2 Floodplain management

A floodplain is an area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by floodwater.[1] Most cities and towns in Queensland are located on floodplains.[2] There are ample benefits associated with making use of fertile floodplain lands, but they come with an obvious drawback: by definition, floodplain land is subject to flooding.

No recommendations made by this Commission, even if implemented by government, can control the forces of nature. At some time in the future, parts of Queensland will experience floods of a magnitude as great as, or greater than, those of the 2010/2011 wet season. Existing science cannot predict when they will happen, or how severe they will be.

Contemporary society does not countenance a fatalistic approach to such inevitabilities, even if their occurrence is unpredictable. There is an expectation that government will act to protect its citizens from disaster, and that all available science should be applied so that the nature and extent of the risk is known and appropriate action taken to ameliorate it.

With that in mind, government agencies need to engage in a process of floodplain management involving a combination of land planning and building controls, emergency management procedures, and structural mitigation measures such as levees and dams. This chapter addresses the preparatory steps government should take to enable the best possible decisions to be made about floodplain management measures. The implementation of particular floodplain management measures is considered in more detail elsewhere in this report and the Commission's interim report.[3]

The most useful scientific exercise currently available to underpin government's response to flood risk is a flood study. A flood study is the scientific investigation of flooding in a particular area, usually the catchment of a river system. It may involve hydrologic and hydraulic investigations, and a statistical analysis of the frequency with which floods have occurred.

Any such process will be only as effective as the science that enables it, and the reliability of results will necessarily depend upon the quality of data. There is no single way of performing a flood study. It can be a simple exercise, or one that is as complex and detailed as resources will allow. The Commission did not attempt to codify the science and practice of flood studies. Rather, it convened a panel of experts and was informed by their consensus as to the status of some existing flood studies, the procedures that would ideally be involved in future studies, and the need to reform the way in which essential data is managed.

The experts' consensus is a good blueprint, but it must be accepted that it is, for the most part, only governments who can afford to undertake major flood studies. As much as any government process, the management of a flood study will be subject to a range of influences. In this context, it was instructive for the Commission to examine the history of flood studies in Brisbane and Ipswich over the last 30 years. That examination reinforced the proposition that a flood study is a scientific exercise, and if the utility of its results is to be maintained

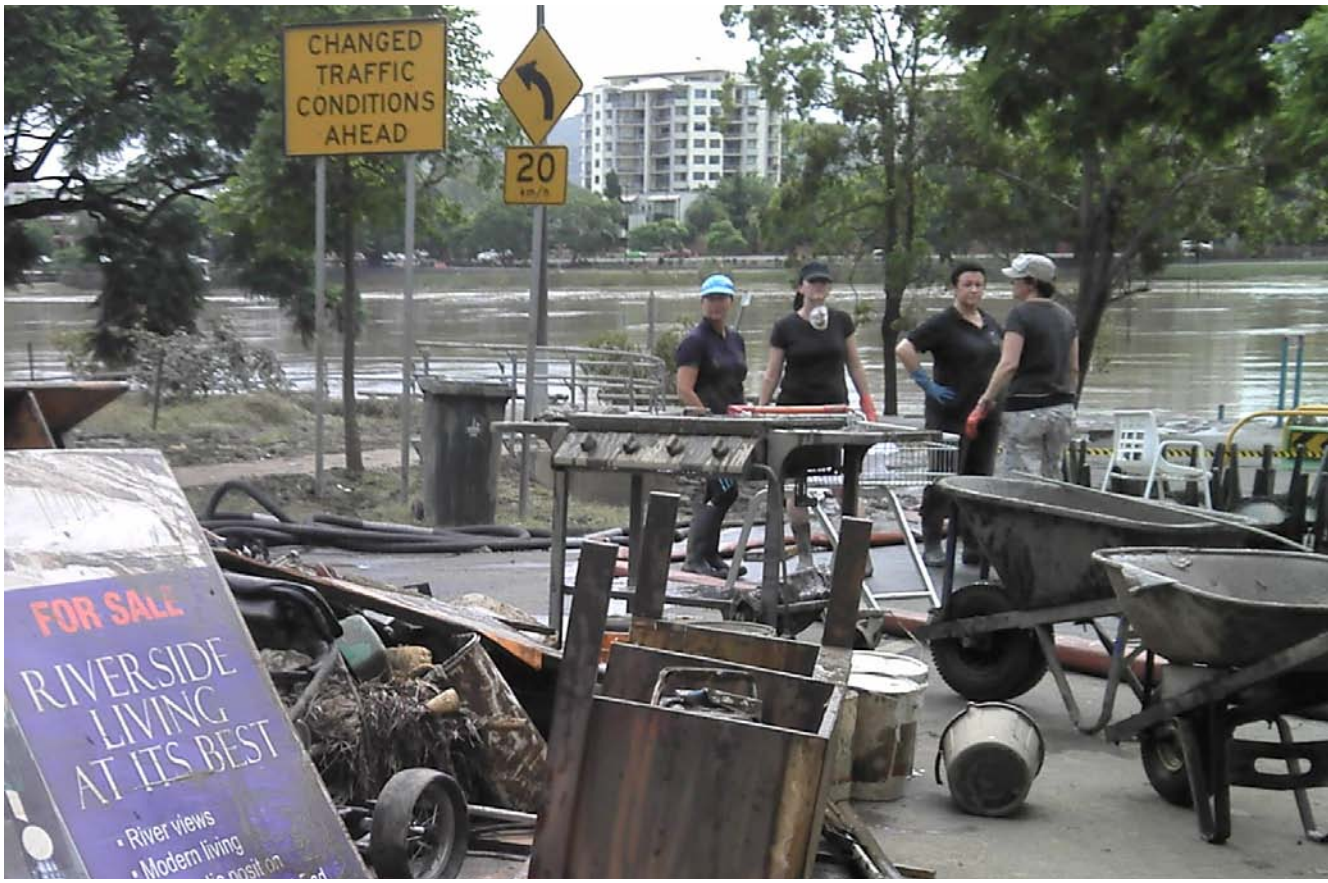
there is an ever present need for governments to stay abreast of scientific developments, and the possibilities they create for the refinement and expansion of existing knowledge.

Once completed, a flood study will be useful only if it can be understood by an audience that extends well beyond the scientific community. To that end, the results can be visually represented in the form of a flood map. A map that reflects the results of a comprehensive flood study is the most valuable form of flood map, and can usefully inform important public and commercial decisions. It can demonstrate not just the potential extent of a flood, but also the risk of its occurrence and the manner in which it might behave. There are, however, other types of flood maps that can also be useful to governments and individuals, depending on the information required and the resources available to provide it. The Commission has endorsed a hierarchy of flood maps that might be used by governments in Queensland, according to their circumstances: see *2.7.3 Assessment of mapping options*.

At most, however, a flood map is a theoretical two-dimensional representation of what is likely to be a complex and dynamic situation involving countless variables. It cannot be assumed that human judgment about such matters will always be assisted by scientific understanding, or governed by common sense and logic.

For example, the Q100 figure, as represented on a flood map depicting it, is intended to convey the proposition that, in any given year, there is a 1 per cent chance that the area depicted will be inundated – to some extent – by floodwater. As the Commission discovered, many members of the public did not understand the term 'Q100' in that way. The very notion that a map depicting a Q100 line was an effective means of communicating the results of a flood study was challenged.[4]

This example is just one illustration of why a government's responsibility does not end with the procurement of a flood map. The complications involved in preparing for and responding to flood are such that it is desirable for governments to implement comprehensive floodplain management plans in accordance with principles which have already been developed for that purpose. By so doing, they might begin to meet the expectation that government protect its constituents from floods which are yet to be experienced, but which will inevitably occur.



Flood damaged property, West End (photo courtesy Paul Rees)

2.1 Principles of floodplain management

Historically, governments have managed the risks associated with occupying the floodplain in a number of ways, from ad hoc decision-making based on past experience through to comprehensive planning and emergency response strategies. Approaches of the former kind are obviously unsatisfactory. Not only do they fail to ensure that a range of potential flood events is considered, they do not address other factors involved in mitigating the impact of flooding and responding to it.

In an attempt to develop a nationally consistent approach to floodplain management, the Standing Committee on Agriculture and Resource Management[5] sought to develop a series of best practice guidelines. These guidelines are set out in its report number 73, Floodplain Management in Australia: best practice principles and guidelines (2000).[6] The National Flood Risk Advisory Group is currently developing a new floodplain management manual that will supersede Floodplain Management in Australia. The Commission has been advised that a draft of the new manual is likely to be finalised by mid-2012. In the meantime, Floodplain Management in Australia is widely considered to set out the best practice principles for floodplain management.[7]

According to Floodplain Management in Australia, best practice requires the identification and implementation of an appropriate mix of four different kinds of floodplain management measures:

- land use planning controls (for example, zoning requirements to ensure compatibility between land use and flood risk)
- building controls (for example, minimum flood levels and flood-proofing)
- structural measures (for example, flood mitigation works such as the construction of levees)
- flood emergency measures (for example, flood warning, evacuation and recovery plans).

Determining precisely which measures are appropriate and how best to distribute resources among them can be a complicated process. With this in mind, Floodplain Management in Australia outlines a series of steps it considers should be undertaken. This process begins in earnest with the conduct of a flood study.[8]

Once a flood study has been completed, the relevant government agency (typically a council) will be in a position to conduct enquiries into the appropriate mix of flood mitigation measures. Where possible, this should be done by way of a formal floodplain management study and guided by appropriate flood mapping. The conclusions drawn from those enquiries can then be implemented in accordance with a floodplain management plan, the development of which is considered in more detail in section *2.6.1 Preparing a floodplain management plan.*

2.2 Flood studies

A flood study allows the likelihood of flooding at particular locations as well as the characteristics of each flood, such as extent of inundation, flow, depth and velocity, to be determined. Flood studies form the foundation upon which floodplain management measures are built; it is not possible to adequately manage the risk of flooding if that risk is not properly understood. There is no single way of doing flood studies: they may be comprehensive or relatively simple.

Flood studies typically have two main components:

- a hydrologic study aimed at determining rainfall and associated stream flows in a range of scenarios
- a hydraulic analysis that estimates the behaviour of flood flow (that is, flow rate, velocity, depth and extent of inundation) as it passes through the floodplain.

Some matters of terminology should be dealt with at the outset. The likelihood of flooding occurring at a particular point is often described in terms of annual exceedance probability (likelihood that a particular flood flow or height will be exceeded in any one year) or average recurrence interval (average period in years between floods of a particular size or greater).[9] A flood with an annual exceedance probability of 1 per cent has an average recurrence interval of 100.[10] The flood line which represents the extent of such a flood is commonly known as the Q100. In this report, the Commission will use the term 'flood with an annual exceedance probability of one per cent' or its shortened form, '1% AEP flood', except where another term may be needed to maintain consistency with the evidence.

The term 'flood hazard' is sometimes used to refer to the behaviour or characteristics of floodwaters (that is, velocity, depth, rate of rise, and length of inundation). However, flood hazard is defined in Floodplain Management in

Australia as 'potential loss of life, injury and economic loss caused by future flood events'.[11] The level of flood hazard in that sense will vary with a number of factors:

- flood behaviour (depth, velocity, rate of rise, duration)
- topography (for example, whether there are evacuation routes, or whether land is surrounded by floodwater)
- the nature of the population at risk and the types of land use in the flooded area
- emergency management issues (such as the adequacy of flood forecasting, flood warning and evacuation plans).[12]

A flood study is a scientific investigation; it involves no matters of policy. It can determine the characteristics of floods with different likelihood of occurring, but cannot determine 'hazard'; the latter involves qualitative considerations such as the nature of land use and the efficacy of evacuation plans. Models created during a flood study can be used to create flood maps – see section *2.7 Flood mapping for land planning controls* below.

2.3 A flood study of the Brisbane River catchment

2.3.1 The expert panel

The Commission heard evidence from a panel of experts about flood studies for the Brisbane and Bremer rivers. Those rivers were of particular interest to the Commission because of the large urban centres – Brisbane and Ipswich – that flooded in January 2011. The Brisbane River panel included eight experts, who were either hydrologists or hydraulic engineers: three engaged by the Commission (Dr Rory Nathan, Mr Mark Babister and Dr Michael Leonard), three engaged by Brisbane City Council (Professor Colin Apelt, Mr Erwin Weinmann and Mr Drew Bewsher) and one engaged by each of Ipswich City Council (Mr Neil Collins) and the Insurance Council of Australia (Mr Sharmil Markar). The Bremer River panel comprised the experts engaged by the Commission, Ipswich City Council and the Insurance Council of Australia.

Expert panel of hydrologists and engineers, Inquiry hearings, 26 October 2011 (photo courtesy The Courier-Mail)

The Commission initially engaged Mr Babister to prepare reports giving his best estimate of the Q100 at certain points along the Brisbane and Bremer rivers.[13] The other experts on the panels responded to Mr Babister's report with reports of their own.[14] Before giving evidence in public hearings of the Commission, the experts participated in a conference with an independent facilitator, Mr Peter Davis SC, and produced a joint expert statement. In that statement, all experts, including Mr Babister, agreed that his estimate was not an appropriate flood level figure corresponding to the Q100 because he had not been able to complete a comprehensive flood study.[15] (Given the short timeframes under which the Commission has worked, Mr Babister was given only four weeks to produce a report;[16] it represented his best efforts in the time available to him to calculate Q100 without the benefit of a comprehensive flood study.[17]) The reports prepared by each expert were critiques of Mr Babister's methodology and results. The joint expert statement diverged significantly from that topic. It focussed on the sort of comprehensive flood study which would be necessary to obtain a sound estimate of the level that would be reached by floods of different probabilities, such as the Q100.[18] The joint expert statement[19] sets out a blueprint for a best practice flood study for the Brisbane River catchment.

2.3.2 A comprehensive study of the Brisbane River catchment

The joint statement of the expert panel recommended that a flood study analyse flood behaviour throughout the entire Brisbane River catchment.[20] That analysis would lead to a determination of the likelihood and characteristics of flood in Brisbane and Ipswich.[21] They suggested that such a study should be conducted over a range of possible floods from the flood with a 50 per cent annual exceedance probability through to the probable maximum flood.[22]

The experts considered that it would not be appropriate for them to prescribe the methodology for conducting the flood study, but did recommend that the study should be comprehensive in use of data sources and range of methodologies.[23] Corroboration of results could be obtained by comparing estimates of flow, height, velocity or depth using different methodologies.[24]

The proposed data, hydrologic investigations and hydraulic investigations to be used in the study are set out in the joint expert statement. The joint statement gives no opinion on the exact order in which different pieces of work should be done, but during public hearings the experts supported an iterative approach to the flood study.[25] That would involve an initial data collection and hydrologic modelling to arrive at estimates of floods of different likelihoods. These estimates would not be final figures, but would be used to determine which factors introduced the most uncertainty. The work would then focus on reducing the uncertainty created by those factors, for example by refining data sets or creating modelled data, thus producing the best returns from the least effort.[26] The process of data collection, hydrologic and hydraulic modelling set out below is likely to need to be undertaken more than once.

Dr Nathan gave a rough estimate of the time required to complete the entire study as three years.[27] That period incorporates time spent developing the framework for the completion of the study with all agencies that are to be involved, including councils and dam operators.[28] He estimated the cost of the study in professional fees as in the 'low numbers of millions'.[29] He estimated that the first iteration, being the characterisation of the flood risk, would take between 12 and 18 months.[30]

1. Collection of data

Significant work is required on data.[31] The experts recommended the collation of existing data along with any review or analysis of it, and the collection of further data on historical events. In addition, the study should involve a fresh analysis and review of data relied upon in previous studies.[32] The creation of a central repository of flood study data may assist in this task: see section *2.5.5 Central repository of flood study data.*

The experts concluded that the following data must be used in the flood study:[33]

- rainfall data including:
  - historical rainfall data (including sub-daily and daily-point rainfall)
  - radar data sets
  - rainfall data, often described as design, synthetic or probabilistic, obtained through the use of rainfall models. Such data sets are often available from the Bureau of Meteorology and include information about average depth over catchment, temporal and spatial patterns
- stream flow, including historical peak, continuous and anecdotal stream flow data, observed flow data from physical gauging[34] and rating curves[35] used at different times in history
- tide levels, including historical and modelled tide levels, astronomical tides and tidal anomalies
- inundation levels and extents during historical floods
- data about how Wivenhoe Dam and Somerset Dam are operated now and have been operated in the past, including discharges and levels in historical and modelled events[36]
- modelled, continuous inflow and outflow data for Somerset and Wivenhoe dams to allow an investigation of the probability of the dam being at certain levels at the start of a flood[37]
- historical land use conditions
- river channel and floodplain characteristics for hydraulic modelling to be performed in current and historical conditions, including:
  - topographic data obtained through LIDAR (light detection and ranging, technology that is used to measure geospatial information) and bathymetry (mapping of river beds)

- structures and other development affecting flood flows
- vegetation on the floodplain
- survey data
- characteristics of the movement of sediment in the Brisbane and Bremer rivers and major tributaries.

Given the iterative nature of the flood study, it would not be necessary for the collection, collation and review of data to be comprehensive before any further investigations were undertaken. The extent to which this initial data collection and collation should be completed before commencement of the study is a matter for the judgment of those carrying out the study.

2. Preparation of hydrologic models

Hydrologic models convert rain falling over land into flow in a stream.[38] Different models are needed for different catchments. For the Brisbane River catchment, hydrologic models relating at least to Somerset and Wivenhoe dams, the Lockyer Creek, the Bremer River and the Brisbane River downstream of Wivenhoe Dam will be required.

The expert panel recommended that the hydrologic models be run in what is known as a Monte Carlo framework.[39]

3. Running hydrologic models in Monte Carlo framework

The benefit of the Monte Carlo framework is that it allows the natural variability of factors which affect flood to be taken into account.[40] It is obvious that there is no single set of conditions that will cause a flood. It is the combined effect of when, where and the extent to which rain falls, dam levels and saturation of the catchment which causes a flood, and there may be many different values ascribed to each one of those features.

