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14 October 2011
Ref: J1985L_3

Mr Scott Sharry
Clayton Utz
Brisbane

By Email: [redacted]

Dear Mr Sharry

QUEENSLAND FLOODS COMMISSION OF INQUIRY
REVIEW OF ASPECTS OF THE REPORT OF WMAWATER (SEPT 2011)

Following your recent telephone instructions I have prepared a review of aspects of the September 2011 report of WMAwater entitled "*Brisbane River 2011 Flood Event – Flood Frequency Analysis*". My advice is set out below. This review has been prepared under significant time constraints and has been limited to the matters listed below in bold type face.

What enquiries and investigations might affect any determination of the 1% AEP flood level following the January 2011 flood event?

1. This question must be answered in the context of information that is already available and the use to which the determination of the new flood levels will be put. Models are only approximations of real behaviour and it is always possible to improve model accuracy through additional effort but the law of diminishing returns applies.

2. For example, in the context of other parts of Queensland where no flood data exists, the sort of approach espoused in the temporary planning policy using the interim floodplain assessment overlay might be appropriate. (However such interim overlays would not be appropriate for Brisbane).

3. Given the (large – by Australian standards) number of flood studies that have already been undertaken and given the interim DFL that Council has implemented, the enquiries and investigations to be undertaken would, in my opinion, be similar to the new flood study that has been proposed, i.e. a full scale review of both flood frequency and rainfall-runoff approaches, in the light of the new information from the 2011 event.

4. In general terms, WMAwater have:

   (a) *Step 1* – used a flood frequency approach to estimate pre-dam flow frequencies;
   (b) *Step 2* – converted this to a post-dams flow regime using a mixture of past (i.e. 2003) and new (i.e. 2011) information; and
   (c) *Step 3* – applied these flows to calculate flood levels using a hydraulic model (that has been improved using 2011 data).

5. I do not find *Step 1* of much benefit. This uses a procedure previously applied by others (e.g. BCC, June 1999) which has also been rejected by others because of

uncertainties in the available data. WMAwater have not addressed these uncertainties (or undertaken sensitivity tests to examine the potential impacts of these uncertainties). I have provided further notes on these uncertainties in the Attachment.

6. In relation to *Step 2*, WMAwater have brought information to light which demonstrates that longer floods with bigger volumes get attenuated less by the dams. This is not in itself remarkable. There are also other factors affecting the attenuation (e.g. spatial and temporal distributions) and the 2011 event has and will continue to provide very valuable information to improve our understanding of hydrology and flood behaviour in the catchment during major flood events.

7. In relation to *Step 3*, the 2011 flood has allowed better calibration of the MIKE11 model and allowed flood level predictions to be made more accurately over more areas of the floodplain (once the design flows were determined).

8. Because of improvements in *Step 2* discussed above, WMAwater indicates the 1% AEP flood levels will be higher. I believe that this will be the likely outcome of the proposed new flood study (although at different levels from those determined by WMAwater). However I do not believe there is much benefit in publishing new estimates of flood levels from the WMAwater report at this time because:

    (a) the flood levels have uncertainties associated with them and the work has not been done to minimise these (e.g. allowing for tides, a more rigorous assessment of river bed/bank changes);
    (b) the proposed new flood study will produce new flood levels which will be different from the WMAwater flood levels; and
    (c) Brisbane City Council has already adopted an interim DFL that is equal to or higher than the 2011 flood level. WMAwater's new 1% AEP flood levels are lower than the interim DFL.

What factors affect the reliability of converting historically recorded levels into flows and whether or not the WMAwater report has had regard, or sufficient regard, to those factors?

9. These factors are:
    (a) uncertainties in the original measurements;
    (b) uncertainties in adjustments made for dredging and other river bed/bank changes;
    (c) uncertainties in discharge estimates due to tidal influences; and
    (d) uncertainties in discharge estimates due to the rating curve.

