prepare a flood mitigation manual by a certain date.[34] No guidance is provided by the Act in relation to circumstances which might trigger the making of such a regulation. To date, no dam owner has been compelled by regulation to prepare a flood mitigation manual. The Commission notes that the manuals for Wivenhoe and Somerset dams and North Pine Dam pre-date this legislative scheme.

Section 371 of the Water Supply Act provides that the chief executive may, by gazette notice, approve a flood mitigation manual. Such an approval must be for a period of no more than five years. There are currently only two approved flood mitigation manuals, one for Wivenhoe and Somerset dams, the most recent revision of which was gazetted on 22 January 2010, and the other for North Pine Dam, the most recent revision of which was gazetted on 17 December 2010.

The Water Supply Act does not contain any criteria against which a flood mitigation manual must be assessed. The Act does provide that the chief executive may get advice from an advisory council before approving the manual, but it does not give any guidance as to the composition of any such advisory council. No advisory council has been convened since the commencement of the Water Act.[35]

Subsequent to the most recent approval of the Wivenhoe and North Pine flood mitigation manuals, the dam safety regulator approved a document entitled *DS 5.1 Flood Mitigation for a Dam*.[36] This document outlines procedures to be followed by DERM officers who are assessing flood mitigation manuals.

Section 372 of the Water Supply Act provides that a dam owner must comply with a requirement issued by the chief executive to amend a flood mitigation manual. In consequence, the regulator can be the instigator of change to a flood mitigation manual. The section does not include any limitations as to the subject matter or scope of a requirement to amend a flood mitigation manual. As far as the Commission is aware, the power to require amendment of a flood mitigation manual has never been exercised.

Importantly, section 373 of the Water Supply Act provides that prior to the expiry of the approval of a flood mitigation manual, the dam owner must 'review, and if necessary, update the manual' and give the manual to the chief executive for approval. The Act does not provide any guidance as to the form or content of a review of a flood mitigation manual.

Interestingly, there is no statutory obligation for a dam owner to comply with its flood mitigation manual. However, section 374(2) of the Water Supply Act provides that an owner of a dam who observes the operational procedures in an approved flood mitigation manual does not incur civil liability for an act done, or omission made, honestly and without negligence.[37]

2.2.3 Flood mitigation and water supply

Only a few referable dams have been built for both water supply and flood mitigation purposes. Dams with flood mitigation capacity are of two types: active flood mitigation and passive flood mitigation dams. Active flood mitigation dams are those where the dam operator controls releases; passive flood mitigation dams are those where the dam operator has effectively no discretionary control over outflows.[38]

Active flood mitigation dams usually have spillway gates or large sluice gates. Wivenhoe Dam is an example. The operators of active flood mitigation dams aim to fill the flood storage compartment of the dam during the peak of the inflows into the dam, so as to maximise the attenuation of outflows from the dam.[39] The Commission accepts that, primarily because of uncertainties associated with rainfall predictions, the achievement of an ideal strategy is usually only possible with the benefit of hindsight.

It is trite to say, yet important to note, that the capacity of flood mitigation dams to contain floods is subject to the volume of rainfall experienced in the dam's catchment. The ability of operators to manage a flood is very limited when the volume of rainfall run-off greatly exceeds the volume of the available flood storage within the dam. The peak of the flood will normally be reduced because a part of the flood is absorbed in raising the water level within the dam. In large floods the principal flood mitigation benefit may arise from delaying the onset of the flood to provide more time for warnings and evacuations.

Even those dams without gates or sluices attenuate floods, even if only to a small extent. The peak discharge or outflow from a water supply dam will be less than, and will occur some time after, the peak inflow.[40] This is the only flood mitigation capacity that by far the overwhelming majority of referable dams possess.

2.2.4 Full supply level

The full supply level of a referable dam is the level to which the water supply compartment of the dam is filled. The full supply level is usually based on engineering studies conducted at the time of the dam's design. The flood mitigation compartments of those few referable dams which have them were also established at the time of the dams' design.

One way of indicating that a dam's full supply level has been reached is to say that it is 100 per cent full. It follows that a dam which has a flood mitigation compartment may, during a flood event, be described as being at 120 per cent of capacity, 150 per cent of capacity and so on.

2.2.5 Resource operations plans and licences

The Water Act governs water resource planning; this Act allows the Minister to make a water resource plan for any part of Queensland 'to advance the sustainable management of water'.[41] Section 95 of the Water Act allows the chief executive (that is, the Director-General of DERM) to prepare a 'resource operations plan'. Resource operations plans outline how water resource plans are to be implemented. Their principal relevance to the Commission's investigations about dams lies in the rules they contain about the operations of dams.

Section 105(1) of the Water Act permits the Director-General to amend a resource operations plan. The Director-General must do a number of things in relation to amending resource operations plans, including providing public notice and allowing for submissions. Section 106 of the Water Act provides that in certain instances, the Governor in Council may make minor or stated amendments to resource operations plans. This may be done without first taking the steps ordinarily required of the Director-General when resource operations plans are amended.

The Moreton Resource Operations Plan, made under the Water Act, commenced on 7 December 2009. It provides that the operating levels 'for infrastructure in the central Brisbane River and Stanley River water supply schemes' – that is, Wivenhoe and Somerset dams – are specified in a designated attachment. The full supply levels set out in the attachment remain those which were set at the time of each dam's completion. They have remained the same through various changes in the legislative scheme governing flood mitigation and water supply and changes in which agency operates the dams, including during floods.

Seqwater holds resource operations licences for Wivenhoe, Somerset and North Pine dams. These licences, issued by DERM officers holding appropriate delegations from their Director-General, require Seqwater to comply with the Moreton Resource Operations Plan. The licences permit Seqwater to interfere with the flow of water in the relevant river to the extent necessary to operate the dam to which the licence applies.

On 14 February 2011, under section 106(b) of the Water Act, the Governor in Council approved an amendment to the Moreton Resource Operations Plan.[42] This amendment allowed Seqwater to submit a 'revised interim program' under the Moreton Resources Operation Plan for the Director-General's consideration. On 17 February 2011, the Director-General approved Seqwater's application for a 'revised interim program'. This approval allowed Seqwater to temporarily reduce the level of Wivenhoe Dam to 75 per cent of full supply level until 31 March 2011. This decision and the process leading to it are discussed in detail below at *2.4 Temporary alteration of full supply level*.

Seqwater had previously held an interim program permitting flood mitigation releases when any of the dams exceeded full supply level. This interim program did not permit releases below full supply level, including pre-emptive releases outside floods.

The full supply levels for Wivenhoe, Somerset and North Pine dams are described in, but not set by, the relevant flood mitigation manuals. For the purposes of the flood mitigation manuals, a flood is taken to commence when the dam reaches prescribed levels above the full supply levels. The flood mitigation manuals require the flood engineers, who operate the dams during floods, to continue releasing water only until the level of the dam decreases to full supply level.

2.2.6 Types of dams

Some large water supply dams are gated. These include the Callide, Coolmunda, EJ Beardmore and Leslie dams.[43] Gates are used to attempt to match spillway discharge to the rate of inflows into a dam.[44]

Some of the gated dams have automatic gates (for example, Coolmunda Dam)[45] and others have gates which require control by operators (for example, North Pine Dam).

Many referable dams have ungated (or uncontrolled) spillways and are designed to commence discharging water in the event that water rises above the level of the spillway (for example, Fairbairn Dam).

The means of construction of referable dams varies. For example, Wivenhoe Dam is an earth and rock fill embankment dam with a concrete spillway and Somerset Dam is a mass concrete dam.[46] Differences in construction have only proved relevant to the Commission's investigations in so far as they influence the manner in which dams are operated during flood events. By way of example, Wivenhoe Dam's construction means that allowing the embankment to overtop would risk the safety of the dam, whereas some other water supply dams are not gated and are designed to withstand limited overtopping during flood events.

2.2.7 Somerset Dam

Somerset Dam is located on the Stanley River. It was completed in 1953, construction having been commenced in 1935, but interrupted because of World War II.[47] The site was identified as a potential dam site following the 1893 flood.[48]

Somerset Dam was built for both water supply and flood mitigation purposes. When construction commenced, the water supply to flood compartment ratio was to be about fifty-fifty.[49] This planned ratio was reviewed in the 1950s[50] and Somerset Dam's full supply level has remained at 99 metres[51] since it was commissioned.[52] When the flood compartment is filled, the dam level reaches approximately 107.45 metres.[53] The water supply compartment of Somerset Dam holds approximately 379 800 megalitres[54] and its flood mitigation capacity is approximately 524 000 megalitres.[55]

Radial gates, sluice gates and regulator valves are used to release water from Somerset Dam.[56]

2.2.8 Wivenhoe Dam

Investigations into the possible construction of a dam on the upper Brisbane River commenced prior to the 1974 floods. In 1971, a report completed by the Co-ordinator General recommended the construction of a dam at Wivenhoe.[57] The Wivenhoe Dam was planned to fulfil both water supply and flood mitigation purposes.

Whatever the source of the apparent popular misconception that Wivenhoe Dam would contain all floods emanating in the upper Brisbane River, it is certainly not any of the engineering investigations conducted in connection with the dam during the past four decades. The Commission has considered many of the engineering reports produced about Wivenhoe Dam. All of these reports recognise that other than for relatively small floods, Wivenhoe Dam is only capable of mitigating floods, not preventing them.

Apart from the limited flood mitigation capacity of the Wivenhoe and Somerset dams, it is important to note that approximately 50 per cent of the Brisbane River catchment is below the dams.[58] Even when the Wivenhoe and Somerset dams completely contain rainfall which would otherwise produce flooding, it is possible that major flooding will occur in Ipswich and Brisbane, simply because of the duration and intensity of rainfall elsewhere in the catchment.

Wivenhoe Dam has a full supply level of 1 165 000 megalitres, which is achieved when the lake level reaches 67 metres. The full supply level was identified at the time of Wivenhoe Dam's design, as was the flood storage compartment of 1 420 000 megalitres. The dam has a gated spillway, with five radial gates and an auxiliary spillway fitted with three erodible fuse plugs, which was completed in 2005 and is discussed in more detail in *2.2.9 Fuse plugs.*

In flooding, Somerset and Wivenhoe dams are operated in conjunction so as to maximise flood mitigation.[59] An operating target line is used to set a goal for balancing the water levels in each dam. The Commission has received no evidence contesting the use of the operating target line.

2.2.9 Fuse plugs

In the late 1990s and early 2000s, significant improvements were made in the procedures used to estimate the maximum floods which could be expected to occur. These are known as probable maximum floods. During the same period, the Australian National Committee on Large Dams (ANCOLD) published a series of guidelines relevant to the assessment of capacities of referable dams.[60] The improvement in flood estimation techniques and the ANCOLD guidelines prompted the undertaking of assessments of the risk of the failure of Wivenhoe Dam. In response to these assessments, Seqwater decided upon a program of works to upgrade Wivenhoe Dam.

The purpose of these upgrades was to reduce the risk of the failure of Wivenhoe Dam, particularly through extreme flood events. For Wivenhoe Dam to fail would be an almost unimaginable disaster; the number of people estimated to be at risk should it fail is 244 000.[61]

Stage 1 of the upgrade included 'upgrading the embankment crest to retain a maximum flood level of EL 80 with nil freeboard' and 'upgrading associated structures as appropriate, including protection of the main spillway gates and bridge, and strengthening of the spillway gravity structure by post tensioning'.[62]

Stage 1 of the upgrade also included construction of an auxiliary spillway designed to enable the dam to pass 'an inflow flood with an [annual exceedance probability] of 1 in 100 000 at a maximum flood level of EL80'.[63] This auxiliary spillway is not gated, but instead is controlled by three fuse plugs, at 75.7 metres, 76.2 metres and 76.7 metres.[64] The fuse plugs are designed to erode should the lake level overtop them. The erosion of a fuse plug would lead to an uncontrolled release of water. This would increase the discharge, the intention being to prevent the failure of the dam by overtopping.

The level at which the Wivenhoe manual requires flood engineers to prioritise the structural safety of the dam remained the same following the insertion of the fuse plugs; at that point (when strategy W4 comes into effect) large outflows to stabilise the lake level must occur, with or without fuse plugs. The Wivenhoe manual states that the senior flood engineer may exercise reasonable discretion in moving to strategy W4 (which requires that the primary consideration is protecting the structural safety of the dam) if earlier commencement is able to prevent triggering of a fuse plug.[65] Under the heading 'Strategy W4B – Fuse Plug Initiation Possible' the Wivenhoe manual prescribes that, providing the safety of the dams is not compromised, where early opening of the gates and/or

varying the operational procedures at Somerset Dam can keep the lake level below 75.5 metres, those steps should be taken to prevent fuse plug initiation.

Should a fuse plug be breached there would be a rapid release of water from Wivenhoe Dam, which it may be possible to offset through gate operations. The flood mitigation capacity of the dam may be reduced for some months while the auxiliary spillway is repaired. There is also the issue of the cost of repairs, although, in the context of the damage occasioned by a large flood, this is of limited relevance.

The Commission is not presently in a position to reach a conclusion about the appropriateness of the Wivenhoe manual's according of importance to the protection of the fuse plugs. This is a matter which may be dealt with in the course of the longer term review of the Wivenhoe manual discussed below in *2.5 Manual of operational procedures for flood mitigation at Wivenhoe Dam and Somerset Dam*.

The Commission notes that Wivenhoe Dam does not presently comply with ANCOLD guidelines in that it could not presently withstand a probable maximum flood. However, the reconstruction of Wivenhoe's saddle dam 2 as a fourth fuse plug spillway is planned. The completion of this further upgrade would mean that the dam's spillway was designed to withstand 100 per cent of the probable maximum flood.[66] Under the *Queensland Dam Safety Guidelines*, this upgrade is not required until 2035. The Commission understands that Seqwater's present plan is to review the requirement for this further upgrade in around 2015.[67]

2.2.10 North Pine Dam

North Pine Dam was completed in 1976. It is located on the North Pine River, immediately upstream of an urban area within the Moreton Bay Regional Council's region.

North Pine dam was built for water supply only. It has a full supply level of 39.6 metres or approximately 214 000 megalitres. It is a mass concrete dam not designed to withstand overtopping. During floods, water is released through the dam spillway using five radial gates.[68]

The North Pine manual refers to the dam as having a flood storage compartment,[69] but this 'compartment' is the five centimetres between the dam's full supply level, 39.6 metres, and the level at which gate openings are triggered, 39.65 metres. [70] This space is only 0.5 per cent of the volume of full supply of North Pine Dam.[71] In effect, the flood storage compartment provides only a short delay between full supply level being reached and flood releases commencing.[72] This means, once the dam is full, floods pass through the reservoir with little mitigation benefit.[73]

In some previous wet seasons, North Pine Dam has been maintained at 95 per cent of full supply level so as to provide a small flood mitigation buffer. The Commission accepts that the main purpose of this was to allow for increased notice to local residents about road closures, which almost inevitably result from any flood release from North Pine Dam.

2.2.11 Regional dams

Many of the most significant issues associated with the operations of regional dams relate to communication issues. These are discussed below at *4.1.4 Warnings about dam spillway outflow*.

2.3 Flood preparedness of Seqwater

The prediction of a La Niña wet season by the Bureau in October 2010 had (or should have had) implications for Seqwater, as an owner and operator of dams in south-east Queensland. All of these dams have the potential, through releases in floods, to affect populations in downstream areas.

2.3.1 Arrangements for flood operations

Seqwater (and its predecessors) engaged SunWater (and its predecessors) to manage the operation of the Wivenhoe, Somerset and North Pine dams during flood events for more than 10 years to 1 July 2011. That arrangement continued to 30 June 2010, under an agreement dated 13 October 2009. The agreement set out, by schedule, the tasks SunWater was to perform for Seqwater in return for a fixed sum.

SunWater was, among other things, to:

- ensure all staff and contractors who may be involved in flood operations are adequately trained[74]
- review the operation of the flood operations centre and the data collection network and report annually as to maintenance and upgrades required[75]
- perform emergency maintenance in the case of equipment failure[76]
- manage flood events in accordance with the standard operating procedures, emergency action plans and the Wivenhoe manual and North Pine manual[77]
- establish and maintain a flood operations centre from which to manage flood events[78]
- check the rainfall gauge network and validate data at rainfall gauges[79]
- connect the rainfall gauge network to the models available in the flood operations centre[80]
- arrange with Seqwater a program of training for flood operations staff[81]
- submit a statement of flood preparedness to Seqwater each year including an assurance that SunWater is prepared to deal with any flood event[82]
- mobilise the flood operations centre for each flood event and manage the event[83]
- prepare a flood event report within two weeks of the end of the flood event.[84]

The agreement in effect delegated many of Seqwater's responsibilities as operator of the dams during times of flood. It appears that Seqwater did not ensure the continuity of the arrangement throughout the 2010/2011 wet season. The agreement expired on 31 October 2010, and was not extended until a further deed was signed on 24 December 2010. That deed backdated the term of the contract to ensure it was continuous; but between 1 November and 23 December 2010, no written contract was in place. Despite that, SunWater continued to provide flood management services in accordance with the agreement and Seqwater accepted those services.[85]

The fact that such an agreement could lapse, albeit only formally, raises concerns about the priority accorded by Seqwater to flood preparedness.

2.3.2 Annual Wivenhoe and North Pine manual review

The agreement for flood management services described above also required SunWater to review the Wivenhoe and North Pine manuals. In July each year, SunWater was obliged to report in writing to Seqwater regarding recommended improvements, or to confirm that the manuals remained satisfactory.[86] This was a requirement additional to the formal review process under part 7 of the Wivenhoe and North Pine manuals.

During this time, SunWater participated in formal reviews of the Wivenhoe manual in 2002, 2004 and 2009 and of the North Pine manual in 2002 and 2007. SunWater's involvement was primarily through Robert Ayre, an employee of SunWater and a senior flood engineer. In 2002 and 2004, Mr Ayre took a lead role in the review and re-drafting of the two manuals.

SunWater could not establish that it provided any advice, in accordance with the requirements of the agreement, in the period 2001 to 2010.[87] In six of the annual reports of activities performed by SunWater under the agreement, SunWater stated that it had 'reviewed' the manuals in the lead up to the wet season.[88] In one, no mention is made of any pre-wet season review of the manuals.[89] In none of the annual reports, however, can be found a

recommended improvement or a confirmation that the manuals remained satisfactory; nor is there any evidence of a request from Seqwater that SunWater comply with this aspect of its obligations.

This omission assumes some significance when it is acknowledged that the Wivenhoe manual has, in important respects, been found to be ambiguous and in need of amendment (see *2.6 Decision-making and conditions at the flood operations centre*).

2.3.3 Tools at the flood operations centre

The flood engineers make operational decisions about dam releases on the basis of the relevant manual. In the Wivenhoe manual, the protection of urban areas from inundation is the primary consideration during strategies W2 and W3, and a lower level consideration when the dam is operated in strategies W1 and W4.

The flood engineers' evidence was that the *Brisbane Valley Damage Minimisation Study* completed in 2007 provided them with some understanding of the consequences of different flows.[90] That study dealt with damage for residential and non-residential areas of the Brisbane, Ipswich and Somerset local council regions at different flow rates.[91] The real time flood monitoring system (used in the flood operations centre for 15 years, with some modifications to both hardware and software) originally included a hydrodynamic model to determine flow velocities and levels along the river system.[92] However, when its hardware platform was changed that model was not retained, and it was not replaced. The flood engineers did not have access to hydrodynamic modelling which would have given more precise indications of flood levels at particular locations downstream during the height of the flood event. They relied instead on the hydrologic models in the real time flood model, although during the drawdown phase they were given access to a hydrodynamic model for the Brisbane River system.[93] They had no hydrodynamic model for the Bremer River at any time during the January 2011 flood event.[94]

One benefit of a hydrodynamic model is that it can account for flow interactions at the confluence of waterways, such as where the Lockyer Creek or the Bremer River meet the Brisbane River.[95] For example, in Ipswich, the height of the Bremer River is affected by whether water is able to flow into an already flooded Brisbane River. Mr Ayre explained that because the hydrologic models do not satisfactorily account for this backwater effect, the flood engineers were not able readily to assess the impacts of discharges from Wivenhoe on flooding in Ipswich.[96] None of the modelling done on the downstream impacts of releases related to impacts in the Ipswich area.[97] It was anticipated that the flood engineers would in the future have access to a hydrodynamic model dealing with Ipswich.[98]

A second benefit of a hydrodynamic model is that it converts flow into height. While water level, flow rate and volume are all important to determine the impacts of flooding, for damage caused to urban areas height of inundation is a significant factor.[99] While none of the parameters of the strategies is expressed in terms of height, one of the flood mitigation objectives under the Wivenhoe manual is to provide protection of urban areas from inundation. The same peak flow at one point can produce different heights at a second point downstream depending on many things, including the time the peak flow endures.[100]

An expert hydrologist engaged by the Commission, Mark Babister, considered that having such a model would be helpful in giving an understanding of the effects of releases from the dam.[101] Mr Ayre accepted that it would have been useful to have a hydrodynamic model at the flood operations centre,[102] although he expressed concern that it might take substantial effort to calibrate it to the event.[103] Mr Babister was of the view that if a model were properly calibrated to historical floods, there would be no need to calibrate it in real time during the event.[104]

The flood engineers say that having a hydrodynamic model would not have affected how they managed the dams during the January 2011 event.[105] However, the Commission considers that the flood engineers should have hydrodynamic models available to them in the flood operations centre to assist determining the downstream impacts of releases from the dams.

During the flood event, the flood engineers requested two pieces of information to assist in their operational decision making – a copy of the damage curves developed by the Brisbane City Council from the Brisbane Valley damage minimisation study 2007[106] and the equations for the flow out of the fuse plug spillway after a fuse plug has triggered at different lake levels.[107] It would be appropriate for those tools also to be available to the flood engineers for all flood events.

2.3.4 Seqwater's flood preparedness activities

Seqwater has various programs and documents in place to guide its operation of its dams, including:

- a dam safety management program[108]
- standard operating procedures prepared in accordance with the dam safety conditions imposed on it by DERM[109]
- five year comprehensive safety inspections of its dams, the most recent on Wivenhoe Dam having been completed in September 2010[110]
- emergency actions plans (see further, *4.1.4 Warnings about dams spillway outflow*)
- the flood mitigation manuals (for a description of the Wivenhoe manual, see *2.5.1 Structure of the Wivenhoe manual.* For a description of the North Pine manual, see *2.10.1 Managing flood events*).

Those documents and programs have long term aims and application. None is specific to an approaching wet season. The first three deal primarily with the safety of the dam; they refer to flooding only in the context of dam failure. To the limited extent that they apply to other flood operations, they simply refer to the manuals. The manuals remain the key documents by which risks of downstream flooding are identified outside of a dam failure situation. See *2.5.8 Longer term review of the Wivenhoe manual.*

Each manual prescribes some preparedness activities to be undertaken by Seqwater. They require that by 30 September each year, Seqwater report to DERM on:[111]

- training and state of preparedness of flood operations staff
- the adequacy of communication and data collection facilities
- the reliability of the communication facilities, real time flood model and ALERT network over the previous 12 months
- the reliability of the system (being the flood monitoring and forecasting system described in part 5 of the Wivenhoe and North Pine manuals) and under prolonged flood conditions
- the accuracy of the forecasted flood flows and heights
- the overall state of preparedness of the system.

A summary of the preparedness activities undertaken before the 2010/2011 wet season in accordance with the manuals' stipulations is contained in the *Flood Operations Preparedness Report Wivenhoe, Somerset and North Pine Dam* (October 2010).[112] The report deals with facilities available at the flood operations centre and the back-up flood operations centre, the performance of the flood model and rainfall gauge network, new rainfall gauges installed, accuracy of the models during the flood events that occurred in 2009/2010 and availability of suitable flood operations staff. The report concludes by saying that although all aspects of the system were satisfactory, Seqwater was already taking steps to renew the system and improvements were expected for the 2010/2011 year. (Similar information about Seqwater's activities to prepare for the 2010/2011 wet season is contained in section 4 of its report on the flood events at Somerset and Wivenhoe dams.[113])

There are limitations in the review undertaken in the *Flood Operations Preparedness Report.* It did not attempt to assess every aspect of Seqwater's ability to comply with the manuals during the wet season. Obvious matters requiring attention were:

- checking whether the people listed on the schedule of flood engineers were registered with the Board of Professional Engineers Queensland, as required by the Wivenhoe and North Pine manuals.[114] It was later discovered that one of the flood engineers was not registered, a breach of part 2.5 of both manuals.[115] See also *2.5.6 Registration of flood engineers*.
- considering access to the flood operations centre and the back-up flood operations centre if Brisbane city were flooded. An inability to reach and use one or the other of those premises could have prevented the flood operations centre from controlling the dams.

Seqwater's flood preparedness activities also do not seem to have extended to matters affecting the practical ability of the flood engineers to carry out their duties. These include:

- the conditions under which staff would have to work in a prolonged flood event, with regard to the availability of food, accommodation, contact with family and friends and fatigue management. See *2.6 Decision-making and conditions at the flood operations centre.*
- the lack of any training exercise which included a situation in which strategy W4 under the Wivenhoe manual was invoked. This flood event was the first time W4 had ever been triggered, in training or in real operations.[116] See *2.5.5 Training.*

There is no evidence to suggest the last two matters adversely affected the flood engineers' performance during the January 2011 flood event. The point is that they were matters which should have been identified and addressed by Seqwater prior to the wet season.

These four examples are not individually significant. However, they reveal that the process by which flood preparation was undertaken was inadequate.

Recommendation

2.1 Seqwater should review all arrangements for the operation of the dams during flood events for the entire wet season by 30 September each year, and ensure that all parties are adequately prepared, in the process ensuring that:

- Seqwater can comply with every aspect of the Wivenhoe and North Pine manuals
- the flood operations centre is ready and capable of operating during any flood event of whatever duration, including in terms of communications, equipment, rostering of and facilities for staff
- the flood operations centre has available to it all tools, studies, equations and data necessary for it to be fully appraised of the consequences of its operation of the dams, including:
  - hydrodynamic model of the Brisbane River downstream of the Wivenhoe Dam
  - hydrodynamic model of the Bremer River
  - copy of damage curves from *Brisbane Valley Damage Minimisation Study 2007*
  - equations for flow out of fuse plugs, if initiated.

2.4 Temporary alteration of full supply level

2.4.1 Fixing and altering the 'full supply level' of dams

As noted in *2.2.5 Resource operations plans and licences*, the *Water Act 2000* allows the chief executive (the Director-General of DERM) to prepare a 'resource operations plan' and to amend it after undertaking a consultation process. In some circumstances however, the Water Act allows a resource operations plan to be amended without undertaking the consultation process; this may be done by the Governor in Council.