In the past, some hydrologists have estimated the Q100 flood (or a flood of any exceedance probability) by assuming that a rainfall event of the same probability will cause such a flood and then modelling the effect of one such rainfall event. For example, a rainfall event with an annual exceedance probability of one per cent might be simulated to determine the peak flow which would occur at different points in a river in a 1% AEP flood. Fixed values have been assigned to all other relevant factors: one saturation factor, one lake level, one spatial and temporal distribution of the rainfall, and so on. Some studies have analysed more than one rainfall event: for example studies done for the Brisbane City Council in 2003 addressed seven rainfall events.[41]

The Monte Carlo framework allows the modelling to be done using thousands of different values[42] for each of the factors that produce floods. Looking at all the different values of the different factors, the model can approximate something like the thousands of possible outcomes. The hydrology expert panel recommended the following factors be varied in different model runs:

- temporal (the period in which rain falls) and spatial (the area over which it falls) patterns of rainfall
- saturation of the catchment
- initial water level in dams
- variability of operating procedures of dams
- physical limitations on operation of the dams
- tidal conditions
- previous and following rainfall events.[43]

Some of the factors will not be independent of each other, but will be related in some way. For example, the degree of saturation in the catchment of the Brisbane River above Wivenhoe and the initial water level in the dams are both dependent on the amount of rain that has fallen in the catchment in the previous weeks, months and years. Common sense dictates that when a large amount of rain has fallen, it is more likely that the dams will be full and the catchment will be saturated. The relationships between factors must be reflected by ascribing mutually consistent values to them. This correlation between data sets must be determined before the Monte Carlo analysis can be performed.[44]

The results of all of those model runs are considered together so that a probability distribution of the peak flow or volume of floods that could occur from a rainfall event of a particular probability can be developed.[45] A probability distribution is a representation of the likelihood of different outcomes occurring. For example, it may be that the modelling shows that 4 per cent of the time, a 1% AEP rainfall event will cause a flood with peak flow greater than

7000 m^3/s, or that 15 per cent of the time, a 1% AEP rainfall event will cause a flood with peak flow greater than 9000 m^3/s. The probability distribution will show how likely it is that certain values of flow will be met or exceeded during a rainfall event of a particular probability.

4. Validation of hydrologic models

The expert panel recommended that the hydrologic models be validated by comparing the results they produce against observed data from historical floods. Models developed in a Monte Carlo framework, taking into account natural variability, should reproduce observed flood behaviour and natural variability of outcomes.[46] In particular, at key locations, the models should be able to reproduce:

- hydrograph attenuation (that is, the extent to which a flood is attenuated as it travels downstream by water's entering floodplains and natural detention basins or absorbing into soil)
- probability distribution of the total flood volume produced by rainfall
- probability distribution of the peak flow produced by rainfall
- probability distribution of timing of flows from major tributaries
- natural flood behaviour observed in no dam conditions and current conditions.[47]

Dr Nathan gave evidence that this reproduction of natural variability might be more important for some factors at different places in the catchment. His evidence was that the reproduction of volume and peak flow was important above Wivenhoe and Somerset dams, whereas the reproduction of peak flow was the most important aspect of validation below the dams.[48]

The expert panel also recommended validating the hydrologic models by comparing peak flows and flood volumes obtained through modelling with values obtained through mathematical analysis of the historical flood record.[49] That latter technique, called flood frequency analysis, produces estimations of the probabilities of different flood heights purely from the historical record. Ideally, such an analysis would occur using data over as long a period as possible; in practice, a flood record of 150 years at the Brisbane Port Office gauge is considered a fairly substantial period of record.[50] Flood frequency analysis uses probability theory to obtain a flood frequency curve for a particular point on a river. The flood frequency curve can be used to determine a value (usually peak flow or height of the flood) for floods of different probabilities (say 10 per cent and 5 per cent, through to a small probability, for example 0.0001 per cent). The results can be compared to the results obtained from the Monte Carlo analysis.

The expert panel recommended that consideration should be given to pooling regional information in the flood frequency analysis.[51] That technique allows observed data from comparable areas to be used as though it occurred in one place, thereby increasing the amount of data available to analyse.[52] This method was used by a firm of consulting engineers and hydrologists, Sinclair Knight Merz, in 2003 to compare and combine data from different gauges in the Brisbane River,[53] but could also be employed to incorporate the use of data from rivers on the Sunshine and Gold coasts.

If the models are not validated, those performing the flood study will need to collect more data and refine the hydrologic models until they are defensible.

5. Hydraulic modelling

A hydraulic model converts flow in a stream into flood heights, thus allowing assessment of the extent of inundation.[54] The expert panel recommended the use of a hydraulic model to determine flood levels, flows and extents over the full floodplain surrounding the Brisbane River and its major tributaries downstream of Wivenhoe Dam.[55]

The hydraulic model will also identify areas influenced by backwater at the confluence of two streams.[56] Backwater effects occur during flood when an excess of water in the larger waterway prevents water from flowing out of a tributary, and the tributary 'backs up', making flood levels upstream of the confluence higher. This is particularly important at the confluence of the Bremer and Brisbane rivers, where significant backwater effects have been observed.[57] The experts emphasised the need to model that backwater carefully and precisely.[58]

The experts considered that there should be one hydraulic model for the whole of the lower Brisbane River area.[59] They recommended use of a standard 'linked one-dimensional two-dimensional model'.[60] That type of model has some parts which are one-dimensional and assume velocity is constant at different points on the cross section of a

river. Other parts are two-dimensional and allow for changes in velocity at different depths and positions from the banks.[61] In this way, the model reflects the fact that some parts of a river system are two-dimensional and others, such as some weirs, are one-dimensional.[62]

It may be necessary to develop a separate, more detailed model of the interaction at the Bremer-Brisbane confluence.[63]

When creating any model, there is a balance to be struck between its complexity and its practicality. One important indicator of its practicality is the length of time it takes to run.[64] The experts recommended that attention be given to that balance, and considered that the model should:

- be able to assess historical changes to the river bathymetry
- run quickly enough to allow detailed calibration work and assessment of changes (the expectation being that hundreds of simulations will be required for this purpose).[65]

The hydrologists and engineers undertaking the study should also consider the ability of the model to deal with the movement of sediment and changes in river bed cross sections during flood events as a means of evaluating the effect of changing river conditions on flood levels.[66]

The results of the hydraulic modelling can be represented as a probability distribution for flood height, depth or velocity at different points along the Brisbane River for a range of floods of varying likelihood (for example Q100, 0.5 per cent, 0.001 per cent).

The iterative nature of the entire flood study means there will be some interplay between the hydrologic and hydraulic modelling. In particular, the experts considered that the rating curves[67] derived for the hydraulic modelling at different places down the river should be considered in the hydrologic modelling.[68]

6. Joint probability considerations

The expert panel identified two areas in which a joint probability analysis was required: the relationships between floods occurring in the Bremer and Brisbane rivers, and between flooding in the lower Brisbane River and elevated ocean levels.

A joint probability problem arises for the Bremer-Brisbane relationship because Ipswich can be affected by flooding in the Bremer River, flooding in the Brisbane River or both.[69] The same rainfall event may cause flooding in both rivers, which means the likelihoods of flooding in each river are linked. A joint probability analysis will determine the likely flooding in one river given the flooding that is occurring in the other. That can be represented in the form of a relationship (for example, a curve, such as a rating curve linking flows in the Brisbane with flows in the Bremer) or in terms of probabilities (for example, that for a given flow in the Brisbane, there is a 90 per cent chance that a flow above a certain level will be occurring in the Bremer).

No methodology for investigating the joint probability question was prescribed by the hydrology expert panel.[70] Those completing the study should seek expert advice as to which approach should be used.

Elevated ocean levels can affect flood heights in Brisbane because it is so close to the mouth of the river.[71] One meteorological condition, such as a cyclone, may cause both flooding in the river and elevated ocean levels.[72] The flood study must, the experts said, consider the interaction between ocean levels and flooding in the Brisbane River catchment, which will affect both the hydrologic and hydraulic modelling.[73]

7. Climate change

The experts agreed that the impacts of climate change should be assessed during the study.[74]

Climate change, and the uncertainties surrounding it, can be taken into account in a Monte Carlo analysis,[75] although it has been observed that the uncertainties surrounding climate change are much greater than other uncertainties in flood studies. Dr Leonard's opinion was that a Monte Carlo analysis should be completed first without taking into account climate change; later, steps could be taken to incorporate climate change into the analysis.[76] Guidance may also be found in the joint Queensland Government-Local Government Association of Queensland Inland Flood Study, completed in 2010, which considered the impacts of climate change.[77]

2.3.3 Responsibility for completing the study

The Commission recommends that the Queensland Government and councils should work together to ensure flood studies are done for all urban areas that do not have current flood information: see recommendations made in section *2.5.3 Ensuring all urban areas have flood studies*, below. Those recommendations apply to the Brisbane River catchment as to all catchments in Queensland. A particular consideration of the state of the study in Brisbane is required, because a study which might involve a significant portion of the work now recommended has already been initiated by the Queensland Government, through Seqwater. That study is called the Wivenhoe Dam and Somerset Dam Optimisation Study.[78] The study's primary aim is to inform the review of the flood mitigation manual applicable at Wivenhoe and Somerset dams. The Commission's view is that the flood study of the catchment might be more efficiently performed outside the confines of the study commenced. That position is further explained in section *17.1.1 The structure for the completion of the scientific investigations.*

That said, it is a matter for the parties involved to determine the structure within which both studies are completed. The Commission considers that the steering committee of the Optimisation Study should determine whether it is more effective for the Brisbane River flood study to be completed inside or outside of it.

Whatever is decided, the Commission considers it the responsibility of the councils, Brisbane City Council, Ipswich City Council and Somerset Regional Council, and the Queensland Government, in accordance with section 2.5, below, to ensure that a flood study with the characteristics recommended is completed. Those agencies should assess the work done (if any) within the Optimisation Study to determine whether further work is necessary for the flood study. If further work is required, that work should be completed on a catchment wide basis in a way determined by those agencies in accordance with the scheme set up for the completion of flood studies under section *2.5.3 Ensuring all urban areas have flood studies.*

Recommendations

2.1 The steering committee of the Wivenhoe Dam and Somerset Dam Optimisation Study should consider whether it would be more effective for the floodplain management investigation to be removed from the Wivenhoe Dam and Somerset Dam Optimisation Study.

2.2 Brisbane City Council, Ipswich City Council and Somerset Regional Council and the Queensland Government should ensure that, as soon as practicable, a flood study of the Brisbane River catchment is completed in accordance with the process determined by them under recommendation 2.5 and 2.6. The study should:

- be comprehensive in terms of the methodologies applied and use different methodologies to corroborate results
- involve the collation, and creation where appropriate, of the following data:
  - rainfall data including historical and design data and radar
  - stream flow data
  - tide levels
  - inundation levels and extents
  - data on the operation of Wivenhoe and Somerset dams
  - river channel and floodplain characteristics including topography, bathymetry, development and survey data
- involve determining the correlation between any of the data sets above
- produce suitable hydrologic models run in a Monte Carlo framework, taking account of variability over the following factors:
  - spatial and temporal rainfall patterns
  - saturation of the catchment
  - initial water level in dams
  - effect of operating procedures
  - physical limitations on the operation of the dams

  - tidal conditions
  - closely occurring rainfall events
- validate hydrologic models to ensure they reproduce:
  - observed hydrograph attenuation
  - probability distributions of observed values for total flood volume and peak flow
  - timing of major tributary flows
  - observed flood behaviour under no dams conditions and current conditions
- produce a suitable hydraulic model or models that:
  - are able to determine flood heights, extents of inundation, velocities, rate of rise and duration of inundation for floods of different probabilities
  - are able to deal with movement of sediment and changes in river beds during floods
  - are able to assess historical changes to river bathymetry
  - are able to be run in a short time to allow detailed calibration and assessment work
  - characterise the backwater effect at the confluence of the Brisbane and Bremer rivers and other confluences as appropriate
- involve analysis of the joint probability of floods occurring in the Brisbane and Bremer rivers (and any other pair of rivers if considered appropriate)
- be iterative, and obtain a short-term estimate of the characteristics of floods of different probabilities in all significant locations in the catchment (at least Brisbane City, Ipswich City and at Wivenhoe Dam) in order to determine the priorities for the rest of the study.

2.3.4 Further investigations required for Ipswich

Once it has received the results of the study to be completed for the entire Brisbane catchment, Ipswich City Council may require more refined data and mapping to assist it in its floodplain management. The further work to be done on the Bremer River would naturally follow the Brisbane River study. However, because of the iterative nature of the Brisbane work, it may be possible to start work on the Bremer River study before the finalisation of the Brisbane River study.[79]

Ipswich City Council may require more work to be done in the way of detailed data collection, hydrologic and hydraulic modelling for the Bremer River and its tributaries than is undertaken in the Brisbane River flood study. The expert panel recommended the following specific steps for Bremer River hydrologic and hydraulic modelling:

- use of Brisbane River historical flood data as well as data from floods in the Bremer River[80]
- validation of the hydrologic model against the probability distribution of flood levels obtained from the historical record at Ipswich.[81] This will be a check on whether the joint probability problem described above has been solved.[82]

Dr Nathan indicated that the extra work required for the Bremer River would take a matter of months, not years.[83] Dr Leonard gave an estimate of nine to 12 months.[84] The cost of the Bremer River work would be significantly less than the Brisbane work.[85]

Recommendation

2.3 Ipswich City Council should determine whether the results, models and maps produced by the Brisbane River flood study are sufficient for its floodplain management. If they are not, Ipswich City Council should ensure appropriate work is done by way of data collection and creation and hydrologic and hydraulic modelling for use in its floodplain management.

2.3.5 Effect of the need for a comprehensive flood study on current planning

The expert panel found that it could not determine whether the most recent Q100 estimates obtained by both Brisbane and Ipswich city councils were appropriate flood level figures,[86] because neither was based on a comprehensive flood study.[87]

Neither Brisbane nor Ipswich City Council is presently using its most recent estimate of Q100 in its planning scheme or temporary local planning instrument. Brisbane City Council uses a 'defined flood level' in its planning scheme of 3.7 metres at the Port Office gauge, 40 centimetres higher than the most recent estimate of the Q100, which was set in 2003 at 3.3 metres.[88] Ipswich City Council's most recent estimate of Q100 is 15.28 metres at the David Trumpy Bridge gauge, obtained in a 2006 flood study. That study was completed after the finalisation of the current Ipswich planning scheme, which sets the flood height corresponding to Q100 at 16.8 metres. That figure was arrived at by an earlier flood study.

That does not render the correctness or otherwise of the councils' most recent estimates of Q100 irrelevant. While Brisbane has moved away from the use of the term Q100, or tying its floor level used for planning controls directly to an estimate of the Q100, it remains a measure by which the conservatism of the defined flood level is judged. If a flood study were to return results with a Q100 higher than Brisbane City Council's defined flood level, the council is likely, prudently, to reconsider its adherence to that line. Equally, new estimates of the Ipswich Q100 might affect planning controls in the Ipswich planning scheme.

The flood levels currently used by both councils should not be discarded because of the hydrology expert panel's finding. Rather, they should remain in place, in the absence of some exceptional reason, while the comprehensive flood study is performed and appropriate flood levels and extents are determined. Brisbane City Council has implemented temporary planning controls that reference the greater of its defined flood level or the 2011 flood line. Ipswich City Council's temporary local planning instrument provides for temporary planning controls that reference equal to the greatest of the defined flood level from its 2006 scheme, and the 1974 and 2011 historical flood lines. That approach is prudent and should be continued until a comprehensive flood study is completed.[89] The use of freeboard[90] in the Brisbane and Ipswich planning schemes over many years has also been a sensible measure in the face of uncertainty surrounding Q100 levels.

2.4 Brisbane and Ipswich council procedures

The previous section dealt with what is now required by way of a flood study for the Brisbane River catchment. This section deals with the means by which two of the councils within that catchment, Brisbane City Council and Ipswich City Council, have approached the task of obtaining and using a flood study in the past.

2.4.1 The Brisbane Q100

From 1976 to March 2011, Brisbane City Council had, as the basis for planning controls related to flood, the same flood level: 3.7 metres at the Port Office gauge.[91] In that time, the council received from expert engineers more than one estimate of the Q100. Estimates ranged between 3.16 metres[92] and 5.34 metres[93] at the city gauge.

The 3.7 metre level was adopted by the council in 1976 on the basis that it represented the peak height that would have been reached by the 1974 flood had it been mitigated by Wivenhoe Dam.[94] The council's submission states that it modelled and reviewed flood levels between 1996 and 2003;[95] that in 2003 an independent expert review panel found the best estimate of Q100 was 3.3 metres at the city gauge; and that the council subsequently decided to maintain the defined flood level used for Brisbane's planning scheme at 3.7 metres.[96] As an explanation of the process by which estimates of the Q100 flood height were obtained, this submission is, while accurate, simplified. It is easier to distil relevant lessons from the expanded account which follows.

The Sinclair Knight Merz study

The council commissioned Sinclair Knight Merz, consultant engineers, to perform a comprehensive flood study in 1996.[97] The final report was delivered to the council in June 1998.[98] It gave a best estimate for Q100 at 5.34 metres at the city gauge,[99] which was 1.64 metres above the level referred to in the council's planning controls (at 3.7 metres).