10. These factors are discussed in the attachment. In summary, based on the information I have been able to look at so far in the time available to me, it is appears:

    (a) there are significant uncertainties associated with the preparation of the discharge estimates prepared by WMAwater for use in their flood frequency analysis;
    (b) these uncertainties directly impact on the estimate of the 1% AEP discharge which WMAwater have derived;
    (c) many of these uncertainties are acknowledged by WMAwater. It would appear that they have had insufficient time available to address these uncertainties;

(d) it would have been good practice to test the sensitivity of the 1% AEP discharge estimate to potential changes in the discharges used to prepare the flood frequency analysis. This has not been done;

(e) the 90% confidence limits for the derived 1% AEP discharge are already moderate (i.e. 10,000m^3/s to 22,000m^3/s). These limits however assume no inaccuracies in the historical discharges. Therefore the true confidence limits will be somewhat larger than those quoted; and

(f) many of the difficulties with carrying out flood frequency analyses at the Port Office gauge have been recognised by previous studies which is why these studies have carried out their analyses further upstream beyond the influence of tides and dredging.

Review the appropriateness of Figure 3 (page 15, WMAwater report) and the use to which it has been put within the report.

11. Figure 3 contains a "*pre to post dam estimation line*" prepared by WMAwater. A copy of Figure 3 has been reproduced below.

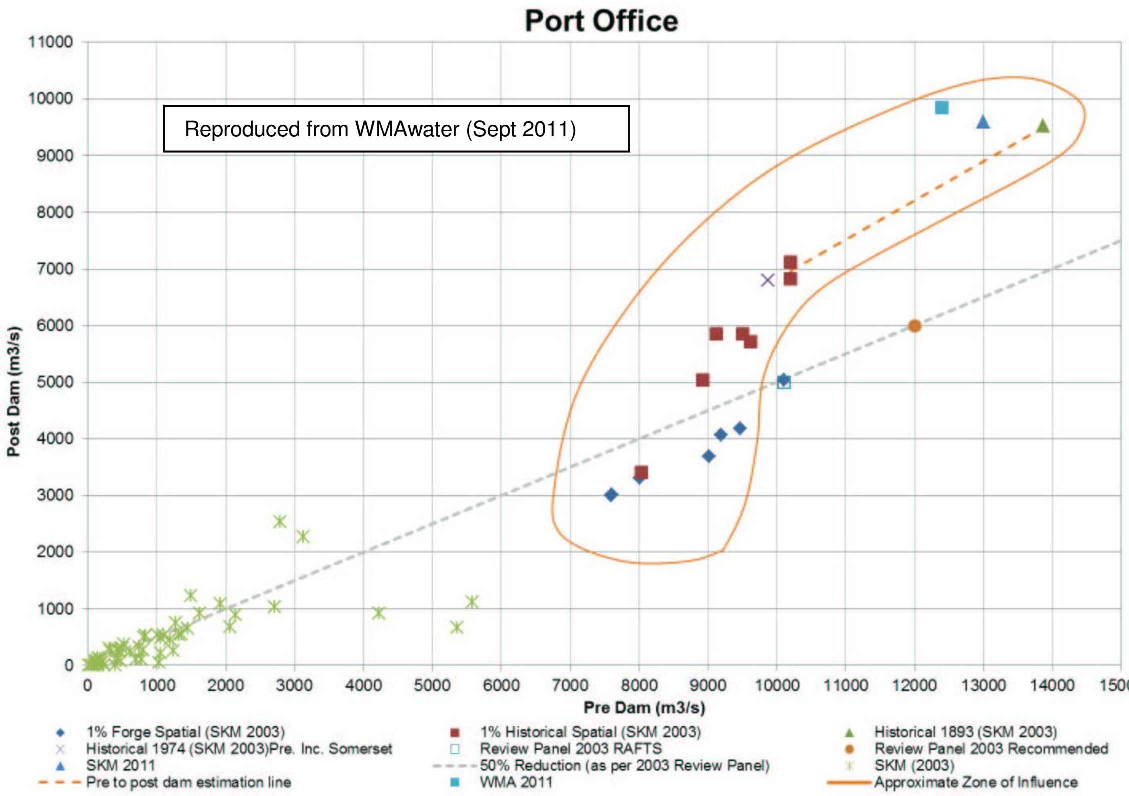

Figure 3: Port Office- Pre and Post dam flow

12. This estimation line was used by WMAwater to convert their pre-dams 1% AEP discharge estimate of 13,000m^3/s to a post-dams discharge of 9,000m^3/s (without the influence of the 2011 event). It was also used (together with 2011 flood data) to estimate the post-dams discharge of 9,500m^3/s (assuming knowledge of the 2011 flood). It is therefore a vital component of WMAwater's process for the determination of 1% AEP flows at the Port Office gauge.