The Moreton Resource Operations Plan specifies by an attachment[117] the operating level for Wivenhoe Dam. It designates the full supply level of that dam as 67 metres, and the full supply volume as 1 165 200 megalitres.[118]

The same 'full supply level' is reflected in the Wivenhoe manual for the operation of the dam, but that manual has no part in setting that level. That much is obvious when it is acknowledged that the provisions of the Wivenhoe manual which include reference to full supply level have application only during a 'flood event'.[119]

2.4.2 Drought and proposals to raise full supply level

South-east Queensland was affected by drought from 2001 to 2009. During this period the water levels of Somerset and Wivenhoe dams were well below the full supply level of each dam.[120] It was only when the combined storage capacity of Somerset, Wivenhoe and North Pine dams reached 60 per cent on 20 May 2009 that the drought was declared over.[121]

Over the preceding decade, south-east Queensland's water supply had been put at some risk. As a result, investigations began into the means by which there could be an increase in the volume of water supply or 'yield' that could be drawn from the Brisbane River catchment. Investigations of this kind included:

- Seqwater's March 2007 report, *Provision of Contingency Storage in Wivenhoe & Somerset Dam* (March 2007 report), prepared in conjunction with the then Queensland Department of Natural Resources and Water. This included investigations for the provision of an additional 200 000 to 600 000 megalitres of contingency storage in the Brisbane River catchment by raising the full supply level of Wivenhoe Dam or Somerset Dam.[122]
- SunWater's December 2007 report, *Assessment of Wivenhoe Dam Full Supply Level on Flood Impacts*, prepared at the request of Seqwater for the purpose of securing south-east Queensland's water supplies. This report considered three full supply levels scenarios, 67 metres (current), 68 metres and 69 metres under certain assumptions,[123] to determine the impact on Wivenhoe and Somerset dams and flooding in areas downstream.[124]
- GHD's December 2009 report, *Report for Wivenhoe Dam Full Supply Level Review Technical Assessment of Raising Potential*, commissioned by Seqwater. This report assessed the structural capacity of Wivenhoe Dam to cope with a two metre increase in full supply level.[125]

The March 2007 report informed the draft *South East Queensland Water Strategy,*[126] while the final *South East Queensland Water Strategy*, released in July 2010, stated that the Queensland Water Commission and Seqwater would conduct a detailed investigation to determine the maximum level to which the working storage of Wivenhoe Dam could be raised without raising the dam wall.[127]

The Water Commission commenced the preliminary investigations required by the *South East Queensland Water Strategy* into raising the full supply level of Wivenhoe in about March 2010.[128] Seqwater became actively involved in the study later that year.[129]

By a briefing note dated 11 October 2010, the Water Commission advised the Minister, Mr Robertson, that raising Wivenhoe Dam's full supply level by one metre would increase yield by 5000 megalitres while any raising of the full supply level 'above one metre actually results in a lower overall yield from the system due to higher evaporation losses'.[130] At that time, a pre-feasibility study was expected to be completed by March 2011 and a feasibility study involving further work was anticipated to take a further 12 months.[131]

As late as 10 January 2011, the chief executive officer of Seqwater, Peter Borrows, wrote to the chief executive officer of the Water Commission to confirm Seqwater's willingness to conduct a flood study on the raising of Wivenhoe Dam's full supply level.[132] At the time of the Commission's public hearings, the investigations were 'paused' but not discontinued.[133]

2.4.3 Community concern

On 10 December 2010 Seqwater's dam operations manager, Robert Drury, met with representatives of the Mid Brisbane River Irrigators Incorporated. That organisation represents irrigators in the mid Brisbane River region, which extends from Wivenhoe Dam to Mt Crosby Weir. Its aim is to promote effective sustainable catchment management and water quality in the region.[134] During that meeting, the Mid Brisbane River Irrigators sought a reduction in the level of Wivenhoe Dam to 70 to 80 per cent of full supply level under the Wivenhoe manual to 'act as a buffer and to enable long, slow water releases with an extended drain down phase to prevent hydraulic drawdown of the river banks, thus replicating a natural flow' and 'avoid the risk of flood' in the coming wet season.[135] Mr Drury advised the Mid Brisbane River Irrigators' representatives that amendment of the Wivenhoe manual was not the appropriate way to effect a temporary reduction in the level of Wivenhoe Dam; they were talking to the wrong people about the issue.[136]

On 23 December 2010, the Chairman of the Mid Brisbane River Irrigators, Ken Schmidt, wrote a letter to Mr Robertson to express concern about the management of water releases from Wivenhoe Dam and their effect on the mid Brisbane River region.[137] The letter expressed the view that the water released from Wivenhoe Dam during October 2010 flooding, combined with the flow from tributaries below Wivenhoe Dam, resulted in major riverbank slumping, loss of vegetation, erosion, and damage to irrigation, stockwater pumps and fences in the mid Brisbane River region. It went on to propose that such damage could be significantly reduced, or avoided

altogether, if the relevant authorities took a number of measures including reducing the lake level of Wivenhoe Dam during the wet season to 80 per cent to better enable it to control the effects of heavy rainfall in the Somerset and Wivenhoe catchments.[138]

On 9 March 2011, Mr Robertson responded to Mr Schmidt's letter, noting the establishment of the Commission. The Minister also noted that on 13 February 2011 he had announced a decision to temporarily reduce the lake level of Wivenhoe Dam to 75 per cent of full supply level.[139]

2.4.4 October 2010 process

In fact, the Minister had, in October 2010, already begun an inquiry into the possibility that the full supply level of Somerset, Wivenhoe, North Pine and Leslie Harrison dams might temporarily be lowered.

On 18 October 2010, James Davidson of the Bureau of Meteorology briefed Cabinet about the seasonal forecast, warning that the 2010/2011 wet season would be unusually intense.[140] The Bureau's seasonal forecast was, in short, for a 75 per cent chance of above median rainfall in south-east Queensland for the period November 2010 to January 2011 and an active cyclone season. Those briefings included warnings that:[141]

- there was a well established and quite strong La Niña pattern, more than 'run-of-the-mill', which was expected to persist until at least March
- there was a historical correlation between La Niña events and tropical cyclones in the Coral Sea
- above normal rainfall would continue over much of Queensland.[142]

As a result, the Minister looked to the office of the South East Queensland Water Grid Manager for advice. (For an explanation of the role of the Water Grid Manager, see *2.1.3 SEQ Water Grid Manager*).

Following discussions with DERM officers,[143] Daniel Spiller, the Water Grid Manager's director, operations, prepared correspondence which was signed by the Minister and, to complete the circle, sent by the Minister to the Water Grid Manager.[144] That correspondence, dated 25 October 2010, requested the Water Grid Manager's urgent advice about options for and benefits of releasing water from 'key storages' – at a minimum, Wivenhoe, North Pine and Leslie Harrison dams – in anticipation of major inflows over the coming summer. Mr Spiller also prepared for the Minister a draft media release announcing 'measures to configure the [water] Grid for improved flood mitigation'. That media release anticipated the results of an 'analysis', even though no analysis had been done – or even commenced – at the time it was prepared.[145]

It should also be noted that the only source from which the Minister sought advice was the Water Grid Manager, which in turn consulted with Seqwater.[146] No advice was sought from anyone within DERM,[147] notwithstanding the interest that this department and other arms of government had (or ought to have had) in the topics of dam safety[148] and flood mitigation.[149]

On 13 December 2010, Mr Robertson met, for various purposes, with the Board of the Water Grid Manager.[150] The Minister gave evidence that on that date he had been verbally briefed about the Water Grid Manager's preliminary view, which was that it thought that a minor reduction was possible but that it would not make an appreciable impact on flood levels.[151]

On the basis of the information received on 13 December 2010, Mr Robertson said, he made the decision not to proceed with the proposal for a temporary reduction of the full supply levels.[152] The process was 'parked'.[153]

There is no record of the Minister's having made this decision or telling anyone about it – then or at any time.[154] He was required to provide the Commission with an account of all discussions on the topics of possible alteration of the full supply level and changes to the level of Somerset and Wivenhoe dams in which he participated between 1 September 2010 and 30 March 2011.[155] He said in evidence that he 'would have' discussed this matter with his Director-General, but this possibility was not raised in his witness statement.[156] No explanation was forthcoming for this apparent failure to comply with the Commissioner's requirement.[157] His Director-General, John Bradley, could not confirm that the Minister made this decision on that day, or at all.[158]

The Minister explained aspects of the process by which he made his decision. Firstly, he took the view that a five per cent reduction in the full supply level was 'meaningless'.[159] The absence of any written record of the decision-making process makes it impossible to determine the basis for this conclusion. If the advice that he received

included the observation that a small reduction in full supply level could minimise operational and community impacts in minor inflow events, then the Minister must be understood to be of the view that these benefits were, in the scheme of that which he was considering, unimportant. Clearly this aspect of his decision did not accommodate the Mid Brisbane River Irrigators' concerns as ultimately expressed on 23 December 2010. See *2.4.3 Community concern*.

Second, it is apparent that the Minister was expecting the relevant advice to come from people who were busy managing the dams at the time.[160] For that reason, so the logic seemed to run, the potential advisors should not be pressed too hard for a response to his initial inquiry. It should be remembered that the only entity from which advice had been sought directly was the Water Grid Manager. It had no operational role in managing the dams, although it sought advice from Seqwater, which did.

In any case, since both were oblivious to the Minister's state of mind, these parties were, as late as 24 December 2010, working to provide a response to the initial inquiry. Even then, it appears that there was some confusion as to who was responsible for bringing this process to a conclusion.

In a letter bearing the date 24 December 2010, the Water Grid Manager finally responded to the request of 25 October 2010. It did not recommend a pre-emptive release on such a scale. The potential water security impacts were considered to be more significant than the benefits, although the nature of the prospective 'benefits' seems to have been the subject of only limited exploration.[161] The letter suggested that a temporary reduction in the level of Wivenhoe and Somerset dams (to 95 per cent of the combined full supply level) might provide some benefits in terms of 'reduced community and operational impacts during minor inflow events'. [162] It was noted, however, that such pre-emptive releases would provide negligible benefits for medium and major flood events. To have any impact on events of those kind, pre-emptive releases of a much greater quantity (about 16 per cent of the 'combined storage capacity' of the dams) would be necessary.[163]

The advice, which drew upon modelling work done by Seqwater,[164] went only so far as to say that there was 'no in principle objection' to Wivenhoe and Somerset dams being drawn down to 95 per cent of the combined full supply level.[165] It was confirmed, as part of this advice, that from a water security perspective, the Queensland Water Commission had also agreed that there were no objections to a release on this scale.[166] The Water Grid Manager's letter reflected in summary form Seqwater's advice about the downstream flood impacts of temporarily lowering the full supply level of Wivenhoe and Somerset dams.

The correspondence concluded with a recommendation that the existing investigations which were examining the opportunity of raising the full supply level (for the purpose of water supply) should be expanded to include options involving the release of additional water once major inflows into the dam were forecast.

At 10.18 am that day, the Water Grid Manager sent to the Water Commission an email indicating that it was 'planning to send [a letter] to Seqwater giving [its] permission to lower Wivenhoe below full supply level down to 95%…'. [167] The Water Grid Manager asked the Water Commission to note the proposed strategy and reply by midday, apologising 'for the short turnaround period'. [168]

Once the Water Commission confirmed it had no objection to the proposed release, the chief executive officer of the Water Grid Manager, Barry Dennien, sent the letter to the chief executive officer of Seqwater.[169] In reply, Mr Borrows enquired whether the letter was 'meant to be a direction to release to levels below FSL [full supply level]' for Wivenhoe, Somerset and North Pine dams.[170] In response, Mr Dennien called Mr Borrows to advise that his letter was not a direction to release water below full supply level.[171]

Ultimately Mr Borrows, 'decided not to progress' the issue.[172]

In sum, an examination of the activities and correspondence reveals that the relevant responsibilities were not the subject of a clear understanding between those involved. The Minister did nothing to resolve this confusion.

2.4.5 February 2011 process

The concept of a temporary reduction in the full supply level of the dams was revisited after the flood events of January 2011. Following a series of meetings and communications between relevant parties, the decision to release 25 per cent of the water then in Wivenhoe Dam was finally implemented.[173] The process, however, was not straightforward. Once again, the relevant responsibilities were not the subject of clear understanding.

In a letter of 20 January 2011, the Minister requested as a matter of priority that Seqwater's report on the recent flood events at Wivenhoe and Somerset dams (required by clauses 2.9 and 7.4 of the Wivenhoe manual) 'include consideration of the appropriate full supply levels'.[174]

On 25 January 2011, Seqwater agreed that it would conduct modelling to provide an indicative assessment of the benefits or otherwise of undertaking a pre-release strategy to pre-emptively reduce the full supply level of the dams.[175] This was confirmed by Seqwater in a letter of 27 January 2011.[176]

In a meeting of 31 January 2011, Mr Robertson requested Seqwater take the lead on communication surrounding this issue.[177] He specified that this was not to be the role of either his department or the Water Grid Manager. Mr Borrows responded by stipulating that his organisation could provide advice as to what an appropriate full supply level might be, but could not make a policy decision.

The next day, 1 February 2011, Mr Borrows met with senior representatives of DERM, the Water Grid Manager and the Queensland Water Commission and reiterated this position.[178] Mr Borrows said that full supply level was a 'policy call of [government]', and noted the tension between maintaining sufficient supply of drinking water and sufficient space for flood storage. Mr Allen, Dam Safety Regulator, of the Minister's own department, supported this assessment. Mr Allen noted that the dam operators were not traditionally asked for any analysis on pre-releases or questions of supply level. These areas were 'out of bounds', because they were levels which are set by state instruments.

By letter dated 4 February 2011, Phil Hennessy, chairman of Seqwater, informed the Minister that Seqwater's modelling was to provide the indicative assessment referred to on 25 January 2011, in order to assist DERM.[179] This was being done 'to assist DERM in formulating its policy position'.[180] He went on to note that, should DERM be satisfied on advice from the Water Commissioner and the Water Grid Manager that, from a water supply security perspective, Wivenhoe Dam's full supply level could be 'reduced in the short term to, say, 75% of its current FSL [full supply level]', then Seqwater could confirm that such a reduction would provide flood mitigation benefits.[181] He also offered assistance to DERM regarding 'the Moreton Resource Operations Plan and the appropriate mechanism by which such a pre-release strategy would be implemented'.[182]

On 7 February 2011, Mr Borrows sent a letter and memorandum entitled *Impact of Reducing the Full Supply Level of Wivenhoe Dam on Flood Discharges* to Mr Bradley.[183] The memorandum presented a number of scenarios for consideration by DERM for it to determine, from a policy perspective, whether the full supply levels of dams should be changed. The scenarios presented in the memorandum provided an approximate analysis. Mr Borrows advised that more accurate estimates would require a detailed investigation and analysis of the entire river system, using multiple flood events and a combination of hydraulic, hydrological and routing models. The relevant part of this analysis, presented as 'option five', pursuant to which the full supply level of Wivenhoe Dam would be reduced to 75 per cent of its full supply level is discussed in greater detail below.

On 8 February 2011, representatives of DERM and Seqwater again met.[184] The exchange began with Mr Bradley enquiring as to the status of the modelling being done by Seqwater. Mr Borrows advised that it had been provided by an email 12 hours earlier. Mr Bradley queried whether this document expressed a recommendation, or whether it was 'simply data'.[185]

In the course of this meeting, Mr Bradley is recorded as saying that:[186]

- DERM 'were asking for explicit advice from Seqwater on the FSL'
- he had a 'different expectation of advice from Seqwater under the manual'
- he 'could not comprehend how an owner and operator can't come to a corporate position of FSL as required by the statutory report under the manual'
- 'Seqwater appeared to be not taking control and that there was no ownership by Seqwater'

- 'the manual was now the operating framework that specifies FSL and was therefore the regulatory instrument'
- 'if the manual was not the instrument to change FSL – what is the other regulatory instrument – it is not the ROP'
- 'the Minister expected the Board [of Seqwater] to provide corporate decisions on FSL'
- Seqwater is the organisation that takes into account 'downstream impacts through the manual'
- 'to not come to a position on the benefits and desirability of changing FSL/releases is a fundamental vacation of the area that [Seqwater] should be expert in'.

Mr Borrows resisted the proposition that the responsibility for setting full supply level rested with Seqwater. He pointed out that the Wivenhoe manual was not the mechanism by which full supply level was set – it was a 'taker' and not a 'decider' of full supply level.[187] Nor was the review of the flood event, as required by the Wivenhoe manual, something that could drive a change to the designated full supply level.[188] Mr Borrows further articulated the fundamental difference between full supply level from a water security point of view and the way in which it was relevant to the Wivenhoe manual. [189] This was not, he said, a Seqwater decision. [190]

On 10 February 2011, Mr Borrows sent to the Minister a letter that reflected a change in position.[191] He had received some advice from the Water Grid Manager the previous day.[192] Mr Dennien had told him that, from a water security perspective, a temporary drawdown of Wivenhoe Dam to 75 per cent of its full supply level was unlikely to 'impact our ability to comply with' the contract for the supply of water from the dams to the Grid Manager.[193] Mr Borrows referred to Seqwater's modelling, which had already been provided to DERM, and concluded that a reduction in the full supply level to 75 per cent would 'provide appreciable flood mitigation benefits'.[194] In the light of the modelling results and the advice from Mr Dennien, Mr Borrrows wrote, 'Seqwater recommends that Wivenhoe Dam's storage level be temporarily reduced to 75% of its FSL in order to temporarily increase its flood mitigation capacity'.

After receiving this correspondence, DERM held a number of discussions to speed up the implementation of Seqwater's recommendation to reduce the storage level of Wivenhoe Dam to 75 per cent of its full supply level.[195] DERM and Seqwater agreed to implement the temporary reduction of the full supply level by, in substance, amending the Moreton Resource Operations Plan to permit Seqwater to submit to Mr Bradley an interim program for operations under which the storage level of Wivenhoe Dam would be reduced to and maintained at 75 per cent of its full supply level until 31 March 2011. On approval of the interim program, Seqwater would duly draw the dam down to 75 per cent of full supply level.[196]

On 13 February 2011, Mr Robertson issued a media statement[197] in which he announced that Seqwater had 'formally recommended that Wivenhoe Dam's [sic] would be temporarily reduced to 75% of its current Full Supply Level'. The Minister reported that the release had been recommended by Seqwater after recent hydrologic analysis, and was a precaution against the 'second strongest La Niña pattern in history'[198] which was continuing to influence the current wet season. According to the media statement, Mr Dennien had advised Seqwater that a reduction to 75 per cent would be manageable from a water security perspective. The proposition that 'the recently completed Wyaralong Dam was now full five years earlier than expected and now storing 103,000 megalitres which is able to be connected to the Water Grid when required' was also attributed to Mr Dennien.

On 14 February 2011 the Water Commission advised Mr Borrows as to the potential impact on the security of water supply if a significant volume of water was released from Wivenhoe Dam.[199] This advice had been shared with Seqwater officers during the course of its preparation, and provided to them on 12 February 2011.[200] In sum, the report concluded that the release of 25 per cent of the dam's water as a temporary measure would meet the risk criteria of the South East Queensland System Operating Plan.[201]

On 14 February 2011, the Governor in Council approved an amendment to the Moreton Resource Operations Plan.[202] The amendment appeared in the government gazette that day.

On 17 February 2011, Seqwater submitted to DERM a revised interim program giving effect to the agreed reduction of full supply level to 75 per cent.[203] On the same day, Mr Bradley approved the revised interim program pursuant to section 13 of the Moreton Resource Operations Plan.[204] The reduction was to have effect until 31 March 2011. While Mr Bradley was the one to *make* the decision under the Water Act, Mr Robertson agreed in

his evidence before the Commission that Mr Bradley was under the direction of himself and Cabinet; that nothing would happen until he and Cabinet had agreed.[205] The Minister is the only one who can *effect* a reduction in full supply.[206]

Even after this process was completed, on 22 March 2011, Mr Borrows responded to the Water Commission's advice. In the course of that letter he expressed the view that it was beyond the scope of Seqwater's function to comment on the water supply security implications of the scenarios presented in the report, other than to provide comment and modelling on the respective flood mitigation impacts of those scenarios.[207]

2.4.6 Relevant and responsible decision-maker

An overall examination of the efforts – in October 2010 and February 2011 – to reduce, temporarily, the full supply level of dams in south-east Queensland for the purposes of flood mitigation leads to a conclusion that reform is necessary.

The water agencies and DERM seem incapable of agreeing upon their respective roles. Seqwater and DERM have had fundamental disagreements about the advice Seqwater should be providing to the Minister.[208] The Queensland Government has maintained its position that Seqwater is the appropriate body to give recommendations to the Minister as to reduction of full supply level in its submissions to the Commission. Seqwater has not, in its submissions to the Commission, departed from the view expressed in its letter of 22 March 2011.[209] The Water Grid Manager also submits that Seqwater should be making recommendations as to alteration of full supply level to the Minister. The Queensland Water Commission is part way through a study into the roles of the different water authorities in Queensland, almost five years after the water authorities were created in 2007.[210]

In that environment, it cannot be left to the water agencies to determine who should provide what advice to the Minister during a consideration of a change in full supply level.

It seems to the Commission that, given the competing interests between which a balance must be struck, the ultimate decision is one for the accountable Minister. The Minister accepted in his evidence before the Commission that he was the only one who could effect a reduction in full supply level.[211]

Of course it is a decision which should be made on advice, but it is not one which can or should be abdicated to agencies whose functions are prescribed by statutes which omit any reference to a responsibility of this kind. Agencies such as Seqwater or the Water Grid Manager cannot be expected to form the overview that is an essential prerequisite to the making of such an important decision.

Recommendations

2.2 It should be accepted that control over temporary alteration of the full supply level of Wivenhoe, Somerset and North Pine dams is solely the function of the Queensland Government acting through the responsible Minister.

2.3 The regulatory framework by which the responsible Minister can effect a temporary alteration to full supply level should be simplified.

2.4 For the purposes of making any decision about a temporary alteration to full supply level, the Minister should receive advice from:

1. Seqwater, as to the flood mitigation impacts of such an alteration
2. the Water Grid Manager, as to the security of water supply implications of such an alteration
3. the Water Commission, as to both the flood mitigation impacts and the security of water supply implications of such an alteration
4. DERM as to an analysis of the above advice, its own advice as to dam safety, the regulatory framework and any other matter within its expertise.

2.4.7 Proposed temporary reduction of Wivenhoe Dam in 2011/2012

The question that remains is what should be done about Wivenhoe Dam's full supply level in preparation for next summer's wet season.

The Commission's recommendation on this issue must be based on the evidence it has received to date, notwithstanding its limitations and the merits of a fuller scientific assessment of the kind the Commission recommends for the longer term. See *2.5.8 Longer term review of the Wivenhoe manual*.

Seqwater performed modelling for DERM of the effect of reducing the Wivenhoe lake level below full supply level after the January 2011 event. A summary of that modelling was provided to DERM on 7 February 2011.[212]

The modelling considered five options; the most relevant here being the situation where the lake level had been drawn down to 75 per cent of full supply level (64.0 metres) and the Wivenhoe manual been amended so that gate operations would occur when the water level exceeded 75 per cent. The modelling showed that for the January 2011 event, the peak flow out of the dam would have been 4512 m^3/s, a 40 per cent reduction on the actual peak flow of the event (7528 m^3/s). The lake level would have peaked at 74.25 metres, as compared to 74.98 metres, so strategy W4 would still have been triggered. [213]

The modelling also indicated that for the 1999 flood, such a starting point would have reduced peak flow by 32 per cent; for the 1974 flood, such a starting point would have reduced peak flow by 24 per cent.[214] Seqwater concluded that 'large changes' to full supply level would be necessary to achieve 'appreciable reductions in flood magnitude'.[215]

In the absence of further modelling, the Commission acknowledges this is merely an estimate. See *2.9 Effects of dam releases*. However, it was the basis for the advice given by Seqwater to the Minister in February 2011[216] and which the Minister presented as proving that a reduction to 75 per cent would provide 'appreciable flood mitigation benefits'.[217] The Commission recognises the other limitations of this modelling which include the following:

- it is based on the gate openings which the Wivenhoe manual specifies for use if the dam operator loses communication with the flood operations centre; this entails set gate openings depending on lake level only[218] and so does not mirror the gate opening strategies actually employed by the flood engineers in the January 2011 flood event
- it is based on the January 2011 flood event and will not necessarily apply to other flood events; in particular, it will do nothing to mitigate floods caused by rainfall downstream of the dams
- no analysis has been done of the effect of a drawdown to 75 per cent of full supply level on the periods of inundation of bridges in the Brisbane Valley.

The Commission also notes the conclusions of the investigations of the Queensland Water Commission[219] and the Water Grid Manager.[220] These indicated that there was little risk posed in the medium term to water security should Wivenhoe and Somerset dams be temporarily lowered to 75 per cent of full supply level. The basis for this assessment was the very wet weather of the past year and the current state of the south-east Queensland water grid, including the then full Wyaralong Dam. These recommendations were made in the absence of an assessment of the true economic and environmental costs of, for example, using the Tugun desalination plant at a greater capacity. The Commission is aware, too, that Wyaralong Dam is not currently connected to the water grid.[221]

On the basis of the available evidence, and because the Commission considers a precautionary approach is best adopted for the short term, given the potential for harm by flooding, the Commission recommends a temporary reduction in the full supply level of Wivenhoe Dam, to 75 per cent of full supply for the 2011/2012 wet season, with a concomitant adjustment to the trigger levels for the strategies in the Wivenhoe manual.

However, the Commission is of the view that this recommendation should only be taken up if the Bureau of Meteorology makes a similar seasonal forecast to that made for the 2010/2011 wet season, expressed with equal or greater confidence, for the 2011/2012 wet season.

Recommendation

2.5 If the Bureau of Meteorology makes a similar seasonal forecast to that made for the 2010/2011 wet season, expressed with equal or greater confidence, for the 2011/2012 wet season, the Queensland Government should temporarily reduce the full supply level of Wivenhoe Dam to 75 per cent, with a concomitant adjustment to the trigger levels for the strategies in the Wivenhoe manual.

2.5 Manual of operational procedures for flood mitigation at Wivenhoe Dam and Somerset Dam

The drought brought home the value of water; the flood showed its capacity for destruction. These events demonstrated that Wivenhoe Dam is at once the most valuable and dangerous piece of public infrastructure in Queensland. The regulation and control of any such item is a matter of importance to the whole community.

The need for such regulation is acute during floods. At such times there will be, in the case of gated dams such as Wivenhoe and Somerset, the capacity for human intervention which can affect, and at times largely dictate, the amount of water which will flow into the Brisbane River.

The quantity of water released, and the rate at which such releases occur are matters that may affect many parties in many different ways. When such interests compete, it is elementary good sense that the considerations which guide the exercise of relevant discretions should be codified and published. To this end, a document such as the *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam* can assist in removing 'any political influence from decisions to retain or release floodwaters'.[222]

These considerations confirm that there should be a manual and there is a public interest which attaches to its effectiveness. It is against this background that particular aspects of the document itself must be assessed.

Although the Wivenhoe manual governs the operation of Somerset Dam as well, for practical reasons the focus of the analysis which follows will be on the provisions which relate to Wivenhoe. There is also a manual for North Pine Dam: the *Manual of Operational Procedures for Flood Mitigation at North Pine Dam.*[223] While similar in form, the operational strategies which pertain to North Pine Dam are very different and much simpler (see *2.10.1 Managing flood events*). The Commission's recommendations which apply to the North Pine manual are dealt with at *2.10.5 Interim review of the North Pine manual* and *2.10.6 Longer term review of the North Pine manual*, below.

2.5.1 Structure of the Wivenhoe manual

The Wivenhoe manual itself is exhibit 21, but attention can be drawn to some of its more noteworthy provisions.

Title and introduction

The Wivenhoe manual's title, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam,* is misleading in more than one way. It is not concerned with dam operating procedures which might generally have the effect of mitigating floods (such as pre-emptive water release) but only with those operational procedures which take place during a flood event. And it is not confined to operational procedures; it contains parts on the preparation for and the review of flood events.[224]

The Commission has identified deficiencies in Seqwater's preparation for flood events – see *2.3.4 Seqwater's flood preparedness activities*. Given the importance of preparation, it should be the subject of explicit requirements. It would seem appropriate, therefore, for such topics to be excised from the Wivenhoe manual and contained in a separate document which could be given force of law by statute or regulation. The provisions relating to review of flood events could be extracted into the same document.

This possibility might be dealt with in a longer term review of the Wivenhoe manual – see *2.5.8 Longer term review of the Wivenhoe manual*.

In its introduction, the Wivenhoe manual acknowledges its own legal status.[225] That is, it is a document which has been prepared in accordance with the Water Supply Act, and which is relevant to the protection from liability provided by section 374 of that Act.

Its use, for the operation of the dams during flood events, is mandatory according to its own terms,[226] but not as a result of any legislative provision.

The Wivenhoe manual remains in force for a 'period of approval'[227] as determined by the Director-General of DERM. The Director-General delegated his power to approve flood mitigation manuals under the Water Supply Act to the Dam Safety Regulator,[228] a position held at all times relevant to this report by Mr Allen. Seqwater is required to review, and if necessary update, the Wivenhoe manual before its approval expires.[229] The currently applicable revision of the Wivenhoe manual was approved by Mr Allen on 22 December 2009.[230]

Direction of operations

Part 2 of the Wivenhoe manual is concerned with the actual operation of the dams during flood events. Seqwater must ensure that sufficient numbers of suitably qualified personnel are available to operate both the dams and a 'flood operations centre' if a flood event occurs.

For the purposes of that requirement, an individual 'suitably qualified' to be a flood engineer is one who holds, along with appropriate engineering qualifications, a certificate of registration as a registered professional engineer of Queensland.

Seqwater must ensure that operational personnel receive 'adequate training' in the various activities involved in flood control operation. The requirements, in this regard, are to be set by the Director-General of DERM.[231]

One suitably qualified individual, a 'duty flood operations engineer' is to be on call at all times. This person must constantly review weather forecasts and catchment rainfall. If, on the strength of the prevailing or predicted weather conditions, it is expected that the full supply level of either Wivenhoe or Somerset dams will be exceeded, then a flood event must be declared.[232] Following the declaration of a flood event, the dams must be operated in accordance with the manual.