Internal review

The manager of Water Resources,[100] the division of the council responsible for flood management policy, received the report. He had a number of concerns related to its methodology,[101] and, after some discussion with council officers from Water Resources and City Design (a division of the council which provides technical services to policy divisions) decided to engage an expert in hydrology from Melbourne to review it.[102] The terms of reference for the review were settled by the manager of Water Resources.[103]

His concerns were confirmed by the expert's report, received in December 1998. The expert took issue with Sinclair Knight Merz's methodology as to the assumption that Wivenhoe and Somerset dams would be at full supply level at the start of a flood, the use of aereal reduction factors and the assumption that no water would be lost to the ground or evaporation.[104] Further, he was concerned by the difference in results between the flood estimated by the design rainfall technique and a flood frequency analysis.[105] As a result of those concerns, the expert concluded that Sinclair Knight Merz's estimate of the Q100 was probably an overestimate.[106] His report otherwise confirmed Sinclair Knight Merz's approach and methodology as appropriate.[107] The expert made recommendations about the work to be done in order to deal with the issues he identified.[108]

The manager of Water Resources decided to act on those recommendations,[109] and enlisted City Design to do the necessary work.[110] City Design worked toward satisfying the expert's recommendations and produced a report in June 1999 which gave a best estimate of Q100 as 5.0 metres at the Port Office gauge.[111] The manager of Water Resources, deciding that the report did not adequately address the expert's concerns,[112] commissioned City Design to perform more work.[113] The unit produced a second report in December 1999 which gave a best estimate of Q100 as 4.7 metres at the Port Office gauge,[114] one metre above the planning control level used by the council. The manager was still not satisfied with the methodology used and considered the December report still did not meet the expert's recommendations.[115] No decisions were taken in respect of the Q100 or related planning controls in response to the June or December report: Water Resources considered further work was required.[116]

Waiting for data

Officers of Water Resources then decided that the council should approach the study in concert with other agencies.[117] They opened channels of communication with the Department of Natural Resources and Mines, the Bureau of Meteorology and the South East Queensland Water Corporation.[118] A technical workshop was held involving these agencies in October 2000. The purpose of the workshop was to determine the best practice methodology that should be adopted for the finalisation of the Brisbane River flood study.[119]

At the workshop, a hydrologist from the department drew the attention of the council officers present to a set of studies then being conducted, in which the department was a participant. They were designed to underpin the application of new procedures in the recent revision of Australian Rainfall and Runoff to regions of Queensland. One of those regions was the Wivenhoe Dam catchment. The studies included modelling of likely releases from the dam if affected by the new design rainfalls.[120] The hydrologist from the department advised the council officers that he expected the results of the study would include an estimate of the flow of the Q100 flood that was closer to the council's current estimate (from pre-1998 studies) than earlier departmental studies.[121] It was anticipated that the work would be finalised by December 2000.[122] The manager of Water Resources decided to put the council's flood study on hold and wait for the department's data to be provided.[123]

The department's data was not provided in December 2000. In fact it was not provided for nearly three years, finally being made available to the council in June 2003.[124] The data was the product of a range of studies conducted by a large number of partners, which took much longer than expected to be concluded. For current purposes it cannot be said that any detriment was suffered because of the period of time taken for the data to become available, but the delay illustrates how flood studies can be frustrated by circumstances outside of the control of the council.[125]

Resolution

The Courier-Mail ran a number of articles in June 2003 about the manner in which the council had dealt with flood study information.[126] The June 1999 City Design report had been released to *The Courier-Mail* without the council's approval and was the object of public scrutiny.[127]

In July 2003, the council decided to continue the flood study with the new data received from the Department of Natural Resources and Mines.[128] There was urgency in the council's approach – it wanted the issue resolved

quickly.[129] This was due partly to media attention and public interest[130] and partly to the length of time that had passed since the study started in 1996.[131] The Lord Mayor decided that the results obtained needed to stand up to examination; an independent review panel was viewed as the way to achieve this outcome.[132] The manager of Water Resources commissioned the independent review panel, which was chaired by the same expert who peer reviewed the 1998 report. The manager of Water Resources also commissioned Sinclair Knight Merz to do the modelling work for the independent review panel to review.[133]

The independent review panel's terms of reference included the sentence '[e]ven if the Q100 changes from 6,800 m^3/s, it is likely that the Development Control Level will remain the same as is currently used in the Brisbane City Plan'.[134] A senior engineer in the Water Resources Branch who wrote the terms of reference said he intended to indicate that if the independent review panel found that the Q100 was lower than previously thought, planning control levels would not be correspondingly lowered.[135]

The independent review panel had five weeks to deliver its report.[136] It did no substantive modelling, but reviewed results provided to it by Sinclair Knight Merz.[137] The consultants from Sinclair Knight Merz were given between one and two months to produce draft reports to be reviewed by the panel.[138] They were not to produce new models, but to use those created in the 1996 to 1998 study.[139] The manager of Water Resources gave evidence that he 'would have' asked them how long it would take to feed the new data and information into the models.[140] No consideration was given as to whether the 1998 models remained appropriate. The independent review panel was involved in setting the scope of the work to be conducted by Sinclair Knight Merz.[141]

The prospect of performing a Monte Carlo analysis to deal with uncertainty was raised during the study. At a project meeting attended by the independent review panel and representatives of Sinclair Knight Merz and Brisbane City Council on 14 August 2003, it was estimated that such an analysis would at least require six weeks of work to convert the hydrologic models. This amount of time was considered to be 'too long'.[142] Draft reports provided to the panel were dated 8 and 28 August 2003. In the draft reports, and in the final report in December 2003, Sinclair Knight Merz outlined the sources of uncertainty and recommended that a Monte Carlo analysis be performed in the future.[143]

Presenting results to full council

The independent review panel delivered its report to the council on 3 September 2003, seven days after the second draft report was received. The panel determined that the best estimate of the Q100 was 3.3 metres at the city gauge, corresponding to a flow of 6000 m^3/s. The panel gave a range of uncertainty around those estimates, putting the possible values between 2.8 and 3.8 metres and 5000 and 7000 m^3/s.[144]

The independent review panel report recognised the inevitable uncertainty that attaches to estimates of the flow or height of a flood of a particular probability.[145] This remaining uncertainty arose in a number of areas including: the accuracy of rating curves; the relationships between, on the one hand, the occurrence of flood-producing storms and saturation of the catchment, and, on the other, storm occurrence and dam levels;[146] and the choice of particular spatial and temporal patterns for the storms used to model the Q100 flow. As to the last point, the panel said that a different estimate of the Q100 might be obtained by the use of different storms. That, the panel said, could be resolved by a full Monte Carlo analysis.[147]

Having made those observations in the body of the report, the panel gave its conclusions in the following terms:

> The panel notes that the current 'best estimates' of Q100 and of the corresponding flood level at the Port Office, provide a sufficient basis for a decision on whether the currently accepted flood levels are broadly acceptable. However, for general flood risk assessments and risk-based flood management decision, more refined flood frequency estimates will ultimately be required.[148]

The report contained five suggested areas of future work. The panel 'strongly recommend[ed]' that a Monte Carlo analysis be performed 'as Council moves towards a risk-based approach to flood management'.[149]

Water Resources prepared a memorandum to civic cabinet, recommending that the independent review panel's best estimate of Q100 of 6000 m^3/s and 3.3 metres at the city gauge be accepted, but that the planning control level be maintained at 3.7 metres.[150] The memorandum reasoned that the current level of 3.7 metres was within the range suggested by the independent review panel for Q100.[151] It noted that there was uncertainty arising from the methods used to estimate flows and heights and climate variability.[152] There was no reference in the memorandum to the foreshadowed requirement for more refined estimates of the Q100 if the council were to make risk-based

flood management decisions.[153] Nor was there reference to the recommendation for Monte Carlo analysis. That is unfortunate. Council officers and elected members should be cognisant of the uncertainties involved in any flood estimate, and make decisions with that in mind.[154]

The draft resolution had the effect of accepting the independent review panel's best estimate of Q100 flow as 6000 m^3/s and determining that the planning control level of 3.7 metres was still 'the most appropriate level'.[155] The draft resolution was recommended to full council by civic cabinet and then adopted by the council on 2 December 2003.[156] The council decided to adopt the 'defined flood level' terminology for this planning control level, moving away from the use of the term Q100.[157]

Reports received after the decision was made

The reports provided by Sinclair Knight Merz to the independent review panel were drafts. The final report of the 2003 investigations was delivered in December 2003. It determined the best estimate of Q100 to be 3.51 metres at the city gauge and 6500 m^3/s. The range of uncertainty was 2.76 metres to 4.41 metres and 5000 to 7000 m^3/s.[158] After further calibration of the hydraulic model, Sinclair Knight Merz provided another estimate of Q100 in February 2004, of 3.16 metres.[159]

There is no evidence that these figures were ever provided to the relevant council committee, the chief executive or the full council. The present manager of the Water Resources Branch, who had reviewed the files, said that no decisions were made as to giving briefings to councillors about the December 2003 report because 'decisions had been made in reliance on the Panel (2003)'.[160] The former manager said he would only have put information in front of council if they had to make a decision on it; for example, if the report had suggested the council needed to revisit the Q100.[161]

The Commission considers that elected representatives should be informed of the results of all flood studies completed for a council. See, further, section *2.5.4 Commissioning, assessment and use of flood studies.*

Recommendations for future work

The 2003 reports of Sinclair Knight Merz and the independent review panel made recommendations for work that should be completed. One recommendation that has gained prominence, given the recommendations of the Commission's expert panel, is the recommendation to perform a Monte Carlo analysis.

Water Resources officers decided not to proceed with the Monte Carlo analysis. There were two reasons given to the Commission for the decision. First, the council's planning control level was at the top of the range for the Q100 produced by the independent review panel.[162] Second, Water Resources, after consultation with City Design, decided the Monte Carlo methodology was not sufficiently developed to be used immediately.[163] Some members of the independent review panel had advised council officers in 2003 that the recommendation went beyond best practice.[164]

The expert panel members who gave evidence before the Commission expressed varying views as to whether the Monte Carlo method was an appropriate method to incorporate into a flood study in 2003, and if not, at what time it was appropriate.[165] Most agreed with Dr Nathan's observation that hydrologists are better placed to conduct a Monte Carlo analysis in 2011 than they were ten years ago.[166] Reference was made to the improvements in computing power between 2003 and 2011,[167] increased understanding of radar,[168] and the benefit of data gained from the 2011 flood.[169] Others said it was feasible in 2003, but on a lesser scale than that possible with current technology.[170]

The question as to when use of the Monte Carlo method might become appropriate was left unasked by the council,[171] which had no formal procedure in place to track the progress of such methodology.[172] The council has not, since 2003, implemented the recommendation to perform a Monte Carlo analysis, although it has completed other flood risk management investigations.[173]

In any case, the implementation of the technique is now supported by the whole of the Commission's expert panel and recommended by the Commission. See recommendation 2.2 above.

2.4.2 The Ipswich Q100

The Commission asked Ipswich City Council about flood studies completed since 2000. Due to changes in personnel at the council, it was unable to provide detailed information about how decisions were made regarding each flood study,[174] but it confirmed the accuracy of a chronology provided by Mr Mark Babister in his Flood Frequency Report on the Bremer River.[175]

Inextricably intertwined with Brisbane

As stated above in section *2.3.4 Further investigations for Ipswich*, the Bremer River flooding issues are a subset of the issues to be addressed in flood studies of the Brisbane River. The work done on the Bremer River has often, sensibly, followed work done by the Brisbane council for the Brisbane River catchment.

Ipswich City Council adopted planning schemes in 2004 and 2006. Both planning schemes include a similar flood overlay, which depicts the council's 'Q20 development line' (a flood line based on a long standing regulation line) and the Q100 flood line.[176]

A major study of the Bremer River was performed by Sinclair Knight Merz in 2000.[177] Sinclair Knight Merz used models produced during its study for Brisbane City Council between 1996 and 1998 to obtain estimates of the Q100 by modelling the passage of a 1% AEP rainfall event through the Bremer River.[178] The flood levels thus obtained were compared to flood levels arrived at by performing a flood frequency analysis on the historical record. The two methods produced levels for the Q100 of 18.65 metres and 18.6 metres respectively at the David Trumpy Bridge, the main gauge in Ipswich.[179]

Those estimates, and other work completed in 2002 by Halliburton KBR for rural areas,[180] were used to create the flood overlay for the 2004 planning scheme.[181] In 2003, whilst in the process of adopting the planning scheme, Ipswich City Council found that Brisbane City Council had changed its estimate of the Q100 flow at the Brisbane city gauge in response to the independent review panel report.[182]

The council decided to amend its overlay so that it was consistent with the independent review panel's conclusion that 6000 m^3/s was the best estimate of the Q100 level at the Port Office gauge in Brisbane.[183] The council had no modelling of the extent to which an event in Ipswich would produce that flow. It used, instead, mapping produced by Sinclair Knight Merz in 2000 based on a 6800 m^3/s peak flow at the Brisbane city gauge.[184] That map was a modified version of the Q50 map produced by Sinclair Knight Merz, but Ipswich City Council began using it as a Q100 map because of the similarity of the peak flow used to create it to Brisbane City Council's latest estimate of Q100 flow.[185] The flood overlay used in the 2006 scheme reflected only minor amendments from the 2004 scheme.[186]

The 2006 studies

Brisbane City Council's new Q100 flow was not the only new piece of information available to the Ipswich City Council at the end of 2003. The council was also provided the dam operation and rainfall data assembled by the Queensland Government, and so long awaited by Brisbane City Council.[187] Funding was obtained for a review and update of the 2000 Ipswich River flood study, a task performed by Sargent Consulting in 2006. That study had the following goals:

- to develop a refined version of the council's hydrologic model to account for the new information received
- to use stochastic (Monte Carlo) simulation to account for variability in spatial and temporal rainfall distributions, saturation and dam levels
- to develop a refined version of the hydraulic model
- to ensure consistency of flood levels and mapping at the border of the Ipswich City Council region and neighbouring councils' regions, including that of Brisbane City Council
- to produce flood mapping and flood overlays for the Ipswich planning scheme.[188]

The Monte Carlo analysis performed by Sargent was not of the scale recommended by the Commission's expert panel. The complexity of the hydrologic model limited the number of times it could be run: manual entry of data was required on each occasion.[189] As the existing model had been expensive to develop and was used by both the Brisbane and Ipswich city councils, it was determined that building a new model was not appropriate.[190] The flow

results obtained for the 1% AEP flood event were 20 to 30 per cent less than those obtained in the 2000 Sinclair Knight Merz study.[191] The Sargent estimate of the 1% AEP flood level at the David Trumpy Bridge was 15.28 metres.[192] The new 1% AEP flood flows and heights were not embraced by the other agencies involved in the study – Brisbane City Council, the Bureau of Meteorology, Seqwater, the Queensland Government, SunWater and Esk Shire Council.[193] Those agencies were concerned that the flows and heights were lower than those identified in previous studies and observed in the catchment.[194] Further, the results were based on the assumption that significant storage would be available in the dams at the start of the flood; other agencies did not agree this was appropriate.[195]

The results of this study have not been considered for inclusion in a planning scheme, as the current Ipswich planning scheme was finalised before the results were received.

Joint probability

The joint probability problem at Ipswich concerns the relationship between floods occurring in the Bremer River and the Brisbane River at the same time. As has been stated, Ipswich City Council's flood estimates should sensibly be attuned to work done on the Brisbane River. The recent history indicates just how dependent the council has been on results from Brisbane River studies.

Generally, modelling commissioned by Brisbane and Ipswich city councils has made assumptions about the magnitude of the flood that is likely to occur in the Brisbane River when a flood is occurring in the Bremer River.[196] For example, some have assumed a 5% AEP flood in the Brisbane and a 1% AEP flood in the Bremer to estimate flood heights in Ipswich.[197]

The Commission's expert panel recommended that a joint probability analysis should be done in a comprehensive Bremer River flood study.[198] Just as saturation and dam levels are likely to be related, so are floods occurring in the Bremer and the Brisbane rivers. Their headwaters are close; one storm system could be responsible, as it was in 2011, for producing floods in each. To adopt a process of assumption about the type of flood that occurs in each is too simplistic an approach; it is not a realistic reflection of what actually occurs. The correlation between the two variables must be investigated.

The result of that investigation will be a set of probability distributions of the flow that is likely to occur in one river, given a particular flow in the other.

The need for a joint probability analysis to be done was identified some time ago. Following the 2003 Brisbane River studies, Ipswich City Council commissioned a review by Sinclair Knight Merz of Ipswich flood modelling and overlays. The Sinclair Knight Merz memorandum, received by the council in January 2004,[199] stated that the coincident flows for the Brisbane and Bremer rivers were significant, but unable to be determined on the material available. A joint probability approach was suggested.[200] The memorandum recommended further work be performed, in particular to deal with the joint occurrence of floods issue. It was suggested that such work might be done in conjunction with Brisbane City Council.[201]

The Sargent study in 2006, in the use of a simplified Monte Carlo framework, investigated the effects of different spatial variations of rainfall across the entire Brisbane River catchment. Part of that study involved different patterns of rainfall over the upper Brisbane River, lower Brisbane River and Bremer River catchments. Variability between storms over the Bremer and Brisbane rivers was part of the analysis, but the variability was not compared to the historical variability between floods in the two rivers.[202] It did not constitute a rigorous analysis of the joint probability. The Commission recommends that such an analysis now be implemented: see recommendation 2.2 above.

The future

The next statutory review of the Ipswich planning scheme is due to commence after 2012.[203] The results of the comprehensive flood study now recommended by the Commission's expert panel are at least three years away. Ipswich City Council should maintain its temporary flood lines in the interim: see section *5.2 Temporary local planning instruments*. The council should be actively involved in the progress of the work to be done for the Brisbane River. See section *2.3.3 Responsibility for completing the study*, above.

2.5 The performance of flood studies in Queensland

2.5.1 Catchment wide flood studies

Having considered both the future and the past of the Brisbane and Ipswich City Council Q100 lines, the Commission's focus turned to general principles that might be applicable to flood studies around Queensland. Parts of the expert panels' joint expert statements are applicable for all catchments. The internal processes of the Brisbane and Ipswich city councils are a useful starting point from which to make some general points about conducting flood studies.

Not all parts of Queensland need a comprehensive flood study. Flood studies are expensive and time consuming; they will be justified only when their results can be used to inform land planning and emergency management decisions that affect a large number of people. The Commission considers that all urban areas should have access to the results of a recent flood study.

It is not best practice to conduct a flood study for an urban area alone or even for a local government area. The performance of individual flood studies for cities and towns can lead to different or imperfect information being used and inconsistencies in predicted flood levels at local government boundaries. A flood study should be completed over a whole catchment to encompass the hydrology and hydraulics of all relevant waterways. This approach is supported by Floodplain Management in Australia,[204] the expert panel and more recently by the Queensland Reconstruction Authority, and a number of submissions to the Commission.[205]

Those two concepts – the expense of a flood study and the fact that it would ideally be conducted for a whole catchment – lead to some difficulty in determining the areas for which flood studies should be initiated. Some urban areas have current flood studies; others have studies that require updating or expansion. Still others have never had a flood study completed. Some of those flood studies are a small part of a catchment wide study, while others have been done on the waterways immediately surrounding the urban area. Some levels of government or communities within a particular catchment might wish a catchment wide study to be initiated now, while others might be happy with the currency of their information.

Requiring the performance of all flood studies over full catchments may involve duplication and unnecessary use of resources. The entire catchment approach is ideal, but not always practicable.

Recommendation

2.4 A recent flood study should be available for use in floodplain management for every urban area in Queensland. Where no recent study exists, one should be initiated.

2.5.2 Who should be responsible for the performance of flood studies?

A question which was hotly debated in submissions before the Commission was which level of government should be charged with conducting flood studies.[206] The question entails twin issues: who is best placed to obtain a flood study from experts and who should fund it.

Councils have, historically, borne the burden of producing flood studies for parts of catchments within their local government areas. They are the principal entities involved in land use planning, development assessment and disaster management; they are the primary users of flood maps and are best placed to assess their flood mapping requirements.[207] The completion of flood maps may require detailed information about local river conditions and previous flooding events.[208] Councils are often the principal custodians of such information, and are best placed to retrieve any knowledge their residents might have about previous flood levels.

Some councils have received substantial assistance from both state and federal governments. The Queensland Government has, in 2011, through the Queensland Reconstruction Authority, collected data about floods which occurred and provided interim floodplain maps to those councils with no mapping. Department of Environment

and Resource Management (DERM) officers review flood maps that are proposed to be used as a flood overlay in a planning scheme to determine whether the department has further information, which it makes available,[209] and they provide advice and direction to councils on request.[210] (DERM does not review the modelling behind a flood map or consider its appropriateness for use in land planning; see section *4.1.7 The role of DERM*.)