13. The procedure used by WMAwater to prepare this line has not been explained in their report. The line appears to be either:

(a) a line representing a 32% reduction in pre-dam flows; and/or
(b) a line drawn between data for the 1893 flood and the highest two "*1% Historical Spatial*" data points.

14. The "*pre to post dam estimation line*" assumes a linear relationship between pre- and post-dams discharges. There will be a reduction in the amount of attenuation as the magnitude of flood discharges and volumes increases during major floods so a curve rather than a line is appropriate.

15. Some of "*1% Historical Spatial*" data on Figure 3 do not appear to be plotted in the correct position. The data likely originates from the "*critical flows*" presented in Appendix H of SKM (2003) for the seven historical spatial patterns considered by SKM. For some of the seven patterns however the data plotted are for different storm durations. Thus the pre-dam and post-dam discharges do not correspond to the same catchment event.

16. The "*Historical 1974*" data point included on the figure includes for the effects of Somerset Dam in the pre-dams discharge. WMAwater appear to be aware of this but it is unclear why it was included on the figure without first making an adjustment to remove the effects of Somerset Dam.

17. The probability of the "*1% FORGE Spatial*" data is known however the probability of the "*1% Historical Spatial*" data is not known. A difficulty arises in using such a diagram in the manner that WMAwater have used it because for a given pre-dam discharge, all of the data points do not have the same probability of occurrence.

18. There is considerable scatter in the data points on Figure 3. Floods come in all shapes and sizes. If all of them were plotted the scatter would likely be much wider than that shown. Floods that have more volume for a given pre-dam discharge will likely plot higher on the figure than those with a lower volume for the same discharge as these are subject to less attenuation by the dams. A range of attenuations is possible.

19. A key question is what attenuation amount from the range of possible attenuation amounts, should be used to attenuate the 1% AEP pre-dam discharge determined by WMAwater from their flood frequency analysis? This issue has not been explored by WMAwater.

20. In conclusion, assuming the pre-dam discharge has a probability of 1%, the post-dam discharge determined using the "*pre to post dam estimation line*" will likely have some bias away from a 1% AEP event.

21. WMAwater have no doubt been under significant time pressures in responding to the questions asked of them by the Commission. They have quickly and rather pragmatically produced an estimate of the 1% AEP post-dams discharge at the Port Office gauge which in my opinion, still contains significant uncertainties.

Yours sincerely

[redacted]

Drew Bewsher
Director

ATTACHMENT TO LETTER OF 14 OCTOBER 2011

Uncertainty in 'Measurements' of Flood Heights at the Port Office Gauge before 1875

22. The Port Office gauge was likely installed between 1875 and 1878[1]. Consequently records prior to 1875 must have been inferred[2]. This process must increase the uncertainty associated with these original 'measurements'.

23. WMAwater's flood frequency analysis makes use of 30 flood peaks[3]. Leaving aside 1893, 1974 and 2011, the two next biggest floods occurred in the period before 1875 where there was no formal tide gauge at the Port Office. These floods were 1841 and 1844.

24. The Brisbane Flood Notice Board[4] which was operational in 1911 as a flood warning system used information from historical floods and contained a diagram which "*includes all the floods about which accurate information is available*". No floods before 1893 are shown.

25. WMAwater have omitted the flood of 1845[5] without explanation. This may be a typographical error or it may have been intentional if they considered the flood data unreliable. It also occurred in the period before formal gauges were installed.