Flood mitigation objectives

The Wivenhoe manual identifies a collection of 'flood mitigation objectives' in part 3. In descending order of importance they are to:

- ensure the structural safety of the dams
- provide optimum protection of urbanised areas from inundation
- minimise disruption to rural life in the valleys of the Brisbane and Stanley rivers
- retain the storage at Full Supply Level at the conclusion of the flood event
- minimise impacts to riparian flora and fauna during the drain down phase of the flood event.

One of these stands apart from the rest: the retention of storage at full supply level is not really something which sits comfortably with description as a flood mitigation objective.

In the course of elaborating on these objectives, the Wivenhoe manual notes that both dams are susceptible to destruction in the event that they are 'overtopped'. It notes also that 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.

Flood classification

Four magnitudes of flooding are classified in part 4 of the Wivenhoe manual: minor, moderate, major and extreme.

Flood monitoring and forecasting system

Part 5 of the Wivenhoe manual describes the real time flood monitoring and forecasting system, which allows for the collection of rainfall and stream flow information. This information is transmitted to the flood operations centre and processed using a real time flood model, which estimates likely dam inflows 'based on forecast and potential

rainfall in the dam catchments'. Seqwater is responsible for improving the operation of the real time flood model over time by, among other things, updating software in line with modern day standards.

Communications

Part 6 of the Wivenhoe manual recognises the interests of different agencies who are dependent upon information from the flood operations centre during times of flood. Specifically, the manual identifies the Bureau of Meteorology, DERM, Somerset Regional Council, Ipswich City Council, and Brisbane City Council as agencies with whom Seqwater must liaise and consult.

The Wivenhoe manual also declares that Seqwater is responsible for the issue of information regarding current and proposed releases from the dams to the media and the public.[233] However, this does not reflect Seqwater's communication practice during the January 2011 flood event. See *2.6.10 Communications*.

Review

Part 7 of the Wivenhoe manual is titled 'Review'. The manual acknowledges that its relevance may change with changing circumstances, and that changes of personnel involved in the management of flood events may result in a diminished understanding of the basic principles upon which the operational procedures are based.[234] To that end, it requires Seqwater to report to the chief executive as to the status of the training of personnel and overall preparedness in the event of flood.

It also requires that, within six weeks of any flood event which requires mobilisation of the flood operations centre, a report be made to the chief executive on the effectiveness of the operational procedures contained in the Wivenhoe manual.

Wivenhoe Dam flood operations

Part 8 of the Wivenhoe manual deals with the operation of Wivenhoe Dam during a flood event.

There are two distinct aspects to the operation of the dam during a flood event. The first is the selection of strategy. The second is the decision as to the amount of water that is to be released from the dams. The second decision will be circumscribed by the first, since three of the four strategies conceived by the Wivenhoe manual set an upper limit for the amount of water which may be released while that strategy is in place. In the fourth, strategy W4, there is no upper limit to the quantum of release.

While the choice of strategy is to be made by the senior flood engineer on duty at any given time, the manner in which the choice is to be made is codified by the Wivenhoe manual.[235] This aspect of the document, and in particular part 8.4, is considered in more detail below.

Following the text in part 8.4 of the Wivenhoe manual there is a series of tables which specify the considerations which will inform the choice of strategy, and the conditions which will apply for so long as each strategy is maintained.

Part 8.5 deals with the factors to be considered when the flood engineers are closing the gates after the peak of the flood has passed. Among them is the requirement that the dams be drawn down to full supply level within seven days after the flood peak has passed through the dams.

Somerset Dam flood operations

Part 9 is concerned with the operation of Somerset Dam and deals with the manner in which it is necessary for both dams to be operated together. As described in *2.2.8 Wivenhoe Dam*, the manual contains a target operating line which sets the optimum lake levels of the dams relative to each other.

Emergency flood operations

Part 10 of the Wivenhoe manual sets out specific provisions for emergency flood operations. It is emphasised that, whatever the circumstances, every endeavour must be made by the progressive opening of operative spillway gates to prevent overtopping of Wivenhoe Dam.

Appendices

There are 11 appendices that address a range of technical and logistic issues. It is worth noting the contents of appendix A. This appendix identifies the agencies, and the responsible people within them, who will hold a controlled copy of the Wivenhoe manual. These include the duty officer from the Department of Emergency Services, the local disaster response co-ordinator from the Somerset Regional Council, Ipswich City Council and Brisbane City Council, and the regional director of Emergency Management Queensland.[236] There is no requirement that any such individual be an appropriately qualified engineer.

2.5.2 Choice of strategy/forecast rainfall

It is fair to say that, during the course of the Inquiry so far, part 8.4 of the Wivenhoe manual has attracted more attention than most other parts of the document. This part of the manual includes the following directions:

The strategy chosen at any point in time *will depend* on the actual levels in the dams and the *following predictions*, which are *to be made using the best forecast rainfall* and stream flow information available at the time:

- Maximum storage levels in Wivenhoe and Somerset Dams
- Peak flow rate at the Lowood Gauge (excluding Wivenhoe Dam releases)
- Peak flow rate at the Moggill Gauge (excluding Wivenhoe Dam releases).

Strategies are likely to change during a flood event as forecasts change and rain is received in the catchments. It is not possible to predict the range of strategies that will be used during the course of a flood event at the commencement of the event. Strategies are changed in response to changing rainfall forecasts and stream flow conditions to maximise the flood mitigation benefits of the dams. [Emphasis added.]

Prior to the January 2011 flood event, few people had occasion to interpret the words of the Wivenhoe manual. Whatever those people understood by the words of part 8.4, and whatever was intended by their author, the Commission considers that their meaning is plain. As written, the Wivenhoe manual requires predictions as to lake level to be made using both forecast rainfall and stream flow information. The Wivenhoe manual does not prioritise one over the other, but does require that both be used.

The choice of strategy depends upon those predictions, the actual levels in the dams and predictions as to flow rates at Lowood and Moggill excluding Wivenhoe releases. No one of these has a decisive effect, but the choice of strategy, however made, will depend upon some assessment of all of them.

2.5.3 Use of forecasts – January 2011

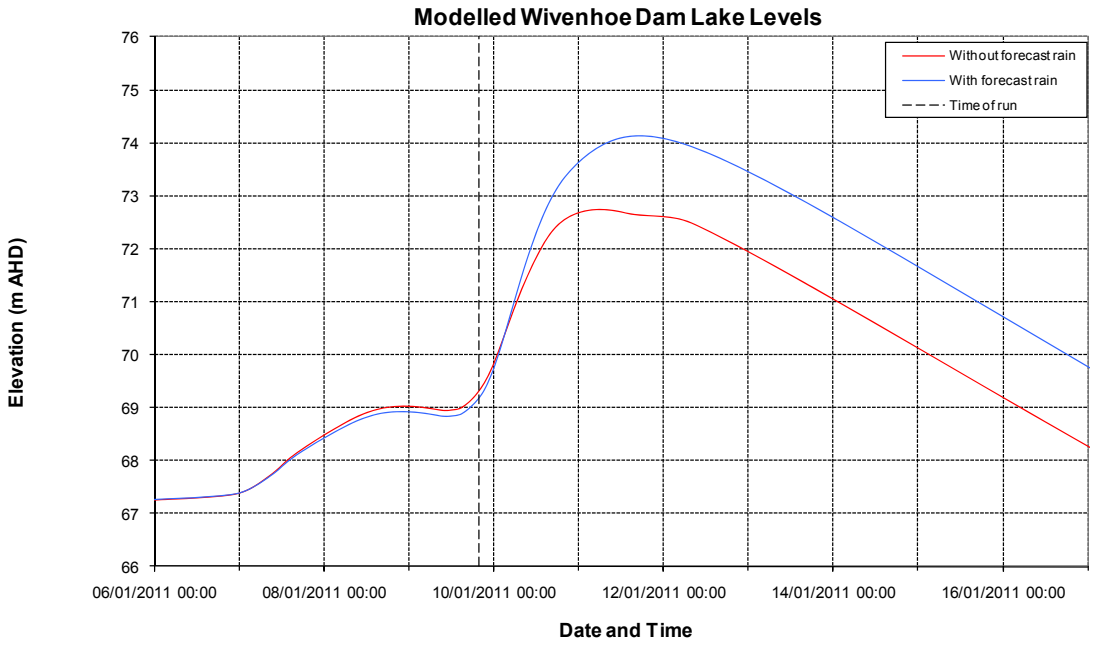
The oral evidence on this issue was variable and at times confusing.[237] In part this may have been as a result of failure, in either question, answer or both, to discriminate between the role of forecast rainfall in the choice of strategy, as opposed to its role in the determination of the releases to be made or for some other purpose.

In any case, so far as the question of the way the flood engineers predicted the lake level in January 2011 is concerned, their evidence admits of only one conclusion. Forecast rainfall was not used for this purpose.

The real time flood model made predictions as to lake level.[238] Mr Ayre, the senior flood engineer,[239] advised the Commission that peak lake level and maximum storage level are interchangeable terms.[240]

The real time flood model provides two predictions of lake level (see *2.6 Decision-making and conditions at the flood operations centre*). They are: a 'with forecast' prediction, which is tracked in a blue line, and a 'without forecast' prediction, which is depicted on the printout in a red line. At 8.00 pm on 9 January, for the first time, the model's 'with forecast' prediction suggested that the level of the lake would exceed 74.0 metres, the tipping point for the purposes of strategy W4. A graphical depiction of the 8.00 pm with and 'without forecast' model results appears below.

Figure 2(a)



Source: Exhibit 22, Model runs.

There were a further 15 model runs between 8.00 pm on Sunday 9 January and 8.00 pm on Tuesday 11 January. In all of those the 'with forecast' model indicated a dam level above 74 metres. There is no record of a suggestion, based on any or all of those models, that a transition to strategy W4 should be made. It was only after runs 34 to 37 inclusive, in all of which the 'without forecast rain' model indicated a peak dam level at or above 74.0 metres, that the decision was made. Terrence Malone, one of the flood operations engineers, did communicate with the Bureau of Meteorology in order to confirm that the rain falling in the dam catchment was likely to continue. It is said that this information was relied upon when the decision was made to transition to strategy W4.[241] However, the inference that forecast rain was, during at least the period between 8.00 pm on 9 January and 3.00 am on 11 January not used by the flood engineers for the purposes of making their lake level prediction – on which their strategy choice would depend – is irresistible.

Indeed, nothing in the submissions received on behalf of Seqwater really contends to the contrary. It is accepted that the flood engineers:

> did not decide to make additional releases, or to transition from one strategy to the next, on the faith of the blue line in the model results. For this purpose, the blue line was accorded zero weight.[242]

The 'red line' was used as the basis of the flood engineers' prediction of the lake level, and was in effect the factor which was decisive in making the decision to transition to strategy W4.[243]

2.5.4 Interpretation and compliance

It has been argued that the approach described above was in fact a faithful application of the Wivenhoe manual as written. The argument rests upon the proposition that as 'skilled addressees' the four flood engineers would have known, however the Wivenhoe manual might be read by anyone else, that they were in fact at liberty to ignore – or give 'zero weight to'– forecast rainfall for the purposes of making predictions as to the level of the lake. As well, Seqwater rejects any suggestion that the tension between the approach adopted and the plain terms of part 8.4 might be a cause to either modify the use of forecast rainfall, or even amend the Wivenhoe manual to make its status clear. Its position is encapsulated in the assertion that 'if the manual is perceived by others to be ambiguous, the fact is of little moment'.[244]

This submission must be rejected. The fact that the current flood engineers may agree on what to others carries a different meaning, will be useless in the event of accident or illness which incapacitates one or more of them. In that

case it may be necessary for others to be appointed as flood engineers at short notice. Indeed the Commission notes that one of the flood engineers who managed the January 2011 event is currently unregistered (see *2.5.6 Registration of flood engineers*) and another is no longer available, with the ending, on 1 July 2011, of the arrangement for SunWater to provide flood management services to Seqwater. At the time of writing, there are just two flood engineers who are both available for flood operations and familiar with the Wivenhoe manual.

It cannot be accepted that the flood engineers will be the only people ever to interpret a document such as the Wivenhoe manual, especially when the document itself acknowledges[245] that the identities of these individuals will change. And the Wivenhoe manual itself contemplates that its readership might extend beyond the flood engineers. That much is obvious when regard is had to the identities of the individuals referred to in Appendix A of the Wivenhoe manual. Moreover, the status conferred upon the manual by section 374 of the Water Supply Act contemplates that its readership may be considerably wider.[246] If only for the last reason, the Wivenhoe manual ought to be intelligible to all who might have an interest in the consequences of its application. Of course it must also function as an operational document that is meaningful to qualified engineers. Properly written, it could and should do both.

It can, therefore, be said that in relation to the requirement that the flood engineers' prediction as to lake level be made using the best available forecast rainfall information, and that the subsequent choice of strategy should depend upon that prediction, there was a failure to comply with the Wivenhoe manual.

That finding, however, must be qualified by the following observations:

- the flood engineers were acting in the honest belief that the Wivenhoe manual did not, and ought not, compel choice of strategy to be made by reference to forecast rainfall
- on the evidence, it is not possible to articulate a method by which it would be possible to predict lake level with any precision or confidently change strategies on the basis of rainfall forecasts. The existing science suggests that such forecasts lack the reliability which would be necessary before they could be incorporated into such a process.

The finding does not therefore necessarily reflect upon the flood engineers operating the dams, nor can any particular consequence flowing from the breach be identified.

However, and at the very least, the need for review of the Wivenhoe manual is underscored by the fact that, as written, it does not reflect the practice unanimously endorsed and adopted by the flood engineers. For a discussion of the interim and longer term review of the Wivenhoe manual, see *2.5.7 Interim review of the Wivenhoe manual* and *2.5.8 Longer term review of the Wivenhoe manual*.

2.5.5 Training

Part 2.7 of the Wivenhoe manual requires that Seqwater ensure operational personnel receive adequate training as required by the chief executive. There is no evidence that the chief executive has ever required anything of Seqwater as to the training to be provided. Training was usually provided by SunWater under its agreement to provide flood management services to Seqwater. See *2.3.1 Arrangements for flood operations*.

Mr Ayre gave evidence that no training exercise in which strategy W4 was invoked had ever been provided.[247] This approach to the topic of training by DERM and Seqwater is flawed. The Wivenhoe manual pre-supposes that training would be beneficial and elementary good sense would in any case suggest as much. Mr Ayre said that incorporating a training exercise into the program which includes triggering W4 would be useful.[248]

Whether the performance of the flood operations centre might have been improved had the flood engineers had the benefit of relevant training will never be known. In order to ensure any such speculation does not attend future events, training across the full range of operating strategies should be undertaken. Consideration should be given to the involvement of independent experts in such training.

Recommendations

2.6 The requirements of the chief executive of DERM as to training of operational personnel should be provided to Seqwater on a regular and formal basis.

2.7 Seqwater should ensure all staff and engineers who may be involved in flood operations are involved in formal training exercises which address the full range of possible operating situations.

2.5.6 Registration of flood engineers

As outlined above in part 2.5.1, the Wivenhoe manual requires Seqwater to nominate one or more 'suitably qualified and experienced persons' to be flood engineers.[249] If approved by the chief executive, the nominated person can appear on a Schedule of Authorities.[250] The qualifications and experience required are set out in part 2.5 of the Wivenhoe manual; the flood engineers must all hold a certificate of registration as a registered professional engineer of Queensland, an appropriate engineering qualification, have knowledge of design principles of large dams and possess relevant science and engineering expertise.[251]

It was discovered after the flood event that one of the flood engineers was not registered with the Board of Professional Engineers Queensland throughout the 2010/2011 wet season. The circumstances in which that flood engineer's registration lapsed were of a personal nature and were perhaps understandable.[252] That lack of registration is a breach of part 2.5 of the Wivenhoe manual. There is no suggestion that the lack of registration had any effect on the operation of the dams; the breach is technical. However, it assumes relevance in the context of Seqwater's failure to check its compliance with the Wivenhoe manual in advance of the wet season. See also *2.3.4 Seqwater's flood preparedness activities*.

2.5.7 Interim review of the Wivenhoe manual

The Commission finds that an interim review of the Wivenhoe manual is required, aimed at resolving uncertainty about the manual's meaning and effect.

It should not be difficult to ensure consistency in the use of language throughout the Wivenhoe manual. This might be achieved by the engagement of a technical writer to assist with re-writing, organising material and reviewing the document for consistency and intelligibility.

Draft changes to the Wivenhoe manual settled upon by Seqwater should be forwarded to independent expert peer reviewers. Following Seqwater's consideration of the expert reviews and the incorporation of any recommended amendments, the draft revision of the Wivenhoe manual should be submitted for approval to DERM before 1 October 2011.

No accompanying changes in strategies are recommended prior to a full review of the Wivenhoe manual.

Recommendations

2.8 Seqwater should:

1. conduct an interim review of the Wivenhoe manual
2. have the draft manual assessed by independent expert peer reviewers
3. consider the expert peer reviews
4. submit the draft manual to DERM for approval under the Act so that it can be approved before 1 October 2011.

2.9 The following matters require particular attention during the interim review of the Wivenhoe manual:

- definition of what 'best forecast rainfall' means
- prescription about how forecast rainfall information is to be used by the flood engineers
- definition of 'predicted lake level' and the use of consistent language throughout the Wivenhoe manual about predicted lake levels
- clarification of options for transition to strategies W2 or W3 from strategy W1
- clarification of the rules for drawdowns of the dams following flood events
- removal of the term 'non-damaging flows' (and similar terms) to describe flows below 4000 m^3/s at Moggill
- clarification of whether W3 allows the flood engineers to release water which would create a flow at Moggill of over 4000 m^3/s
- precise definition of the maximum mechanical capability of the gate opening mechanism
- clarification of how part 8.6 should be followed in strategy W4, including clarifying the use of the word 'generally'.

2.5.8 Longer term review of the Wivenhoe manual

The Commission finds that a fundamental review of the Wivenhoe manual is required in the longer term. It is acknowledged that a review of this type may take many months or even years to finalise. It is also the case that such a review may be expensive. However, the Commission is of the view that both time and money are well spent on this project. The intent of recommending a complete review of the Wivenhoe manual is to ensure that the final document enables the optimal use of the flood mitigation capabilities of Wivenhoe and Somerset dams. In light of the risks associated with flood releases from these dams, particularly during large floods, the community should be left in no doubt that the Wivenhoe manual reflects current best practice in hydrology, meteorology and dam management.

The Commission acknowledges that there will be costs and benefits associated with any set of draft strategies identified during the review of the Wivenhoe manual. For example, it might be determined during the review that in certain types of floods, a draft set of strategies for operating the dams minimises flood damage in parts of Brisbane at the cost of severe flooding and resultant damage to the Fernvale area. It is for the Queensland Government, based on advice as to the results of the review of the Wivenhoe manual and studies into water security and the impact on the floodplain, to endorse a set of strategies which best satisfies the needs of the community. Any decision by government should follow extensive consultation with councils and the community.

The Wivenhoe manual should not be substantially re-written until such a preferred set of strategies is decided upon by the Queensland Government. The Commission's focus therefore is on the task of identifying technical work which must be undertaken before options as to strategies can be presented to government.

The recommendations below are for a review of the hydrology used for the Wivenhoe manual and other technical work which the Commission finds should be done before any preferred strategies for the operation of the dams can be settled on or substantial re-writing of the Wivenhoe manual commences. The proposals are based upon the evidence of the expert hydrologist engaged by the Commission, Mr Babister, together with the evidence of other expert witnesses, including Dr Rory Nathan, Emeritus Professor Colin Apelt, Mr Allen and the four flood

engineers. A draft list of proposed work was sent to Mr Babister, all of the expert witnesses engaged by Seqwater and DERM, expert witnesses identified by Brisbane City Council and Ipswich City Council, Mr Allen, Ronald Guppy of DERM, Peter Baddiley of the Bureau, Barton Maher of Seqwater and the four flood engineers. Comments, where received, were taken into account in formulating the proposals below. This list of work, although extensive, should not be seen as complete. Inevitably, further requirements will be identified as the review progresses.

The first stage of the review will entail scientific investigations. The second stage will involve modelling. The specific recommendations relating to each of those two stages follows. Recommendations as to further stages of review will be dealt with in the Commission's final report.

This review should be supervised by a steering committee which includes senior representatives from DERM, Seqwater, the Water Commission, the Water Grid Manager, Brisbane City Council, Ipswich City Council and Somerset Regional Council. Each of these agencies has particular expertise in flood mitigation and managing floods in south east Queensland.

The role of the steering committee in undertaking the technical phase of the review is to:

1. select and supervise a project manager
2. support the project manager in making arrangements for the completion of the technical work, discussed below
3. select and oversee the expert review panel, described below
4. provide the government with reports as to the progress of the review
5. have the expert review panel assess the completed technical work
6. report to government as to a range of potential strategies for the operation of the dams.

The Bureau has indicated that it does not wish to be involved in the steering committee. The Commission notes the Bureau's expertise in meteorology and hydrology. It would be desirable if the Bureau participated in the review.

SunWater likewise does not wish to be involved in the steering committee. The Commission understands that SunWater's reluctance to be involved in the steering committee is based on the fact that it is no longer providing any flood management services in connection with Wivenhoe and Somerset dams. The Commission notes that SunWater is a highly skilled dam operator and considers that it would be useful if SunWater were involved in the review.

A small panel of independent experts should examine technical work undertaken during the review. These experts should possess professional qualifications and experience relevant to the review and be recognised leaders in their fields. The panel should at least include members with backgrounds in hydrology, meteorology and dam operations. In order to maintain public confidence in the independence of the review of technical work, members of this panel should not have been previously involved in studies or work used as a basis of previous versions of the Wivenhoe manual or in writing it. It may be necessary to engage interstate, or even overseas, experts so as to ensure that an independent examination of the highest calibre is made of the technical work produced during the review.

Recommendations

2.10 Seqwater should act immediately to establish:

1. a steering committee to oversee the long term review of the Wivenhoe manual including senior representatives of at least DERM, Seqwater, the Water Commission, the Water Grid Manager, Brisbane City Council, Ipswich City Council and Somerset Regional Council
2. a technical review committee comprised of independent experts in at least hydrology, meteorology and dam operations to examine all technical work completed as part of the review.

2.11 The steering committee should ensure the scientific investigations and modelling outlined in recommendation 2.12 and 2.13 are completed. It should also assess the need for any other work to be done, and instigate any other investigations or work considered necessary for a full and proper review of the Wivenhoe manual.

2.12 The following scientific investigations should be carried out prior to modelling work under the supervision of the steering committee and reviewed by the technical review committee:

1. review of the design hydrology:
   a. using a stochastic or Monte Carlo or probabilistic approach
   b. taking into account observed variability in temporal and spatial patterns of rainfall
   c. taking into account observed variability in relative timings of inflows from the dams and downstream tributaries.
2. production of a digital terrain model incorporating a bathymetric survey of all critical sections of creeks and rivers upstream and downstream of the dam relevant to flood modelling
3. assessment of the reliability of the 24 hour, the three day and the five day rainfall forecasts
4. consideration of whether and how weather radar can be incorporated into decision making
5. requesting information from the Bureau of Meteorology as to its willingness to provide ensemble forecasts
6. consideration as to whether and how ensemble forecasts can be incorporated into decision making.

2.13 The following modelling work should be carried out under the supervision of the steering committee and reviewed by the technical review committee:

1. modelling across the range of full supply levels, operating strategies and flood events (historical, design and synthetic) in each case assessing the consequences in terms of risk to life and safety and economic, social and environmental damage. In terms of operating strategies, using a full range of strategies including:
   a. a stepped change from W3 to W4
   b. moving to a higher rate of release earlier in W1
   c. bypassing W1
   d. altering maximum release rates under W3
   e. operating the gates in conjunction with the initiation of any of the fuse plugs in order to achieve a lower rate of discharge
2. simulations to test the robustness of relying on the 24 hour, the three day and the five day rainfall forecasts
3. development of a probability distribution for the time between closely spaced flood peaks in the catchment using historical records.

2.6 Decision-making and conditions at the flood operations centre

Until 1 July 2011, SunWater had responsibility under a contract with Seqwater for establishing a flood operations centre and ensuring it had appropriate facilities to manage Wivenhoe, Somerset and North Pine dams during floods.[253] The flood operations centre at the time of the flood event was located at SunWater's premises in Turbot Street, Brisbane; the operations at Wivenhoe, Somerset and North Pine dams were directed from those premises.

The centre was led by four flood engineers, highly experienced in all aspects of flood operations including flood forecasting and modelling, hydrology, meteorology and dam operations. They were assisted by nine flood officers (technical assistants) working on roster, whose duties included reviewing rainfall and stream flow data and making entries in the flood event log. No-one may perform the role of engineer unless he or she holds current registration as a professional engineer and has been approved by the chief executive of DERM.[254]

During the 2010/2011 wet season, there were four flood engineers approved by the chief executive under the Wivenhoe and North Pine manuals: Robert Ayre from SunWater, John Ruffini from DERM and Terrence Malone and John Tibaldi from Seqwater. Each flood engineer was on call three out of every four weeks throughout the year. One engineer was always on 'close call', which required that he be available to receive communications from Seqwater and the Bureau of Meteorology and be able to attend the flood operations centre to mobilise it for flood operations within two hours.[255] When a flood event is declared, the engineers leave their usual employment, and work in the flood operations centre in shifts.

These four men have been acting in this high-pressure role, some for many years, without any additional payment and with little recognition. Nothing in the evidence heard or the material received by the Commission suggested anything other than that they are diligent and competent and acted in good faith throughout the flood event.

2.6.1 Weather forecasts

In January 2011, the flood engineers had Bureau of Meteorology information available to them; in particular, they could see the state of the weather radar on the Bureau's web site and they received 24 hour quantitative precipitation forecasts for the dams' catchment. Radar provides an effective tool for the detection of rain, but the Bureau cautions that in some circumstances it can produce poor estimates, overestimating or under estimating rainfall rates by factors of two or more. [256]

Seqwater observed in its flood event report on the operation of Somerset Dam and Wivenhoe Dam[257] that the quantitative precipitation forecasts corresponded reasonably well (with some slight overestimating) with the actual average rainfall recorded in its gauges in the dams' catchment up until 4.00 pm, 8 January 2011. In contrast, in the period between 4.00 pm, 8 January and 10.00 am, 11 January, the 24 hour forecasts regularly underestimated the average rainfall which was subsequently recorded as falling in the dams' catchment: the average recorded falls were generally two to three times what was predicted. At 10.00 am, Tuesday 11 January, that situation reversed: the morning forecast was of 100 millimetres to be received on average in the dams' catchment over the ensuing 24 hours, as compared with an average of 51 millimetres actually recorded; and in the afternoon 75 millimetres forecast as compared with an average of 12 millimetres recorded.[258]

However, this qualification should be made in relation to the recorded falls: as identified in the Seqwater report, there is a lack of rain gauges in the catchment immediately above the Wivenhoe Dam. This meant that rainfall in that area (likely to result in rapid lake rises) was not recorded.[259] In addition, Dr Nathan, a hydrological expert engaged by Seqwater, points to there being fewer gauges at high elevations of the Wivenhoe and Somerset catchment than at the lower elevations. This may have meant that some rainfall in that area was not recorded.[260] Generally, and not unusually, the flood engineers had to contend with gaps in the information available from rainfall gauges in the catchment, which diminished the value of the rainfall data able to be captured by the ALERT gauge network. For a description of ALERT gauges, see *4.1.1 Warning mechanisms*.

In 2001, one of the flood engineers, Mr Ayre, prepared a report for Seqwater, titled *Feasibility of Making Pre-releases from SEQWC Reservoirs* which concluded that the quantitative precipitation forecasts were not sufficiently reliable to form the basis of operational decision making for the dam. Mr Baddiley of the Bureau of Meteorology gave the flood engineers advice to the same effect in 2006,[261] reiterating it in 2010. [262]

This topic should be the subject of ongoing review. See also *2.5.8 Longer term review of the Wivenhoe manual* that an assessment of the reliability of forecasts for the dams' catchment form part of the longer term review of the Wivenhoe manual.

2.6.2 Rainfall gauges

Rainfall gauges are inherently limited by their size and location: they can only measure rainfall that falls directly above them. As rain can fall intensely over a small area as well as lightly over a larger area – and everything in between – there is no guarantee a gauge will give an accurate representation of the rainfall in the area around it. That limitation has implications for the reliability of rainfall forecasts and the ability to test the accuracy of models using rainfall as the primary input; for example, the hydrologic models that form part of the real time flood model.