The Commonwealth Government, through Geoscience Australia, is responsible for providing topographic data, including digital elevation model data and contours.[211] The availability of that information substantially reduces the cost of completing a flood study and producing a flood map.[212] It also supports projects for the production of national guidelines.[213] Both the Commonwealth and the Queensland governments contribute equally to flood study projects that have obtained a grant under the Natural Disaster Resilience Program.[214] That program commenced in 2008 and has allocated approximately half of its $44 million in funds; a portion of those funds have been for flood study projects.[215]

It is clear, however, that the current arrangements have not been effective in ensuring the completion of adequate flood studies across the state.

The Queensland Government submitted that flood studies, and associated mapping, should remain the responsibility of councils.[216] It says that the lack of flood studies and maps reflects a failure by some councils to prioritise their completion. It does not deny that some councils are incapable of performing flood studies on their own, but it points to the provision of technical advice by the Queensland Government to councils through DERM and the Queensland Reconstruction Authority.[217]

Many councils, and their representative body, the Local Government Association of Queensland, on the other hand, assert that the Queensland Government should play a far greater role than it has in the past.[218] That role, they say, should entail co-ordinating the conduct of flood studies and the development of flood mapping, as well as providing funding and technical assistance.[219] They indicate that local governments do not have sufficient resources to undertake flood studies themselves.[220] Another argument for state responsibility for, or at least co-ordination of, flood studies is their catchment wide nature: catchments often extend well beyond local government boundaries.

There are reasonable arguments on both sides of the debate, although one suspects that they are underpinned by a uniform disinclination to accept the funding burden. The Commission is not in a position to determine how the three tiers of government – federal, state and local – should allocate their resources. What is clear is that catchment wide flood studies are needed in many areas, and the three levels of government should co-operate to ensure they are produced.

2.5.3 Ensuring all urban areas have flood studies

The Commission does not intend to prescribe in detail how the Queensland Government and the councils work together to ensure flood studies are completed for those urban areas that require it. There are some basic steps that are required for that process.

First, the urban areas that do not have current flood risk information will need to be identified. Those areas should be ranked in order of priority depending on their need for the information. This will depend on a number of factors, including population, date of last flood, date of last flood study and frequency of floods in the historical record.

Having determined the priorities, flood studies should be conducted, whether catchment wide or on a narrower basis if appropriate, in those areas that require them within a reasonable time. Decisions will also need to be made about how those flood studies will be carried out, how each level of government will be involved and from whom technical and financial resources will be sought to complete the flood studies. One avenue might be to request assistance from the Commonwealth Government.

Recommendations

2.5 The Queensland Government, in consultation with councils, should determine which urban areas in Queensland do not have access to flood information from a current flood study. The Queensland Government should rank those areas in order of priority in accordance with their need for updated flood information by reference to factors including:

a. population

b. sophistication of land use planning and emergency management measures already in place in those areas

c. currency of any flood risk information available to the council

d. approximate frequency of damaging floods in the area according to the historical record.

2.6 By reference to the order of priority determined in accordance with recommendation 2.5, the Queensland Government and councils should together ensure that the council responsible for each urban area in Queensland has access to current flood study information. This will include determining:

a. a process or processes by which the flood studies will be completed, including the involvement of the Queensland Government and relevant councils

b. how, and from whom, the necessary technical and financial resources will be obtained

c. a reasonable timeframe by which all flood studies required will be completed.

2.5.4 Commissioning, assessment and use of flood studies

A continuing obligation

Flood studies are often performed reactively, undertaken after a large flood or in response to the availability of a new method or data set.[221] The obligation to maintain up-to-date information is a continuing one: all councils should ensure they have access to up-to-date flood information and act on it for land planning and disaster management preparation. How the results of flood studies are used in land planning and emergency management are discussed in more detail in sections 2.6, 2.7 and 2.8 below.

The decision to commission a flood study

Flood studies should, ideally, be commissioned for whole catchments. As set out above, though, it might be that a particular urban area needs a flood study immediately whereas others within the catchment have current information. In that sense, a flood study for an area smaller than an entire catchment might be appropriate in the short term. In the long term, it would make sense for councils responsible for different areas within a catchment to organise their new flood studies to be done together on a catchment wide basis.

Before the start of any flood study, it would be prudent to enquire as to work being done by others in developing scientific techniques that may be relevant to the study. Enquiries should be made of the Bureau of Meteorology, DERM, dam operators, surrounding councils and research centres.

The work to be done in a flood study will logically follow any work done by Commonwealth or state agencies such as the Bureau or DERM.[222] A flood study completed on the best available data or in accordance with the most recent scientific techniques will be more accurate. On the other hand, there are continuing advances in the ways information is gathered, data is analysed and modelling is run. It may be that a flood study will be out of date only a few years after completion. The body conducting the flood study must decide what data or scientific development is worth waiting for, and when to go ahead with what is currently available. The balance is between accuracy of the final result and obtaining updated results quickly.

If the decision is made to wait, timelines should be set for the completion of work that is to be done by each agency. If unexpected delays are encountered during the waiting period, this should be brought to the attention of the chief executives or elected representatives of all councils involved in the study.

Initiating the study

Flood studies can be conducted internally within state or local governments or by external consultants. The people chosen should have the relevant expertise and access to the data, models and local information necessary to complete it.[223] If possible, where data analysed or created by other agencies is to be used, it should be checked by those performing the flood study.[224] The central repository recommended in section *2.5.5 Central repository of flood study data*, should assist in this process.

The decision as to the scope of the flood study will determine many aspects of the results, in particular the level of certainty which attaches to them. If resources were unlimited, there would undoubtedly be a recent and comprehensive flood study for all catchments. As they are not, there must be a balance between the resources to be expended and the level of certainty of the results.[225] For a catchment wide flood study, decisions will need to made within each council involved as to how much can be spent from their budgets. Any contribution by state or federal governments must also be taken into account. Councils should be heavily involved in the determination of the scope of the work of the study, as they will use the results upon completion. Therefore, all relevant councils should consider the options for the scope of the flood study and their implications for resources and certainty.

Once a scope of work has been determined, detailed instructions will need to be drafted. This should be done by persons with technical expertise in hydrology and hydraulics. It should not involve any statement of the likely planning or emergency management decisions which may flow from decisions of those performing the flood study.[226] The science should be kept separate from the policy.

Assessment and use of results by councils

Regardless of who completes or funds the flood studies, it will be councils who use the information in them to make decisions about land planning and emergency management to reduce the flood risk to their communities. Once a flood study is completed, it is councils who must take responsibility for its assessment and use.

At the end of the flood study, results should be presented to all councils affected. Some councils will have internal officers skilled in hydrology to review flood study reports.[227] In all cases, council officers should engage in frank discussion with hydrologists or engineers completing a flood study, to ensure that any limitations and any uncertainty attaching to its results are clearly understood. Experts must take some responsibility, too, for ensuring the uncertainties attaching to their results are clearly stated. It was conceded in evidence before the Commission that hydrologists and engineers have not always done a good job of communicating uncertainty and the implications of that uncertainty for future decisions.[228]

If a council is not satisfied with the methodology by which a flood study is completed, an independent review may be appropriate; although care must be taken not to become mired in an extensive trail of expert reviews and opinions. Uncertainty and limitations are inevitable;[229] they can be factored into the risk management processes that should be used by councils before acting on the results.

The use to which flood studies are put depends heavily on local circumstances; the Commission can make no recommendation that has universal application. At the conclusion of each flood study relevant to the council's region, it should be presented to the full council. Consideration should be given to the impacts of the result on current land planning and emergency management arrangements. Council officers can usefully provide information and advice to assist in those decisions.[230]

Recommendations for further work

Where a flood study report makes recommendations for further work, it should be elected representatives who determine, after receiving risk based advice, whether the further work suggested should be completed.[231] For a catchment wide flood study, it may be the elected representatives from all agencies involved in the flood study who make the decision together. Officers of state and local governments do, of course, add value by their recommendations as to whether further work should be completed, but should not be deciding the matter. This is the only way to achieve the balance between the public interest in obtaining highly accurate flood levels and the cost of the resources required to obtain them.

It would be useful for larger councils and the Queensland Government, who may receive many expert reports with varying recommendations, to create and maintain a database of those recommendations to track their implementation. If particular recommendations are not able to be immediately implemented because of the state of

the science, or other investigations that are continuing, steps should be taken to ensure they are acted upon when practicable.

Recommendations

2.7 As far as is practicable, councils should maintain up-to-date flood information.

2.8 When commissioning a flood study, the body conducting the study should:

- check whether others, such as surrounding councils which are not involved in the study, dam operators, the Department of Environment and Resource Management, and the Bureau of Meteorology, are doing work that may assist the flood study or whether any significant scientific developments are expected in the near future, and decide whether to delay the study
- discuss the scope of work with the persons to perform the flood study as well as surrounding councils which are not involved in the study, dam operators, the Department of Environment and Resource Management, and the Bureau of Meteorology.

2.9 Elected representatives from councils should be informed of the results of each flood study relevant to the council's region, and consider the ramifications of the study for land planning and emergency management.

2.10 Elected representatives from all agencies involved in a flood study should be informed of recommendations made for future work, and determine, on a risk basis, whether that further work is to be completed.

2.5.5 Central repository of flood study data

The panel of experts described in section 2.3.1 was frustrated in their consideration of the Brisbane River and Bremer River Q100 levels by the lack of a central repository for data needed for flood studies. Mr Babister gave evidence that there were numerous examples of data that was not available to others conducting studies or to him in his examination of this topic. One example was data created by the Queensland Government in 2003, showing the attenuation provided by the dams for modelled rainfall events.[232] Dr Nathan gave the example of LIDAR data (high resolution data on the topography of the earth) which allows hydrologists to define the potential of a flood plain to absorb rainfall, carrying capacity of rivers and the extent of inundation which would be caused by a flood of a certain height.[233]

The expert panel recommended that a central repository of flood-related data be created, maintained and updated.[234] That recommendation was made in the context of determining what would be required to obtain a robust estimate of the Q100. The Commission has only considered the appropriate characteristics of the repository through the prism of what is required for flood studies used in land planning. The repository could be useful for other agencies or address other data deficiencies. For example, it could be used to provide information to insurers, or to provide flood maps to the public (see section 2.9 below regarding the provision of information to the public). Whether the repository is used to fulfil those purposes is a question for those responsible for the repository.

Responsibility for the repository of data

Different suggestions were made as to which agency should be responsible for such a repository. DERM[235] and the Bureau of Meteorology[236] were nominated, as, more generally, were Queensland[237] and Commonwealth governments.[238] Dr Nathan suggested that councils would be best placed to maintain the repository for their catchments.[239]

Geoscience Australia, a Commonwealth agency, maintains a database of flood studies around Australia. It has a web portal which allows access to flood studies around Australia.[240] The Natural Disaster Insurance Review report recommended that an agency be created to co-ordinate a national repository of flood risk information.[241]

These initiatives might negate the need for a separate repository of data for Queensland. The Commonwealth and Queensland governments should determine, jointly, whether the repository should be established within those initiatives or as a separate entity. In any case, they must ensure that the data needed for flood studies is available to all who might need it.

Contents of the repository of data

At a minimum, the repository should hold the data listed as necessary for the completion of a comprehensive flood study.[242] Some data will simply need to be collated. Other data does not yet exist, and will be created as flood studies are performed for catchments around Queensland. As those flood studies are performed, the data used or created from models and the analysis of it should immediately be given to the repository.

The data should be accompanied by the results of any review or analysis of that data.[243] The methodology used to obtain the data should also be specified. That information will assist those using the data to determine how much reliance should be placed on it.[244]

The repository's records must make it possible to ascertain what the data held was at any particular point in time so that those subsequently considering work done in reliance on it can understand the basis on which the work was done.[245]

Where a flood study is to be performed by independent consultants, the obligation for ensuring that all data used or created is available to the central repository should fall on the council or other body commissioning the study. All levels of government should contribute to the body of knowledge about floods in Queensland.

Access

The experts considered that the data should be available for access by all agencies involved in the creation and use of flood studies;[246] that would include, at least, the Bureau of Meteorology, dam operators and all levels of government.

A range of issues will need to be considered in the decision as to who should have access to the database: questions of intellectual property, impacts on land values, insurance prices and liability for incorrect information.[247] To deal with these issues, the agency with responsibility for the repository may need to create contractual arrangements for the deposit of, and access to, the data.[248]

The complexity of such issues should not be allowed to prevent the development of the repository. A repository would ensure the availability of data to those undertaking flood studies and increase the accuracy of those flood studies. At the same time, it should have the effect of reducing costs,[249] an important consideration; on the evidence before the Commission, cost is a major obstacle in the way of councils wishing to undertake flood studies. See section *2.5 The performance of flood studies in Queensland*.

Recommendation

2.11 The Queensland Government and Commonwealth Government should ensure the existence and maintenance of a repository of data of the type used in flood studies. The database should include the types of data which the expert panel specified as needed for a comprehensive flood study. Councils, Queensland and Commonwealth Government agencies and dam operators should be able to deposit and obtain access to data.

2.6 Using flood studies in floodplain management

Performing flood studies and producing flood maps is of little use unless the information gained is used by government and provided to others.

Firstly, all levels of government must use effectively the information they have gained. Councils require such information to impose appropriate planning controls, set minimum floor levels for development of different types and institute effective emergency management procedures. That may be done under the auspices of a floodplain management plan. The Queensland Government similarly needs such information, in its case to attend to state-wide concerns, such as the construction of dams, flood mitigation or the placement of public infrastructure. Those decisions should be made as part of a floodplain management approach consistent with the best practice principles outlined in Floodplain Management in Australia.

Secondly, the information should be provided to the public and others with a legitimate need for it. Floodplain Management in Australia states that communities in areas susceptible to flood should be made aware of the flood risk to which they are subject.[250] The focus is on their need to understand emergency management procedures, such as evacuation, in which they may be involved during a flood.[251] The Commission considers that individuals might also benefit from the provision of information for land planning purposes. Government can do only so much; individuals' decisions within the scope of land planning, such as decisions about where and how to build, have an impact on the resilience of the community to flood: see section *2.9 Distribution of flood information*, below.

2.6.1 Preparing a floodplain management plan

Floodplain Management in Australia describes a floodplain management plan as the cornerstone of effective floodplain management. Such a plan should outline the mix of land planning and building controls, emergency management plans and structural flood mitigation measures to be employed in a catchment. Decisions as to the distribution of resources across these types of measures are complex; they require economic, social and environmental costs and benefits to be weighed against each other.[252] Floodplain Management in Australia recommends that this decision-making process be informed by the results of a floodplain management study. Such a study involves the identification of people and property at risk of flooding, an assessment of the acceptability of different levels of flood risk and a consideration of the relative merits of possible management measures.[253]

Floodplain Management in Australia recommends that a floodplain management plan should be reviewed at regular intervals of not more than 10 years and after severe flood events.[254] There may be significant expenses associated with the establishment and review of floodplain management plans. In the case of larger, fast-growing regions or those particularly susceptible to flooding, however, the benefits are likely to outweigh the costs. Those benefits include reduced risk to human life and public health, improved decision-making in relation to appropriate land use, integration of land use planning, emergency management and structural floodplain management measures, and increased community understanding of flood risks.[255]

2.6.2 Responsibility for floodplain management

The Commission considers that councils should be responsible for the development of floodplain management plans. Councils are responsible for the imposition of development conditions and have detailed knowledge of local river conditions and past flood events. They are best positioned to engage in the investigations necessary to determine the appropriate mix of floodplain management measures.

This is not, however, to say that other government agencies should not play a role in floodplain management. Floodplain Management in Australia states that the role of state and territory governments is to co-ordinate the implementation of floodplain management plans in accordance with appropriate standards,[256] which may involve providing advice to councils in the areas of planning, hydrology and emergency management. It also notes that the Commonwealth Government has previously been involved in floodplain management by way of, for example, financial assistance for the development and implementation of floodplain management plans, flood forecasting by the Bureau of Meteorology and financial relief to ameliorate the effects of flooding.

Councils' concerns about their financial and technical ability to produce flood maps are equally applicable to the creation of floodplain management plans. However, the need for floodplain management plans to integrate a range of measures (such as planning scheme controls and emergency management planning) that are most appropriately

administered at a local level requires that councils be primarily responsible for the creation and implementation of such plans. Many councils may require assistance from higher levels of government to develop floodplain management plans. All three levels of government should work together to ensure that all councils are able to adequately manage the flood risk posed in their local areas.

2.6.3 Councils' floodplain management activities

It appears that many councils had not implemented a comprehensive management plan that accords with best practice principles as at the 2010/2011 wet season. The best practice principles are just that: they are not mandatory. And it must be said that there is a vast disparity in size and resources between Queensland's largest and smallest councils. Accordingly, the Commission recognises that it is not possible for all councils to develop floodplain management plans that adhere with best practice principles in all possible respects.

By no means, however, should this be taken as a suggestion that the best practice principles ought to be discarded. As discussed above, adherence to the process and principles set out in Floodplain Management in Australia by developing a single, overarching, floodplain management plan, is likely to result in a more efficient distribution of resources among various floodplain management measures.

It was not possible for the Commission to engage in a comprehensive review of the floodplain management measures adopted by each council within the state. Nevertheless, the Commission's investigations revealed that councils have implemented a range of useful floodplain management measures.

Brisbane City Council, as Queensland's (and Australia's) largest local government has substantial resources and staff with expertise in the technical disciplines necessary to conduct effective floodplain management.[257] As is to be expected, the council has invested a great deal of resources on flood-related planning and mitigation.[258] The measures it has implemented provide a useful illustration of the kinds of floodplain management mechanisms that councils can adopt.

In 2005, for example, Brisbane City Council established the Lord Mayor's Taskforce on Suburban Flooding.[259] The taskforce was required to consider a range of flood-related issues, with a particular focus on creek and local flooding. In the years following the release of the taskforce's report, the council has implemented a range of floodplain management measures including:

- investigations of flood risk, including undertaking flood studies for a number of creeks, and modelling the probable maximum flood of the Brisbane River[260]
- the voluntary home purchase scheme[261]
- drainage works programs[262]
- emergency management measures including the establishment of a local disaster management group, a local disaster co-ordination centre, a disaster management plan[263] and the development of the 'Bender' flood model and the Brisbane River Flood Forecasting System allowing predictions to be made as to the peak level of flood waters at various locations
- initiatives aimed at informing the community of flood risk, including community awareness and education programs, the provision of free flood maps and FloodWise property reports,[264] and early warning alert services regarding the possible impact of creek flooding and severe storms.[265]

Brisbane City Council is not the only council taking active steps towards the implementation of an appropriate range of floodplain management measures. The Rockhampton Regional Council, for example, arranged for a detailed flood study to be conducted after the 2010/2011 wet season.[266] This flood study included hydrologic and hydraulic modelling of the impact of 2, 5, 10, 20, 50, 100 average recurrence interval flood events and the probable maximum flood, as well as a brief consideration of emergency management planning, community awareness, and planning controls. The study commissioned by Rockhampton Regional Council should not be mistaken for a comprehensive floodplain management plan, but it is likely to provide a useful foundation from which the council will be able to develop one.