26. WMAwater ranks the 1841 flood as the next biggest flood after 1893 (and bigger than 2011). In relation to the 1841 flood, the Bureau of Meteorology have reported "*its exact height is uncertain*"[6]

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[1] The Maritime Safety Queensland website at http://www.msq.qld.gov.au/Tides/Sea-level-measurement-in-Queensland.aspx records that "*The Engineer-in-Chief of the Harbours and Rivers Department from 1875 to 1889, William Nisbet, established permanent tide gauges in the Brisbane River for river works and dredging projects*". Further "*by 1878, six gauges were installed between Brisbane and Lytton*".

[2] In the time available to me I have not found any records of the original measurements themselves or the method used to infer the flood height peak at the Port Office gauge site (except for the reference to the 1841 flood quoted by WMAwater at their Paragraph 40).

[3] There is a general lack of detail in WMAwater's report (which is no doubt due to the limited time they had available for its preparation). It is not always obvious what data sources they have used. WMAwater do not list all the floods they used. Only the largest floods are reproduced in their Table 7. Therefore it's difficult to be confident about exactly which floods they used. Nevertheless their Table 6 shows they used 30 floods (or 31 if 2011 was included). As Table 1 of BCC (June 1999) also used 30 floods, I have assumed WMAwater used the same ones as in BCC's flood frequency analysis.

[4] http://www.bom.gov.au/hydro/flood/qld/fld_history/brisbane_notice_board.shtml This BoM article contains an extract from G.G. Bond, Divisional Officer, Brisbane, 24th January, 1911 which states "*This was a notice board for giving information to the general public of the rise and fall of flood waters at the various flood warning stations on the Brisbane River and tributaries has been erected under the clock tower of the General Post Office at the main Queen-street entrance by courtesy of the Deputy Postmaster-General*".

[5] Note also that WMAwater has not included 1845 in their list of big floods (refer their Table 8). BCC (June 1999) gave it an unadjusted height of 6.5mAHD making it a 'Rank 6' flood.

[6] Brisbane Floods, January 1974. BoM, 1974. http://www.bom.gov.au/hydro/flood/qld/fld_reports/brisbane_jan1974.pdf.

Uncertainty in Adjustments Made for Dredging and Other River Bed/Bank Changes

27. In relation to these adjustments, WMAwater have followed the approach used in BCC (June 1999), i.e.

    (a) between 1864 and 1917 subtract 1.52m (i.e. 5ft) from the measurements to account for dredging over this period; and
    (b) prior to 1864 subtract 1.92m for the above dredging and the removal of the entrance bar.

28. I have a number of difficulties associated with this approach:

    (a) changes in the river bed and banks between 1841 and 2011 have been numerous and significant[7]. There have been many more changes than the two 'step' changes in 1864 and 1917 assumed by WMAwater;
    (b) even when considering the river conditions during the 1841 floods, Henderson, in his address to Parliament in 1896 stated "*it should not be forgotten that the river conditions were then very different from what they are now*". Changes since 1896 to today would also likely have been significant;
    (c) further with the relocation of the port to Fisherman Islands in the mid to late 1970s there will have been a reduction in maintenance dredging upstream (i.e. from the new port to the City) and likely aggradation of the river bed since that time;
    (d) the height adjustments assumed by BCC and used by WMAwater are tenuous and based on very old information of doubtful accuracy (my opinion)[8]. The adjustments would also likely vary with flood magnitude. More rigorous hydraulic modelling using different river bed/bank conditions should be undertaken to identify the adjustment to be made to every recorded river height in order to provide a homogenous data set from which to prepare a more rigorous flood frequency analysis;[9]
    (e) the results of this analysis could produce discharge estimates somewhat different from that currently used. For example by reference to WMAwater's Figure 8, a 1.0m change in height would produce discharge changes of from 1,500 m^3/s to 2,500m^3/s over the range of interest (i.e. stage heights ranging from 8mAHD to 2mAHD). These are significant discharge changes which could noticeably alter the flood frequency results and the prediction of the 1% AEP discharge.