While some witnesses before the Commission contended that more gauges were needed in certain areas (for example, the part of the Wivenhoe catchment immediately surrounding the lake and high elevations of the Wivenhoe catchment and the upper reaches of the Lockyer catchment), cost will be a factor in how many should be installed. There should be an appraisal, which must involve the Bureau of Meteorology, as to the locations in which gauges are most needed in order to improve the accurate predictions of floods. See also *4.1.1 Warning mechanisms*.

Recommendation

2.14 The Commission recommends that a review be conducted of the number and distribution of ALERT gauges within the Wivenhoe and Somerset catchments. This review should include an assessment of the usefulness and cost effectiveness of installing more gauges, particularly at high elevations in the catchment. Such an assessment would appropriately involve the Bureau of Meteorology, DERM and Seqwater, and the relevant local councils.

2.6.3 Stream gauges

There are a number of gauges on the Brisbane River between Wivenhoe Dam and the Port Office gauge. All of these gauges are river height gauges and do not directly measure flow. In fact, there is no evidence before the Commission that a gauge which directly measures flow in a natural watercourse is available.

Flow can be determined from river height by the use of a rating curve, developed over time by physically measuring the flow (using, in recent times, Doppler sonar) at varying heights. Rating curves have some inherent limitations. Large river heights and flows only occur during floods and so are quite rare; the flow at the larger heights may never have been measured. Measurement of flow at key gauges during flood events enables improvement of the rating curve, but for obvious reasons, the measurement process, often undertaken by boat, can be dangerous. (Near the peak of the 6 to 19 January 2011 flood event, DERM measured the flow at Jindalee to improve its rating curve.[263]) The rating curve is extrapolated mathematically to heights greater than have actually been observed.

For the reasons identified, there is always some uncertainty in stream flow estimates.[264] Another problem is that waterways often have a different rating for rising waters and falling waters because the flow is not uniform. The rating curve represents some middle point; an approximation for both rising and falling waters. A third obstacle to accuracy arises when a stream breaks its banks as the flow height increases, so that some of the flow occurs out of the steam channel (that is, in the floodplain). In those circumstances, the height in the stream may be a less reliable indicator of the flow. Despite those limitations, the use of a rating curve is the standard practice for estimating flows from river height.[265]

2.6.4 The real time flood model

The flood engineers used the real time flood monitoring system for flood monitoring and forecasting.[266] It consists of a data capture module (FLOOD – Col), a data analysis module (FLOOD – Ops) and the gate operations spreadsheet. The information in the FLOOD – Col database is obtained through rainfall and water level gauges (of which there are 129 in the Brisbane River basin), the data being transmitted in real time by radio telemetry to the flood operations centre computers. The rainfall and the water level gauges, the radio network and the data collection software combine to form an automated local evaluation in real time system (the ALERT system).

The FLOOD – Ops software uses data from the FLOOD – Col database to calculate areal rainfall and produce hydrographs of runoff. It contains a suite of individual hydrologic models to determine runoff in the catchments of Somerset and Wivenhoe dams, the Lockyer Creek, the Bremer River and the Pine River.[267]

The third component of the real time flood model is the gate operations spreadsheet. This allows the flood engineers to input a specific gate operations strategy and assess the consequences of that strategy for lake level and flows downstream. The model results provided in Seqwater's flood event report are a graphical depiction of the effects of one gate opening scenario.[268] Those graphs are the result of the one strategy saved into the spreadsheet and kept as a record, but are not necessarily the strategy actually implemented or even intended to be implemented at that time.[269]

In oral evidence and each of their statements, the flood engineers did not volunteer that there had been more than one strategy input into the spreadsheet. In a report provided after the draft findings were issued,[270] Seqwater explained that the flood engineers continuously amended the strategy in the spreadsheet throughout the event.

For comments on the completeness of this record-keeping, see *2.6.9 Records of decision-making*.

2.6.5 'With forecast' and 'without forecast' model runs

The runs of the model that predicts the lake level at Wivenhoe received significant attention during the public hearings of the Commission. This is a hydrologic model that converts rain falling in the dam catchments into inflows into the dam and subsequent changes in lake level.

There are two situations modelled at each time: the 'without forecast' model which excludes forecast rainfall and the 'with forecast' model which includes forecast rainfall.[271]

The 'without forecast' model assumes that no further rain will fall and only models the effect on lake level of the rain already on the ground.[272]

The 'with forecast' model includes both the rain already on the ground and the most recent quantitative precipitation forecast issued by the Bureau.[273]

The full quantitative precipitation forecast was included in each model run regardless of the time of the model run. This meant that sometimes the forecast included in such a model run would represent a figure larger than the actual forecast because some part of the forecast rain had already fallen as rain on the ground before the time of the model run.[274]

In practice, this variable approach had no consequence, because the flood engineers did not give the 'with forecast' model any weight (see *2.5.3 Use of forecasts – January 2011*).[275] If the 'with forecast' model is to be used, there should be further investigation as to the most appropriate way in which to input rainfall forecast into models run substantially after the forecast's time of issue.

2.6.6 Estimating flows from the Lockyer and Bremer

The real time flood model estimates the flows coming out of the Lockyer Creek and the Bremer River using a suite of hydrologic models. A hydrologic, or runoff routing model, uses rainfall data and estimates of the proportion of the rainfall which turns into runoff (that is, which does not soak in) and the time which the runoff from each part of the catchment takes to flow into the stream. These inputs are used to estimate the flow in the stream. The Bureau uses the same type of model to estimate flow.

The rainfall gauge and rating curve limitations discussed above limit the accuracy of this estimate. In addition, it is difficult to estimate how much rainfall turns into runoff and makes its way into the stream. That depends on factors such as loss to groundwater and the saturation of the soil, which are not constant.

To check the hydrologic model which estimates lake level, Seqwater continually updates its estimate of these factors by comparing the model results to actual lake level rises.[276]

The flood engineers check these runoff estimates by comparing the hydrologic model results as to flow in the Bremer River and the Lockyer Creek against flow estimates for those waterways gained from using the height measurement from a gauge and the rating for that gauge.[277] Seqwater's flood event report indicated that its runoff routing models for the Lockyer and Bremer catchments matched closely to the Bureau estimates.[278]

It is more difficult to produce a hydrologic model for the Lockyer Creek catchment because it has complex terrain including floodplains.[279]

It is clear that backwater effects, which occur when water is prevented from entering an already flooded channel, were a factor in the flooding in the Ipswich area during January. Mr Ayre gave evidence that Seqwater's hydrologic model does not 'satisfactorily account for backwatering effects'[280] and that the flood engineers did not carry out any modelling to predict flood heights in Ipswich.[281] Mr Babister, the Commission's expert hydrologist, recommended that Seqwater obtain a hydrodynamic model which would properly account for those effects.[282] Mr Ayre agreed that access to such a model would be useful.[283]

2.6.7 Estimating flow at Moggill

Given the significance of the flow at Moggill in the Wivenhoe manual,[284] it is necessary to examine the manner in which that figure is estimated.

There are two ways in which the flood engineers can estimate the flow at Moggill. One is to route the releases from Wivenhoe down the river incorporating flows from downstream tributaries using the runoff routing model in the real time flood model. The other, more approximate approach is to simply add the releases from Wivenhoe to the estimates of flows from the Lockyer Creek and Bremer River. Mr Ayre gave evidence that the flood engineers generally used the latter approach[285] because the former took longer to accomplish.[286]

The flood engineers must also confront the difficulty of estimating flows in the Lockyer and Bremer from rainfall in the order of 16 hours ahead because of the time it takes for water released from Wivenhoe to reach Moggill. For example, they must estimate what rain is going to fall in the Ipswich area hours in advance to determine what flow will be emerging from the Bremer when the current Wivenhoe release reaches Moggill.

Seqwater has judged the Moggill gauge to be the best location to estimate flows in the Brisbane River because it is the first gauge location after the confluence of the Bremer River and the Brisbane River.[287] However, estimations of the flow at Moggill are affected by the geography of the location. It is adjacent to a hairpin bend in the river and is affected by tides.

The flood engineers maintained that the tidal influence at Moggill was subsumed at 2000 m^3/s.[288] This question will be the subject of further review by Mr Babister.

Seqwater calibrates or checks its model results during the flood event from the real time flood model against estimated stream flow figures obtained by using rating tables for the Moggill gauge.[289] Both estimates can be checked against a measurement physically taken by hydrographers.

An examination of the figures shows that there can be variation between the estimated and measured flow. At the height of the flood on 12 January 2011, a joint DERM and Seqwater hydrographic team gauged the flow six times at Jindalee,[290] just downstream of Moggill, and measured the average flow at around 9800 m^3/s. Seqwater's hydrologic model estimated the flow at that time to be 9300 m^3/s.[291]

In broader scientific terms, such variance might be perfectly acceptable. However, given the significance that the flow rate at Moggill assumes for the purposes of the Wivenhoe manual, it would be prudent for the review of the manual to acknowledge the inaccuracy inherent in such estimations.

2.6.8 Working conditions at the flood operations centre

Mr Malone was the engineer on duty when the flood event was declared on 6 January 2011. For the first part of the flood event, the flood engineers worked singly in 12-hour shifts, until 7.00 pm on 9 January 2011, when two engineers worked each shift until the flood peak had passed.[292] The decision to work in pairs meant that their shifts were separated by only 12 hours.[293] From Tuesday 11 January, three of the four engineers were forced to stay in the flood operations centre because they could no longer reach their homes. They slept in a meeting room in the building housing the centre. The engineers not on duty regularly offered assistance to those who were. Some of the technical assistants were also unable to reach their homes; a number had concerns about flooding of their homes and the safety of their family members.[294]

The Commission understands that from 1 July 2011 the flood operations centre will be located at new premises with facilities for food preparation and a rest area, and suitable accommodation nearby should staff have to work more than one shift.[295]

A great deal was demanded of the flood engineers over the period of the flood event; they were working in conditions which were stressful, fatiguing and physically uncomfortable. While there is a good deal to be said for operating with a small, tight team in the management of a flood crisis, the demands placed on the four flood engineers in the January event were excessive. The Commission recommends that Seqwater give urgent attention to the engagement of a fifth flood engineer. There is also the question of succession planning: there is an obvious need for training of their prospective replacements. As one of the flood engineers pointed out, there would be advantages to engaging trainee flood engineers whose responsibilities during a flood event would include modelling, so as to free the flood engineers from that task.[296]

Recommendations

2.15 Seqwater should:

- immediately recruit and train additional flood engineers to ensure at least five flood engineers are available for flood operations
- establish a formal flood event operation training program for junior engineers to ensure the flood operations centre will be staffed by appropriately qualified and experienced personnel in the medium and long term.

2.16 In addition to the on duty flood engineer(s), Seqwater should ensure that the flood operations centre is staffed by a trainee flood engineer on each shift (in addition to the technical assistants) to conduct the modelling.

2.17 Seqwater should ensure that, during major flood events, flood engineers do not have responsibility for, and are not required to, organise food, sleeping arrangements or access to facilities, such as power supply and communications equipment.

2.6.9 Records of decision-making

During flood events, Seqwater's internal flood procedures manual requires that an 'event log', a document recording significant events, be maintained at all operational sites including the flood operations centre.[297] During the January 2011 flood events at Somerset, Wivenhoe and North Pine dams, the technical assistants in the flood operations centre kept a combined event log for all three dams on a computer. In a number of instances, mistakes were later identified by the flood engineers in the recording of details in the flood event log, including, in some instances, the terms of significant conversations.[298] Some telephone conversations were not recorded at all; in others the participants were incorrectly identified. The log did not record all model runs undertaken or the time at which they were undertaken,[299] and no note was made of decisions to change strategy or their basis.[300]

Some of the deficiencies are explicable, although undesirable. The technical assistants recording telephone discussions were often not participants in them.[301] They were not always informed about the flood engineers' actions as they were taken.[302] There was no particular form or process for the recording of information, and the entries were not checked by the flood engineers.[303]

A comprehensive and consistent approach to maintaining the flood log would:

- allow flood engineers coming onto shift to have an accurate understanding of the situation they were entering
- assist in providing consistent information to councils and other agencies
- assist in post-event debriefs and training exercises.

To achieve those goals, the log must also record significant decisions, including transitions between strategies under the Wivenhoe manual and changes in releases at all dams. The decision and reasons for it must be clearly stated in the log.

The flood engineers themselves will have to shoulder some responsibility for checking the flood event log contemporaneously as the ones involved in the conversations. Seqwater may have to change the procedure for handovers between flood engineers to ensure the flood engineers going off shift have sufficient time to complete this task.

It would also be prudent if records (hard copy or electronic) relevant to decisions made using the gate operations spreadsheet were kept, including:

- each version of the gate operations spreadsheet which contains a different input gate operation scenario
- all graphical depictions of model runs produced
- a version of the gate operations spreadsheet which contains the gate operation scenario which will be implemented marked so that it is clear it is the one agreed to be implemented
- a note of key reasons why the particular scenario decided upon is the most appropriate one.

Such records would be useful both for handovers between shifts and for post-event reviews and training exercises.

Recommendations

2.18 An accurate record should be kept of reasons for key decisions, including changes in strategy and releases. Documents relevant to key decisions should also be kept, including:

- each version of the gate operations spreadsheet which contains a different input gate operation scenario
- all graphical depictions of model runs produced
- a version of the gate operations spreadsheet which contains the gate operation scenario which will be implemented marked so that it is clear it is the one agreed to be implemented.

2.19 Seqwater should ensure that all telephone calls within the flood operations centre are digitally recorded to create an accurate record of decision-making during major flood events.

2.20 Seqwater should develop procedures which require the flood engineers to check the entries in the flood operations centre's flood event log at a near contemporaneous time, such as the end of their shift, to ensure accuracy and the recording of significant events. Seqwater should make sure that the operation of the flood operations centre enables the flood engineers to comply with that procedure.

2.6.10 Communications

The flood mitigation manuals and the emergency action plans for Somerset, Wivenhoe and North Pine dams require the flood engineers to provide information during flood events to a number of agencies, including the Bureau of Meteorology, DERM, Somerset Regional Council, Moreton Bay Regional Council, Ipswich City Council and Brisbane City Council.[304]

Following flooding in October 2010, arrangements for communications between these agencies, not including the Moreton Bay Regional Council, were also formalised by the draft *Protocol for the Communication of Flooding Information for the Brisbane River Catchment – including Floodwater Releases from Wivenhoe and Somerset Dams* initiated by the Queensland Government through DERM and Emergency Management Queensland.[305]

For discussion on warnings about dam releases generally, and under these documents, see *4.1.4 Warnings about dam spillway outflow*.

The focus of this part of the report is how the 2010/2011 flood events at Somerset, Wivenhoe and North Pine dams tested the flood operations centre's communication capacity and the areas of improvement which can now be identified. Despite difficulties experienced contacting some agencies, there has been no suggestion that the flood engineers did not do everything possible, with the information and tools they had available to them, to give useful information to the councils and other agencies.

Situation reports and technical situation reports

During the January 2011 flood event, the flood engineers sent situation reports by email between three and four times a day to various agencies, giving information about recorded rainfall, lake level, and rate of release from the dams, as well as information as to projected releases and their likely impact.[306]

The dam operations manager of Seqwater, Robert Drury, also provided edited versions of the situation reports, called 'technical situation reports', to the Water Grid Manager, who in turn sent them on to different agencies such as the Queensland Police Service, DERM and the Department of the Premier and Cabinet.[307]

These arrangements were in accordance with the draft *Protocol for the Communication of Flooding Information for the Brisbane River Catchment*.[308]

There was some overlap between the entities who received the situation reports and the technical situation reports; the local disaster co-ordinator of the Somerset Regional Council recalled that he often received the same information from both the flood engineers and Mr Drury.[309]

Improvements to this process suggested by some of the flood engineers include:

- the use of a pro forma for situation reports and training for recipient agencies to ensure consistent interpretation of the pro forma material[310]
- the production of a single document for all interested parties rather than the production of several different messages for a range of different agencies.[311]

Recommendation

2.21 Seqwater should produce a template situation report in consultation with the flood engineers and recipient agencies. As part of this process, consideration should be given as to whether the quality and timeliness of the dissemination of information about flood operations would be improved if a single document, rather than a situation report and a technical situation report, were used for the purpose of communicating flood operations to all concerned parties. The template situation report should include, at a minimum, dedicated space for the following:

- meteorological observations and situation, including forecasts
- identification of the current operating strategy
- the strategy, aims and objectives of the flood engineers
- actual and expected releases
- any other comments.

Communication with councils

The chief means of communication between the flood operations centre and local councils was the provision of situation reports.

The flood engineers also contacted local governments by telephone during the event, including when strategies were changing, such as after the 3.30 pm engineer conference on 9 January 2011[312] and after Wivenhoe Dam was moved into strategy W4 in the morning of 11 January 2011.[313] The flood event log of communications with the flood operations centre also indicates numerous telephone calls from staff of all four councils requesting information and discussing strategy with the flood engineers.[314]

Difficulty was encountered in contacting some of the councils at critical times; some calls were not answered.[315] Flooding elsewhere prevented some contact, including with the local disaster co-ordinator of Somerset Regional Council from the night of 10 January to the afternoon of 11 January when his area lost power which cut email access and decreased phone reception.[316] That meant the flood engineers could not speak to him directly when attempting to advise of the transition to strategy W4, but had to leave a message.[317]

The local disaster co-ordinator of the Ipswich City Council gave evidence that he found the communications from the flood operations centre very useful in organising the council's response to flooding.[318] The local disaster co-ordinator of Somerset Regional Council indicated that the flood engineers gave more information to him than they agreed to under the draft Protocol, recognising that his council had less hydrological expertise than Brisbane and Ipswich.[319] He indicated he was aware he could contact the flood engineers 24 hours a day and he found them helpful to deal with.[320]

While the evidence about the flood engineers' interactions with councils was positive, there are concerns about the flood engineers themselves carrying the burden of communication, see *2.6.10 Communcations, Need for dedicated communications resources*.

Communication with the Bureau of Meteorology

The flood engineers had regular informal discussion with the Bureau of Meteorology regarding rainfall forecasts,[321] including at key times, such as when considering a transition to strategy W4 at Wivenhoe on the morning of 11 January.[322] Bureau forecasters are available directly to the flood engineers to answer queries.[323] The Bureau lost some of its telephone lines when power was lost in the central business district of Brisbane,[324] but it provided the flood engineers with alternative contact details.[325]

Mr Ayre gave evidence that the lines of communication between the flood operations centre and the Bureau were 'excellent' and 'serve[d] their purpose well'.[326] However, he did consider that there was scope to improve the communications between the flood operations centre and the Bureau. He said that the flood engineers' understanding of the meteorological situation would be improved by formalising the communication between the two entities during flood events.[327] In particular, Mr Ayre suggested the frequency and type of information to be obtained by the flood operations centre from the Bureau should be clarified.[328]

One of the other flood engineers, Mr Tibaldi, who was generally on duty with Mr Malone (a flood engineer who had previously worked at the Bureau), said that of the two of them, generally it was Mr Malone who would call the Bureau because he was familiar with the people there.[329] While such familiarity is useful, it would assist for all flood engineers to have close relationships with Bureau staff to improve the transfer of information between the two entities.

Recommendation

2.22 Seqwater should create a regular forum for discussion between all operational staff of the flood operations centre and Bureau staff to:

- increase the knowledge of flood operations centre staff about the Bureau's products, abilities, advice and operations
- reach agreement as to the frequency and type of information to be shared between the Bureau and the flood operations centre during a flood event
- discuss advances in technology and science in areas including forecasting, data collection and modelling
- build relationships between the staff of both organisations.

Need for dedicated communications resources

According to one of the flood engineers, Mr Ayre, one of the reasons the flood operations centre was staffed by two flood engineers from Sunday 9 January 2011, was in recognition of the fact that, during large flood events, more people are affected, require information and express interest in the event's management.[330]

This sentiment was reflected by the breadth of information requests made to the flood operations centre during the January 2011 flood event which included:[331]

- contributing to a briefing for the Premier[332]

- preparing a powerpoint presentation for the chief executive officer of Seqwater about the operation of Somerset and Wivenhoe dams[333]
- contributing to a Ministerial Briefing Note for an Emergency Cabinet meeting[334]
- preparing responses to media enquiries.[335]

Mr Ayre also considered it important that the flood operations centre have a limited and focussed role in the provision of communications to other agencies during a flood event, in order to allow the flood operations centre to focus its attention upon 'matters such as the rainfall and inflow data, lake levels, directives, status of the dams and any other issue that may arise during a flood event'.[336] Another of the flood engineers, Mr Malone, similarly considered that there should be 'some dedicated resources more closely related to the flood operations centre' providing information about the flood operations centre's activities to the public.[337]

In the Commission's view, direct communication by the flood operations centre with other agencies is critical to the management of flood events; but it would be preferable if the flood engineers had a limited role in the provision of communications extraneous to their flood operation duties.

Recommendation

2.23 Seqwater should give consideration to creating a communications position within the flood operations centre filled by an engineer with experience in dam operations and emergency management processes.

Communication with the public

Notwithstanding *4.1.4 Warnings about dam spillway outflow*, the Commission recognises that the volumes of current and expected releases from Seqwater's dams may be of acute interest to some members of the public. This information would, in the ordinary course of events, be communicated to councils electronically, so it would seem unlikely that posting that same information on the website would be an onerous undertaking. Indeed, the original source of this idea was one of the flood engineers.[338]

Recommendation

2.24 Seqwater should give consideration to posting information about current and future releases on its website during flood events as one method of ensuring accurate and timely information is available to the public.

2.7 Chronology of the operation of Wivenhoe and Somerset dams in January 2011

As well as statements, testimony and reports, the chronology that follows relies on results of the real time flood model saved into spreadsheets and provided to the Commission by Seqwater.[339] Comments on the completeness of the records kept by Seqwater of the decision-making process of the flood engineers are made in *2.6.9 Records of decision-making*.

In the 24 hours to 9.00 am on 6 January 2011, the Wivenhoe and Somerset dams' catchment experienced steady rainfall in the order of 20 to 50 millimetres. At 7.00 am that day, the Wivenhoe lake level was 67.31 metres and the Somerset lake level was 99.34 metres.[340] Flood releases are expected at those lake levels;[341] consequently the flood operations centre was mobilised at 7.42 am. The start of this flood event was similar to those that affected the dams in October and December 2010 – but that is where the similarity ends.

2.7.1 The beginning: the bridges

7.00 am, 6 January to 8.00 am, 8 January

Flood releases are not made at Wivenhoe Dam until the lake level exceeds 67.25 metres.[342] The first strategy to be used to operate the dam is W1; the primary consideration at this stage is minimising disruption to downstream rural life. The aim is to keep particular downstream bridges open for as long as possible.

There are seven important bridges downstream of Wivenhoe Dam, the submerging of which causes inconvenience and leaves some communities isolated. All bridges are below the intersection of the Lockyer Creek and the Brisbane River, so flows from the Lockyer catchment also affect them. As the lake level rises, the focus of the strategy changes to higher bridges.

In the first 24 hours after the flood event was declared, rain in the order of 10 to 30 millimetres fell in the catchments above the dams. In the next 24 hours, to 9.00 am on 8 January, totals around 100 millimetres fell in the upper catchment, with falls around 10 millimetres elsewhere.[343] Inflows from that rainfall caused the lake level progressively to trigger the five sub-strategies of W1, as the following table illustrates.

Figure 2(b)

Strategy	Bridge aimed to be kept open (maximum flow until bridge is submerged)[344]	Lake level trigger (m)	Trigger for commencement of strategy and status of gates[345]
W1A	Twin Bridges (50 m^3/s including the Lockyer Creek) Savages Crossing (110 m^3/s including the Lockyer Creek) Colleges Crossing (175 m^3/s including the Lockyer Creek)	67.25	7.42 am, 6 January. All gates closed.
W1B	Colleges Crossing (175 m^3/s including the Lockyer Creek) Burtons Bridge (430 m^3/s including the Lockyer Creek)	67.50	Lake level measured at 67.52m, at 2.00 am, 7 January. All gates closed.
W1C	Burtons Bridge (430 m^3/s including the Lockyer Creek) Kholo Bridge (550 m^3/s including the Lockyer Creek)	67.75	Lake level measured at 67.75m at 9.00 am, 7 January. All gates closed.
W1D	Kholo Bridge (550 m^3/s including the Lockyer Creek) Mt Crosby Weir Bridge (1900 m^3/s including the Lockyer Creek)	68.00	Lake level measured 68.03m at 3.00 pm, 7 January. First gate opened at 3.00 pm, 7 January.
W1E	Mt Crosby Weir Bridge (1900 m^3/s including the Lockyer Creek) Fernvale Bridge (2000 m^3/s including the Lockyer Creek)	68.25	Lake level measured at 68.26m at 10.00 pm, 7 January. Transition to W3 at 8.00 am, 8 January when the lake level measured 68.52m.

2.7.2 Transition to strategy W3

8.00 am, 8 January

The Wivenhoe manual requires a transition to strategy W2 or W3 when the Wivenhoe lake level exceeds 68.50 metres, as it did at 8.00 am on 8 January.[346] Strategy W2 requires the releases from Wivenhoe to be managed so that the flow in the Brisbane River does not exceed the naturally occurring peaks at Lowood and Moggill.[347] At 8.00 am, the requirements of strategy W2 were impossible to meet: the predicted natural peak was 530 m^3/s at Lowood and 770 m^3/s at Moggill, while releases from Wivenhoe were already in the order of 900 m^3/s.[348]

The flood engineers moved immediately to strategy W3, which on their understanding required the flow at Moggill to be limited to 4000 m^3/s, the threshold of non-damaging flows in urban Brisbane, according to the Wivenhoe manual.[349]

2.7.3 Rise and fall

8.00 am, 8 January to 12.00 pm, 9 January

From 8.00 am to 5.00 pm on 8 January, the lake level at Wivenhoe rose extremely slowly, from 68.52 metres to 68.65 metres. The rate of rise averaged just 1.4 centimetres per hour. The lake stabilised at 68.65 metres until 11.00 pm and then decreased slowly, recording 68.54 metres at 12.00 pm on 9 January.