Recommendation

2.12 Councils in floodplain areas should, resources allowing, develop comprehensive floodplain management plans that accord as closely as practicable with best practice principles.

2.7 Flood mapping for land planning controls

There is a variety of land use planning measures councils can employ to manage floodplains. They include devising appropriate assessment criteria, and determining minimum floor levels for different types of development. Many of them are dealt with in more detail in chapters 3 to 11 of this report. The Commission's focus in this chapter is the production of mapping, a key tool to translate knowledge of flood risk into effective land planning controls.

2.7.1 The absence of flood maps in Queensland

Flood maps are based on the results of flood studies and, by showing information about the extent, likelihood and characteristics of flooding, as well as its consequences, can form the basis of decisions about the best way to use land in the floodplain.[267]

There is currently a lack of flood mapping in Queensland planning schemes. A recent report commissioned by the Queensland Reconstruction Authority in conjunction with the Department of Local Government and Planning reviewed 127 of Queensland's 137 planning schemes[268] and established that 80 out of the 127 planning schemes reviewed (63 per cent) contained no flood-related mapping.[269] Of the remaining 47 planning schemes with maps, only 23.6 per cent were completed in accordance with the guideline to State Planning Policy 1/03: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*.[270] It must be recognised that the review assessed the existence of flood mapping in the context of Queensland planning schemes and is therefore not conclusive as to the proportion of councils who have created flood maps for other purposes. However, even taking its restricted scope into account, the review's conclusions lead the Commission to find that there is, in Queensland, a wholly inadequate level of flood mapping.

There are two principal reasons for the inadequate level of flood mapping within Queensland:

- There is no requirement that councils undertake flood mapping by the operation of State Planning Policy 1/03, the *Sustainable Planning Act 2009*, or any other piece of legislation.
- In almost every case, creating a comprehensive flood map involves undertaking a detailed flood study: an expensive, time consuming and technically complex process, beyond the reach of many councils.

2.7.2 The effectiveness of flood maps in land planning

Flood maps are used in the preparation of planning schemes, and the assessment of development applications. As to the first process, councils need enough information to understand the risk of flooding and to put in place the appropriate planning controls to minimise or eradicate the effects of flooding on people and property.[271] Decisions about what controls to put in place, and where they should operate, should be informed by a clear understanding of the risk of flooding, obtained by reference to information about the chance of flooding, and its potential consequences for people and property. The second process – the assessment of development applications – usually requires council assessment officers to have regard to a planning scheme's flood overlay map. Such maps depict the land constrained by flooding and to which the council has attached planning controls.

The cost of creating the flood map will almost always be an issue. But employing significant resources is not always necessary. If development pressures are small and the potential for damage from flooding is minimal, the costs incurred creating a detailed flood map using a flood study may not be justified.[272] However, for towns and cities with substantial populations, and for areas where development is expected to occur, there is a clear need to understand where and when flooding will occur, so that its effects can be mitigated.[273]

The costs of flood mapping are not only borne by governments. Developers may incur costs too: councils can require additional flood investigations about the likelihood and behaviour of flooding at a proposed site. Preparing

this material can be costly, a fact which should be considered when councils engage in the process of determining the most appropriate map for their purposes.[274]

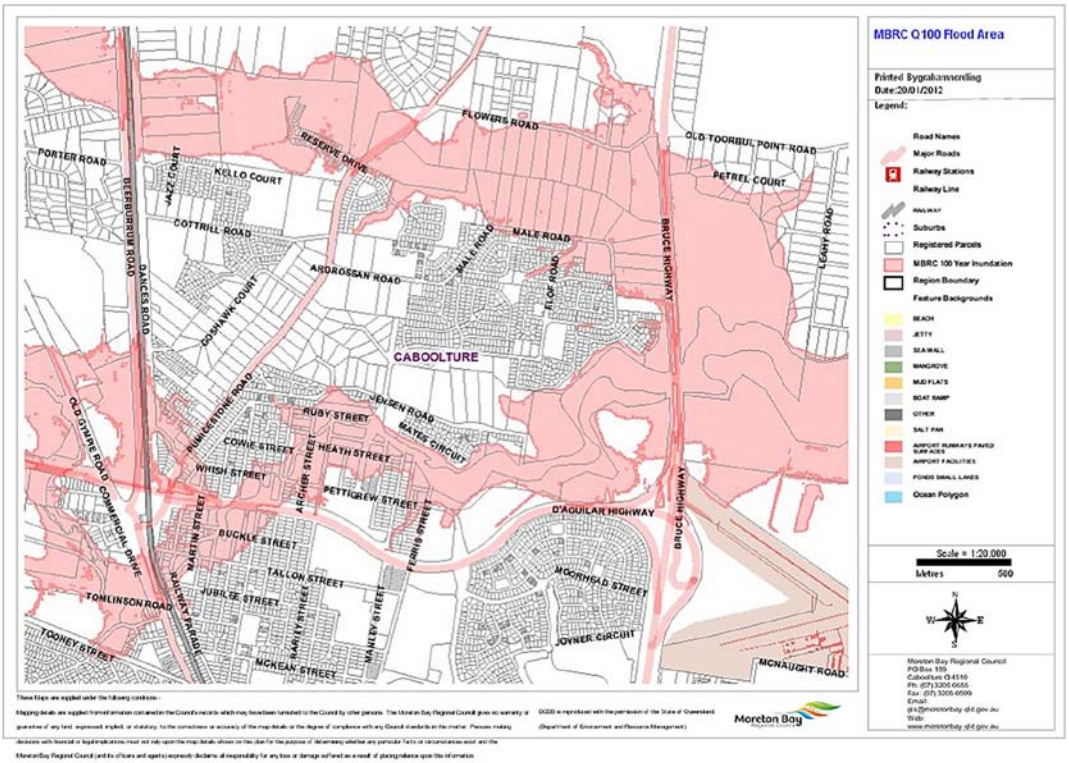
Having regard to the requirements of the land planning system, the Commission has assessed each type of map against the following criteria:[275]

1. whether the map allows a proper assessment of flood risk
2. whether the map can be used effectively as an overlay in a planning scheme
3. whether the map is efficient in terms of the costs incurred by the government (local or state, or both) in generating the map.

2.7.3 Assessment of mapping options

Q100

Queensland's State Planning Policy 1/03: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* requires planning schemes to nominate a flood event, referred to as a defined flood event, which determines the land subject to flood-related planning controls.[276] Where councils have decided to do so, most have nominated a single flood event with a 1% AEP (Q100) to govern planning decisions in their area. This is no surprise: the 1% AEP flood has traditionally been considered the acceptable level of risk for most forms of development in Australia.[277]



Moreton Bay Regional Council Q100 flood areas at Caboolture
Source: Statement of Chris Warren, Moreton Bay Regional Council, 12 September 2011

This focus on the Q100 and one defined flood event should not continue. Q100 represents only one possible flood. Reliance on a single defined flood event contains this limitation: there are only two areas by reference to which planning controls relevant to flood can be set – the area inside, and the area outside the line depicting the extent of the flood. Restricting development within the extent of the 1% AEP flood will manage a portion of the risk,[278] but it does not deal with the risk of floods that are less frequent, but more severe, or those that will occur more often, but with less damaging consequences.[279] Instead, the various areas to which planning controls apply should be selected having regard to the likelihood, behaviour and consequences of the full range of possible floods, up to and including the probable maximum flood.[280]

The case of Ipswich is instructive. Flood levels in the Bremer River can vary dramatically. Several members of the expert panel sought to emphasise that in Ipswich the consequences of a flood greater than a 1% AEP could be devastating, and far graver than would be experienced by Brisbane should a flood of the same probability occur. In cases such as Ipswich's, it is vitally important to have an understanding of floods greater than a 1% AEP flood and to put in place the appropriate controls.

It would appear that, having received the Commission's draft findings to this effect, the Queensland Government has acknowledged the need for this shift in approach to planning; as is apparent from the Queensland Reconstruction Authority's draft guidelines released for public consultation in January 2012, *Planning for stronger, more resilient floodplains: Part 2 - Measures to support floodplain management in future planning schemes*.

Once a council has a current flood study with a hydraulic model it can produce a map showing flood likelihood and behaviour without incurring significant costs.

Likelihood and behaviour mapping

A flood behaviour map shows information as to likelihood of flooding in particular locations, and the characteristics of the flood, such as velocity, rate of rise and depth. Likelihood is often indicated by lines showing the extent of floods of different likelihoods. The characteristics of a flood can be shown in zones.

A map showing both likelihood and behaviour is best practice. It is supported by Floodplain Management in Australia,[281] State Planning Policy 1/03[282] and expert land planners engaged by the Commission.[283] It allows the risk of flooding to be understood across the full spectrum of floods, thus enabling the appropriate flood-related planning controls to be used in development assessment.[284] Those controls can differ between different 'zones of risk', taking into account the likelihood of flooding alone, the behaviour of flooding alone, or the combination of likelihood and behaviour.[285]

Given the wide range of information depicted, it is unsurprising that a flood behaviour map is the most expensive map to produce. Most hydraulic models created during a flood study can produce maps which show likelihood or behaviour. Simpler models may not be able to produce behaviour data accurately; if a council intends to obtain a flood behaviour map, the base model should be chosen with that in mind.[286] The behaviour maps produced by such a model will each be for a flood of a particular probability. The council will then have a sheaf of maps, each relevant to a flood of a particular likelihood. Using all those maps might be useful in an emergency management context, as it is not always clear at the start of a flood how large it will be.

However, for use in a planning scheme, councils will have to choose how to aggregate the information obtained from the model. Detailed information about the likelihood of flooding, and its characteristics, or the use of many maps, may prove too complicated for a planning scheme.[287] The Commission heard from two expert town planners on this point; each suggested that limiting the information depicted on the map to two or three 'hazard' categories – 'low', and 'high', with 'medium' as the additional option – would suffice for

Central Highlands Regional Council Emerald 2008 flood map
Source: Attachment to statutory declaration of Luke Lankowski, Central Highlands Regional Council, 1 September 2011

land planning purposes.[288] A council will have to make qualitative judgments on a risk basis as to the zones it wants to show on its map, having regard to the particular planning controls that might attach to each.[289] Floodplain Management in Australia offers some guidance about the type of flood behaviour which could define these hazard categories. For example, 'high hazard' is characterised by flood depths of up to 1.0 metre and velocities of up to 1.5 metres per second.[290] How that information is combined with information about likelihood is a decision for councils. The Queensland Reconstruction Authority, in its draft guideline, *Planning for stronger, more resilient floodplains: Part 2 - Measures to support floodplain management in future planning schemes*, released in January 2012 also supports the approach of three 'hazard' categories and provides some guidance about how a council may classify land for planning purposes.

To date, this approach to flood mapping has rarely been undertaken in Queensland,[291] although the Commission is aware of flood mapping conducted for the Rockhampton Regional Council which has produced separate maps showing flood velocity, flood depth and flood 'hazard' – the latter being a combination of velocity and depth.[292]

The Commission notes that the Victorian planning system requires planning schemes to nominate certain flood-related zones – urban floodway zone, floodway overlay, land subject to inundation overlay and special building overlay. These zones are differentiated in terms of the flood behaviour in those areas. Different planning controls apply within each zone. For example, land that conveys floodwaters in areas where the flood risk is high because of existing or contemplated development, are designated as being in the 'urban floodway zone'. Within this zone, most land uses are prohibited.[293] Such maps may be appropriate for use in Queensland.

Likelihood maps

A flood likelihood map is a map showing the extent of floods of several different probabilities, for example, a 0.5% AEP flood (Q200), a 1% AEP flood (Q100) and a 5% AEP flood (Q20). Each flood extent is represented by a line on the map.[294] While such a map does not show information about the behaviour of flooding, it at least shows the frequency with which parts of the floodplain are subject to inundation. That allows planning controls to be attached to more than one zone, for example: development in areas shown to flood with greater frequency should be subject to stricter planning controls. By allowing multiple zones of planning control to be established, it is closer to best practice than the approach – currently supported by State Planning Policy 1/03 – of mapping a single defined flood event.[295]

Maps of floods of several different annual exceedance probabilities offer a judicious substitute for flood behaviour mapping[296] and, because they often demand less sophisticated flood modelling for its creation, may be more easily attained. It should require little further work or expense to produce once a flood study that produces a hydraulic model has been completed; the model itself can produce a map capable of being inserted into a planning scheme.[297]

Historical flood maps

A historical flood map shows the extent of a particular flood that has occurred in the past. It may simply be an aerial photograph of that flood. For instance, the 2010/2011 floods were captured by high definition photographs obtained by DERM in the days and weeks after flood peaks.[298] Maps were then created by cartographers who determined the maximum extent of the flood from water and debris marks and by reference to information from local residents. Historical flood maps can also be derived from recorded data – such as stream gauge heights and peak recorded flood levels – and photographs and personal accounts of historic floods.[299] Recorded data from an historical event, such as gauge heights, could also be run through a hydraulic model to determine its extent.

Maps of historical floods can be used as defined flood events in planning schemes. These maps are attended by the same problems as a map of a certain defined flood event – such as a 1% AEP flood – in that they restrict planning controls to differentiation between only two zones (outside and within the extent of the historical flood).

Caution must be exercised when using historical maps to make decisions about land planning. How likely it is that a flood will occur is an important factor in determining what flood-related land planning controls should be put in place.[300] Historical flood maps cannot convey information about likelihood, unless they incorporate further information such as that produced by a flood frequency analysis. State Planning Policy 1/03 attempts to deal with this problem: it recommends that a council perform a flood frequency analysis and estimate the extent of inundation that would be experienced should a flood similar to the historical flood event reoccur by assessing changes to the floodplain.[301] The Commission supports councils' taking such steps before using historical flood events to regulate development in their regions.

The cost of preparing a map of an historical event will likely be lower than a flood map of behaviour and likelihood, or even just likelihood. Councils may choose to use the Queensland Reconstruction Authority's maps of the 2010/2011 flood. Additional costs are likely to be incurred conducting further analysis to determine the historical flood's likelihood of recurrence.

Queensland Reconstruction Authority maps

The Queensland Reconstruction Authority has created a set of maps titled 'Interim Floodplain Assessment Overlays' that are intended to have a role in Queensland's planning schemes. These maps are part of a broader project undertaken by the Queensland Reconstruction Authority which also includes the creation of the Temporary State Planning Policy 2/11: *Planning for stronger, more resilient floodplains* and is supported by a guideline. The operation of the Temporary State Planning Policy is discussed in more detail in section *4.2 Temporary state planning policy.*

These maps were created using satellite imagery of individual sub-basins and imposing the locations of towns and gauging stations onto the image. Ordered drainage data,[302] contour data[303] and the 2010/2011 flood line were also layered onto the satellite image, as was the 'floodplain data set', which comprises Pre-clear Vegetation Mapping of Landzone 3 (Alluvium), Landzone 1 (Estuarine) and SALI (Soil Flooding Limitation Mapping) data.[304]

Through the use of these data sets, the maps depict areas of soil and vegetation characteristics compatible with the land having been previously inundated by floodwaters, at some unknown point in history,[305] adjusted to take into account current contour information[306] and the 2010/2011 flood line.[307] The hard copy maps identify the locations of gauging stations, the expectation being that the user can then make inquiries as to the range of flood levels recorded at any particular gauge.[308]

Assessment of flood risk

The interim floodplain maps do not depict an annual exceedance probability, nor do they provide any information about the risk or probability of flooding occurring in the future, or the frequency with which flooding has occurred in the past.[309] The maps' failure to show at least the likelihood of flooding means that they are, like historical flood maps without further analysis, of limited use in determining appropriate land planning controls.

The maps are expected to be refined by councils,[310] by reference to existing flood studies, records, photographs and local knowledge.[311] The authority has noted that, in some cases, where the process of local validation has occurred there is a correlation between the interim floodplain line and the results of flood studies.[312] However, as one council engineer observed, any correlation 'defies logic';[313] it is not a reason to support the use of the maps in a land planning context.

Use of the maps in planning schemes

According to the Queensland Reconstruction Authority, applicants, or councils, can obtain details of the highest recorded flood levels for the gauging stations identified on the map, and use this information to determine appropriate minimum floor levels.[314] Again, however, this process gives no indication of the likelihood of flooding, and it remains necessary to establish how the highest historical flood level translates to a potential flood level for the proposed development site.[315]

The maps may, the authority suggested, 'trigger' further consideration of flood risk on a site specific basis; for development proposed within the interim floodplain area, the applicant would be expected to demonstrate the absence of flood risk.[316] The Commission considers that the use of the floodplain data set – soil and vegetation characteristics to identify areas congruent with previous flooding – limits the maps being used in this way. By incorporating the floodplain data set, even refined by reference to contour lines and the 2010/2011 flood line, the interim floodplain maps risk capturing too large an area. For several councils, the interim floodplain maps cover large tracts of their region which had not previously been considered liable to inundation.[317] If a requirement were imposed on all applications within the extent of the interim floodplain map to provide more detailed, site-specific information, it could impose an onerous burden on a disproportionately large number of applicants.

The interim floodplain maps are a level above having no flood data at all. By showing topographical information, the 2010/2011 flood line, and areas which may have been inundated in the past, the maps depict – in the words of the authority – 'an area of interest for potential flooding'.[318] Councils may choose to use the maps to determine areas within their region which require more detailed flood studies and mapping. The guideline produced by the Queensland Reconstruction Authority contemplates use of the maps in this fashion, asserting that the interim

floodplain maps 'provide a framework for communities to decide priorities for more detailed flood studies'.[319] The Commission agrees.

Cost

The Queensland Reconstruction Authority's interim floodplain maps are freely available for use by councils. Councils choosing to adopt the maps into their planning scheme will incur little expense. There may, however, be some costs involved in validating the maps, although the authority has offered to assist councils with fewer resources to do this. The Commission acknowledges the extensive work that has gone into the interim floodplain maps. Working with DERM, the Queensland Reconstruction Authority has, over a matter of months, created maps covering most of Queensland.[320] Even were resources available, it would have been impossible, in the timeframes imposed on the Authority, to collate the data required to map flood risk across the entire state.[321]

Creating a flood map from topography information

It is important that the land planning system can accommodate circumstances where the risk of flooding is unknown.[322] One outcome of the large scale flooding that occurred across Queensland in December 2010 and January 2011 is that locations in Queensland for which very limited flood data existed now have data – such as rainfall and streamflow – from a large historical event.