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[7] The following document provides a more complete description of the river changes particularly over the 20th Century (which is missing from the references quoted by WMAwater):
http://www.marine.uq.edu.au/marbot/publications/CRC%20coastal%202003_HC%20report/Ch%209%20Appendices.pdf

[8] I note that WMAwater at their Paragraph 100 says that they tested dredging in SKM's MIKE11 model and found that the 1.52m adjustment was 'probably appropriate'. No details however are provided so it is impossible to test this. In particular it is not known what depth and width of dredging was assumed and over what sections of the river.

[9] This is supposedly what WMAwater have recommended at the end of their Paragraph 2. It is noted that river bed cross sections are available from a survey undertaken in 1873. There are also numerous and detailed records of the dredging works undertaken over more than a century. A comprehensive assessment of these records needs to be undertaken (together with review of other river bed surveys) and revised hydraulic models describing the river at various time periods. A more complete series of height adjustments could then be prepared to allow the historical records at the Port Office gauge to be related in 2011 river conditions. This would also need to allow for tide adjustments.

Uncertainty in Discharge Estimates due to Tidal Influences

29. Figure 2 of Cossins (1978) plots the recorded stage hydrograph at Port Office during the 1974 flood. This figure has been reproduced below and demonstrates how tides can influence the Port Office flood heights and how these effects are dampened as the flood height rises.

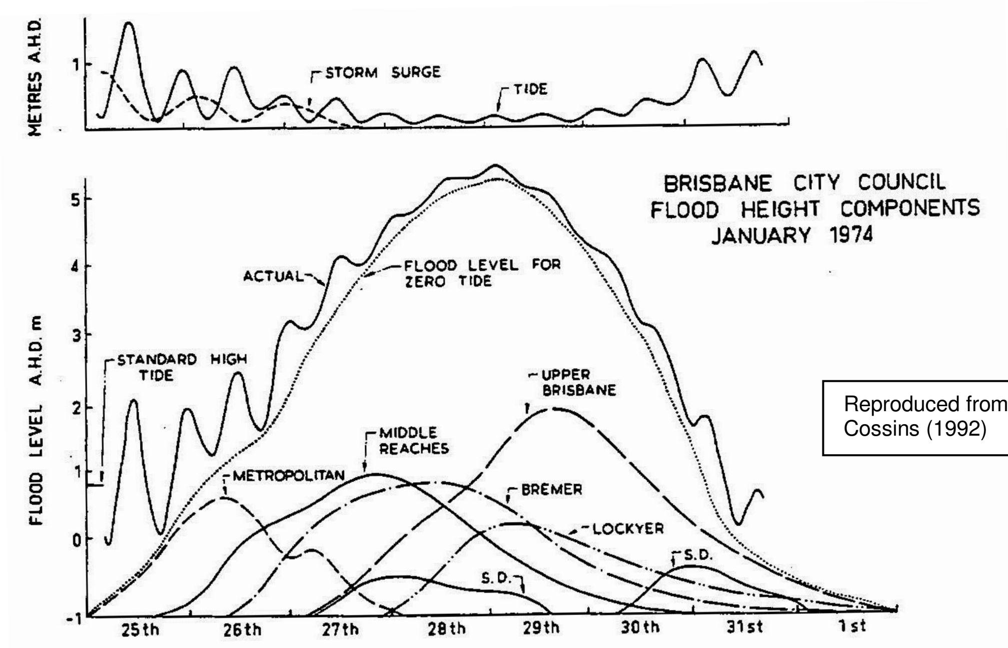

Fig. 2: Flood height components for January 1974 at Brisbane City Gauge in metres above Australian Height Datum.

Reproduced from Cossins (1992)

30. For example, when the flood height is say 1.5mAHD, at least ±0.5m or more could be due to normal tidal activity. Bigger ranges would likely occur if storm surges were present (as these often accompany floods) or spring tides. This tidal influence diminishes as the flood height rises but even at a flood level of 4mAHD, some tidal influence can be exerted.

31. The flood series used by WMAwater disregarded flows lower than 2,000m^3/s.[10] From the 'derived rating' curve in their Figure 8, this flow corresponds to a level of 1.4mAHD. Very considerable tidal influences would likely be present at this level.