The flood engineers' strategy during this time was to minimise releases.[350] Two bridges remained open (Fernvale Bridge and Mt Crosby Weir) and at this stage the flood engineers thought that they would be able to keep them open.[351]

On 8 January, Somerset, still operated under its second strategy focussed on minimising impacts below Wivenhoe Dam,[352] held water back to allow the runoff from the upper Brisbane River catchment to run through Wivenhoe.[353] From 8.00 am on 9 January, the sluice gates were progressively opened to move the dam levels back to the target operating line (a best case relationship between the level at Wivenhoe and the level at Somerset).[354]

The forecast from the Bureau of Meteorology indicated high rainfall in south-east Queensland for the next four days, from 8 January through to Wednesday 12 January.[355] On 8 January, the falls in the catchments upstream of the dams were relatively small, generally less than 30 millimetres, with some instances over 40 millimetres. With the lake level under 69 metres, the flood engineers were comfortable maintaining releases of under 1250 m^3/s. They reasoned that if the forecast rain did fall, there was sufficient storage capacity in the lake to contain it.[356]

Figure 2(c)

Hour	Lake level (m)	Predicted peak exc forecast rainfall[357]	Predicted peak inc forecast rainfall[358]	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
8.00 am 8/1	68.52			1515	927	895
9.00 am	68.55			1649	980	950
10.00 am	68.56			1755	1031	1002
11.00 am	68.59			1399	1085	1050
12.00 pm	68.60			1260	1138	1095
1.00 pm	68.61			1530	1189	1136
2.00 pm	68.61	68.7 (at 7.00 pm 8 Jan)	69.1 (at 4.00 am 10 Jan)	1799	1239	1181
3.00 pm	68.63			1581	1240	1224
4.00 pm	68.64			1418	1241	1263

Hour	Lake level (m)	Predicted peak exc forecast rainfall[357]	Predicted peak inc forecast rainfall[358]	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
5.00 pm	68.65			1227	1242	1302
6.00 pm	68.65	68.8 (at 9.00 pm 8 Jan)	69.2 (at 8.00 am 10 Jan)	1255	1242	1340
7.00 pm	68.65			1255	1242	1377
8.00 pm	68.65			1255	1242	1413
9.00 pm	68.65			1282	1242	1449
10.00 pm	68.65			1091	1242	1485
11.00 pm	68.65			899	1242	1522
12.00 am 9/1	68.64			926	1241	1552
1.00 am	68.63	68.7 (at 7.00 pm 8 Jan)	68.9 (at 3.00 pm 10 Jan)	925	1240	1588
2.00 am	68.62			943	1286	1623
3.00 am	68.61			1189	1285	1660
4.00 am	68.60			970	1285	1697
5.00 am	68.60			802	1336	1733
6.00 am	68.58	68.8 (at 10.00 pm 8 Jan)	69.3 (at 1.00 am 11 Jan)	1047	1335	1769
7.00 am	68.57			1046	1334	1755
8.00 am	68.56	68.7 (at 7.00 pm 8 Jan)	69.5 (at 3.00 am 11 Jan)	773	1334	1742
9.00 am	68.55	68.9 (at 12.00 pm 10 Jan)	69.8 (at 12.00 am 11 Jan)	1182	1333	1730
10.00 am	68.53			1536	1332	1719
11.00 am	68.54			1646	1332	1737
12.00 pm 9/1	68.54	69.2 (at 7.00 pm 10 Jan)	70.4 (at 2.00 am 11 Jan)	2080	1384	1763

Notes to table:

1. The figures in the Estimated Flow at Moggill column have been taken from Seqwater's modelling, run 45, completed at 12.00 pm, 19 January 2011. The flow at Moggill is estimated by the use of a rainfall runoff model which forms part of the real time flood model.
2. Releases from Wivenhoe Dam reach Moggill approximately 16 hours after release, although the exact time taken depends on the size of the release.[359]

2.7.4 Heavy rain and the threat of urban flooding

12.00 pm, 9 January to 9.00 pm, 9 January

In the 24 hours from 9.00 am on 9 January, widespread heavy rain fell in the dam catchments. Across the catchments, rainfall gauges recorded falls between 100 and 200 millimetres, with falls as high at 310 millimetres recorded.[360]

Heavy falls were also recorded in areas below the dams: up to 113 millimetres in the lower Brisbane River catchment, 86 millimetres in the Lockyer Creek catchment and 68 millimetres in the Bremer River catchment.[361]

At 2.12 pm, the Bureau issued a flood warning for the Brisbane River and Stanley River above Wivenhoe Dam which predicted heavy rainfall in the catchments for all of 9 and 10 January.[362]

At 3.30 pm, all four flood engineers met to discuss the strategy to be adopted. Wivenhoe's lake level was 68.61 metres, and they were in strategy W3. The seven day forecast indicated three days of solid rain ahead, and a severe weather warning was current for the dam catchments.[363] The three day ACCESS[364] forecasts predicted average falls of 140 millimetres in the Somerset catchment and 170 millimetres in the Wivenhoe catchment. The five day ACCESS forecasts predicted average falls of 141 millimetres in the Somerset catchment and 171 millimetres in the Wivenhoe catchment.[365] A large volume of water was on the ground and expected to flow into the dam and cause the lake level to rise to 70.5 metres.[366] The 'with forecast' model of the lake level showed a peak of 71.8 metres. The Bureau's ACCESS model and general synoptic forecast indicated the rainfall system currently drenching the dam catchments was expected to move south in 24 to 36 hours.

The four flood engineers decided to maintain releases at around 1400 m^3/s in an attempt to keep Fernvale Bridge and Mt Crosby Weir Bridge open, given rainfall was expected to increase the flows from the Lockyer Creek and the Bremer River.[367] The flood engineers were concerned that if they increased releases and the rain system moved south, they might increase flooding downstream.

Modelling was performed by the flood engineers just before that meeting, at 3.00 pm. The 'without forecast' model run shows the flow at Moggill peaking at around 1850 m^3/s.[368] The corresponding 'with forecast' model run shows flow at Moggill peaking at just over 2600 m^3/s. (As explained earlier, the gate strategy saved in the spreadsheet is not necessarily the one implemented.) The gate strategy input into the model was to make no change to the gate openings (at approximately 1400 m^3/s) until well after the peak when the gates would begin to be closed. That gate strategy left a buffer, even if the full amount of forecast rain were to fall, between the expected flows (2613 m^3/s peak) and damaging flows in Brisbane (4000 m^3/s according to the Wivenhoe manual) of almost 1400 m^3/s.

The situation report at 9.04 pm, 9 January recorded very heavy rainfall in the previous six hours.[369] Inflows into the dam increased dramatically, from 3448 m^3/s at 3.00 pm to 7935 m^3/s at 11.00 pm, 9 January. The lake level responded quickly to these inflows, rising from 68.58 metres at 2.00 pm on 9 January to 69.80 metres by midnight and reaching 71.36 metres by 8.00 am on 10 January.

The predicted peak lake level from the 'without forecast' model which until midday on 9 January was consistently below 69.0 metres, was then predicted to reach 72.7 metres in the model run at 8.00 pm on 9 January. (The 'with forecast' model run at 8.00 pm was the first to return a peak lake level of over 74 metres, the trigger point for strategy W4.)

On the basis of these developments, at 9.04 pm the flood engineers abandoned all plans of keeping Fernvale Bridge and Mt Crosby Weir Bridge open. The inflows were too high to maintain sufficiently low releases.[370]

Figure 2(d)

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
12.00 pm 9/1	68.54	69.2 (at 7.00 pm 10 Jan)	70.4 (at 2.00 am 11 Jan)	2080	1384	1763
1.00 pm	68.56			2054	1385	1767
2.00 pm	68.58	70.0 (at 12.00 am 11 Jan)	71.3 (at 11.00 am 11 Jan)	3448	1386	1777
3.00 pm	68.61	70.5 (at 12.00 am 11 Jan)	71.8 (at 11.00 am 11 Jan)	4136	1388	1792
4.00 pm	68.70	70.9 (at 11.00 pm 10 Jan)	72.7 (at 9.00 am 11 Jan)	3946	1394	1822
5.00 pm	68.77	71.2 (at 12.00 am 11 Jan)	73.0 (at 10.00 am 11 Jan)	4733	1398	1867
6.00 pm	68.86			5454	1404	1933

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
7.00 pm	68.97	72.1 (at 3.00 am 11 Jan)	73.9 (at 1.00 pm 11 Jan)	5848	1411	1923
8.00 pm	69.10	72.7 (at 6.00 am 11 Jan)	74.1 (at 5.00 pm 11 Jan)	7338	1419	1912
9.00 pm 9/1	69.24			7659	1428	1969

2.7.5 Water continues to flow in

9.00 pm, 9 January to 8.00 am, 10 January

Inflows had continued to build through the night, peaking at 10 095 m^3/s at 8.00 am on 10 January. The expectation from the Bureau's forecast issued at 10.38 pm, 9 January was that very heavy rainfall would be experienced downstream of the dams' catchments as the system which had been over the dam catchments moved south.[371] Dam levels were rising at both Wivenhoe and Somerset and increased gate openings were planned for each.[372]

At 12.45 am, 10 January, Mr Ruffini, one of the flood engineers on duty (with Mr Ayre) took a call from Ken Morris of the Brisbane City Council. Mr Morris took issue with a statement in the most recent situation report that the limit of non-damaging flows downstream of Moggill was 4000 m^3/s, stating that the council's information was that 3500 m^3/s was the correct figure. Mr Ruffini agreed to excise references to non-damaging flow limits from the situation reports (as it was properly a matter for the council to comment on), but the engineers decided to continue to use the 4000 m^3/s figure because of its presence in the Wivenhoe manual.[373] When Mr Malone and Mr Tibaldi started their shift the next morning at 7.00 am, and discussed the issue with the council at 9.40 am,[374] they indicated that they would attempt to limit the flow at Moggill to 3500 m^3/s; which reflected the council's view that that figure represented the lower limit of damaging flows in urban Brisbane and was consistent with the W3 aim of protecting urban areas from inundation.[375]

At around 6.30 am, the flood engineers were aware that the upper Brisbane River (above Wivenhoe Dam) had peaked in the early hours of the morning. Releases were around 1800 m^3/s compared to inflows of 9312 m^3/s. The lake level was 70.77 metres and rising sharply, having risen 40 centimetres in the last two hours. However, with inflows from the upper catchment diminishing, the flood engineers expected the event could be contained within strategy W3. Given the rainfall was predicted to move downstream, and was already starting to have an impact on the Lockyer catchment and metropolitan Brisbane, the flood engineers continued to minimise releases in an effort to reduce inundation of urban areas as far as possible.[376]

The situation report issued at 6.30 am, 10 January warned that the threshold of damaging discharge in urban areas might be exceeded within 24 to 48 hours if predicted rainfall in the downstream tributary catchments eventuated.[377]

Figure 2(e)

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
9.00 pm 9/1	69.24			7659	1428	1969
10.00 pm	69.44			7646	1440	1968
11.00 pm	69.60			7935	1450	1944
12.00 am 10/1	69.80			7936	1462	1923
1.00 am	69.97	72.9 (at 5.00 am 11 Jan)	74.7 (at 10.00 pm 11 Jan)	8449	1473	1906
2.00 am	70.17			8732	1539	1890
3.00 am	70.36	73.0 (at 6.00 am 11 Jan)	74.8 (at 12.00 am 12 Jan)	9133	1605	1893
4.00 am	70.57	72.8 (at 6.00 am 11 Jan)	74.5 (at 12.00 am 12 Jan)	8759	1672	1951
5.00 am	70.77			8933	1740	1947
6.00 am	70.96			9312	1806	1947
7.00 am	71.16			9351	1875	1944
8.00 am 10/1	71.36			10095	1944	1993

2.7.6 Holding Moggill to 4000 m^3/s

8.00 am, 10 January to 12.00 am, 11 January

As quickly as the inflows had risen, to 10 095 m^3/s at 8.00 am on 10 January, so now they fell (with some interruptions to the downwards trajectory): to 4574 m^3/s by 11.00 pm, 10 January. But the large inflows had had a marked effect on the lake level, and the flood engineers were forced to escalate releases.

At 9.16 am, the Bureau issued a flood warning for the Brisbane River and Stanley River above Wivenhoe Dam.[378] It stated that up to 300 millimetres of rain had fallen in the catchment in the previous 24 hours and that further heavy rainfall was expected to continue through the day.

Around midday on 10 January, the flood engineers still intended to keep flows in the Brisbane River at Moggill to 3500 m^3/s,[379] the figure mentioned in their discussions with the Brisbane City council. The 10.00 am quantitative precipitation forecast issued by the Bureau indicated 50 to 100 millimetres of rain was expected in the next 24 hours in the dam catchments.[380]

By 3.00 pm, the plan to keep flows at Moggill to 3500 m^3/s was overtaken by significant rain falling in the dams' catchment: the aim was changed to hold the flow at Moggill to 4000 m^3/s.[381] The dam levels at Wivenhoe and Somerset were both rising; at Wivenhoe, the lake level was 72.54 metres, having risen 13 centimetres in the previous hour and over a metre since 8.00 am. Somerset was now releasing about 1700 m^3/s into Wivenhoe, which was releasing about 2500 m^3/s downstream.[382] The inflows were falling and the predicted peak of Wivenhoe, from the 'without forecast' model, was 73.6 metres.[383] The 'with forecast' model run predicted a lake level peak of 75.2 metres, which was expected to occur at 11.00 am on 12 January.[384]

At 5.32 pm, the flood engineers were advised, by an email from the Bureau of Meteorology, of a flash flood event in the Lockyer Creek catchment.[385] That email sets out rises in river heights at gauges, but at that stage the advice did not extend to rainfall, flow or volume information. The flood engineers also received the following warnings from the Bureau:

- flash flood warning issued for Lockyer Creek at 5.00 pm,[386] which reported 'very heavy rainfall' and 'extreme rises' in the Lockyer Creek
- flood warning issued for Lockyer Creek, Bremer River, Brisbane River and Warrill Creek at 6.12 pm[387] which reported 'moderate to major flooding' in Lockyer Creek and Bremer River, expecting further heavy rainfall; 'major flood peak' for the Lockyer of around 13 metres, expected rises to about 14.5 to 15 metres.

At 6.43 pm, the flood engineers issued a situation report. The most recent modelling had been done at 5.00 pm. The 'without forecast' model showed a predicted peak flow at Moggill of 3946 m^3/s; the 'with forecast' model showed a predicted peak flow of 4529 m^3/s.[388] The situation report stated '[t]he flash flooding experienced in the upper areas of the Lockyer Creek have [sic] been examined and are [sic] not expected to significantly increase Brisbane River flows above the current projection of 4000 m^3/s at Moggill'. That statement seems to have been made on slender grounds**.** When the 5.00 pm model run (which showed the flow, without forecast rain, remaining below 4000 m^3/s) was performed, no detailed information had been received about the magnitude of the rainfall in the Lockyer catchment or the flows from the Lockyer Creek.

During an 8.00 pm telephone conference, the Bureau advised the flood engineers that it estimated the rainfall in the Lockyer catchment to be as much as 600 millimetres.[389]

The flood engineers reviewed Bureau modelling which suggested the flow from the Lockyer Creek would exceed 1400 m^3/s; added to the Wivenhoe releases, it would tip the Moggill gauge over what they regarded as the 4000 m^3/s threshold.[390]

The flood engineers worked on options to hold back releases until after the Lockyer peak had entered the Brisbane River. Mr Ayre contacted the dam safety regulator, Mr Allen, to discuss a possible departure from the procedures of the Wivenhoe manual to exceed 74.0 metres for a short period without invoking strategy W4.

By midnight, the lake level was 73.26 metres; inflows had fallen to 4654 m^3/s while outflows were 2713 m^3/s. The flow at Moggill was 3405 m^3/s. The strategy remained to contain flows at Moggill to 4000 m^3/s, the flow which, in the engineers' view, the Wivenhoe manual set as the upper limit of non-damaging flows.[391]

Figure 2(f)

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
8.00 am 10/1	71.36			10095	1944	1993
9.00 am	71.56	72.9 (at 7.00 am 11 Jan)	74.5 (at 5.00 am 12 Jan)	9731	2015	2085
10.00 am	71.78			7267	2031	2146
11.00 am	71.95			8059	2044	2199
12.00 pm	72.07	73.3 (at 12.00 pm 11 Jan)	75.6 (at 10.00 am 12 Jan)	9026	2053	2285
1.00 pm	72.26			7384	2067	2416
2.00 pm	72.41			7856	2077	2555
3.00 pm	72.54	73.6 (at 3.00 pm 11 Jan)	75.2 (at 11.00 am 12 Jan)	8411	2087	2675
4.00 pm	72.70	73.7 (at 3.00 pm 11 Jan)	75.7 (at 2.00 pm 12 Jan)	6568	2155	2789
5.00 pm	72.84	73.8 (at 3.00 pm 11 Jan)	74.6 (at 7.00 am 12 Jan)	5116	2277	2893
6.00 pm	72.92			5286	2399	3025
7.00 pm	72.99			4946	2517	3130

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
8.00 pm	73.06	73.6 (at 4.00 pm 11 Jan)	74.3 (at 9.00 am 12 Jan)	4920	2695	3207
9.00 pm	73.11			5026	2699	3265
10.00 pm	73.17			4488	2705	3324
11.00 pm	73.22			4574	2709	3374
12.00 am 11/1	73.26	73.5 (at 7.00 pm 11 Jan)	74.1 (at 7.00 am 12 Jan)	4654	2713	3405

2.7.7 Another downpour

12.00 am, 11 January to 8.00 am, 11 January

As at midnight on 11 January, the Bureau's most recent quantitative precipitation forecast, (issued at 4.00 pm the previous day) predicted average falls of 25 to 50 millimetres with isolated falls to 100 millimetres.[392]
At 10.00 am, 11 January, the quantitative precipitation forecast for the dams' catchment advised expected falls of over 100 millimetres in the next 24 hours.

The inflows into the dams continued to decrease until 2.00 am. In the early hours of 11 January, however, intense rainfall again fell over the dam catchments. The intensity of the rainfall was not captured by rain gauges; but the flood engineers realised heavy rain must be falling because of the increase in Wivenhoe's lake level. The hydrologic model was not matching well with the lake level rises. A reverse process was carried out which estimated the rainfall which must have occurred to cause the observed rise in lake level. The estimate was of over 700 millimetres, an enormous amount. As a result of that estimate, inflow estimates increased sharply, up to 6817 m^3/s by 6.00 am and 8060 m^3/s by 8.00 am. Discharge from the dam was fairly constant, around 2700 m^3/s. The lake level was moving steadily up toward 73.5 metres.

At 3.00 am and 4.00 am, the two flood engineers on duty (Mr Ayre and Mr Ruffini) performed modelling on the predicted lake levels. The models indicated the lake level would peak at or above 74.0 metres, both with and without forecast rainfall. The flood engineers did not move to strategy W4 at this time, which they considered would require stabilising the lake level by opening the gates quickly to match outflows and inflows. [393] Instead they strove to keep the dam operating in strategy W3. With unknown inflows from the Lockyer Creek, a rainfall system moving south to areas downstream of the dam and a dam level more than 0.5 metres below 74.0 metres, the flood engineers did not want to release large volumes until they considered it absolutely necessary.[394] They maintained constant releases from Wivenhoe at just over 2700 m^3/s but directed that three sluice gates at Somerset be shut to decrease the inflow into Wivenhoe.[395]

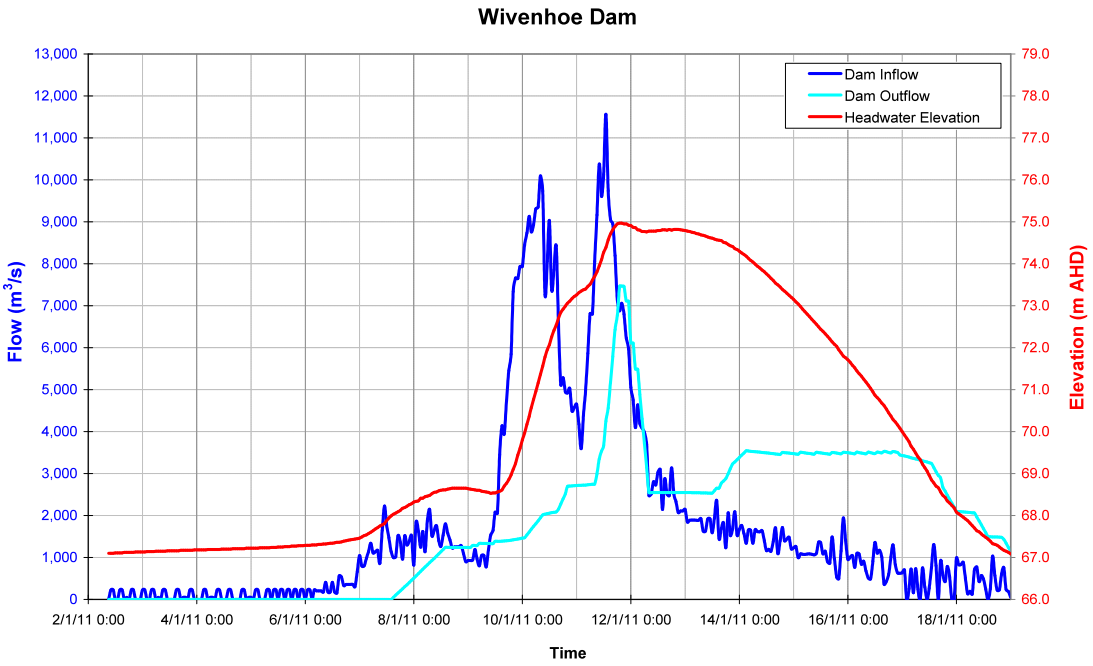
At 7.00 am, the other two flood engineers (Mr Malone and Mr Tibaldi) began their shift. They quickly performed modelling and noted the rapid increase in inflows into the dam during the previous two hours.[396] They sought advice from the Bureau, which agreed with their predicted inflow figures and confirmed that the heavy rain being experienced over the dams' catchment would continue.[397] The rate of rise in Wivenhoe's lake level and inflows and the confirmation of continuing heavy rain finally ended the hope that the flood could be contained in strategy W3. Strategy W4 was invoked, for the first time in Wivenhoe's history, at 8.00 am.

Figure 2(g)

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
12.00 am 11/1	73.26	73.5 (at 7.00 pm 11 Jan)	74.1 (at 7.00 am 12 Jan)	4654	2713	3405
1.00 am	73.31			4175	2717	3439
2.00 am	73.35	73.9 (at 3.00 am 12 Jan)	74.6 (at 11.00 am 12 Jan)	3594	2721	3423
3.00 am	73.38	74.0 (at 4.00 am 12 Jan)	74.8 (at 12.00 pm 12 Jan)	4388	2724	3409
4.00 am	73.40	74.1 (at 5.00 am 12 Jan)	74.9 (at 1.00 pm 12 Jan)	4974	2726	3399
5.00 am	73.46			5866	2731	3392
6.00 am	73.51			6817	2736	3394
7.00 am	73.61	74.3 (at 4.00 am 12 Jan)	76.2 (at 9.00 pm 12 Jan)	6802	2745	3404
8.00 am 11/1	73.70	74.5 (at 4.00 am 12 Jan)	75.1 (at 12.00 pm 12 Jan)	8060	2753	3481

The figure below indicates the two peaks in inflow affecting the dam between 9 and 12 January.

Figure 2(h)



Source: Seqwater, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, page iv.

2.7.8 Increasing releases in W4

8.00 am, 11 January to 11.00 pm, 11 January

The only consideration when operating Wivenhoe in accordance with W4 is the safety of the dam. The strategy is to open the gates continuously, as far as is safely possible, until outflows match inflows and the lake level stabilises. In these circumstances, it meant that a rapid rise in releases from the dam was inevitable.

At the start of W4, outflows were 2753 m^3/s and inflows 8060 m^3/s. The strategy at 12.00 pm was to attempt to limit releases to 4500 m^3/s.[398] Further rainfall prevented this being achieved, and by 6.00 pm, the flood engineers were predicting releases of around 8000 m^3/s.[399]

Inflows peaked at 11 561 m^3/s at 1.00 pm, when outflows had increased to 4250 m^3/s. The lake peaked at 74.97 metres at 7.00 pm when outflows for the first time exceeded inflows: 7464 m^3/s to 6876 m^3/s. Throughout, the flood engineers were reviewing strategies every 30 minutes.[400]

The following gate opening sequence was adopted to deal with the rapid rises in inflow: the gates were opened to 6.0 metres by 12.00 pm, then all five gates were opened to 7.0 metres at 1.00 pm, 7.5 metres at 2.00 pm, 8.5 metres at 3.00 pm, 9.5 metres at 4.00 pm, 10.5 metres at 5.00 pm, 11.0 metres at 6.00 pm and then held constant at 12.0 metres from 7.00 pm to 9.00 pm.[401] The sharp incline in the light blue line in the graph above indicates the increase in releases as a consequence of these gate openings.

By 9.00 pm the flood engineers were satisfied that the lake level had stabilised and would start to fall. Their strategy was to close the gates as quickly as they had opened them, attempting to limit as far as possible the flood which would be caused by such high flows out of the dam.[402] Each gate opening was reduced to 5.0 metres by 7.00 am on 12 January.

Figure 2(i)

Hour	Lake level (m)	Predicted peak exc forecast rainfall	Predicted peak inc forecast rainfall	Inflow (m^3/s)	Outflow (m^3/s)	Estimated Flow at Moggill (m^3/s)
8.00 am 11/1	73.70	74.5 (at 4.00 am 12 Jan)	75.1 (at 12.00 pm 12 Jan)	8060	2753	3481
9.00 am	73.81			9165	2991	3652
10.00 am	73.95	75.0 (at 3.00 am 12 Jan)	76.5 (at 8.00 pm 12 Jan)	10376	3347	3876
11.00 am	74.10			9606	3533	4182
12.00 pm	74.27			10120	3667	4613
1.00 pm	74.39	75.0 (at 3.00 am 12 Jan)	76.2 (at 9.00 pm 12 Jan)	11561	4250	4905
2.00 pm	74.57	75.1 (at 3.00 am 12 Jan)	76.3 (at 10.00 pm 12 Jan)	9739	4562	5245
3.00 pm	74.71			9055	5167	5562
4.00 pm	74.81			8947	5786	5823
5.00 pm	74.89			8196	6432	6041
6.00 pm	74.95			7141	6774	6204
7.00 pm	74.97	75.0 (at 10.00 pm 11 Jan)	75.2 (at 3.00 pm 12 Jan)	6876	7464	6305
8.00 pm	74.97			7060	7464	6352
9.00 pm	74.95	74.7 (at 8.00 pm 12 Jan)	No run	6797	7458	6350
10.00 pm	74.95			6229	7111	6393
11.00 pm 11/1	74.92			5964	7103	6555

2.7.9 The days after: the drawdown

9.00 pm, 11 January to 12.00 pm, 19 January

Once the lake level had stabilised, the flood engineers' strategies were firmly focussed on downstream impacts. The Wivenhoe manual requires that both Wivenhoe and Somerset dams be drawn down to full supply level within seven days of the peak of the flood passing through the dam. According to Seqwater's modelling, the flow at Moggill peaked at 12 095 m^3/s at 11.00 am on 12 January 2011.[403] After the Brisbane River at the City Gauge peaked early in the morning of 13 January, the strategy at Wivenhoe was to control the flow at Moggill at 3500 m^3/s.[404] Seqwater's modelling showed the flow below 4000 m^3/s by 8.00 pm on 13 January, and below 3500 m^3/s by 10.00 am on 16 January 2011.[405]

Releases from Wivenhoe were increased as the flows from the Lockyer Creek and the Bremer River decreased, balancing the downstream water levels.[406]

As the gates were shut and the flows decreased, the rural bridges were re-opened.

The gates were finally shut at 12.00 pm, 19 January.

2.8 General comments on the operation of Wivenhoe Dam

2.8.1 The interpretation of strategy W3

Strategy W3 is outlined on page 28 of the Wivenhoe manual, which states:

> The intent of Strategy W3 is to limit the flow in the Brisbane River at Moggill to less than 4000 m^3/s, noting that 4000 m^3/s is the upper limit of non-damaging floods downstream ... depending on natural flows from the Lockyer and Bremer catchments, it may not be possible to limit the flow at Moggill to below 4000 m^3/s. In these instances, the flow at Moggill is to be kept as low as possible.

The flood engineers' common interpretation of strategy W3 is that it does not allow releases from Wivenhoe that produce a flow at Moggill taking into account flows from the Lockyer and Bremer catchments of more than 4000 m^3/s.[407] That interpretation is open from the words of the Wivenhoe manual.

A different interpretation is that W3 allows the discharge from Wivenhoe to cause a flow at Moggill (taking into account flows from the Lockyer and Bremer catchments) above 4000 m^3/s if that is necessary to minimise inundation in urban areas, which is the primary consideration under strategy W3. That situation may arise where inundation at lower levels is considered necessary to reduce the risk of large scale inundation; for example, to guard against the event that a heavy rainfall forecast proves well-founded, and larger dam releases are necessary. If that view is preferred, there is a strong case for saying that the flood engineers should have modelled the effects of increasing the flow at Moggill to, for example, 4500 m^3/s or 5000 m^3/s or even higher, and compared the results with the results of maintaining the Moggill flow at 4000 m^3/s until W4 was invoked and then rapidly increasing releases to stop the lake level rising.[408]

Modelling from Seqwater suggests that an increase in releases earlier in W3 would not have reduced the flood peak downstream of Moggill; it remains to be seen whether the review of the modelling currently being undertaken by Mr Babister confirms that conclusion. It must be emphasised however, that the ambiguity of the Wivenhoe manual on the question means that it is impossible for the Commission to say the flood engineers were in breach of the Wivenhoe manual in taking the approach that such releases were prohibited. Their reading was open on the manual's words.

The flood engineers also state that preventing the lake level from reaching the trigger level of strategy W4 is not a consideration when operating the dam under strategy W3.[409]

The actual words articulating strategy W3 do not directly indicate that any consideration of the triggering of W4 should enter the flood engineers' decision-making. However, the triggering of W4 was in the flood engineers' minds according to the flood event report that was jointly authored by them.[410] In any case, given that the aim of W3 is to provide protection against urban inundation and strategy W4 necessarily entails such inundation,[411] it is hard to see why the prospect of triggering W4, and the avoidance of it, would not be rational considerations in operating under strategy W3.

The fact that more than one interpretation is open on these points is not to say that the flood engineers' interpretation is without merit or that it will not produce better flood mitigation results. They are, however, examples of the sort of ambiguity that arises from the current wording of the Wivenhoe manual. That wording should be changed in the interim review of the Wivenhoe manual: see *2.5.7 Interim review of the Wivenhoe manual*.