However there will remain areas in Queensland where the likelihood of flood remains unknown. It is important that those areas are identified, so that it is clear that the absence of information about flooding does not indicate the absence of flood risk; rather, that it has not been evaluated. The Gladstone planning scheme, for example, uses the designation of 'Unknown Extent of Flooding (Lack of Information)' in the flood and storm surge mapping for its 1 per cent annual exceedance probability overlay.

The Commission considers that there are two principal options for councils in this situation:

1. Councils identify, on a map, areas of 'unknown flood extent'. For development proposed in these areas, certain basic information of relevance to flooding considerations should accompany every development application;[323] for example, information about the elevation of a proposed development and its location relative to watercourses.[324] Upon assessment of this basic information a council may consider further information is necessary; if so, it can be sought at a second stage of the development process.[325]
2. Councils create maps showing areas with topographical features that indicate some chance (albeit crudely determined) of flooding. Only those proposing to develop in that area would be required to provide additional, site based information about flooding. This assessment requires access to information about a council region's topography, for example, a contour map. What this kind of map would show might be referred to as a 'flood investigation area'.[326]

Both options rely heavily on identifying topographical characteristics synonymous with flooding: this is a rudimentary approach to assessing flood risk, and should be used only as a last resort.[327] Where councils choose to produce their own map, they may incur some costs in obtaining the necessary topographical information.

The best flood maps

It is not feasible, nor is it necessary, for sophisticated flood mapping to be completed on a state-wide basis.[328] There are locations where flood mapping is imperative, such as those with a large population and high levels of development (Ipswich, for example). For locations such as rural areas that are subject to low or no development, the expense of detailed flood mapping may well outweigh the potential benefits.

The Commission has ranked the flood maps in order of appropriateness for use in land planning:

1. Flood maps which depict both the likelihood of flooding and the characteristics of flooding.
2. Flood maps which depict a number of different levels of flood likelihood, for example probable maximum flood, 1 per cent (Q100) and 5 per cent (Q20) and 0.2 per cent (Q500).
3. Q100 maps – flood maps which depict the 1 per cent annual exceedance probability alone.
4. Historical flood maps.
5. Queensland Reconstruction Authority interim floodplain maps.
6. Mapping using topography.

Recommendations

2.13 For urban areas or areas where development is expected to occur:

a. councils with the requisite resources should develop a flood map which shows 'zones of risk' (at least three) derived from information about the likelihood and behaviour of flooding

b. councils without the requisite resources to produce a flood behaviour map should develop a flood map which shows the extent of floods of a range of likelihoods (at least three).

2.14 For non-urban areas or areas where limited development is expected to occur councils should consider, on a risk basis, what level of information about flood risk is required for the area, and undertake the highest ranked of the following options which is appropriate to that need and within the capacities (financial and technical) of the council:

a. a map showing 'zones of risk' (at least three) derived from information about the likelihood and behaviour of flooding

b. a map showing the extent of floods of a range of likelihoods (at least three)

c. a flood map based on historic flood levels that have been subjected to a flood frequency analysis to estimate the annual exceedance probability of the selected historical flood

d. a historic flood map without flood frequency analysis

e. the Queensland Reconstruction Authority Interim Floodplain Assessment Overlay as a way to determine those areas for which further flood studies are required, or

f. the Queensland Reconstruction Authority Interim Floodplain Assessment Overlay (preferably refined using local flood information) as a trigger for development assessment.

2.15 Councils should ensure that areas for which there has been no assessment of the likelihood of flooding are indicated on a map and that, as part of the development assessment process for these, there is at least some enquiry into whether a site proposed for development could be subject to flooding.

2.8 Use of flood information in emergency management

The Commission's interim report made detailed findings and recommendations about emergency management measures.[329] Further comment is provided in this chapter because of the integral role that flood modelling and flood mapping play in preparing for and responding to a disaster. Emergency management measures are the only measures available to address the 'residual risk' of flooding.[330] The residual risk is that faced by the community even after all structural measures have been built (dams, levees and so on), planning controls put in place and building standards imposed to guard against flood.[331]

The primary aim of emergency management, prior to and during a flood, is to reduce the damage caused by an actual flood.[332] During a flood, this is best achieved by accurately predicting the flooding that will occur, warning the community and, where necessary and possible, evacuating people and property.[333] When planning for a future flood event, it is necessary to have an understanding of the full range of flood events so as to plan for any eventuality.[334]

Clearly, emergency management decision-making would benefit from access to detailed flood maps which show floods over a range of likelihoods – up to and including the probable maximum flood – as well as the behaviour of the flooding.[335] These requirements can only be delivered by a flood behaviour map, such as that described in section *2.7.3 Assessment of mapping options*.

While flood maps are an undeniably useful tool for emergency management, during a flood, decision-making is best informed by the use of a real-time flood model.[336] Real-time flood models use current rainfall and river height data to predict the likely extent of flooding.

During the 2010/2011 floods, the Bureau of Meteorology used a hydrologic forecasting model which collected real-time rainfall and river level data, and combined that data with forecast rainfall data to make predictions about likely

flood levels.[337] The Bureau communicated its flood level predictions to Queensland's state disaster coordination centre, emergency services agencies, local governments and dam operators[338] as well as to the public via the Bureau's website and other forms of media, such as the radio. The Bureau's predictions, in many cases, substantially informed the emergency measures taken by the government and the community in response to the flooding.[339]

As noted in the Commission's interim report, Brisbane City Council also has such a model – the 'Bender'[340] – which it uses during a flood to provide property specific information to the public (through its call centre) and to determine the majority of response and recovery activities.[341] Ipswich City Council expects to make available to the public a 'real time' flood mapping product which the council intends will assist residents to respond to flood disasters as they happen.[342]

That is not to say that less sophisticated flood modelling and mapping serve no purpose in planning for or responding to a flood event. The Commission's interim report described how, during the 2010/2011 floods, emergency management personnel relied on information about water heights provided by rural landowners living near watercourses to inform their response.[343] Similarly, emergency responses can be informed by reference to historic floods, which provide a sense of the possible effects of a predicted flood.

2.9 Distribution of flood information

The distribution of flooding information to the community helps people to protect themselves, and their property, from flooding. During a flood emergency, individuals require property specific flood information to understand their own risk of flooding; and, if they are at risk, whether and when to evacuate. Individuals also use flood information to make decisions about whether to undertake a certain development or purchase a property or business.

Information provided to the public may take the form of general flood information, such as a map showing the likely extent of flooding for a whole city, or it may be property specific information which sets out flood heights for a particular property.

2.9.1 Providing flood information and mapping to the public

Mapping for use by the public should provide information that is useful to them in their decisions about land planning and response to an emergency. That should include information about the likelihood of flooding at a particular place, its depth, and the level of hazard to persons and property posed by it.

The usefulness of a particular map to the public mirrors its usefulness in a planning scheme; those that show little in the way of likelihood of flooding or deal with only one flood event are of less use than those that deal with the likelihood and behaviour of a full range of floods. A point of difference is the need for the public to know depth of flooding. Planning scheme maps may show the extent of flooding, but are unlikely to contain information about depth. However, flood levels are important to members of the public because they directly relate to the amount of damage caused to property; it would be helpful for maps showing depth to be publicly available.

Maps should not be provided without explanation; a map that provides behaviour and likelihood information is unlikely to be easily understood without guidance. An appropriate measure is to include with the map an explanatory note.[344] Any explanatory note should, to be understandable, avoid confusing terminology such as Q100.[345] The Commission heard evidence that some people whose property was above the Q100 level thought they were 'safe' from flooding;[346] others thought that floods would occur only once every 100 years. The Commission considers the best approach is to describe likelihood of flood in terms of annual exceedance probability as a percentage. That, at least, makes clear that *every year* there is a chance of flood occurring at the property. In its interim report, the Commission made findings and recommendations about how to convey property specific information to the community so that it can be understood.[347]

Brisbane City Council's approach to the provision of flood information is a useful example. It makes available, free of charge, FloodWise property reports that provide information about January 2011 flood levels,[348] estimated flood levels, source of flooding, minimum and maximum ground levels, minimum habitable floor level for building and development, and whether a property is located within a waterway corridor.[349] In a similar vein, Ipswich City Council makes available property specific flood reports which identify minimum and maximum ground heights and the 1974 and 2011 flood event levels by reference to the eave height of the property.[350]

All flood mapping commissioned or adopted by government should be made available to the public. If commissioned flood maps are not, in the event, adopted by government, an explanatory note should suffice to prevent public confusion.

The most useful, and cost effective, means of publishing such information is on government websites (local and state government). The Commission recognises that not all councils will have a website capable of providing all flood mapping to the public. Some councils may choose to charge a small fee for the provision of property specific flooding information, to cover administrative costs. While this is a matter for determination by individual councils, any decision about charging a fee must be weighed against the importance of ensuring all members of the community have access to information about flooding. Insurance companies may require 'higher resolution' or digital versions of the flood maps produced by local, state or federal authorities (and vice versa).[351] It is a matter for the entities involved to decide what commercial arrangements are put in place to manage the sharing of this information.

There are, of course, numerous legal and commercial issues which might arise through the release of flood mapping products, including issues surrounding liability, licensing, intellectual property, property values and the pricing of insurance.[352] These matters present challenges for the development of any information sharing model. However, the paramount consideration should be protection from the effects of flooding, which can be achieved, at least in part, through the provision of flood mapping.

Recommendations

2.16 Councils and the Queensland Government should display on their websites all flood mapping they have commissioned or adopted.

2.17 Flood maps, and property specific flooding information intended for use by the general public, should be readily interpretable and should, where necessary, be accompanied by a comprehensible explanatory note.

2.9.2 Flood information for dealing with property

It emerged from evidence before the Commission that purchasers of property, in making the decision to purchase, did not turn their minds to the property's vulnerability to flood.[353]

To be properly informed, individuals dealing with property should be aware of the flood risk at the property and any flood-related constraints on development. Awareness of flood risk is dealt with substantially above. The conditions of a development approval attach to the land the subject of the application and bind any subsequent owner or occupier of the land.[354] Accordingly, it is important that subsequent owners and occupiers are aware of the conditions of all previous development approvals. That information could be communicated in a number of ways: through planning and development certificates, rates notices, real estate contracts or online.

Planning and development certificates

The *Sustainable Planning Act 2009* makes provision for the public to obtain from a council a limited, standard or full 'planning and development certificate' (for a prescribed fee).[355] Each of the standard and full certificates identifies any development conditions that attach to the land.[356] The limited certificate does not. These types of certificates are sometimes requested by prospective buyers of land as a part of the conveyancing process. However, in Queensland, there is no requirement to obtain such a certificate during the conveyancing process.[357]

In New South Wales, when land is sold the seller must attach a 'Section 149 Planning Certificate' to the contract for sale.[358] A Section 149 Planning Certificate is issued in accordance with the *Environmental Planning and Assessment Act 1979* and contains information on how a property may be used and restrictions on development (including flooding information). If a Section 149 Planning Certificate is not attached to the contract for sale, the buyer may have the right to rescind the contract and seek compensation from the seller.[359]

The Queensland Government Planner said that this approach would have utility in Queensland.[360] The Local Government Association, however, argued that the disclosure requirements for contracts for sale of land in Queensland were already onerous. Adopting the requirement for a planning certificate would be likely to impose an unfair cost burden on the vendors of property.[361] In the absence of evidence as to those cost implications, the Commission notes the arguments, but makes no recommendation.

Rates notices

The Queensland Government Planner also suggested that the existence of development conditions that relate to flood-affected land could be communicated by placing a notification on a rates notice. Ipswich City Council's view, however, was that this method of alerting subsequent landowners of the conditions was unlikely to be completely successful. The difficulties identified included that:

- the recipients of the notice might not be the occupants of the land
- it would be difficult for councils to identify which conditions should be included
- collating all decision notices to attach to each rates notice would be administratively difficult and time and resource intensive.[362]

The Commission is also of the view that the difficulties associated with including the information on a rates notice militate against any recommendation that rates notices include such information.

Land contracts

The Commission sees merit in a mechanism to bring prospective purchasers' attention to the issue of flood risk and flood-related development constraints prior to signing a contract. That might be achieved by including in standard contracts of sale a condition which makes the contract subject to the purchaser's obtaining a satisfactory flood search. That style of condition currently exists for building and pest inspections in the standard Real Estate Institute of Queensland contract for residential properties. Just as not all purchasers retain the building and pest inspection conditions in the contract, so too could purchasers choose to delete the flood report condition. But at least the issue would have been brought to their attention and a decision made.

Online information

Another way a member of the public can obtain information about conditions binding the use of land, and in most cases overlays affecting the use of land, is through a database known as 'PD Online'. PD Online databases allow the user to carry out a search on a particular property to identify development approvals relevant to the land. However, not all councils offer the PD Online service; and for those that do, the information is limited to approvals issued after a certain date, given that it is not feasible for councils to upload all historic development approvals. It would be of considerable public benefit for all councils to offer PD Online databases.

Recommendations

2.18 Councils that do not currently do so should consider offering an online database which allows the public to conduct a search on a parcel of land to find development approvals relevant to that parcel of land.

2.19 The Queensland Government should consider implementing a mechanism by which prospective purchasers of property are alerted to the issue of flood risk. To that end, the Queensland Government should consider consulting the Real Estate Institute of Queensland and the Law Society of Queensland as to the appropriateness of amending standard contract conditions so as to include a 'subject to flood search' condition, or other means of achieving the same objective.

2.10 Guidelines for the preparation of flood studies and flood management plans

The Commission considers that all levels of government would benefit from access to guidelines for the performance of flood studies, the production of flood maps[363] and the development of floodplain management plans. Several relevant guidelines already exist. For example:

- Floodplain Management in Australia provides a detailed overview of best practice floodplain management.
- Australian Rainfall and Runoff sets out a series of guidelines for the performance of flood studies and the calculation of flood risk.
- The guideline produced by the Queensland Reconstruction Authority *Planning for stronger, more resilient floodplains: Part 1 - Interim measures to support floodplain management in existing planning schemes* aims to assist councils to incorporate floodplain management principles into their existing planning schemes.
- The draft guideline produced by the Queensland Reconstruction Authority *Planning for stronger, more resilient floodplains: Part 2 - Measures to support floodplain management in future planning schemes* aims to assist councils to integrate floodplain management principles and processes into future planning schemes.

Some of those guidelines are in a state of flux. The second part of the Queensland Reconstruction Authority guideline is a draft. The most recent version of Australian Rainfall and Runoff was published in 1987 and is significantly out of date. A review of this document has begun but has been delayed by a failure to secure adequate funding.[364] Evidence before the Commission suggested that that the new version of Australian Rainfall and Runoff will support the use of Monte Carlo analysis.[365] The completion of this review is likely to assist significantly in the conduct of flood studies. It is clearly desirable that funding be made available for the completion of the work.

The National Flood Risk Advisory Group is currently developing a new floodplain management guideline that will supersede Floodplain Management in Australia. This document is expected to be finalised in June 2012.[366] The Queensland Government should use its membership of the group to ensure that the principles set out in the new floodplain management guideline are appropriate for Queensland conditions. If the new guideline is not sufficiently adapted to the Queensland context, the Queensland Government should take responsibility for the preparation of guidelines appropriate for use in this state.

As a final note, the results of the National Flood Risk Advisory Group's review will also be relevant to the terms of Queensland's State Planning Policy 1/03*: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide*. State Planning Policy 1/03 is supported by a guideline which suggests the use of a floodplain management approach in line with the best practice principles set out in Floodplain Management in Australia, and provides a summary of those principles as they relate to land planning.[367] Depending on the terms of the new best practice floodplain management guidelines, it may be necessary to amend State Planning Policy 1/03 and the attached guideline. This further underscores the need for the Queensland Government to be involved in the National Flood Risk Advisory Group's review of best practice floodplain management.

Recommendations

2.20 The Queensland Government should endeavour to ensure that Queensland conditions are appropriately considered in the National Flood Risk Advisory Group's review of best practice principles.

2.21 In the event that the review does not adequately account for Queensland conditions, the Queensland Government should produce a document that provides appropriate guidelines for floodplain management in the Queensland context.

2.22 The Queensland Government should determine whether existing guidelines are sufficient for councils to understand best practice in the performance of flood studies and the production of flood maps. If a lack of current guidelines is identified, the government should create and circulate guidance material for councils.

(Endnotes)

1 State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p26].

2 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: Best practice principles and guidelines, SCARM Report 73, 2000 [p xiv].

3 See chapters 3 and 5 of the interim report in relation to disaster management and emergency response, and chapter 2 of the interim report in relation to dam operation (note that a consideration of where and when to build levees and dams has not been part of the Commission's investigation). Chapters 3-9 of this report deal with matters of land planning and building controls.

4 The efficacy of such a process was questioned in other reports prepared in response to the 2010/2011 floods: see, for example, Brisbane City Council, Joint Flood Taskforce Report, May 2011.

5 The Standing Committee on Agriculture and Resource Management is a permanent standing committee established to assist the Agriculture and Resource Management Council of Australia and New Zealand (a ministerial council) with the development of policies, guidelines and programs in relation to agriculture and land and water resource issues.

6 It should be noted that Emergency Management Australia has published a condensed manual based on the SCARM Report 73. See Emergency Management Australia, Manual 19: Managing the Floodplain, 1999.

7 Emergency Management Australia, Manual 19: Managing the Floodplain, 1999 [p1]; Exhibit 497, Second Statement of Peter Baddiley, 11 May 2011, Annexure PB2-4.

8 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p13-14].

9 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p96].

10 Note that this inverse relationship between annual exceedance probability and average recurrence interval is not consistent across the full range of annual exceedance probabilities. See www.bom.gov.au/water/designRainfalls/ifd/glossary.shtml.

11 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p97].

12 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p69]; State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p37: para A2.28].

13 Exhibit 883, Document number 7, Common expert reading list A, Brisbane, Mark Babister, WMAwater, Brisbane River 2011 Flood Event – Flood Frequency Analysis.

14 Exhibit 883, Document numbers 7-16, Common expert reading list A, Brisbane.

15 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p12: para 39; p13: para 44].

16 Transcript, Hydrology Expert Panel, 26 October 2011, Brisbane [p4392: line 43-50].

17 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p13: para 42].

18 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p5-11].

19 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011.

20 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p5: para 13].

21 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p5: para 13].

22 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p5: para 14].

23 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p6: para 15].

24 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p6: para 15].

25 Transcript 26 October 2011, Brisbane: Rory Nathan [p4367: line 47 – p4368: line 5]; Michael Leonard [p4371: line 28; p4371: line 56]; Sharmil Markar [p4368: line 20]; Mark Babister [p4372: line 13]; Neil Collins [p4368: line 27] cf [p4424: line 6]; Drew Bewsher, 26 October 2011, Brisbane [p4369: line 4]; Colin Apelt, 26 October 2011, Brisbane [p4369: line 29].

26 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4426: line 7].

27 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4373: line 42].

28 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4374: line 29].

29 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4377: line 12].