32. It is likely that about two thirds of the 30 floods used in their flood frequency analysis had peak heights less than 3mAHD at the Port Office gauge. The calculation of these flows based on the derived rating will therefore be sensitive or very sensitive to the influence of tides.

33. A rigorous analysis would see each of these events analysed to remove the effect of tides.[11] (This approach has been suggested in previous studies).

[10] WMAwater's Table 10

Uncertainty in Discharge Estimates due to Rating Curve

34. This section addresses uncertainties in the conversion of flood height to discharge other than those due to measurement accuracy, dredging and tides which have been discussed above.

35. The adjustments for river bed/bank changes discussed above were made to ensure the rating curve remained stationary over the period of the flood frequency analysis. The rating curve shown in WMAwater's Figure 8 demonstrates how flood height and discharge are related at the Port Office under current conditions.

36. There are six data items included in WMAwater's Figure 8 which are discussed below. (The first two are listed under Item a):

(a) *SKM (June 1998)* and *SKM (June 1998)* – these appear to be based on recorded levels from historical floods with flows estimated from the MIKE11 models used in those studies - but I can't be sure;

(b) *SKM (2011)* – appears to be obtained directly from the MIKE11 model noting that this model was calibrated to the 2011 flood records;

(c) *1893 Event* – the orange box on Figure 8 is based on flood heights ranging from 8.35mAHD to 6.83mAHD.[12] The discharge range is 11,300m^3/s to 16,900m^3/s.[13] As discussed in the footnotes, the most likely estimate of the 1893 event is 6.83mAHD and 11,600m^3/s – so the orange box should be centred on this point (which approximates the lower left hand corner of the existing box).

(d) *1974 Event* – 5.45mAHD was the recorded height for this event. WMAwater states that previously the discharge was thought to be 9,800m^3/s but this has been revised upwards to 10,900m^3/s based on information learnt during the 2011 event.

(e) *2011 Event* – due to time limitations I have not had time to check these values.

37. By a review of the comments made in the previous paragraph, it would appear that the 2011 event has resulted in a shift of the upper section of the rating curve to the right, i.e. in the absence of the 2011 information, and based only on information from the floods of 1893 and 1974, and the previous SKM ratings, the upper part of the rating curve would have been further to the left. This 'shift' could be real (i.e. due to a better understanding of high flow behaviour obtained from the 2011 event and the better models), or, it could be due to other factors e.g. changes in the

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[11] Note that whilst the bigger floods will be influenced little by tides, the impacts on the smaller floods can still influence the shape of the ultimate flood frequency curve and the prediction of the 1% AEP discharge, and the confidence limits surrounding it.

[12] 8.35 is the recorded flood height. 6.83=8.35-1.52 (i.e. includes the adjustment for dredging). There is an inconsistency here. The centre of the box has a flood height of 7.59mAHD. This is not the height of 6.83mAHD which WMAwater has used in their Table 8.

[13] These discharges are derived from Table 10.2 of Appendix A10 of BCC (June 1999) – and are also discussed from Page 7 onwards of BCC (Dec 1999). The analysis in this later document suggests the best estimate of the 1893 flood is 11,600m^3/s which is close to the lower bound of the discharge range in the orange box. Again an inconsistency exists.

bed/banks, channel roughness, etc that haven't been adequately explained/understood to date. It may also be a combination of both these causes.

38. Whatever the reason, to use the 'derived rating' on Figure 8 to estimate all the historical discharges (i.e. for use in the flood frequency analysis) does not seem appropriate and must introduce further uncertainties into the analysis which is subsequently presented by WMAwater in their Section 7.[14]

39. A likely consequence will be that the discharges used in the flood frequency analysis are over estimated, including the discharge estimate of the resultant 1% AEP event.

[14] This might best be seen by examining the discharges listed in WMAwater's Table 7. These discharges have been obtained from the 'derived rating' on Figure 8. For example the 1893 discharge is higher than 11,600m^3/s, and the 1974 discharge is higher than both 9,800m^3/s and 10,900m^3/s [refer Paragraph 36(c) and 36(d) above].