2.8.2 An earlier move to W4?

It is arguable that, objectively considered, and taking forecast rainfall into account, the conditions existed at 3.00 pm, 10 January 2011 for a move to W4. The lake level was 72.54 metres, having risen more than a metre since 8.00 am that morning. The predicted peak, according to the 'without forecast' model was 73.6 metres; according to the 'with forecast' model it was 75.2 metres. The inflows far exceeded releases (8411 m^3/s to 2087 m^3/s) and had shown no sign of any consistent fall. The 10.00 am quantitative precipitation forecast was predicting 50 to 100 millimetres in the catchment; it was raining at the dam;[412] the three day forecast, issued at 10.00 pm the night before, predicted peak inflows in the range of 8000 m^3/s. It was known that the lake level was capable of rising two or three metres in the space of 24 hours.

However, hindsight judgment of this kind can be confounded by events. Had the engineers taken the approach suggested, the result for downstream communities might well have been worse, for the simple reason that there was an unknown factor at that stage. The extraordinary flooding in the upper Lockyer Creek had started about two hours earlier. Those flows would add significantly to the water moving down the Brisbane River. Meanwhile, the flows into the Wivenhoe Dam actually started to decrease from 3.00 pm on 10 January until the early hours of the following morning. The example is useful to illustrate this proposition: there will always be a range of possible judgments, and the one which might seem most appropriate on the evidence may not, as events unfold, produce the optimal outcome. The best approach is to ensure that the flood engineers are guided in their decision-making by a clear, unambiguous manual, based on the best available science, and are equipped with ample and up-to-date modelling tools.

2.8.3 Gate openings in W4

The explanation of strategy W4 on page 29 of the Wivenhoe manual says the following about gate openings:

> Opening of the gates is to occur generally in accordance with the requirements of Section 8.6, until the storage level of Wivenhoe Dam begins to fall.
>
> There are no restrictions on gate opening increments or gate opening frequency once the storage level exceeds 74.0 AHD, as the safety of the dam is of primary concern at these storage levels.

Seqwater asserts that no flexibility exists in the implementation of strategy W4.[413] That proposition cannot be sustained; while the gates must be opened continuously until the lake level begins to fall, the rate at which they can be opened is entirely discretionary. That flexibility is clearly shown by the gate opening sequences implemented by the flood engineers in strategy W4, discussed at *2.7.8 Increasing releases in W4*. Such flexibility is important because the rate, volume and period of releases can have a substantial influence on the eventual peak lake level and peak dam outflow.[414] The senior flood operations engineer during the January 2011 event, Mr Ayre, agreed in his evidence that the flood engineers had complete flexibility over how and when to release water in W4, except for some minor limitations (for example, the requirement to have all the gates fully open by the time the first fuse plug initiates at 75.5 metres).[415]

Part 8.6 of the Wivenhoe manual states that the target minimum interval for individual gate openings of 0.5 metres is 10 minutes. It also says that interval can be decreased if the safety of the dam is at risk, which it necessarily is in strategy W4. It says that each gate can be opened more than five metres in one hour, and sets a normal sequence of gate openings. It is unclear from the use of 'generally' exactly which portions of part 8.6 should be followed when in W4. Little detail is given of the mechanical capability of the system for operating the gates.

This is an area of the Wivenhoe manual which lacks precision as to what can be done and how it should be done, the language of which should be made considerably clearer. See *2.5.7 Interim review of the Wivenhoe manual*.

2.8.4 Reaction to Brisbane City Council advice regarding threshold of damaging flows in Brisbane

The issue of the flood engineers' response to the Brisbane City Council's advice that the real threshold of non-damaging flows at Moggill was 3500 m^3/s can be dealt with briefly.

The Commission does not consider that there was anything untoward either in the decision by Mr Ayre and Mr Ruffini to continue to work off the 4000 m^3/s figure because it appeared in the Wivenhoe manual or in the later, short-lived attempt by Mr Malone and Mr Tibaldi to keep flows at Moggill to 3500 m^3/s. Both sets of engineers were, in their respective approaches, continuing to take account of their interpretation of the primary consideration under strategy W3, the protection of urban areas from inundation.

2.9 Effects of dam releases

2.9.1 Dam releases and the flow at Moggill

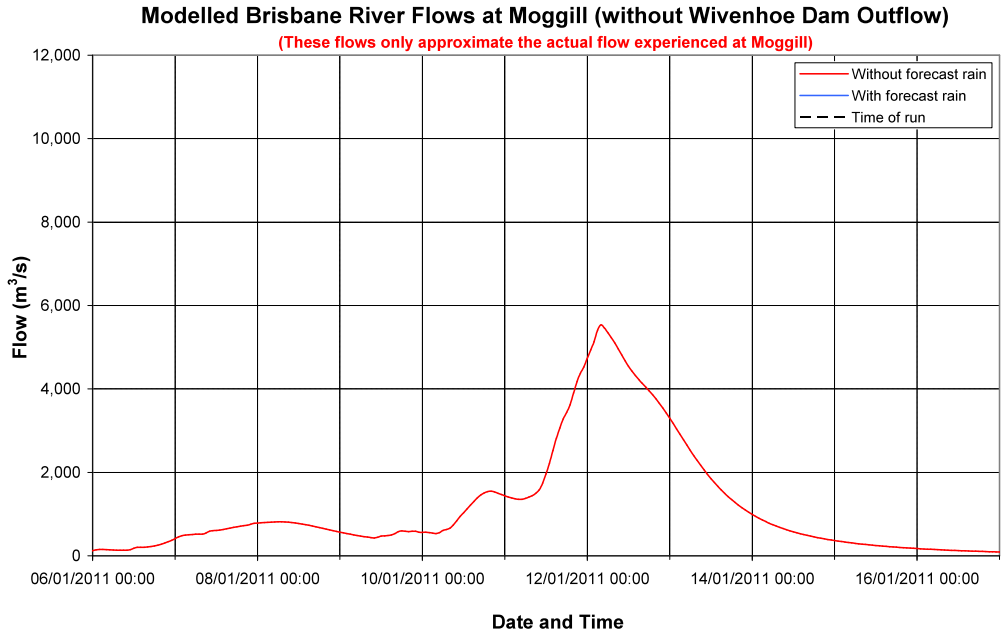
The flow at Moggill is influenced by Wivenhoe releases, rainfall leading to inflows into the Brisbane River downstream of Wivenhoe and flows from the Lockyer Creek and the Bremer River.

Water released from Wivenhoe reaches Moggill in approximately 16 hours, depending on the amount of water released and other variables.[416] The table below allows a comparison between the releases from Wivenhoe and the flow at Moggill 16 hours later.

It may be noted that the peak release from Wivenhoe was at 7.00 pm on 11 January (7464 m^3/s) and the peak flow at Moggill was 16 hours later at 11.00 am on 12 January (12 095 m^3/s). Drawing a conclusion from these figures is complicated by the fact that the flows from the Lockyer Creek and Bremer River were also affecting Moggill at this time; however, those figures at least show that the water from Wivenhoe constituted a significant portion of the peak of 12 095 m^3/s at Moggill.

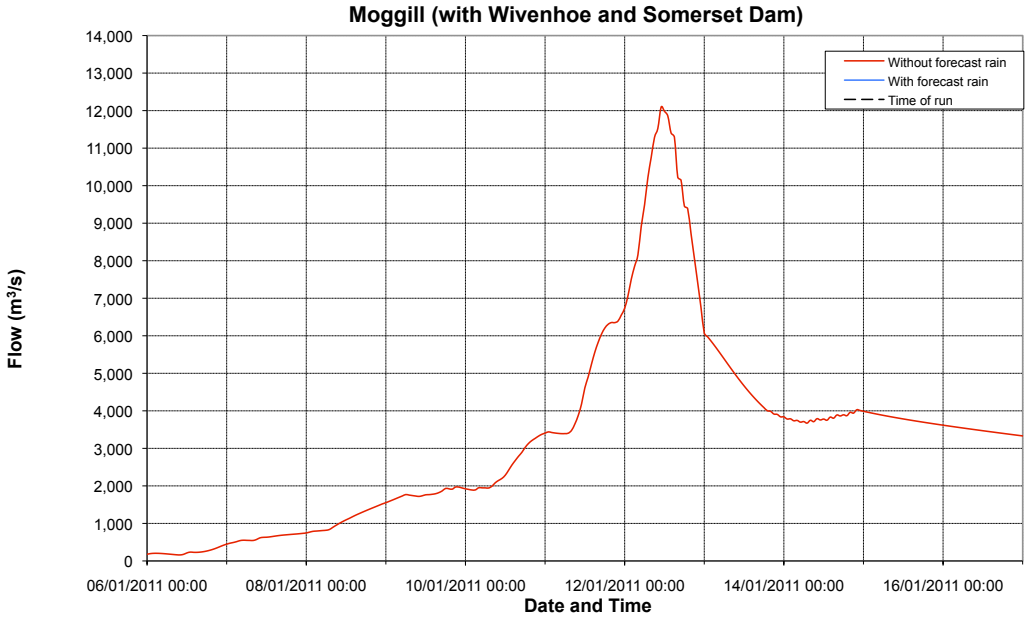
According to Seqwater's modelling,[417] the difference between the two graphs below illustrates the contribution of Wivenhoe discharge to the flow at Moggill.

Figure 2(j)



Source: Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 45. (Note: original graph supplied has only red line.)

Figure 2(k)



Source: Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 45. (Note: original graph supplied has only red line.)

A comparison can also be made regarding the recession of flow at Moggill. The table below shows that for 12 hours the flow at Moggill receded at a similar rate to the flow from Wivenhoe, which was rapidly decreased by the flood engineers from the evening of 11 January. For example, the flood engineers reduced outflow by about 5000 m^3/s from 7464 m^3/s at 8.00 pm on 11 January to 2547 m^3/s by 8.00 am on 12 January. Sixteen hours later at Moggill, the flows decreased by about 5900 m^3/s from 11 981 m^3/s at 12.00 pm 12 January to 6076 m^3/s at 12.00 am 13 January.

From that time onwards though, the rate of change in flow diverged. At Wivenhoe, releases were kept roughly the same (within 10 m^3/s) from 8.00 am 12 January to 9.00 am 13 January. In that same period 16 hours later at Moggill, the flow decreased from 6076 m^3/s at 12.00 am 13 January to 3871 m^3/s at 1.00 am 14 January. It can be inferred that this decrease in flows relates to the recession of the flows from the Lockyer, and/or the Bremer and/or rainfall or other local stream flows flowing into the Brisbane River below Wivenhoe.

Figure 2(l)

Time of release	Release (m^3/s)	Time 16 hours later	Flow in Moggill 16 hours later
10/01/11 11:00	2044	11/01/11 03:00	3409
10/01/11 12:00	2053	11/01/11 04:00	3399
10/01/11 13:00	2067	11/01/11 05:00	3392
10/01/11 14:00	2077	11/01/11 06:00	3394
10/01/11 15:00	2087	11/01/11 07:00	3404
10/01/11 16:00	2155	11/01/11 08:00	3481
10/01/11 17:00	2277	11/01/11 09:00	3652
10/01/11 18:00	2399	11/01/11 10:00	3876
10/01/11 19:00	2517	11/01/11 11:00	4182
10/01/11 20:00	2695	11/01/11 12:00	4613

Time of release	Release (m^3/s)	Time 16 hours later	Flow in Moggill 16 hours later
10/01/11 21:00	2699	11/01/11 13:00	4905
10/01/11 22:00	2705	11/01/11 14:00	5245
10/01/11 23:00	2709	11/01/11 15:00	5562
11/01/11 00:00	2713	11/01/11 16:00	5823
11/01/11 01:00	2717	11/01/11 17:00	6041
11/01/11 02:00	2721	11/01/11 18:00	6204
11/01/11 03:00	2724	11/01/11 19:00	6305
11/01/11 04:00	2726	11/01/11 20:00	6352
11/01/11 05:00	2731	11/01/11 21:00	6350
11/01/11 06:00	2736	11/01/11 22:00	6393
11/01/11 07:00	2745	11/01/11 23:00	6555
11/01/11 08:00	2753	12/01/11 00:00	6734
11/01/11 09:00	2991	12/01/11 01:00	7067
11/01/11 10:00	3347	12/01/11 02:00	7510
11/01/11 11:00	3533	12/01/11 03:00	7854
11/01/11 12:00	3667	12/01/11 04:00	8158
11/01/11 13:00	4250	12/01/11 05:00	8918
11/01/11 14:00	4562	12/01/11 06:00	9489
11/01/11 15:00	5167	12/01/11 07:00	10214
11/01/11 16:00	5786	12/01/11 08:00	10754
11/01/11 17:00	6432	12/01/11 09:00	11287
11/01/11 18:00	6774	12/01/11 10:00	11524
11/01/11 19:00	7464	12/01/11 11:00	12095
11/01/11 20:00	7464	12/01/11 12:00	11981
11/01/11 21:00	7458	12/01/11 13:00	11860
11/01/11 22:00	7111	12/01/11 14:00	11401
11/01/11 23:00	7103	12/01/11 15:00	11290
12/01/11 00:00	6118	12/01/11 16:00	10230
12/01/11 01:00	6109	12/01/11 17:00	10143
12/01/11 02:00	5492	12/01/11 18:00	9460
12/01/11 03:00	5483	12/01/11 19:00	9385
12/01/11 04:00	4888	12/01/11 20:00	8727
12/01/11 05:00	4304	12/01/11 21:00	8079
12/01/11 06:00	3727	12/01/11 22:00	7428
12/01/11 07:00	3143	12/01/11 23:00	6764
12/01/11 08:00	2547	13/01/11 00:00	6076
12/01/11 09:00	2547	13/01/11 01:00	5973
12/01/11 10:00	2547	13/01/11 02:00	5864
12/01/11 11:00	2547	13/01/11 03:00	5749
12/01/11 12:00	2547	13/01/11 04:00	5629
12/01/11 13:00	2547	13/01/11 05:00	5507
12/01/11 14:00	2549	13/01/11 06:00	5383

Time of release	Release (m^3/s)	Time 16 hours later	Flow in Moggill 16 hours later
12/01/11 15:00	2549	13/01/11 07:00	5258
12/01/11 16:00	2548	13/01/11 08:00	5135
12/01/11 17:00	2550	13/01/11 09:00	5013
12/01/11 18:00	2548	13/01/11 10:00	4894
12/01/11 19:00	2550	13/01/11 11:00	4778
12/01/11 20:00	2550	13/01/11 12:00	4665
12/01/11 21:00	2550	13/01/11 13:00	4557
12/01/11 22:00	2549	13/01/11 14:00	4454
12/01/11 23:00	2548	13/01/11 15:00	4355
13/01/11 00:00	2547	13/01/11 16:00	4260
13/01/11 01:00	2547	13/01/11 17:00	4170
13/01/11 02:00	2546	13/01/11 18:00	4085
13/01/11 03:00	2544	13/01/11 19:00	4004
13/01/11 04:00	2544	13/01/11 20:00	3987
13/01/11 05:00	2542	13/01/11 21:00	3914
13/01/11 06:00	2541	13/01/11 22:00	3905
13/01/11 07:00	2540	13/01/11 23:00	3840
13/01/11 08:00	2539	14/01/11 00:00	3839
13/01/11 09:00	2537	14/01/11 01:00	3781
13/01/11 10:00	2536	14/01/11 02:00	3787
13/01/11 11:00	2534	14/01/11 03:00	3735
13/01/11 12:00	2534	14/01/11 04:00	3745
13/01/11 13:00	2592	14/01/11 05:00	3699
13/01/11 14:00	2650	14/01/11 06:00	3714
13/01/11 15:00	2650	14/01/11 07:00	3672

Notes to table:

1. The Wivenhoe outflow figures are from the Dam Inflow and Flood Release Details section of the Seqwater Flood Event Report, 2 March 2011 (Exhibit 24), pages 154 to 166.
2. The figures in the Estimated Flow at Moggill column have been taken from Seqwater's modelling, run 45, completed at 12.00 pm, 19 January 2011. The flow at Moggill is estimated by the use of a rainfall runoff model which forms part of the real time flood model.

2.9.2 Modelling of the impact of dam releases on flooding

It is not disputed by any party that releases from Wivenhoe contributed significantly to flooding downstream. The proportions of that contribution are the subject of continuing modelling work.

Seqwater has engaged Sinclair Knight Merz to update a hydrodynamic model of the Brisbane River to simulate the January 2011 flood event. (As discussed elsewhere in more detail, a hydrodynamic model is considered to provide more accurate estimates of the effect of releases in terms of flood levels and inundation areas than hydrologic models.) See also *2.3.3 Tools at the flood operations centre* and *2.6 Decision-making and conditions at the flood operations centre*.

The Commission engaged Mr Babister to review and assess that modelling. It was not until 5 July 2011 that Mr Babister and Sinclair Knight Merz agreed on a model build and calibration. His review, completed on 13 July 2011, was received by the Commission after the process of printing this Interim Report had begun. His report has been

published on the Commission's website. It will be examined and the Commission will receive further submissions as to the conclusions which might be drawn from it for the purposes of its final report.

The Commission is of the view that nothing said by Mr Babister affects the recommendations which have been made in this Interim Report.

To the extent the Commission has found Seqwater has not complied with the Wivenhoe manual, that non-compliance has been of limited functional significance. The effect of failing to take into account forecast rainfall cannot be quantified because the evidence before the Commission allows no clear conclusion as to how and to what extent it should have been factored into lake level prediction. Consequently, no conclusions can be drawn about the consequences of non-compliance, whether on the basis of the modelling performed for Seqwater, or any other modelling done for the event.

That is not to say that such modelling work has no purpose. The modelling can provide analysis of the timing and quantity of releases and be used to test whether different operating strategies may have had different consequences. Those issues are part of the Commission's recommendations as to the process by which the future Wivenhoe manual should be developed. See also *2.5.8 Longer term review of the Wivenhoe manual*.

2.9.3 Effect of releases on riverbanks

The Commission received several submissions from people who live or work in the mid Brisbane River region, extending from Wivenhoe Dam to Mt Crosby Weir,[418] and along the Brisbane River north of Wivenhoe Dam,[419] most notably the township of Harlin. Many of those making submissions own land that suffered severe erosion or bank slumping (where chunks of bank material become unstable and topple into the river in a single event) during the 2010/2011 wet season.[420]

For some of these landowners the loss of land has been substantial:[421] a resident of Borallon whose land borders the Brisbane River reports the loss of 15 acres of land[422] while a Harlin landowner describes losses of up to 30 acres from his property.[423] Others comment more generally, stating that large areas of land have been washed away along kilometres of the riverbanks in these regions.[424]

The Minister for Energy and Water Utilities, Mr Robertson, gave evidence that he had viewed the riverbanks below Wivenhoe Dam since the 2010/2011 flooding and agreed there had been significant damage to these riverbanks.[425]

Under the Moreton Resource Operations Plan, Seqwater, as the holder of the Resource Operations Licence,[426] is required to undertake inspections of the streams within the Central Brisbane River and Stanley River water supply scheme for evidence of bank slumping resulting from the operation of Seqwater's water infrastructure.[427] The Commission is advised that Seqwater is carrying out preliminary surveys and assessments of the remedial works required within relevant areas.[428]

Whether the operation of Wivenhoe and Somerset dams during the 2010/2011 wet season caused or contributed to instability, slumping or erosion of the Brisbane River's banks is, in Seqwater's view, a matter for detailed expert evidence. This view is also shared by Terry Wall, the acting Director-General of DERM, who considers a comprehensive geomorphological assessment necessary to determine the causative effect of the bank slumping.[429]

While there is strong evidence that the releases from Wivenhoe Dam had an effect on the banks downstream of it,[430] the Commission's view is that this is a matter more properly considered in its final report, and that Seqwater should be allowed, as it proposes, to adduce expert evidence on the topic.

2.10 Operation of North Pine Dam

2.10.1 Managing flood events

As with Wivenhoe and Somerset dams, Seqwater is not obliged by legislative or regulatory rules to operate North Pine Dam during a flood event in a particular manner. Seqwater, as the owner of North Pine Dam, is immune from civil liability if it, honestly and without negligence, operates North Pine Dam in compliance with the current *Manual of Operational Procedures for Flood Mitigation at North Pine Dam*.[431]

The North Pine manual has only one flood operation strategy: to release the whole volume of a flood through the dam while attempting to keep the volume of the outflows lower than the volume of the inflows.[432] To achieve this strategy, the North Pine manual specifies that the dam's gates are to be opened to particular increments at particular time intervals determined by the lake level.[433]

Overtopping of North Pine Dam is likely to result in dam failure.[434] The dam's emergency action plan identifies that, if North Pine Dam were to fail, the safety of 838 people would be at risk.[435] Unsurprisingly, then, the primary objective of the North Pine manual flood operation strategy is ensuring the structural safety of the dam.[436]

The second objective is to minimise disruption to the community in areas downstream of the dam.[437] This objective involves minimising the incidence of submergence of bridges, such as Youngs Crossing, and public areas downstream of the dam.[438]

The other objective of the procedures in the North Pine manual is the minimisation of impacts to riparian flora and fauna during the drain down phase of a flood event.[439] The retention of full supply level at the conclusion of a flood event is included as an objective but, as noted in *2.5.1 Structure of the Wivenhoe manual*, it does not in truth warrant description as a flood mitigation objective.

The North Pine manual articulates the general aim of the flood engineers: to empty stored floodwaters as quickly as possible while meeting all of these objectives.[440]

During flood events, Seqwater transfers control over North Pine Dam from its own staff to a dedicated flood operations centre.[441] For a description of the workings of the flood operations centre, see *2.6 Decision-making and conditions at the flood operations centre*.

2.10.2 Wet season flood events

North Pine Dam experienced 18 separate flood events between Sunday 10 October 2010 and Saturday 5 March 2011.[442] The flood operations centre was mobilised for each event before the lake level reached the gate opening trigger.[443] The table below details the duration and extent of these flood events, as specified in the text of Seqwater's *2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam* (May 2011) and *January 2011 Flood Event Report on the Operation of North Pine Dam* (11 March 2011).[444]

Figure 2(m)

Flood event	Start	End	Peak inflow (m^3/s)	Peak outflow (m^3/s)	Peak lake level (metres)
1	11 Oct 2010 6.00 am	14 Oct 2010 8.00 am	950	907	40.12
2	16 Oct 2010 6.00 am	16 Oct 2010 6.00 pm	220	200	39.68
3	4 Dec 2010 7.05 am	5 Dec 2010 7.00 am	(not specified)	151	39.64
4	6 Dec 2010 12.35 pm	7 Dec 2010 3.00 pm	200	332	39.82
5	9 Dec 2010 7.10 pm	10 Dec 2010 5.00 am	(not specified)	152	39.66
6	14 Dec 2010 7.20 pm	15 Dec 2010 5.00 am	(not specified)	104	39.67
7	16 Dec 2010 7.40 pm	17 Dec 2010 5.15 am	90	80	39.63
8	18 Dec 2010 7.10 pm	19 Dec 2010 7.00 am	(not specified)	152	39.68
9	19 Dec 2010 9.10 pm	21 Dec 2010 5.00 am	200	200	39.68

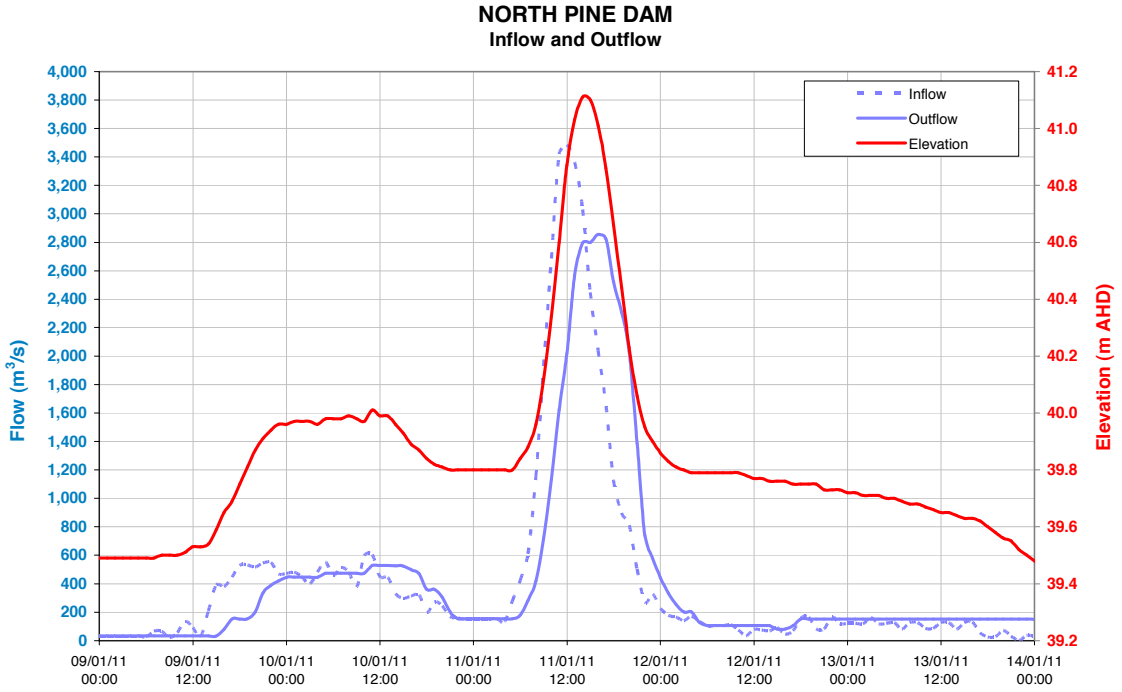
Flood event	Start	End	Peak inflow (m^3/s)	Peak outflow (m^3/s)	Peak lake level (metres)
10	23 Dec 2010 7.20 pm	24 Dec 2010 4.45 am	(not specified)	197	(not specified)
11	25 Dec 2010 7.15 pm	26 Dec 2010 7.15 am	(not specified)	275	(not specified)
12	26 Dec 2010 8.00 pm	29 Dec 2010 7.00 am	450	200	39.77
13	1 Jan 2011 7.30 pm	2 Jan 2011 7.00 am	(not specified)	200	39.66
14	6 Jan 2011 7.42 am	14 Jan 2011 5.00 am	3 484	2 854	41.11
15	18 Jan 2011 9.15 pm	19 Jan 2011 5.00 am	(not specified)	200	(not specified)
16	20 Jan 2011 12.40 am	20 Jan 2011 2.00 pm	550	150	(not specified)
17	21 Feb 2011 9.00 pm	22 Feb 2011 6.15 am	150	200	(not specified)
18	4 Mar 2011 7.00 pm	5 Mar 2011 7.00 am	65	48	(not specified)

Excluding the flood event of 6 January 2011 to 14 January 2011 (flood event 14 in the above table), the other 17 flood events can be described as frequent flood events.[445] The chance that such an event will occur in any one year is less than 1 in 50.[446]

The flood event of 6 January 2011 to 14 January 2011 was the biggest flood event ever experienced at North Pine Dam, both in terms of inflow volume and inflow rate.[447] The peak inflow (3484 m^3/s) to North Pine Dam was estimated to occur at 12.00 pm on 11 January 2011.[448] Two hours later, the peak lake level for the event, 41.11 metres, was reached. This was 1.51 metres above North Pine Dam's full supply level, but 3.68 metres below the level of its embankment crest.[449] Another two hours later, at 4.00 pm, the peak outflow from North Pine Dam was estimated as being 2854 m^3/s.[450]

The graph below shows North Pine Dam's lake level, inflows and outflows during the 6 January 2011 to 14 January 2011 flood event.

Figure 2(n)



Source: Seqwater, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011, page 68.

At 5.30 pm on 6 January 2011, the flood operations centre issued North Pine Directive 1. It required gate operations to commence at 7.00 pm that night, subject to Moreton Bay Regional Council's confirmation that Youngs Crossing had been closed.[451] In fact, the gate openings at North Pine Dam were delayed until about 7.15 pm because the gates at Youngs Crossing were not closed until 7.00 pm.[452] Youngs Crossing remained closed to traffic until the morning of 14 January 2011.[453]

As the graph above shows, releases dramatically escalated on Tuesday 11 January 2011 when intense rainfall produced unprecedented inflows at North Pine dam from about 7.00 am to 2.00 pm.[454] During this seven hour period, 85 gate operations were undertaken.[455]

The prescribed gate operating intervals aim to minimise adverse impacts on the river system caused by rapid rises in downstream water levels.[456] The North Pine manual states that the opening intervals can be reduced if the gates are at risk of being overtopped or the safety of the dam is at risk; in that case they are 'generally not allowed' to fall more than three increments behind the prescribed setting for the given lake level.[457] The North Pine manual also permits reduction in the closing intervals to preserve storage and reduce downstream flooding.[458]

The evidence of one of the senior flood engineers, Mr Ayre, is that the gate opening and closing intervals provided by part 8.6 of the North Pine manual were followed at all times except during the rapid rise in water levels on 11 January 2011, and directly following the flood peak.[459] In the first of these periods the gate opening intervals were reduced to manage rapid water level rises; the reasonable inference is that this was to preserve the safety of the dam.[460] The interval was appropriately adjusted to ensure the gates were never more than three increments behind the minimum setting for the given lake level.[461] Following the peak the gate closing intervals were reduced to preserve storage and reduce downstream flooding.[462]

2.10.3 Safety concerns

Two key issues in relation to the safety of North Pine Dam emerged during the flood event of 6 January 2011 to 14 January 2011: the reliability of North Pine Dam's design flood hydrology and the adequacy of its gate operating systems. These issues, and Seqwater's investigations and proposed actions to redress them are discussed below.