30 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4436: line 18].

31 Transcript, Sharmil Markar, 26 October 2011, Brisbane [p4368: line 11]; Transcript, Neil Collins, 26 October 2011, Brisbane [p4368: line 27]; [p4424: line 26]; Transcript, Erwin Weinmann, 26 October 2011, Brisbane [p4370: line 53].

32 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p6-7: para 19].

33 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p8: para 20].

34 For example, DERM completed a physical gauging of flow at Jindalee during the 2011 flood event of the Brisbane River. See section *2.6.3 Stream gauges* of the Commission's interim report.

35 A rating curve is a mathematical representation of the relationship between flood flow and height at a particular place along a river. For more information about rating curves, see section *2.6.3 Stream gauges* of the Commission's interim report.

36 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4363: line 16]; Transcript, Mark Babister, 26 October 2011, Brisbane [p4391: line 28].

37 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4363: line 20].

38 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4361: line 47].

39 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p8: para 22].

40 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4363: line 45].

41 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council [p20].

42 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4364: line 8].

43 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p8: para 22].

44 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4412: line 32]; Transcript, Mark Babister, 26 October 2011, Brisbane [p4413: line 2].

45 See, in a different context, Transcript, Michael Leonard, 26 October 2011, Brisbane [p4426: line 46].

46 Transcript, Mark Babister, 26 October 2011, Brisbane [p4365: line 3]; Transcript, Rory Nathan, 26 October 2011, Brisbane [p4365: line 48].

47 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p9: para 23].

48 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4365: line 41].

49 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p9: para 24].

50 See the discussion in Exhibit 883, Document number 7, Common expert reading list A, Brisbane, Mark Babister, WMAwater, *Brisbane River 2011 Flood Event – Flood Frequency Analysis* [p27-29].

51 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 25].

52 Transcript, Mark Babister, 26 October 2011, Brisbane [p4366: line 6].

53 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4366: line 18].

54 Transcript, Brisbane River Flood Frequency Expert Panel, 26 October 2011, Brisbane [p4361: line 47].

55 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 26].

56 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 26].

57 Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p5: para 13].

58 Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p12: para 36].

59 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 27].

60 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 28].

61 Trevor Johnson, Cardno, *Flooding Behaviour*, 11 November 2011 [p2].

62 Trevor Johnson, Cardno, *Flooding Behaviour*, 11 November 2011 [p3].

63 Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p12: para 36].

64 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 28].

65 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 28].

66 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 28 – p11: para 30]; Transcript, Neil Collins, 26 October 2011, Brisbane [p4391: line 5].

67 For information about rating curves, see section *2.6.3 Stream gauges* of the interim report.

68 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p10: para 29].

69 Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p5: para 13].

70 One option is the Laurenson method used by Mark Babister in Exhibit 883, Babister, Hardwick-Jones and Gray, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis, October 2011, document number 1 on Ipswich Common Expert Reading List A [p19: para 50].

71 Transcript, Mark Babister, 26 October 2011, Brisbane [p4366: line 22].

72 Transcript, Mark Babister, 26 October 2011, Brisbane [p4366: line 30].

73 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p11: para 31].

74 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p11: para 34].

75 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4367: line 5].

76 Transcript, Michael Leonard, 26 October 2011, Brisbane [p4367: line 22].

77 Available at www.climatechange.qld.gov.au/pd/inlandfloodstudy.pdf.

78 For a description of this study, see section *17.1.1 The structure for the completion of the scientific investigations*.

79 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4435: line 39]; Transcript, Neil Collins, 26 October 2011, Brisbane [p4437: line 19].

80 Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p7: para 21].

81 Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p10: para 25].

82 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4432: line 49].

83 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4435: line 57].

84 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4438: line 23].

85 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4437: line 6].

86 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p12: para 39]; Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p15: para 49].

87 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p12: para 39]; Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p15: para 49].

88 This defined flood level does not appear in Brisbane's planning scheme itself. The information is maintained elsewhere.

89 See section 5.2 *Temporary local planning instruments*. See also the evidence of Mr Collins and Mr Babister, members of the hydrology expert panel on this point: Transcript, 26 October 2011, Brisbane [p4441].

90 Freeboard is a height allowance that provides for uncertainty in the distance between the expected height of the water surface and the above floor.

91 Brisbane City Council, Submission No. 2, 8 April 2011 [p2: para 2.2]; [p9: para 4.7].

92 Sinclair Knight Merz, *City Design – Flood Modelling Services, Recalibration of the Mike11 Hydraulic Model and Determination of the 1 in 100 AEP Flood Levels*, 5 February 2004 [p11].

93 Exhibit 547, Sinclair Knight Merz, Brisbane River Flood Study, June 1998, Appendices [p0245].

94 Brisbane City Council, Submission No. 2, 8 April 2011 [p9: para 4.7].

95 Brisbane City Council, Submission No. 2, 8 April 2011 [p12: para 4.26].

96 Brisbane City Council, Submission No. 2, 8 April 2011 [p28: para 7.9-7.10]. That account is similar to the one provided in the statement of Martin Reason, the council's acting manager of City Planning and Economic Development. See Exhibit 544, Statement of Martin Reason, 1 September 2011 [p10: para 26]; [p15: para 45]; [p19: para 57]; [p20: para 60-61].

97 Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p10].

98 Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p11].

99 Exhibit 547, Sinclair Knight Merz, Brisbane River Flood Study, June 1998, Appendices [p0245].

100 Water Resources was named Waterways before being merged with the Infrastructure Management Branch in 2002: see Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p8].

101 Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p11].

102 Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p11]; Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p8]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p14: para 55]; Transcript, Barry Ball, 10 November 2011, Brisbane [p4897: line 50].

103 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p9].

104 Exhibit 883, Document number 37, Common expert reading list B, Brisbane, Professor Russell Mein, Brisbane River Flood Study: Review of Hydrological Aspects [p3-5].

105 Exhibit 883, Document number 37, Common expert reading list B, Brisbane, Professor Russell Mein, Brisbane River Flood Study: Review of Hydrological Aspects [p5-6].

106 Exhibit 883, Document number 37, Common expert reading list B, Brisbane, Professor Russell Mein, Brisbane River Flood Study: Review of Hydrological Aspects, 9 December 1998 [p1].

107 Exhibit 883, Document number 37, Common expert reading list B, Brisbane, Professor Russell Mein, Brisbane River Flood Study: Review of Hydrological Aspects, 9 December 1998 [p2].

108 Exhibit 883, Document number 37, Common expert reading list B, Brisbane, Professor Russell Mein, Brisbane River Flood Study: Review of Hydrological Aspects, 9 December 1998 [p6-7].

109 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p10]; Transcript, Barry Ball, 10 November 2011, Brisbane [p4898: line 49].

110 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p10]. City Design are the ordinary supplier of hydrology studies to Water Resources.

111 Exhibit 883, Document number 38, Common expert reading list B, Brisbane, City Design, Sinclair Knight Merz, Brisbane River Flood Study (Draft), June 1999 [p9].

112 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p12]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p17: para 72-73]; Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p5: para 23].

113 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p13]; Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p5: para 24]; Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4828: line 50].

114 Exhibit 883, Document number 39, Common expert reading list B, Brisbane, Brisbane City Council, Further Investigations for the Brisbane River Flood Study, December 1999 [p3].

115 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p16].

116 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p17: para 70]; [p18-19: para 82-86]. See also Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p15].

117 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4829: line 30]; Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p19].

118 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p7: para 35]; Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p19].

119 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p19: para 86].

120 Transcript, Barry Ball, 10 November 2011, Brisbane [p4899: line 30].

121 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p8: para 37]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p20-21: para 88]; Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p19]; Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4845: line 42].

122 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p8: para 37]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p20-21: para 88]; Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p19]; Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4830: line 39]; Transcript, Barry Ball, 10 November 2011, Brisbane [p4899: line 20].

123 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p19]; Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p8: para 38].

124 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p28: para 107(b)]; Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p6: para 29].

125 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p21, 24].

126 Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p1].

127 The Crime and Misconduct Commission investigated allegations of official misconduct in not releasing the June 1999 report to the public, and produced a report in March 2004 which did not find any misconduct, but did make recommendations as to the council's record keeping processes: Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004 [p1].

128 See Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p26-27]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p23: para 92(a)].

129 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4834: line 54].

130 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4833: line 47].

131 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4834: line 56].

132 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p26].

133 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p27].

134 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p9: para 44].

135 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p10: para 45].

136 Transcript, Colin Apelt, 26 October 2011, Brisbane [p4383: line 41].

137 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p27]; Transcript, Erwin Weinmann, 26 October 2011, Brisbane [p4383: line 24].

138 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4377: line 54].

139 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p32-33].

140 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p32].

141 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4835: line 22].

142 Exhibit 884, Statement of Roderic Nathan, 4 October 2011, Annexure RJN-31 [p3]. See also Transcript, Rory Nathan, 26 October 2011, Brisbane [p4382: line 28].

143 The Crime and Misconduct Commission investigated allegations of official misconduct in not releasing the June 1999 report to the public, and produced a report in March 2004 which did not find any misconduct, but did make recommendations as to the council's record keeping processes: Crime and Misconduct Commission, Brisbane River Flood Levels, March 2004. Exhibit 883, Document number 5, Common expert reading list A, Brisbane, Sinclair Knight Merz, Flood Frequency Analysis for Brisbane River Catchment Summary Report: Flood Frequency Analysis of Brisbane River (Draft), 8 August 2003 [p4]; Exhibit 883, Document number 4, Common expert reading list A, Brisbane, Sinclair Knight Merz, Brisbane River Flood Study: Further Investigations of Hydrology & Hydraulics Incorporating Dam Operations and CRC Forge Rainfall Estimates (Draft), 29 August 2003 [p4].

144 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council [p22].

145 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council, Executive summary [p i, p22].

146 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council [p19-20].

147 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council [p20].

148 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council [p22].

149 Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council [p22: para 5.2(a)].

150 Exhibit 544, Statement of Martin Reason, 1 September 2011 [p6: para 23]; Annexure MJR-6, Attachment A [p1: para 1(c), (d)].

151 Exhibit 544, Statement of Martin Reason, 1 September 2011, Annexure MJR-6 [p3].

152 Exhibit 544, Statement of Martin Reason, 1 September 2011, Annexure MJR-6 [p3].

153 Exhibit 544, Statement of Martin Reason, 1 September 2011 Annexure MJR-6 [p2-3].

154 Transcript, Erwin Weinmann, 26 October 2011, Brisbane [p4390: line 17].

155 Exhibit 544, Statement of Martin Reason, 1 September 2011, Annexure MJR-6, Attachment A [p1: para 1(i), (ii)].

156 Exhibit 544, Statement of Martin Reason, 1 September 2011, Annexure MJR-7 [p3: para 100].

157 Exhibit 544, Statement of Martin Reason, 1 September 2011, Annexure MJR-6, Attachment A [p1: para 1(iv)].

158 Exhibit 883, Document number 6, Common expert reading list A, Brisbane, Sinclair Knight Merz, Brisbane River Flood Study: Further Investigation of Flood Frequency Analysis Incorporating Dam Operations and CRC-Forge rainfall estimates – Brisbane River (Final), 18 December 2003 [p5].

159 Exhibit 883, Document number 2, Common expert reading list A, Brisbane, Sinclair Knight Merz, City Design – Flood Modelling Services, Recalibration of the Mike11 Hydraulic Model and Determination of the 1 in 100 AEP Flood Levels, 5 February 2004 [p11].

160 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p29: para 116]. See also [p63: para 232].

161 Exhibit 952, Transcript of Interview – Commission Staff with Barry Ball, 7 November 2011 [p43-44].

162 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p15: para 61].

163 Exhibit 947, Statement of Gavin Blakey, 4 November 2011 [p19-21: para 77-86]; Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4837: line 1]; Transcript, Barry Ball, 10 November 2011, Brisbane [p4904: line 3].

164 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4838: line 29].

165 Transcript, 26 October 2011, Brisbane [p4388-4389, 4397-4401].

166 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4397: line 39]. See Transcript, 26 October 2011, Brisbane [p4397-4401].

167 Transcript, Sharmil Markar, 26 October 2011, Brisbane [p4398: line 15]; Transcript, Neil Collins, 26 October 2011, Brisbane [p4398: line 46]; Transcript, Drew Bewsher, 26 October 2011, Brisbane [p4399: line 16].

168 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4397: line 49].

169 Transcript, Drew Bewsher, 26 October 2011, Brisbane [p4399: line 27].

170 Transcript, Neil Collins, 26 October 2011, Brisbane [p4398: line 25]; Transcript, Michael Leonard, 26 October 2011, Brisbane [p4401: line 16]; Transcript, Erwin Weinmann, 26 October 2011, Brisbane [p4400: line 24].

171 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4840: line 5].

172 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4838-4843].

173 See section 2.6.3, above.

174 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p4-5: para 14-15].

175 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p11: para 23].

176 Ipswich City Council, Submission No. 2, 28 April 2011 [p54: para 18.6(b)-(c)].

177 Exhibit 883, Document number 1, Common expert reading list A, Ipswich, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis (Final Report), October 2011 [p12: para 26].

178 Exhibit 883, Document number 1, Common expert reading list A, Ipswich, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis (Final Report), October 2011 [p12: para 26]. The chief executive officer of Ipswich City Council gave evidence that that section of Mr Babister's report was accurate: Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p11: para 23].

179 Exhibit 883, Document number 1, Common expert reading list A, Ipswich, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis (Final Report), October 2011 [p12: para 26].

180 Second Submission of Ipswich City Council, 28 April 2011 [p38-39: para 14.8]; Babister's Bremer Report [p12: para 27]; [p14: para 33, Table 1].

181 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p14: para 37].

182 See *Resolution*, above and Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-3 [p1].

183 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p17: para 51]; Annexure CCW-10; Annexure CCW-14.

184 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p16: para 45].

185 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p15-18: para 44-52]; [p21: para 63].

186 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p22: para 65].

187 Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-1 [p1].

188 Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-1 [p2].

189 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p8: para 21(c)].

190 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p8: para 21(c)].

191 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p9: para 21(d)].

192 Exhibit 883, Document number 1, Common expert reading list A, Ipswich, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis (Final Report), October 2011 [p14: Table 1].

193 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p9: para 21(e)]; Annexure CCW-1 [p9].

194 Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-23.

195 Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-23.

196 Exhibit 883, Document number 1, Common expert reading list A, Ipswich, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis (Final Report), October 2011 [p17: para 38-39].

197 Exhibit 883, Document number 1, Common expert reading list A, Ipswich, WMAwater, Supplementary Report – Ipswich Flood Frequency Analysis (Final Report), October 2011 [p17: para 39].

198 See section *2.3.5 A comprehensive study of the Brisbane River catchment.*

199 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p19: para 55].

200 Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-7 [p8]. See also Annexure CCW-20.

201 Exhibit 1017, Statement of Carl Wulff, 8 November 2011, Annexure CCW-7 [p8].

202 Sargent Consulting, Ipswich Rivers Flood Study Rationalisation Project: Phase 3 – "Monte Carlo" Analysis of Design Flows (Final Report) [p18-19].

203 Exhibit 1017, Statement of Carl Wulff, 8 November 2011 [p7: para 19].

204 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p7].

205 Exhibit 992, Submission of RACQ – Flood Mapping [p1]; Exhibit 993, Submission Local Government Association of Queensland [p1]; Exhibit 994, Submission of Insurance Council of Australia – Flood Mapping [p1]; Exhibit 995, Submission of Ipswich City Council – Flood Mapping [para 3.2]; Exhibit 919, Submission of Commonwealth Government – Flood Mapping [p2: para 10]. It is also supported in the Queensland Reconstruction Authority draft guidelines *Planning for stronger, more resilient floodplains: Part 2 - Measures to support floodplain management in future planning schemes*, which was released for public consultation in January 2012.

206 Exhibit 996, Submission Four of Brisbane City Council [p12]; Exhibit 917, Submission of State of Queensland – Flood Mapping [p4]; Exhibit 992, Submission of RACQ – Flood Mapping [p1]; Exhibit 994, Submission of Insurance Council of Australia – Flood Mapping [p1]; Exhibit 993, Submission of Local Government Association of Queensland [p1]; Exhibit 995, Submission of Ipswich City Council – Flood Mapping [para 1.2(b), 3.1, 37].

207 Exhibit 917, Submission of State of Queensland – Flood Mapping [p4]; Exhibit 993, Submission from Local Government Association – Flood Mapping [p4]; Exhibit 996, Submission Four of the Brisbane City Council [p12].

208 Exhibit 996, Submission Four of Brisbane City Council [p12]; Exhibit 995, Submission of Ipswich City Council – Flood Mapping [para 3.9].

209 Transcript, Russell Cuerel, 5 October 2011, Brisbane [p3708: line 50]; Exhibit 728, Statement of Russell Cuerel, 14 September 2011 [p5: para 8(b)].

210 Transcript, Russell Cuerel, 5 October 2011, Brisbane [p3702: line 10].

211 Exhibit 919, Submission of the Commonwealth Government – Flood Mapping [p3: para 16]; Exhibit 917, Submission of the State of Queensland – Flood Mapping [p6].

212 Exhibit 917, Submission of the State of Queensland [p6].

213 Exhibit 917, Submission of the State of Queensland – Flood Mapping [p6]; Exhibit 919, Submission of the Commonwealth Government – Flood Mapping [p3-4: para 24].

214 Exhibit 919, Submission of the Commonwealth Government – Flood Mapping [p5: para 33]; Exhibit 917, Submission of the State Government – Flood Mapping [p8]; Exhibit 534, Statement of Gary Mahon, 8 September 2011 [p24: para 119; p25: para 120].

215 Exhibit 534, Statement of Gary Mahon, 8 September 2011 [p24-25: para 119-120].

216 Exhibit 917, Submission of the State of Queensland – Flood Mapping [p4-5]. Since this submission was received, the Queensland Reconstruction Authority has released, for public consultation, a draft guideline *Planning for stronger, more resilient floodplains: Part 2 - Measures to support floodplain management in future planning schemes*. At page 5 it indicates that, while the Queensland Government's position is that responsibility for flood mapping should rest at the local level, there is a significant role for regional planning committees to oversee and co-ordinate at the catchment level.

217 Correspondence from Queensland Government, 29 February 2012.

218 Exhibit 993, Submission of the Local Government Association of Queensland – Flood Mapping [p3]; Exhibit 994, Submission of the Insurance Council of Australia – Flood Mapping [p1: para 2.1]; Exhibit 995, Submission of Ipswich City Council – Flood Mapping [para 3.7]; Exhibit 992, Submission of RACQ Insurance – Flood Mapping [p1-2].

219 Exhibit 995, Submission of Ipswich City Council – Flood Mapping [para 3.7]; Exhibit 993, Submission of Local Government Association of Queensland [p3]; Exhibit 994, Submission of the Insurance Council of Australia – Flood Mapping [p1: para 2.1]; Exhibit 992, Submission of RACQ Insurance – Flood Mapping [p1-2].