Bewsher

Drew BEWSHER

QUALIFICATIONS

Bachelor of Engineering (Hons), University of Tasmania, 1975.
Master of Science in Civil Engineering, California Institute of Technology USA, 1977

AFFILIATIONS:

Fellow, Institution of Engineers, Australia.
Past Chairman, Sydney Water Engineering Panel and Western Sydney Water Engineering Panel, Institution of Engineers, Australia.
Member, College of Civil Engineers, Institution of Engineers, Australia.
Chartered Professional Engineer, NPER-3 Registration

FIELDS OF SPECIAL COMPETENCE

Thirty years experience in water related projects in Australia, America and South East Asia. This work has included floodplain management studies, river hydraulics and flood studies, computer modelling, hydrological studies, irrigation and salinity modelling, urban drainage investigation and design, water quality investigations, dam break studies, environmental planning and environmental impact assessment, construction supervision and the project management and economic evaluation of water resources projects. He has also provided expert testimony in legal proceedings related to flooding and drainage matters in the Supreme Court, District Court, and Land and Environment Court, and other tribunals in NSW and elsewhere.

EXPERIENCE

1986 to date | Bewsher Consulting Pty Ltd, NSW, Australia, Director

Principal responsible for a number of projects including:

Floodplain Risk Management Studies and Plans for approximately 30 NSW councils including those for the Georges River, Mullet/Brooks Creek, Fairy/Cabbage Creek, Bowral, Coffs Creek, Camden Haven, Upper Parramatta River, Grafton, Lower Clarence River, Tweed River, Gwawley Bay, Prospect Creek, Billabong Creek, Berrima, Towradgi Creek, Haslams Creek, Mudgee, North Wentworthville, Carlingford, Brickfield Creek, Cabramatta Creek, Boundary Creek, Eastern Creek, Narrabri, Scone, Molong and the Paterson River.

Independent technical audits and expert advice associated with hydrologic modelling and water resources issues in Australia. This has included expert technical support to the Snowy Water Inquiry and numerous Government projects relating to water efficiency savings throughout the Murray-Darling Basin including Menindee Lakes, technical auditor of the Murray-Darling Basin Commission 'Cap' models involving over 20 valley models developed by four states and the ACT, expert advice on various projects related to the Murray-Darling Basin Salinity Management Strategy, expert review of IQQM models and environmental flow objectives for the NSW government, expert independent assessment of hydrological components of major infrastructure projects and EISs, together with numerous reviews carried out for the private sector.

Flood risk assessment and computer modelling of flood behaviour for over 500 projects in urban and rural areas of Australia. This has included assessment of risks to life and property, simulation of flow behaviour using one and two dimensional models, stormwater and urban drainage assessments, and consideration of a range of related environmental, riparian corridor and water quality issues.

Expert testimony in excess of 30 court proceedings relating to development applications, valuation of floodprone land, personal injury claims and other issues relating to flooding, hydrology and stormwater drainage issues.

Policy formulation for floodplain development. This has included the preparation of over 20 Development Control Plans for local councils in NSW to ensure new developments meet best practice standards for floodplain management. The scope of these policies has also addressed floodprone caravan parks, on-site stormwater detention and a range of broader stormwater management issues.

Design and management of flooding and drainage infrastructure projects. These projects comprise detention basins, major trunk stormwater systems, creek rehabilitation, and the civil works associated with numerous floodplain and stormwater projects.

1980 to 1986 | Sinclair Knight & Partners Pty Ltd, Australia

Specialist Water Engineer working on numerous development, government aid, mining and World Bank projects in NSW, Malaysia, and the islands of Sumatra and Java in Indonesia.

1978 to1980 | River Murray Commission, Australia

Investigation Engineer responsible for modelling of water resources of the Murray-Darling Basin, assisting the Executive Engineer with river operations and various investigations into the water resources of basin, and the preparation of water accounting procedures.

1977 | Camp, Dresser & McKee, USA

Engineering investigations of flood behaviour and river hydraulics in the Los Angeles Basin.

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