Reliability of the design flood hydrology

The design flood hydrology for North Pine Dam was reviewed by SunWater in October 2007.[463] A hydrologic model was developed and calibrated to three pre-dam floods and four post-dam events.[464] According to this study, the peak lake level of North Pine Dam during the 6 January 2011 to 14 January 2011 flood event (41.11 metres) was consistent with a flood event with a chance of occurring in any one year of close to 1 in 10 000.[465]

However, the catchment average rainfall intensity for the 12 hour period to Tuesday 11 January 2011 at 3.00 pm (which included the period of the heaviest rainfall recorded in the North Pine catchment) indicated that the rainfall event had between a 1 in 200 and a 1 in 500 chance of occurring in any one year.[466]

The discrepancy in the assessment of the rarity of the flood event as determined on the one hand by the peak lake level, and on the other hand by the catchment average rainfall intensity of the 12 hour period to Tuesday 11 January 2011 at 3.00 pm, raises questions about the design flood hydrology for North Pine Dam.[467]

The current assessment of the maximum flood which North Pine Dam is capable of passing without the dam failing is based on the operating rules in the North Pine manual and the design flood hydrology.[468] Therefore, questions about the accuracy of the design flood hydrology have direct implications for the current assessment of North Pine Dam's flood capacity. Because North Pine Dam is required to be able to pass a flood of a particular size under the DERM *Guidelines on Acceptable Flood Capacity for Dams,*[469] uncertainty about North Pine Dam's flood capacity in turn affects the assessment of whether North Pine Dam complies with these safety guidelines.

Adequacy of the gate operating mechanism

During the 6 January 2011 to 14 January 2011 flood event, North Pine Dam reached a peak lake level that was only 50 centimetres below the level of the electric winch motors which control the dam's gates.[470] If the electric winch motors become submerged, they cannot operate and normal control of the gates is lost.[471] This may result in overtopping of the dam.[472]

Currently, if failure or submergence of the electric winch motors were to occur, an auxiliary gate operating mechanism (a trailer mounted motor with petrol driver generator) would allow the winches to be operated from the crest of North Pine Dam.[473]

In September 2010, Seqwater commenced a project to provide an additional backup system for the operation of the dam's gates. The project has identified a preferred option (an independent hydraulic system) to operate the gates and is now part of Seqwater's *North Pine Dam Acceptable Flood Study Investigations* (discussed below).

Seqwater's investigations

The Commission is advised that Seqwater is undertaking a project called *North Pine Dam Acceptable Flood Study Investigations* aimed at, among other things, investigating and improving the reliability of the design flood hydrology and the adequacy of the gate operating systems for North Pine Dam.[474] Seqwater proposes to report to the Dam Safety Regulator, Mr Allen, on at least a monthly basis in relation to its progress with this project.

Seqwater is reviewing the dam hydrology and flood event details as part of these investigations. It has engaged an engineering firm to review this work and identify further work required to evaluate the performance of North Pine Dam.[475]

The investigations include the following tasks:

- a review of the rainfall data to determine the rarity of the 6 to 14 January 2011 flood event
- a review and recalibration of the design flood hydrology by using the rainfall and flow data obtained in the 6 to 14 January 2011 flood event
- a review of the rating curves (which show the relationship between outflow and lake level) for the gates
- a review of the storage curve (which shows the storage volume of North Pine Dam at given lake levels)
- a review of the structural adequacy of the dam
- a review of the gate operational procedures to assess the impact on flood capacity
- improvement of the gate operating mechanism.

In conducting these investigations, Seqwater is prioritising the identification of the maximum flood that can be safely passed by the dam.[476]

2.10.4 Personal safety of the dam operator

On 11 January 2011, from about 11.00 am until about 7.00 pm, the area in which the primary controls for North Pine Dam's gates are located was inundated with flowing water.[477] The dam operator working during those hours operated the gates from this area at risk to his personal safety. The water reached a level about half way up the operator's lower leg; he described the velocity of the water was such that if he tripped and fell he could have been washed out of the area.[478]

A safety harness was available for the operator's use and he had the option of operating the gates from a control room inside the dam wall which was not affected by water.[479] He elected to operate the gates from the inundated platform because it was the only location from which he could observe the gates while opening.[480]

Seqwater has since installed a duplicate electronic gate control panel which will allow gate operations to be undertaken from a higher position.[481] The Commission is satisfied that the installation of the duplicate electronic gate panel will remove this particular safety risk to dam operators in similar future flood events.

2.10.5 Interim review of the North Pine manual

Part 8.4 of the North Pine manual sets out the flood operation strategy for North Pine Dam.[482] It states that the gate opening settings shown in Appendix C of the North Pine manual are normally used to determine flood releases but permits departures from those settings in limited circumstances. One of those circumstances is that, subject to the senior flood engineer's exercising his reasonable discretion under part 2.8 of the North Pine manual to depart from the manual, pre-release of water is allowed to reduce the risk of the dam overtopping.

The meaning of 'pre-release' in this context is unclear. It could permit releases of water before the onset of a flood event. It could also mean that the flood operation engineers can open the gates more quickly than the sequence prescribed by the North Pine manual.

One of the senior flood engineers gave evidence that he would expect pre-releases under part 8.4 to occur when he (or another senior flood engineer) had relatively good knowledge about the magnitude of the likely inflows. The only practical example he suggested was where a gate malfunction made pre-releases necessary in order to accommodate a loss of release capacity.[483]

What is meant by the term 'pre-release', and in turn the basis on which early release of water (not in accordance with usual gate openings) is permitted under the North Pine manual, remains obscure.

As for the Wivenhoe manual (see *2.5.7 Interim review of the Wivenhoe manual*) the Commission finds that an interim review of the North Pine manual is required before the onset of the next wet season to ensure the manual clearly identifies the permitted practice.

Recommendations

2.25 Seqwater should:

1. conduct an interim review of the North Pine manual
2. have the draft manual assessed by independent expert peer reviewers
3. consider the expert peer reviews
4. submit the draft manual to DERM for approval under the Act so that it can be approved before 1 October 2011.

2.26 Particular attention should be paid during the interim review of the North Pine manual to clarifying the circumstances in which pre-releases under part 8.4 are permitted.

2.10.6 Longer term review of the North Pine manual

Seqwater's view is that the very large size of the flood event of 6 to 14 January 2011 necessitates a formal review of the North Pine manual[484] and the Commission agrees. The Commission also considers, particularly in light of the dam's location in an urban area and the risks associated with its failure, that the community has a right to expect that the North Pine manual should incorporate current best practice in hydrology, meteorology and dam management.

As with the review of the Wivenhoe manual, the Commission acknowledges that the review of the North Pine manual may involve considerable time and expense, but considers this kind of investment, managed well, would serve the public interest.

To ensure the review is comprehensive and takes into account the views of all of the agencies affected by the operation of North Pine Dam, the Commission recommends that the review of the North Pine manual be supervised by a steering committee of senior representatives from DERM, Seqwater, the Water Commission, the Water Grid Manager, Brisbane City Council and the Moreton Bay Regional Council. As to the involvement of the Bureau of Meteorology and SunWater, the comments in *2.5.8 Longer term review of the Wivenhoe manual* apply equally here.

The role and function of the steering committee should be substantially as described at *2.5.8 Longer term review of the Wivenhoe manual*.

The Commission specifically recommends that the steering committee determine whether any hydrological studies in addition to Seqwater's review of the design flood hydrology[485] are required to be carried out. The results of these hydrological studies should be incorporated into the review of the North Pine manual. The steering committee should engage independent experts to peer review the technical work undertaken during the review.

Further, the steering committee should oversee modelling which assesses the consequences in terms of risk to life and safety, and economic, social and environmental damage of all potential operating strategies and full supply

levels. However, the responsibility for identifying which operating strategy best satisfies the needs of the community rests with the Queensland Government.

Once draft changes to the North Pine manual are settled upon, the steering committee should engage independent experts to peer review the draft manual before it is submitted to DERM for approval.

Recommendations

2.27 Seqwater should act immediately to establish:

1. a steering committee to oversee the long term review of the North Pine manual including senior representatives of at least DERM, Seqwater, the Water Commission, the Water Grid Manager, Brisbane City Council and the Moreton Bay Regional Council
2. a technical review committee comprised of independent experts in at least hydrology, meteorology and dam operations to examine all technical work completed as part of the review.

2.28 The steering committee should:

1. oversee the continuation of Seqwater's *North Pine Dam Acceptable Flood Study Investigations* in accordance with the scope and program of activities advised to the Commission as at 6 May 2011
2. determine whether any hydrological studies, in addition to those undertaken as part of the *North Pine Dam Acceptable Flood Study Investigations*, are required
3. ensure that modelling across a range of full supply levels and operating strategies, including variations of the gate increments and gate opening intervals is undertaken
4. ensure all of the above work is reviewed by the technical review committee.

2.10.7 North Pine River crossings

Youngs Crossing (on Youngs Crossing Road, Petrie) and AJ Wyllie Bridge (on Gympie Road, Petrie) are both located downstream of North Pine Dam. They are the only two points at which cars can cross the North Pine River. Youngs Crossing is controlled by the Moreton Bay Regional Council while A J Wyllie Bridge is a state controlled road.

Youngs Crossing was closed during each of the 18 flood events which occurred during the period 10 October 2010 to 5 March 2011,[486] including from 7.00 pm on 6 January 2011 to early on the morning of 14 January 2011.[487] Over the October to March period, the flood engineers tried, where they could, to limit disruption to the community downstream of North Pine Dam by minimising the period during which the crossing was closed to traffic and avoiding closures during peak traffic periods. Even so, the frequent closures of Youngs Crossing during this period caused inconvenience to that community.

The two northbound lanes (low bridge) and two southbound lanes (high bridge) of A J Wyllie Bridge suffered damage and were closed following the 2010/2011 floods.[488] During the closure of A J Wyllie Bridge, traffic was diverted via the Bruce Highway or Youngs Crossing Road.[489] Emergency repairs to the low bridge were undertaken to enable one lane of traffic to pass in each direction by 25 January 2011.[490] On 24 March 2011 the Minister for Main Roads, Fisheries and Marine Infrastructure announced that the high bridge would be demolished and a new bridge constructed.[491]

Closure of either one of Youngs Crossing or A J Wyllie Bridge causes congestion and delays on other major roads. The bridge closures have been the subject of concern to North Pine residents[492] and the Moreton Bay Regional Council.[493]

One of the flood engineers considered that upgrading Youngs Crossing, so that it would need to be closed less frequently by releases from North Pine Dam, would make a big difference to the operation of North Pine Dam and resolve most of the local community's issues with the dam.[494]

As shown on the table in *2.10.2 Wet season flood events* above, the peak outflow from North Pine Dam exceeded 300 m^3/s on three occasions during the period 10 October 2010 to 5 March 2011. Seqwater's *2010/2011 Wet*

Season Flood Events Report on the operation of North Pine Dam concludes that if Youngs Crossing were raised so that it would only be inundated by flows exceeding 300m^3/s, it is unlikely to have been closed by 16 of the 18 flood events.[495]

Recommendation

2.29 The Moreton Bay Regional Council should investigate options for the upgrade of Youngs Crossing and undertake a cost-benefit analysis of these to determine an outcome which best serves the public interest.

2.10.8 Isolation of some Whiteside residents

The submission of the North Pine Residents Association proposed that Seqwater permit vehicular access via North Pine Dam's wall to emergency vehicles and residents of Vores Road and Grant Street, Whiteside (a suburb adjacent to North Pine Dam), when Vores Road, the residents' only evacuation route, becomes impassable because of the flooding of Whiteside Creek.[496] The President of the residents association estimated that about 40 houses or 150 people became isolated by the flooding of Whiteside Creek and the closure of Vores Road. This was thought to have occurred about six times in the prior year and a half.[497]

North Pine Dam's wall is not a designated road, but its crest could serve as a single lane concrete roadway.

The chief executive officer of Seqwater indicated that Seqwater would be open to allowing emergency services vehicles to use North Pine Dam's wall as an alternative access route but, because it is an operating work site, it would be too dangerous to permit residents use of the dam wall as a general alternative access route.[498]

The Commission accepts that the dangers identified by Seqwater make it impracticable for Whiteside residents to use North Pine Dam's wall as an access road during flood events.

However, access arrangements for emergency services vehicles to reach the affected residents when isolated, which may include the use of North Pine Dam's wall, should be put in place before the commencement of the next wet season.

Recommendation

2.30 The Moreton Bay Regional Council should consult with Seqwater and the local police, ambulance and fire and rescue services to make arrangements for emergency vehicles to access Vores Road and Grant Street, Whiteside, when Vores Road is closed by the flooding of Whiteside Creek.

(Endnotes)

1 Administrative Arrangements Order (No.1) 2011.

2 Administrative Arrangements Order (No.2) 2011.

3 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p9].

4 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p9].

5 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p21].

6 Exhibit 43, Transcript of Interview by Commission staff of John Ruffini [p2-3].

7 Section 266 of the *Water Act 2000* provides that such applications must be made to the chief executive (Director-General of DERM).

8 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p11].

9 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p38-41].

10 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p9].

11 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p23].

12 Section 345, *Water Act 2000*.

13 Section 346(g), *Water Act 2000*.

14 Exhibit 393, Statement of Peter Borrows, Annexure PB-2.

15 Exhibit 397, Statement of Peter Allen [p37-38: para 110-112; p 42: para 125].

16 Queensland, Parliamentary Debates, Legislative Assembly, 30 October 2007 (Hon AP Fraser, Second Reading Speech) [p3905].

17 Submission of Seqwater, 11 March 2011 [p16: para 57].

18 Sections 45 and 46, *South East Queensland Water (Restructuring) Act 2007*.

19 Queensland Urban Utilities, Allconnex Water and Unity Water.

20 Exhibit 17, First Statement of Robert Ayre [p12: para 51].

21 Submission of Seqwater, 11 March 2011 [p6: para 11; p15: para 51(a)].

22 Submission by Seqwater, 11 March 2011 [p16: para 59].

23 Exhibit 501, First Statement of Robert Keogh [p9: para 4].

24 Exhibit 501, First Statement of Robert Keogh [p13].

25 Section 360ZH, *Water Act 2000*.

26 The other portfolio Ministers are responsible for taking some proposed regulations to the Executive Council.

27 Section 95, *Water Act 2000*.

28 Chapter 2, Part 4, *Water Act 2000*.

29 Section 353(1), *Water Supply (Safety and Reliability) Act 2008*.

30 Section 359A, *Water Supply (Safety and Reliability) Act 2008*.

31 Submission of the State of Queensland, 11 March 2011, Volume 9, Section 6 [p13].

32 Section 10, *Water Supply (Safety and Reliability) Act 2008*.

33 Exhibit 390, Statement of John Bradley, Annexure JNB-06 'DERM *Water Supply (Safety and Reliability) Act 2008* Water Supply (Chief Executive) Delegation (No.1) 2010'. These delegations are permitted by section 15(1) of the *Water Supply (Safety and Reliability Act) 2008*.

34 Section 370, *Water Supply (Safety and Reliability) Act 2008*.

35 Exhibit 397, Statement of Peter Allen [p7: para 28].

36 Exhibits 49 and 391, DERM, DS5.1 Flood mitigation manual for a dam.

37 Section 374(4) provides that for the purposes of the section 'owner' of a dam includes the operator of the dam, a director of the owner or operator, an employee of the owner or operator or an agent of the owner or operator.

38 Exhibit 501, First Statement of Robert Keogh [p22-23].

39 See, for example, Exhibit 501, First Statement of Robert Keogh [p22].

40 Exhibit 501, First Statement of Robert Keogh [p21]; Exhibit 407, Report to the Queensland Floods Commission of Inquiry, Mark Babister, 11 May 2011 [p12].

41 Section 38(1), *Water Act 2000*.

42 Exhibit 390, Statement of John Bradley, Annexure JNB-19.

43 Exhibit 501, First Statement of Robert Keogh [p13].

44 Exhibit 501, First Statement of Robert Keogh [p13].

45 Exhibit 501, First Statement of Robert Keogh, Schedule 17 [p4].

46 Submission of Seqwater, 11 March 2011 [p27: para 123-124].

47 Exhibit 397, Statement of Peter Allen [p5: para 19].

48 For a detailed history as to the investigations leading to the construction of Somerset Dam, see Submission of Geoffrey Cossins, received 10 March 2011 [p6-7].

49 Submission of Geoffrey Cossins, received 10 March 2011 [p7].

50 Submission of Geoffrey Cossins, received 10 March 2011 [p7].

51 All references to metres in this chapter are to metres AHD (Australian Height Datum).

52 Exhibit 397, Statement of Peter Allen [p5: para 21].

53 Submission of Seqwater, 11 March 2011 [p31: para 130(b)].

54 Exhibit 17, First Statement of Robert Ayre [p18: para 88].

55 Submission of Seqwater, 11 March 2011 [p31: para 30(b)].

56 Submission of Seqwater, 11 March 2011 [p28: para 28].

57 See Exhibit 397, Statement of Peter Allen [p3: para 10], reference to 'Future Brisbane Water Supply and Flood Mitigation', June 1971.

58 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011[pi].

59 Exhibit 17, First Statement of Robert Ayre [p59-60: para 281-290].

60 For example, Guidelines on Assessment of the Consequences of Dam Failure, ANCOLD, 2000; Guidelines on Selection of Acceptable Flood Capacity for Dams, ANCOLD, 2000.

61 Exhibit 397, Statement of Peter Allen [p3: para 9].

62 Exhibit 426, Statement of Barton Maher [p3: para 14].

63 Exhibit 426, Statement of Barton Maher [p3: para 14].

64 Exhibit 17, First Statement of Robert Ayre [p12: para 291].

65 There are conditions attaching to the exercise of reasonable discretion by the senior flood engineer - see Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p7-8].

66 Exhibit 397, Statement of Peter Allen [p4: para 14].

67 Exhibit 426, Statement of Barton Maher [p3: para 15].

68 Submission of Seqwater, 11 March 2011 [p37].

69 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p18].

70 Exhibit 17, First Statement of Robert Ayre [p19: para 96]; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p4].

71 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p4].

72 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p4].

73 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p4].

74 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p6].

75 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p7].

76 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p8].

77 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p10].

78 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p10].

79 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p11].

80 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p12].

81 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p12].

82 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p13].

83 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p14].

84 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p15].

85 Letter from Holding Redlich (representing SunWater) to Commission dated 6 July 2011; Letter from Allens Arthur Robinson (representing Seqwater) to Commission dated 6 July 2011.

86 Exhibit 416, Seqwater SunWater Service Level Agreement – Flood Management Services, Service Schedule [p4].

87 Training & Flood Preparedness for Seqwater Dams for the Year Beginning 30 September 2009, SunWater, October 2009; Training & Flood Preparedness for Seqwater Dams for the Year Beginning 30 September 2008, SunWater, October 2008; Training & Flood Preparedness for SEQWater Dams for the Year Beginning 30 September 2007, SunWater, October 2007; Training & Flood Preparedness for SEQWater Dams for the Year Beginning 30 September 2006, SunWater, October 2006; Statement of Preparedness for 2004-2005 Wet Season, SunWater, October 2004; Report on Training and Flood Preparedness for SEQWCo. Dams for Year Beginning 30 September 2002, SunWater, October 2002; Report on Training and Flood Preparedness for SEQWater Dams for Year Beginning 30 September 2001, SunWater, September 2001; SunWater Annual Reports on Contract with Seqwater, 2006-2007, 2005-2006, 2004-2005, 2003-2004, 2002-2003, 2002-2001, 2000-2001; SunWater Monthly Work Activities Status Report, Oct 2005, Nov 2005, Mar 2006, Jul 2006, Aug 2006, Sept 2006, Oct 2006, Nov 2006, Dec 2006, Jan 2007, Feb 2007, Mar 2007, Apr 2007, May 2007, Jan 2008, Feb 2008, Mar 2008, Apr 2008, May 2008.

88 SunWater Annual Reports on Contract with Seqwater, 2006-2007, 2005-2006, 2004-2005 2003-2004, 2002-2003, 2001-2002.

89 SunWater Annual Report on Contract with Seqwater, 2000-2001.

90 Transcript, 11 April 2011, Brisbane [p83: line 30].

91 Exhibit 403, Statement of Kenneth Morris, Annexure KJM-03. Note that the report deals with the Esk Shire Council area which has now been incorporated into the Somerset Regional Council.

92 See Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p13].

93 Transcript, 12 April 2011, Brisbane [p110: line 45].

94 Transcript, 13 April 2011, Brisbane [p216: line 30].

95 Exhibit 407, Report to the Queensland Floods Commission of Inquiry, Mark Babister, 11 May 2011 [p35-36].

96 Transcript, 13 April 2011, Brisbane [p215: line 45].

97 Transcript, 13 April 2011, Brisbane [p216: line 8].

98 Transcript, 13 April 2011, Brisbane [p216: line 30].

99 Mark Babister and Rhys Hardwick-Jones, Review and Comment on Seqwater Report, 6 July 2011 [p11: para 28].

100 Mark Babister and Rhys Hardwick-Jones, Review and Comment on Seqwater Report, 6 July 2011 [p9: para 22].

101 Exhibit 407, Report to the Queensland Floods Commission of Inquiry, Mark Babister, 11 May 2011 [p36].

102 Transcript, 12 April 2011, Brisbane [p110: line 45]; Transcript, 13 April 2011, Brisbane [p216: line 30].

103 Transcript, 12 April 2011, Brisbane [p110: line 45].

104 Mark Babister and Rhys Hardwick-Jones, Review and Comment on Seqwater Report, 6 July 2011 [p13: para 31].

105 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p28].

106 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p84] (entry at 8.50 pm, 9 January 2011).

107 Exhibit 48, Email from Rob Drury to Flood Engineers including email from Flood Engineers to Barton Maher, 14 January 2011; Transcript, 15 April 2011, Brisbane [p375: line 41].

108 Exhibit 426, Statement of Barton Maher, Annexure 4(m).

109 Exhibit 426, Statement of Barton Maher, Annexure 4(k). See also Exhibit 426, Statement of Barton Maher, Annexure 4(r).

110 Exhibit 426, Statement of Barton Maher, Annexure 4(h).

111 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p17]; Exhibit 29, Manual of Operational Procedures for Flood

Mitigation at North Pine Dam, Revision 5, 2010 [p16-17].

112 Exhibit 26, Flood Operations Preparedness Report – Wivenhoe, Somerset and North Pine Dam, October 2010; Seqwater Supplementary Submission, 2 June 2011 [p96: para 420].

113 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p39-45].

114 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p6]; Exhibit 29, manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p6-7].

115 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p6]; Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p6-7].

116 Transcript, 12 April 2011, Brisbane [p115: line 57].

117 Exhibit 396, DERM, Moreton Resource Operations Plan 2009, Attachment 5 [p91].

118 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p19]; Appendix C.

119 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, parts 1.1, 2.2, 3.1, 3.5, 8.4, 8.5, 9.3, 9.4 and 10.3. See also, the evidence of Minister Robertson about the mechanism by which full supply level is determined and altered: Transcript, 11 April 2011, Brisbane [p29: line 40].

120 Exhibit 9, Graph: Historical dam levels, Wivenhoe & Somerset dams.

121 Exhibit 417, Statement of Barry Dennien, Annexure C, South East Queensland Water Strategy, 2010 [p148].

122 Exhibit 426, Statement of Barton Maher, Annexure BM-5, Provision of Contingency Storage in Wivenhoe & Somerset Dams, 2007 [p13].

123 Assumptions included a range of flood events of different magnitude and duration, modifying the gate operation triggers for small flood events and the situation in which one gate at Wivenhoe Dam was inoperable.

124 Exhibit 426, Statement of Barton Maher, Annexure BM-6, SunWater, Assessment of Wivenhoe Dam Full Supply Level on Flood Impacts, 2007 [p1].

125 Exhibit 426, Statement of Barton Maher, Annexure BM-7, GHD, Report for Wivenhoe Dam Full Supply Level Review Technical Assessment of Raising Potential, 2009.

126 Exhibit 432, Statement of Daniel Spiller [p39: para 139].

127 Exhibit 417, Statement of Barry Dennien, Annexure C, South East Queensland Water Strategy, 2010 [p98 and 143].

128 Exhibit 418, Statement of Karen Waldman [p17: para 11.2].

129 Exhibit 393, Statement of Peter Borrows [p3: para 20].

130 Exhibit 11, Statement of Stephen Robertson, Annexure SR5.

131 Exhibit 11, Statement of Stephen Robertson, Annexure SR5.

132 Exhibit 393, Statement of Peter Borrows, Annexure PB-2.

133 Transcript, 18 May 2011, Brisbane [p2277: line 10]; Exhibit 418, Statement of Karen Waldman [p17-18: para 11.3-11.4].

134 Exhibit 422, Statement of Kenneth Schmidt, Annexure 2 [p3: para 1].

135 Exhibit 422, Statement of Kenneth Schmidt, Annexure 2 [p14: para 58-59].

136 Exhibit 422, Statement of Kenneth Schmidt, Annexure 2 [p14: para 60].

137 Exhibit 14, Letter from Kenneth Schmidt to Minister Robertson, 23 December 2010.

138 Exhibit 14, Letter from Kenneth Schmidt to Minister Robertson, 23 December 2010.

139 Exhibit 15, Letter from Minister Robertson to Kenneth Schmidt, 9 March 2011.

140 Exhibit 11, Statement of Stephen Robertson [para 5-7]; Exhibit 37, Statement of James Davidson. [p27-28: para 106-107]; Transcript, 11 April 2011, Brisbane [p31: line 21]; Transcript, 14 April 2011, Brisbane [p284: line 50].

141 Exhibit 390, Statement of John Bradley [p2: para 9]; Exhibit 11, Statement of Stephen Robertson [para 5-7]; Exhibit 37, Statement of James Davidson, Annexure JD-1 [p28: para 107(f)]; Transcript, 14 April 2011, Brisbane [p31: line 21].

142 Exhibit 11, Statement of Stephen Robertson [para 6].

143 Exhibit 432, Supplementary Statement of Daniel Spiller [p6-16: para 21-60]; Transcript, 18 May 2011, Brisbane [p2263:line 8]; Transcript, 16 May 2011, Brisbane [p2036: line 38].

144 Exhibit 390, Statement of John Bradley, Attachment JNB-09; Exhibit 417, Statement of Barry Dennien [p13: para 46]; Annexure E [p276-287].

145 Exhibit 417, Statement of Barry Dennien, Annexure E [p255-258]; Transcript, 16 May 2011, Brisbane [p2035: line 30].

146 Exhibit 417, Statement of Barry Dennien, Annexure E [p345-350]; Transcript, 16 May 2011, Brisbane [p2067: line 10]; Transcript, 16 May 2011, Brisbane [p2236: line 28].

147 Transcript, 16 May 2011, Brisbane [p2037: line 8]; Transcript, 16 May 2011, Brisbane [p2042: line 7].

148 Chapter 4, *Water Supply Act (Safety and Reliability) Act 2008*; Transcript, 16 May 2011, Brisbane [p2037: line 36]. See also *2.2.1 Referable Dams*.

149 Refer to *2.1.1 Department of Environment and Resource Management*. See also Transcript, 16 May 2011 [p2037: line 41].

150 Exhibit 11, Statement of Stephen Robertson [para 64]; Exhibit 417, Statement of Barry Dennien [p18-20: para 63]; Transcript, 11 April 2011, Brisbane [p34: line 56].

151 Transcript, 11 April 2011, Brisbane [p35: line 6].

152 Transcript, 11 April 2011, Brisbane [p43: line 25].

153 Transcript, 11 April 2011, Brisbane [p44: line 25].

154 Transcript, 11 April 2011, Brisbane [p42: line 11; p44: line 51]; Transcript, 16 May 2011, Brisbane [p2237: line 7]; Transcript, 18 May 2011, Brisbane [p2263: line 57]; Transcript, 18 May 2011, Brisbane [p2266: line 22]; Transcript, 18 May 2011, Brisbane [p2278: line 19].