220 Exhibit 993, Submission of Local Government Association of Queensland [p3-4].

221 Transcript, Julie McLellan, 9 November 2011, Brisbane [p4812: line 41]; Exhibit 951, Transcript of Interview – Commission Staff with Barry Ball, 28 October 2011 [p2].

222 Transcript, Barry Ball, 10 November 2011, Brisbane [p4899: line 42]; Exhibit 951, Transcript of Interview – Commission Staff with Barry Ball, 28 October 2011 [p2-3].

223 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4827: line 17]; Exhibit 951, Transcript of Interview – Commission Staff with Barry Ball, 28 October 2011 [p2].

224 Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4835: line 47].

225 See Exhibit 951, Transcript of Interview – Commission Staff with Barry Ball, 28 October 2011 [p5-6].

226 See also the statement in the independent review panel terms of reference Exhibit 883, Document number 1, Common expert reading list A, Brisbane, Independent Review Panel (Russell Mein, Colin Apelt, John Macintosh, Erwin Weinmann), Review of Brisbane River Flood Study: Report to the Brisbane City Council. See Transcript, Gavin Blakey, 9 November 2011, Brisbane [p4834: line 12].

227 See Exhibit 951, Transcript of Interview – Commission Staff with Barry Ball, 28 October 2011 [p7].

228 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4387: line 51]; Transcript, Michael Leonard, 26 October 2011, Brisbane [p4388: line 7].

229 See, for further information about the limitations of models, section *16.14 The effect of releases from Wivenhoe Dam on flooding in the Brisbane River*.

230 See Exhibit 951, Transcript of Interview – Commission Staff with Barry Ball, 28 October 2011 [p10].

231 Transcript, Barry Ball, 10 November 2011, Brisbane [p4905: line 14].

232 Transcript, Mark Babister, 26 October 2011, Brisbane [p4362: line 9].

233 Transcript, Mark Babister, 26 October 2011, Brisbane [p4362: line 32; p4363: line 7].

234 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p6: para 17]; Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p7: para 19].

235 Transcript, Erwin Weinmann, 26 October 2011, Brisbane [p4415: line 23]; Transcript, Colin Apelt, 26 October 2011, Brisbane [p4416: line 20].

236 See also: Transcript, Mark Babister, 26 October 2011, Brisbane [p4415: line 14].

237 Transcript, Erwin Weinmann, 26 October 2011, Brisbane [p4415: line 23]; Transcript, Mark Babister, 26 October 2011, Brisbane [p4415: line 6]; Transcript, Colin Apelt, 26 October 2011, Brisbane [p4416: line 20].

238 Transcript, Drew Bewsher, 26 October 2011, Brisbane [p4415: line 47].

239 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4417: line 16].

240 See www.ga.gov.au/flood-study-search.

241 Inquiry into flood insurance and related matters, September 2011, www.ndir.gov.au/content/report/downloads/NDIR_final.pdf, recommendation number 25.

242 See section *2.3.2 A comprehensive study of the Brisbane River catchment*, above.

243 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p6: para 18].

244 Transcript, Sharmil Markar, 26 October 2011, Brisbane [p4420: line 26].

245 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4417: line 38]. See also Exhibit 995, Ipswich City Council – Flood Mapping Submission, 4 November 2011 [para 3.22].

246 Exhibit 881, Joint Expert Statement of the Brisbane River Flood Frequency Panel, 25 October 2011 [p6: para 17].

247 Exhibit 919, Submission of the Commonwealth Government – Flood Mapping [p6: para 39]; Exhibit 917, Submission of State of Queensland – Flood Mapping [p8-9]; Exhibit 993, Submission of Local Government Association of Queensland – Flood Mapping [p5].

248 Exhibit 996, Brisbane City Council – Flood mapping submission Four dated 4 November 2011 [p14]; Exhibit 992, Submission of RACQ – Flood Mapping [p3].

249 Transcript, Rory Nathan, 26 October 2011, Brisbane [p4363: line 1-10].

250 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p xv].

251 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p27, 36]; Emergency Management Australia, Manual 19 - Managing the Floodplain, 1999 [p xiii, xiv].

252 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p14].

253 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p14-15].

254 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p57].

255 Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p51]; Submission of Colin Apelt, 7 November 2011 [p2].

256 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p24]; Exhibit 968, Floodplain Development Manual: the management of flood liable land [p14]. Similarly, the New South Wales Government's Floodplain Development Manual provides that the State Government's role in floodplain management encompasses policy and legislative support, the provision of specialised technical advice, the provision of emergency management and financial assistance through a subsidised program of floodplain risk management works and measures. See also National Flood Risk Advisory Group, Flood Risk Management in Australia: Vision, Objectives and Guidance, printed in The Australian Journal of Emergency Management, Vol. 23, No. 4 [p24].

257 Exhibit 961, Statement of Drew Bewsher, 9 November 2011 [p1].

258 Council has submitted that it has spent approximately $870 million on flood-related planning, mitigation, awareness and response initiatives since 2004: Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p34-35: para 139].

259 Exhibit 946, Statement of Julie McLellan, 4 November 2011, Annexure JAM-12.

260 Exhibit 299, Statement of Gordana Petroccitto, 3 May 2011, Attachment GP-02.

261 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p36: para 149].

262 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p37: para 152(d)].

263 Exhibit 946, Statement of Julie McLellan, 4 November 2011 [p43: para 168].

264 Initial Submission of Brisbane City Council [p12]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [para 163].

265 Initial Submission of Brisbane City Council [p10]; Exhibit 946, Statement of Julie McLellan, 4 November 2011 [para 164].

266 Exhibit 1020, Statement of Evan Pardon, 20 October 2011, Attachment 2].

267 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p14]; Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p28: para 5.3.4].

268 For the full list of planning schemes see the Department of Local Government and Planning website: www.dlgp.qld.gov.au/local-area-planning/local-government-planning-schemes.html.

269 Exhibit 538, Statement of Brendan Nelson, 15 September 2011, Attachment BJN-13 [p12].

270 Exhibit 538, Statement of Brendan Nelson, 15 September 2011, Attachment BJN-13.

271 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p28: para 5.3.4].

272 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p29: para 5.4.6]; Exhibit 917, Submission of the State of Queensland – Flood Mapping [p4]. See also the public consultation draft guideline *Planning for stronger, more resilient floodplains: Part 2 - Measures to support floodplain management in future planning schemes*, at page 11.

273 Transcript, Gary White, 7 November 2011, Brisbane [p4608: line 12]; Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p28: para 5.4.5].

274 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p29: para 5.4.9-5.4.10].

275 A town planner consulted by the Commission suggested some of these criteria. See Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p28: para 5.3.4; p29: para 5.4.8-5.4.10; p30: para 5.6.2].

276 State Planning Policy 1/03: *Mitigation the Adverse Impacts of Flood, Bushfire and Landslide* [p16: para A3.2].

277 Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p10: para 7.14]; State Planning Policy 1/03: *Mitigation the Adverse Impacts of Flood, Bushfire and Landslide* [p16: para A3.2]; Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p10: para 18]; Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p75].

278 Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, October 2011 [p7: para 7.3].

279 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effects of Flood*, 10 November 2011 [p19: para 4.1.5]; Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry*, October 2011 [p7: para 7.3; p8: para 7.10; p10: para 7.14]; Exhibit 881, Joint Expert Statement

of the Brisbane River Flood Frequency Panel, 25 October 2011 [p4: para 10]; Exhibit 882, Joint Expert Statement of the Bremer River Flood Frequency Panel, 25 October 2011 [p4: para 10]; Exhibit 971, Drew Bewsher and John Maddocks, Do we need to consider floods rarer than 1% AEP?', 2003 [p1, 4-5]; Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p18-9].

280 Transcript, Steve Reynolds, 11 November 2011, Brisbane [p4954: line 50]; Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p18: para 4.1.4 – p19: para 4.1.5].

281 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p73].

282 State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p33: A2.11; p35: A2.19].

283 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effects of Flood*, 10 November 2011 [p30: para 5.6.2]; Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p24: para 79]; Exhibit 966, Report of Paul Grech, *Report to the Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p28: para 13.7 - p30: para 13.8].

284 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p20: para 4.3.3]; Exhibit 966, Report of Paul Grech, *Report to the Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p19: para 10.5].

285 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood,* 10 November 2011 [p28: para 5.3.4]; Transcript, Greg Vann, 11 November 2011, Brisbane [p4990: line 1–15]; Exhibit 966, Report of Paul Grech, *Report to the Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p20: para 10.7].

286 Trevor Johnson, Cardno, *Flooding Behaviour*, 11 November 2011 [p3-4].

287 Transcript, Steve Reynolds, 11 November 2011, Brisbane [p4955: line 48].

288 Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p24: para 79]; Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p20: para 10.7]; Transcript, Paul Grech, 11 November 2011, Brisbane [p4971: line 15].

289 Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p20: para 10.7].

290 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p71].

291 Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p24: para 76].

292 Exhibit 1020, Statement of Evan Pardon, 20 October 2011, Attachment 2.

293 Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011, Appendix C [p6].

294 Transcript, Steve Reynolds, 11 November 2011, Brisbane [p4955: line 13]; Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p22: para 68]; Transcript, Greg Vann, 11 November 2011, Brisbane [p4990: line 3].

295 State Planning Policy 1/03: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p16: para A3.1-A3.2].

296 Transcript, Steve Reynolds, 11 November 2011, Brisbane [p4955: line 18]; Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p25: para 80].

297 Report of Trevor Johnson, 11 November 2011 [p4-5].

298 Exhibit 927, Statement of Steven Jacoby, 17 October 2011 [p2: para 12].

299 State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p35-36: para A2.23].

300 For a description of what constitutes a flood frequency analysis, see section *2.3.2 A comprehensive flood study of the Brisbane River catchment*; Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p22; para 4.5.4 – 4.5.5].

301 State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p35: para A2.23].

302 Ordered drainage data is a stream classification system used to determine a hierarchy of streams. Once this data set is overlaid on the map, it is possible for DERM officers to select the stream orders, or drainage lines, to include on the Interim Floodplain map. (Exhibit 538, Statement of Brendan Nelson, 15 September 2011 [p13: para 256(d)].

303 Generally 10 metre contours. More accurate contours are used, if they are available. Exhibit 927, Statement of Steven Jacoby, 17 October 2011, Attachment SKJ-11 [p7].

304 Exhibit 927, Statement of Steven Jacoby, 17 October 2011, Attachment SKJ-11.

305 Transcript, Steven Jacoby, 8 November 2011, Brisbane [p4726: line 1; p4727: line 51]; Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2819: line 40].

306 Transcript, Steven Jacoby, 8 November 2011, Brisbane [p4729: line 1].

307 Exhibit 927, Statement of Steven Jacoby, 17 October 2011, Attachment SKJ-11 [p8: para 9].

308 Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2823: line 40]; Transcript, Brendan Nelson, 20 September 2011, Brisbane [p2833: line 55].

309 Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2817: line 44; p2821: line 1]; Transcript, Brendan Nelson, 20 September 2011, Brisbane [p2830: line 30]; Transcript, Brendan Nelson, 8 November 2011, Brisbane [p4706: line 15].

310 Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2820: line 19; p2821: line 28; p2823: line 28]; Transcript, Brendan Nelson, 20 September 2011, Brisbane [p2829: line 46; p2831: line 1; p2831: line 24; p2836: line 43].

311 Exhibit 925, Supplementary Statement of Brendan Nelson, 21 October 2011 [p7: para 229]; Statement of Brendan Nelson, 30 November 2011 [p28: para 495; p29: para 501].

312 Third statement of Brendan Nelson, 30 November 2011 [p14: para 431].

313 Transcript, Robert Fredman, 13 October 2011, Gympie [p4064: line 3].

314 Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2823: line 45].

315 Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2823: line 45].

316 Transcript, Brendan Nelson, 19 September 2011, Brisbane [p2819: line 26; p2820: line 9]; 20 September 2011, Brisbane [p2834: line 39]; Exhibit 927, Statement of Steven Jacoby, 17 October 2011, Attachment SKJ-11 [p11]; Statement of Brendan Nelson, 30 November 2011 [p25: para 481]. See also Temporary State Planning Policy 2/11: *Planning for stronger, more resilient floodplains*, November 2011 [p20-21].

317 Exhibit 999, Statement of Paul Bawden, 13 October 2011 [p2: para 4]; Exhibit 998, Statement of Phil Berting, undated [p2: para 4]; Exhibit 766, Statement of Andrew Fulton, 6 October 2011 [p2: para 3.1].

318 Exhibit 926, Supplementary Statement of Brendan Nelson, 21 October 2011, Attachment BJN-43 [p8].

319 *Planning for stronger, more resilient floodplains: Part 1 - Interim measures to support floodplain management in existing planning schemes* [p9].

320 Exhibit 927, Statement of Steven Jacoby, 17 October 2011 [p4: para 22; p7: para 37].

321 Transcript, Brendan Nelson, 8 November 2011, Brisbane [p4707: line 54].

322 Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, October 2011 [p22: para 10.10].

323 Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p26-27: para 91]; Transcript, Steve Reynolds, 11 November 2011, Brisbane [p4959: 21].

324 The Guidelines to the State Planning Policy suggest that care should be taken when using such information to make a determination about flood risk. See, State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p36: para A2.25].

325 Exhibit 962, Report of Steve Reynolds, *Flood Mapping in Queensland Planning Schemes*, 9 November 2011 [p27: para 91(d)]; Transcript, Steve Reynolds, 11 November 2011, Brisbane [p4959: line 30].

326 Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, October 2011 [p22: para 10.12].

327 State Planning Policy 1/03 Guideline: *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* [p36: para A2.25 – p37: para A2.26].

328 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p28: para 5.4.4]; Exhibit 917, Submission from the State of Queensland regarding Flood Mapping [p4].

329 See: Queensland Floods Commission of Inquiry, Interim Report, Chapters 3 - 6, 2011 [p 112 - 227].

330 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p36: para B.4; p59: para H.1].

331 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p99].

332 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p17].

333 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p17].

334 Emergency Management Australia, Manual 19 - Managing the Floodplain, 1999 [p3: para 10].

335 Exhibit 1007, Standing Committee on Agriculture and Resource Management (SCARM), Floodplain management in Australia: best practice principles and guidelines, SCARM Report 73, 2000 [p18-19, 69].

336 Report on the Environmental Scan into a National Approach to Flood Modelling, June 2011 [p5: para 21].

337 Exhibit 37, Statement of James Davidson, 4 April 2011, JD-1 [p8: para 46].

338 Exhibit 37, Statement of James Davidson, 4 April 2011, JD-1 [p772: para 1].

339 For a more detailed discussion of the Bureau's flood predictions and warnings during the 2010/2011 floods, see Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 4.2.

340 Exhibit 404, Statement of Ken Morris, 3 May 2011 [p13: para 3.1-p15: para 3.14].

341 Exhibit 404, Statement of Ken Morris, 3 May 2011 [p15: para 3.10].

342 Exhibit 854, Statement of Carl Wulff, 13 October 2011 [p6: para 40].

343 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 4.1.2 [p135].

344 Exhibit 917, Submission of the State of Queensland – Flood Mapping [p9]; Exhibit 994, Submission of Insurance Council of Australia – Flood Mapping [p4: para 8.1]; Exhibit 996, Submission Four of Brisbane City Council [p13, 16].

345 Arnison, P, Gotterson, R, Apelt, C, Independent Review of Brisbane City Council's Response to the January 2011 Flood [p18]; Exhibit 736, Statement of Jeanenne Wilkinson [p14: para 70, 71]; Transcript, Mark Middendorp, 21 September 2011, Brisbane [p2956: line 55].

346 Exhibit 965, Report of Greg Vann, *Planning Aspects of Alternative Approaches to Mapping the Effect of Flood*, 10 November 2011 [p18: para 4.1.2]; Exhibit 561, Statement of Peita McCulloch, 15 September 2011 [p3: para 5]; Transcript, Peita McCulloch, 20 September 2011, Brisbane [p2880: line 37]. See also: Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 4.1.2 [p135].

347 Queensland Floods Commission of Inquiry, *Interim Report*, 2011, Section 4.1.2 [p135].

348 For the purposes of generating the January 2011 Brisbane River flood level for the Brisbane City Council FloodWise Property Report, information was derived from the Queensland Reconstruction Authority maps. See Brisbane City Council, FloodWise Property Report', www.brisbane.qld.gov.au/community/community-safety/disasters-and-emergencies/types-of-disasters/flooding/understanding-your-flood-risk/floodwise-property-report/index.htm, accessed 22 January 2011.

349 Not all sources of information are available for every lot within Brisbane City Council's jurisdiction.

350 Exhibit 854, Statement of Carl Wulff, 13 October 2011 [p3: para 20].

351 Exhibit 993, Submission of Local Government Association of Queensland – Flood Mapping, November [p6]; Exhibit 992, Submission of RACQ – Flood Mapping, 3 November 2011 [p5].

352 Exhibit 919, Submission of the Commonwealth Government – Flood Mapping [p6: para 39].

353 Transcript, 19 September 2011, Anthony Leighton [p2793: line 50]; Transcript 27 September 2011, David Dunworth [p3225: line 20].

354 Section 245, *Sustainable Planning Act 2009*.

355 Section 737, *Sustainable Planning Act 2009*.

356 Sections 738-740, *Sustainable Planning Act 2009*.

357 Conveyancing practice in Queensland is regulated by the *Property Agents and Motor Dealers Act 2000*.

358 See section 52A of the *Conveyancing Act 1919* (NSW) and section 4 and schedule 1 of the *Conveyancing (Sale of Land) Regulation 2010* (NSW). These provisions provide that a seller must attach a Section 149 Property Certificate for the land the subject of the contract for sale.

359 Section 52A(7), *Conveyancing Act 1919* (NSW).

360 Transcript, Gary White, 7 November, Brisbane [p4628].

361 Correspondence from King and Company, 24 January 2012.

362 Exhibit 912, Statement of John Adams, 25 October 2011 [p12: para 38].

363 The introduction of national guidelines for flood mapping was recommended in the Natural Disaster Insurance Review report. See: Natural Disaster Insurance Review, Inquiry into Flood Insurance and related matters, Recommendation 25, September 2011, www.ndir.gov.au/content/report/downloads/NDIR_final.pdf, accessed 22 January 2011.

364 Transcript, Mark Babister, 26 October 2011, Brisbane [p4373: line 11].

365 Transcript, Mark Babister, 26 October 2011, Brisbane [p4373: line 25].

366 Exhibit 919, Submission of the Commonwealth Government – Flood Mapping [p3-4: para 24].

367 It does not represent a comprehensive approach to floodplain management: See Exhibit 966, Report of Paul Grech, *Report to Queensland Floods Commission of Inquiry Addressing Town Planning Issues*, 15 October 2011 [p16: para 8.18].