155 Exhibit 10, Requirement to Provide Statement to the Honourable Stephen Robertson MP [p1-2: para 5-6, 10 and 11].

156 Transcript, 11 April 2011, Brisbane [p43: line 39]; Exhibit 11, Statement of Stephen Robertson.

157 Transcript, 11 April 2011, Brisbane [p42: line 11; p44: line 51].

158 Transcript, 16 May 2011, Brisbane [p2039: line 1].

159 Transcript, 11 April 2011, Brisbane [43: line 39; p45: line 10].

160 Transcript, 11 April 2011, Brisbane [p35: line 34; p36: line 36; p38: line 3; p40: line 21].

161 Exhibit 417, Statement of Barry Dennien, Annexure E [p923].

162 Exhibit 11, Statement of Stephen Robertson, AnnexureSR11; Exhibit 417, Statement of Barry Dennien [p20: para 64].

163 Exhibit 11, Statement of Stephen Robertson, Annexure SR11.

164 Exhibit 427, Statement of James Pruss, Annexure JP2, JP3; Exhibit 417, Statement of Barry Dennien, Annexure E [p494-495; p545-547].

165 Exhibit 11, Statement of Stephen Robertson, Annexure SR11.

166 Exhibit 11, Statement of Stephen Robertson, Annexure SR11 [p2].

167 Exhibit 418, Statement of Karen Waldman [p5: para 4.6-4.8]; Annexure [p11-37].

168 Exhibit 418, Statement of Karen Waldman, Annexure [p11].

169 Exhibit 393, Statement of Peter Borrows, Annexure PB-10 [p56-58].

170 Exhibit 393, Statement of Peter Borrows, Annexure PB-10 [p59].

171 Exhibit 393, Statement of Peter Borrows [p4: para 33-34].

172 Exhibit 393, Statement of Peter Borrows [p4: para 34].

173 Exhibit 390, Statement of John Bradley [p12: para 68]; Annexure JNB-22, JNB-23.

174 Exhibit 393, Statement of Peter Borrows, Annexure PB-13.

175 Exhibit 393, Statement of Peter Borrows [p6: para 50].

176 Exhibit 393, Statement of Peter Borrows, Annexure PB-15.

177 Exhibit 393, Statement of Peter Borrows [p6: para 52]; Annexure PB-16.

178 Exhibit 393, Statement of Peter Borrows [p6-7: para 53-56]; Annexure PB-17.

179 Exhibit 393, Statement of Peter Borrows, Annexure PB-18.

180 Exhibit 393, Statement of Peter Borrows, Annexure PB-18.

181 Exhibit 393, Statement of Peter Borrows, Annexure PB-18.

182 Exhibit 393, Statement of Peter Borrows, Annexure PB-18.

183 Exhibit 393, Statement of Peter Borrows [p7: para 58]; Annexure PB-19.

184 Exhibit 393, Statement of Peter Borrows, Annexure PB-21.

185 Exhibit 393, Statement of Peter Borrows, Annexure PB-21 [p199].

186 Exhibit 393, Statement of Peter Borrows, Annexure PB-21 [p199-200]; Transcript, 16 May 2011, Brisbane [p2047: line 54].

187 Exhibit 393, Statement of Peter Borrows, Annexure PB-21 [p199-201].

188 Exhibit 393, Statement of Peter Borrows, Annexure PB-21 [p200].

189 Exhibit 393, Statement of Peter Borrows, Annexure PB-21 [p200].

190 Exhibit 393, Statement of Peter Borrows, Annexure PB-21 [p200].

191 Exhibit 393, Statement of Peter Borrows [p7: para 61]; Annexure PB-23.

192 Exhibit 393, Statement of Peter Borrows [p7: para 60]; Annexure PB-22. The Commission notes the date on the letter, 9 February 2010, is plainly an error.

193 Exhibit 393, Statement of Peter Borrows, Annexure PB-22.

194 Exhibit 393, Statement of Peter Borrows, Annexure PB-23.

195 Exhibit 390, Statement of John Bradley, Annexure JNB-18.

196 Exhibit 390, Statement of John Bradley, Annexure JNB-18.

197 Exhibit 393, Statement of Peter Borrows, Annexure PB-30.

198 Exhibit 393, Statement of Peter Borrows, Annexure PB-30.

199 Exhibit 393, Statement of Peter Borrows, Annexure PB-31.

200 Exhibit 418, Statement of Karen Waldman [p23: para 12.14-12.16]; Annexure [p339-377].

201 Exhibit 393, Statement of Peter Borrows, Annexure PB-31 [p268].

202 Exhibit 390, Statement of John Bradley [p11: para 62-63]; Annexure JNB-19.

203 Exhibit 390, Statement of John Bradley [p11: para 65]; Annexure JNB-21.

204 Exhibit 390, Statement of John Bradley [p12: para 68]; Annexure JNB-22, JNB-23.

205 Transcript, 11 April 2011, Brisbane [p31: line 1].

206 Transcript, 11 April 2011, Brisbane [p36: line 15].

207 Exhibit 393, Statement of Peter Borrows, Annexure PB-32 [p285].

208 Exhibit 393, Statement of Peter Borrows Annexure PB-17; Annexure PB-21.

209 Exhibit 393, Statement of Peter Borrows, Annexure PB-32.

210 Exhibit 418, Statement of Karen Waldman [p10: para 9.3]; Annexure [p202-241].

211 Transcript, 11 April 2011, Brisbane [p36: line 31].

212 Exhibit 393, Statement of Peter Borrows, Annexure PB-19.

213 Exhibit 393, Statement of Peter Borrows, Annexure PB-19 [p4].

214 Exhibit 393, Statement of Peter Borrows, Annexure PB-19 [p4].

215 Exhibit 393, Statement of Peter Borrows, Annexure PB-19 [p6].

216 Exhibit 393, Statement of Peter Borrows, Annexure PB-23.

217 Ministerial media statement of the Honourable Stephen Robertson, Transcript: press conference on Wivenhoe Dam releases, 13 February 2011. Available at: www.cabinet.qld.gov.au/mms.

218 Exhibit 393, Statement of Peter Borrows, Annexure PB-19 [p2].

219 Exhibit 393, Statement of Peter Borrows, Annexure PB-31.

220 Exhibit 417, Statement of Barry Dennien, Annexure E [p2110-2118].

221 Ministerial media statement of the Honourable Stephen Robertson, Transcript: press conference on Wivenhoe Dam releases, 13 February 2011. Available at: www.cabinet.qld.gov.au/mms.

222 Exhibit 397, Statement of Peter Allen [p6: para 23].

223 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010.

224 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, parts 2 and 7.

225 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 1.1.

226 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 1.7.

227 Of up to five years, see also: Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, part 1.6.

228 Exhibit 390, Statement of John Bradley, Annexure JNB-06.

229 Exhibit 21, *Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam*, Revision 7, 2009, part 7.5.

230 Exhibit 398, Statement of Ronald Guppy [p4: para 25].

231 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 2.7.

232 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 2.2.

233 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 6.3.

234 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 7.1.

235 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009, part 2.3.

236 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, Revision 7, 2009 [p50].

237 See Transcript, 11 April 2011, Brisbane [p85: line 30]; [p86: line 50]; Transcript, 12 April 2011, Brisbane [p103: line 51]; [p104: line 1]; [p108: line 47]; [p162: line 22]; [p163: line 1]; [p167: line 1]; [p183: line 32]; [p186: line 4]; Transcript, 13 April 2011, Brisbane [p200: line 48]; [p206: line 4]; [p230: line 19]; [p239: line 1]; [p245: line 39]; [p261: line 24]; Transcript 14 April 2011, Brisbane [p320: line 4]; [p321: line 29]; [p323: line 45]; [p324: line 19]; [p336: line 27]; Transcript, 15 April 2011, Brisbane [p381: line 41]; [p384: line 2]; [p441: line 29]; [p444: line 43]; [p447: line 9]; [p449: line 18].

238 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p97].

239 See *2.6 Decision-making and conditions at the flood operations centre*.

240 Transcript, 11 April 2011, Brisbane [p82: line 1].

241 Transcript, 15 April 2011, Brisbane [p409: line 54]; Transcript, 15 April 2011, Brisbane [p464: line 40].

242 Second Supplementary Submission of Seqwater, 3 June 2011 [p45: para 190(b)].

243 Transcript, 11 April 2011, Brisbane [p86: line 50].

244 Second Supplementary Submission of Seqwater, 3 June 2011 [p7: para 27].

245 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, part 7.1.

246 Section 374 of the *Water Supply (Safety and Reliability) Act 2008* (Qld) provides Seqwater with immunity from civil liability for an act done (honestly and without negligence) whilst observing the procedures for which the manual provides.

247 Transcript, 12 April 2011, Brisbane [p115: line 57].

248 Transcript, 12 April 2011, Brisbane [p116: line 4].

249 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, part 2.4.

250 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, part 2.6.

251 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam, part 2.5.

252 Transcript, 18 May 2011, Brisbane [p2248: line 51].

253 Exhibit 416, Service Level Agreement – Flood Management Services.

254 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p6].

255 Exhibit 42, Statement of John Ruffini [p5: para 26].

256 Exhibit 37, Statement of James Davidson, Annexure JD-1 [p876].

257 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011.

258 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p55-58].

259 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p111].

260 Exhibit 409, January 2011 Flood Event: Report on the operation of Somerset Dam and Wivenhoe Dam, Review of Hydrological Issues, Final A, 11 March 2011, Rory Nathan [p3].

261 Exhibit 496, First Statement of Peter Baddiley, Annexure PB-7.

262 Exhibit 36, Email from Peter Baddiley to Rob Drury dated 1 December 2010.

263 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p18-19]; Exhibit 33, Second Statement of Terrence Malone [p1: para 3(a)-(b)].

264 Exhibit 407, Report to the Queensland Floods Commission of Inquiry, Mark Babister, 11 May 2011 [p14].

265 The Institution of Engineers Australia, Australian Rainfall and Run-off (Book 6); Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p13].

266 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p4-6].

267 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p4].

268 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix A.

269 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p5].

270 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p4-6].

271 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix A.

272 Exhibit 45, First Statement of Terrence Malone [p10: para 44].

273 Transcript, 11 April 2011, Brisbane [p87: line 46].

274 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix A; Transcript, 11 April 2011, Brisbane [p87: line 46]; Transcript, 15 April 2011, Brisbane [p449: line 35]; Transcript, 15 April 2011, Brisbane [p455: line 38]; Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p23-24].

275 Second Supplementary Submission of Seqwater [p4: para 14].

276 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p106]; Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation

of Operational Methods and Decision-Making Practices, July 2011 [p22].

277 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, part 7.

278 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p112].

279 Exhibit 45, First Statement of Terrence Malone [para 64].

280 Transcript, 13 April 2011, Brisbane [p215: line 48].

281 Transcript, 13 April 2011, Brisbane [p216: line 10].

282 Exhibit 407, Report to the Queensland Floods Commission of Inquiry, Mark Babister, 11 May 2011 [p35-36].

283 Transcript, 13 April 2011, Brisbane [p216: line 30].

284 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p28].

285 Transcript, 12 April 2011, Brisbane [p109: line 40].

286 Transcript, 12 April 2011, Brisbane [p110: line 10].

287 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p16].

288 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p15].

289 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p18].

290 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p18].

291 Exhibit 33, Second Statement of Terrence Malone [p1: para 3(a)-3(b)].

292 Exhibit 17, First Statement of Robert Ayre [p24: para 125].

293 Exhibit 17, First Statement of Robert Ayre [p91: para 396].

294 Exhibit 17, First Statement of Robert Ayre [p91: para 395].

295 Letter from Allens Arthur Robinson (representatives for Seqwater) to Commission, 6 June 2011 – Arrangements in New Flood Operations Centre.

296 Exhibit 17, First Statement of Robert Ayre [p91: para 396-397].

297 Exhibit 426, Statement of Barton Maher, Annexure BM4(b).

298 Exhibit 45, First Statement of Terrence Malone [p14-15: para 77-79]; Exhibit 43, Transcript of Interview by Commission staff with John Ruffini [p64: line 30].

299 Transcript, Brisbane, 11 April 2011 [p89: line 45]; Transcript, Brisbane, 11 April 2011 [p92: line 41].

300 Transcript, Brisbane, 11 April 2011 [p93: line 35].

301 Exhibit 43, Transcript of Interview by Commission staff with John Ruffini [p65: line 28]; Exhibit 46, Transcript of Interview by Commission staff with Terrence Malone [p11: line 30; p14: line 6].

302 For example, there were some conversations which were not attributed to any flood engineer: Exhibit 44, Transcript of Interview by Commission staff with Robert Ayre, (30 March 2011) [p27: line 13].

303 Exhibit 51, First Statement of John Tibaldi [p6: para 24-25]; Exhibit 17, First Statement of Robert Ayre [p49: para 234]; Exhibit 43, Transcript of Interview by Commission staff with John Ruffini [p73: line 15]; Exhibit 44, Transcript of Interview by Commission staff with Robert Ayre [p30: line 5].

304 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p15]; Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam [p14]; Exhibit 327, Seqwater Wivenhoe Dam Emergency Action Plan, Appendix A; Exhibit 314, Seqwater North Pine Dam Emergency Action Plan, Appendix A; Seqwater, Somerset Dam Emergency Action Plan, Appendix A.

305 Exhibit 417, Statement of Barry Dennien, Appendix D; Exhibit 430, Statement of Robert Drury [p2: para 11].

306 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix E.

307 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix F. For an example of where the SEQ Water Grid Manager has provided a technical situation report, see Exhibit 417, Statement of Barry Dennien, Annexure E [p1340].

308 Exhibit 417, Statement of Barry Dennien, Appendix D; Exhibit 430, Statement of Robert Drury [p2: para 11].

309 Transcript, 10 May 2011, Brisbane [p1617: line 47].

310 Exhibit 42, Statement of John Ruffini [p15: para 92]. Mr Robert Ayre similarly suggested a 'more structured and consistent approach' to the information contained in situation reports and technical situation reports would an improvement: Exhibit 17, First Statement of Robert Ayre [p92: para 402].

311 Exhibit 44, Transcript of Interview by Commission staff with Robert Ayre, 30 March 2011 [p14: line 44].

312 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam Appendix M [p82].

313 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam Appendix M [p90].

314 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix M; Exhibit 23, Unredacted flood event log.

315 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix M [p79, 82, 88]; Exhibit 17, First Statement of Robert Ayre [p50: para 240]; Exhibit 322, Statement of Tony Jacobs [para 7(d), 8(c), 8(d), 9(c), 10(b)-(e)].

316 Exhibit 322, Statement of Tony Jacobs [para 7(d), 8(c), 8(d), 9(c), 10(b)-(e)].

317 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix M [p89] (entry at 8.16am, 11 January 2011).

318 Transcript, 20 May 2011, Ipswich [p2403: line 49].

319 Transcript, 10 May 2011, Brisbane [p1617: line 29].

320 Transcript, 10 May 2011, Brisbane [p1618: line 10].

321 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix M; Exhibit 17, First Statement of Robert Ayre [p49: para 237].

322 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix M [p88-89].

323 Transcript, 13 April 2011, Brisbane [p236: line 41].

324 Exhibit 17, First Statement of Robert Ayre [p50: para 240].

325 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, Appendix M [p99] (entry at 6.43 am, 13 January 2011).

326 Transcript, 13 April 2011, Brisbane [p236: line 45].

327 Exhibit 17, First Statement of Robert Ayre [p49: para 237; p92: para 404]; Transcript, 12 April 2011, Brisbane [p116: line 57].

328 Exhibit 17, First Statement of Robert Ayre [p49: para 237].

329 Exhibit 55, Transcript of Interview by Commission staff with John Tibaldi [p17: line 4].

330 Exhibit 44, Transcript of Interview by Commission staff with Robert Ayre [p14: line 29].

331 Bundle of emails sent between 7 and 17 January 2011 in relation to the communications role of the flood engineers and effectiveness of the draft communications protocol.

332 Email from Peter Allen to Duty Engineer, 11 January 2011 4.54 pm.

333 Email from Duty Engineer to Robert Drury, 12 January 2011 1.17 pm.

334 Email from Rob Drury to 'Duty Seq', 16 January 2011 6.43 pm.

335 Email from John Tibaldi to Peter Borrows, 17 January 2011 2.36 pm.

336 Exhibit 17, First Statement of Robert Ayre [p48: para 229].

337 Exhibit 46, Transcript of Interview by Commission staff with Terrence Malone [p5: line 27].

338 Exhibit 45, First Statement of Terrence Malone [p8: para 28].

339 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1'.

340 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix M [p78].

341 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p25, 39].

342 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p21].

343 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p65-66] cf Appendix O [p126-129] which indicate falls less than 50 millimetres.

344 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p24-26].

345 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p10-13; p154-155].

346 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p23, 27, 28].

347 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p27].

348 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p13].

349 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p28].

350 Exhibit 18, Supplementary Statement of Robert Ayre [p17].

351 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p16]; Appendix E [p13-14] (Situation Report, 6.32 am, 8 January 2011); Appendix E [p15-16] (Situation Report, 2.22 pm, 8 January 2011).

352 Exhibit 21, Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam [p39].

353 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p13-14] (Situation Report, 6.32 am, 8 January 2011).

354 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p16].

355 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p13-14].

356 Exhibit 18, Supplementary Statement of Robert Ayre, 29 March 2011 [p16-17].

357 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix A.

358 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix A.

359 Exhibit 18, Supplementary Statement of Robert Ayre, Annexure 1.

360 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p68].

361 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p68].

362 Exhibit 497, Second Statement of Peter Baddiley, Annexure PB2-8(20) [p12].

363 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p17-18] (Situation Report 6.15 am 9 January 2011).

364 Australian Community Climate and Earth-System Simulator. See Exhibit 37, Statement of James Davidson, Annexure JD-1 [p59: para 25].

365 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p57].

366 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 18.

367 Exhibit 18, Supplementary Statement of Robert Ayre [p22-24].

368 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 18.

369 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p21-22] (Situation Report 9.04 pm 9 January 2011).

370 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p21-22] (Situation Report 9.04 pm 9 January 2011).

371 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p23-24] (Situation Report 13, 1.14 am 10 January 2011); Second Statement of Peter Baddiley, Annexure PB2-8(20) [p13].

372 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p23-24] (Situation Report 13, 1.14 am 10 January 2011).

373 Exhibit 44, Transcript of Interview by Commission staff with Mr Robert Ayre [p20].

374 Exhibit 403, First Statement of Kenneth Morris [p20].

375 Exhibit 51, First Statement of John Tibaldi [p13].

376 Transcript, 13 April 2011, Brisbane [p251: line 9].

377 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p25-26] (Situation Report 14, 6.30 am 10 January 2011).

378 Exhibit 497, Second Statement of Peter Baddiley, Annexure PB2-8(20) [p14].

379 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p28-29] (Situation Report 15, 12.16 pm 10 January 2011).

380 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix C [p176].

381 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p20].

382 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p30-31] (Situation Report 16, 6.43 pm 10 January 2011).

383 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 28.

384 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 28.

385 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p32-33] (Situation Report 17, 11.56 pm 10 January 2011); Exhibit 18, Supplementary Statement of Robert Ayre, 29 March 2011 [p40-41: para 114-117].

386 Exhibit 37, Statement of James Davidson, Annexure JD-1 [p815].

387 Exhibit 497, Second Statement of Peter Baddiley, Annexure PB2-8(21) [p49].

388 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 30.

389 Exhibit 18, Supplementary Statement of Robert Ayre [p40-41].

390 Exhibit 18, Supplementary Statement of Robert Ayre [p41].

391 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p32-33]. (Situation Report 17, 11.56 pm 10 January 2011),

392 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix C [p177-178].

393 Transcript, 14 April 2011, Brisbane [p352: line 10]; Transcript, 15 April 2011, Brisbane [p408: line 1].

394 Exhibit 18, Supplementary Statement of Robert Ayre [p48-49].

395 Exhibit 18, Supplementary Statement of Robert Ayre [p49].

396 Transcript, 15 April 2011, Brisbane [p409: line 38].

397 Transcript, 15 April 2011, Brisbane [p410: line 15]; Transcript, 15 April 2011, Brisbane [p464: line 40].

398 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p36] (Situation Report 19, 12.11 pm 11 January 2011).

399 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p37] (Situation Report 20, 6.00 pm 11 January 2011).

400 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p37] (Situation Report 20, 6.00 pm 11 January 2011).

401 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p158-159].

402 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p26].

403 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 45.

404 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix E [p45-46] (Situation Report 25, 5.43 am 13 January 2011).

405 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 45.

406 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p29].

407 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p11-12].

408 While the flood engineers' evidence is that they modelled different gate opening scenarios using the gate operation spreadsheet, the Commission cannot determine whether any flood engineers modelled these particular scenarios because few records were kept.

409 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p12].

410 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011 [p17].

411 Exhibit 51, First Statement of John Tibaldi [p8: para 37]; Exhibit 45, First Statement of Terrence Malone [p11: para 54].

412 Exhibit 24, January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam, 2 March 2011, Appendix O [p144].

413 Seqwater, Operation of Wivenhoe Dam and Somerset Dam January 2011 Flood Event Explanation of Operational Methods and Decision-Making Practices, July 2011 [p12].

414 Mark Babister and Rhys Hardwick-Jones, Review and Comment on the Seqwater Report, 6 July 2011 [p11: para 27].

415 Transcript, 12 April 2011, Brisbane [p101: line 35].

416 Exhibit 18, Supplementary Statement of Robert Ayre, Annexure 1.

417 Exhibit 524, Full time-series sets and spreadsheets used to create the values and graphs contained in Appendix A to the January 2011 Flood Event Report on the Operation of Wivenhoe and Somerset Dams and the document named 'Appendix A1', Run 45.

418 For example, Submission of the Mid Brisbane River Irrigators, Submission of Merven Hoppner, Submission of Darren Zanow, Submission of Pine Mountain Botanics Pty Ltd, Supplementary Submission of Pine Mountain Botanics Pty Ltd and Submission of Jocelyn Bailey.

419 For example, Submission of Christopher McConnel; Submission of Douglas and Cheryl McDade; Submission of Mark and Jenny Moore; Submission of Barrie Dunning, 24 February 2011; Submission of Barrie Dunning, 10 March 2011; Submission of Barrie Dunning, 31 March 2011; Submission of Neil and Dennis O'Connor; Submission of Keith Moore; Submission of Robert Brown and Helen Wordsworth; Submission of Ray and Jane Miller.

420 Exhibit 14, Letter from Kenneth Schmidt to Minister Robertson, 23 December 2010; Submission of Jocelyn Bailey [p2], Transcript, 14 April 2011, Brisbane [p300: line 25], Submission of Neil O'Connor [p1], Submission of Helen Wordsworth and Robert Brown; Submission of Barrie Dunning, 31 March 2011; Submission of Barrie Dunning, 24 February 2011 [p1, 3]; Submission of Barrie Dunning, 10 March 2011 [p1] and Submission of Douglas and Cheryl McDade [p4].

421 Transcript, 14 April 2011, Brisbane [p300: line 25].

422 Exhibit 504, Statement of Russel Bernitt [p7: para 26].

423 Submission of Barrie Dunning [p3].

424 Exhibit 14, Letter from Kenneth Schmidt to Minister Robertson, 23 December 2010; Submission of Bruce and Cheryl McDade [p4].

425 Transcript, 11 April 2011, Brisbane [p72: line 19].

426 Submission of Seqwater, 11 March 2011 [p21: para 82]; Attachment 3.

427 Sections 159, 162, 165 and 166, Moreton Resource Operations Plan 2009.

428 Statement of Terry Wall, Annexure TWW-4.

429 Statement of Terry Wall [p7: para 24].

430 Statement of Terry Wall, Annexure TWW-4 [p3]; Transcript, 12 April 2011, Brisbane [p191: lines 25].

431 Section 374, *Water Supply (Safety and Reliability) Act 2008*; Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, August 2010.

432 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p19].

433 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p19]; Appendix C.

434 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p9].

435 Exhibit 314, North Pine Dam Emergency Action Plan, Revision 2, September 2010 [p5]. See also, section 346(2), *Water Supply (Safety and Reliability) Act 2008* (Qld).

436 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p9].

437 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p9].

438 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p10].

439 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p9].

440 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010 [p10].

441 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p10-15]; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p13-14].

442 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p8].

443 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p8]; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p11]; Exhibit 18,

Supplementary Statement of Robert Ayre, [p5: para 15(a)].

444 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p56-64]; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p6, 11].

445 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p22].

446 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p22].

447 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p6].

448 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p91].

449 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p91].

450 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p91].

451 Exhibit 18, Supplementary Statement of Robert Ayre [p4: para 14(a)].

452 Exhibit 18, Supplementary Statement of Robert Ayre [p5: para 16].

453 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p10].

454 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p10].

455 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p10]; Exhibit 17, First Statement of Robert Ayre [p90: para 390].

456 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010 [p20].

457 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010 [p20].

458 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010 [p20-21].

459 Exhibit 17, First Statement of Robert Ayre [p90: para 390-391].

460 Exhibit 17, First Statement of Robert Ayre [p90: para 390-391].

461 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010 [p20].

462 Exhibit 17, First Statement of Robert Ayre [p90: para 391].

463 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010, Appendix E.

464 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010, Appendix E.

465 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p124].

466 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p7].

467 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p131]; Exhibit 397, Statement of Peter Allen [p51: para 149(a)].

468 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010, Appendix E; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p85].

469 Exhibit 397, Statement of Peter Allen [p50: para 144]; Exhibit 426, Statement of Barton Maher, Annexure BM3(a) [p18].

470 Exhibit 17, First Statement of Robert Ayre [p79: para 368].

471 Exhibit 17, First Statement of Robert Ayre [p70: para 317].

472 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010 [p23].

473 Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010, Appendix D; Exhibit 17, First Statement of Robert Ayre, [p70: para 317].

474 Seqwater, North Pine Dam Acceptable Flood Study Investigations, 4 May 2011; Seqwater, North Pine Dam – AFC Assessment Project Status Report, 6 May 2011.

475 Seqwater, North Pine Dam Acceptable Flood Study Investigations, 4 May 2011.

476 Seqwater, North Pine Dam – AFC Assessment Project Status Report, 6 May 2011.

477 Exhibit 429, Statement of Brett Schultz [p4: para 26].

478 Exhibit 429, Statement of Brett Schultz [p4: para 26, 30].

479 Exhibit 429, Statement of Brett Schultz [p4: para 30, 31].

480 Exhibit 429, Statement of Brett Schultz [p5: para 32].

481 Transcript, 12 April 2011, Brisbane [p124: line 29]; Exhibit 429, Statement of Brett Schultz [p5: para 33].

482 Exhibit 29, Manual of Operational Procedures for Flood Mitigation at North Pine Dam, Revision 5, 2010 [p19].

483 Transcript, 12 April 2011, Brisbane [p123: line 28].

484 Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p131].

485 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, 2011 [p77].

486 Outflow required to close Youngs Crossing to traffic is $10m^3/s$: Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p128]; Exhibit 29, Manual of operational procedures for flood mitigation at North Pine Dam, Revision 5, 2010, Appendix B. The peak outflows from North Pine dam of each of the 18 flood events substantially exceeded $10m^3/s$: Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, May 2011 [p56-64]; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p6, 11].

487 Exhibit 18, Supplementary Statement of Robert Ayre [p5: para 16]; Exhibit 30, January 2011 Flood Event Report on the operation of North Pine Dam, 11 March 2011 [p10].

488 Exhibit 425, Statement of Emma Thomas [p9: para 40].

489 Exhibit 425, Statement of Emma Thomas [p9: para 40].

490 Exhibit 425, Statement of Emma Thomas [p9: para 41].

491 Exhibit 425, Statement of Emma Thomas [p9: para 45]; Annexure N.

492 Exhibit 310, Statement of Dr Peter Hackney, Attachment 1; Transcript, 9 May 2011, Brisbane [p1515: line 26].

493 Transcript, 9 May 2011, Brisbane [p1524: line 40].

494 Exhibit 43, Transcript of Interview by Commission staff with John Ruffini, 30 March 2011 [p17: line 12].

495 Seqwater, 2010/2011 Wet Season Flood Events Report on the Operation of North Pine Dam, 2011 [p76].

496 Exhibit 310, Statement of Dr Peter Hackney, Attachment 2.

497 Transcript, 9 May 2011, Brisbane [p1516: line 30].

498 Transcript, 18 May 2011, Brisbane [p2261: line 9].