In the matter of the Queensland Floods Commission of Inquiry 2011
A Commission of Inquiry under the Commissions of Inquiry Act 1950
And Pursuant to the Commissions of Inquiry Order (No. 1) 2011

Statement of Dr Bruce Abernethy

On the 16th day of November 2011, I, Dr Bruce Abernethy, c/- floor 11, 452 Flinders Street, Melbourne in the State of Victoria, say as follows:

1. I am currently employed by Sinclair Knight Merz (SKM) as Manager, Southeast Australian Water and Environment Operations.
2. Attached to this statement and marked "BA-1" is a copy of a document entitled "Brisbane River Flood, January 2011. Statement to commission of inquiry: bank erosion in the mid-Brisbane River" (Report).
3. The report was prepared by SKM at the requirement of the Queensland Floods Commission of Inquiry.
4. I believe the contents of the Report are true and correct.
5. The opinions in the report are opinions that I hold.
6. Attached to this statement and marked "BA-2" is a copy of my curriculum vitae.

[redacted]

~~Sworn~~/ Affirmed by the deponent)
at 452 Flinders Street)
in Melbourne)
on the 16th day of November 2011)
Before me:)

Signature of Dr Bruce Abernethy

[redacted]

Signature of witness

[redacted]
452 Flinders St, Melbourne 3000
An Australian Legal Practitioner
within the meaning of the
Legal Profession Act 2004

In the matter of the Queensland Floods Commission of Inquiry 2011
A Commission of Inquiry under the Commissions of Inquiry Act 1950
And Pursuant to the Commissions of Inquiry Order (No. 1) 2011

Statement of Dr Bruce Abernethy

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[redacted]

Signature: Bruce Abernethy

[redacted]

Signature: Witness

BA-1

Brisbane River Flood, January 2011

STATEMENT TO COMMISSION OF INQUIRY: BANK EROSION IN THE MID-BRISBANE RIVER

- Final
- 16 November 2011

Brisbane River Flood, January 2011

STATEMENT TO COMMISSION OF INQUIRY: BANK EROSION IN THE MID-BRISBANE RIVER

- Final
- 16 November 2011

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Contents

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1. Introduction

Background

1. This report has been prepared in response to a request from the Queensland Floods Commission of Inquiry (the "Commission") to provide information and opinion on:
   a) *the general correlation between the rate of water releases from impoundments and the destabilisation or erosion of riverbanks downstream; and*
   b) *the likely impact on riverbank erosion, slumping and instability of a more gradual drawdown of Wivenhoe Dam from 9:00pm on 11 January 2011 onwards.*

Hydrological context

2. Human occupation and development of stream margins and floodplains are often adversely affected by floods and by channel adjustment. In response, flood mitigation schemes that include large reservoirs are conceived to reduce the frequency and duration of high flows in the downstream reaches. These schemes can be very effective. Work by Shields *et al*. (2000) on rivers in the United States shows a reduction in lateral channel migration rates by factors of three to six. However, rivers respond to impoundment in a variety of ways over varying time-scales.

3. Interpretation of short term channel adjustments resulting from particular flows (whether released from storage, produced from unregulated catchments, or combination) is confounded by the background longer-term adjustment to changes in the overall flow regime. As seen in Figure 1, the higher flows (those exceeded 50% of the time) conveyed by the mid-Brisbane River have been moderated during the period of regulation. Hence, taking a flood-by-flood view of channel change belies the complexity of the Brisbane River's ongoing adjustment to the closure of Wivenhoe Dam in 1984. Moreover, interpretation is further complicated by the contribution of flow from tributaries. Downstream from Wivenhoe Dam, the flow regime progressively reverts to that of the natural river as inflows from unregulated tributaries, particularly from Lockyer Creek and Bremer River, and local runoff contribute to the overall flow in the river.

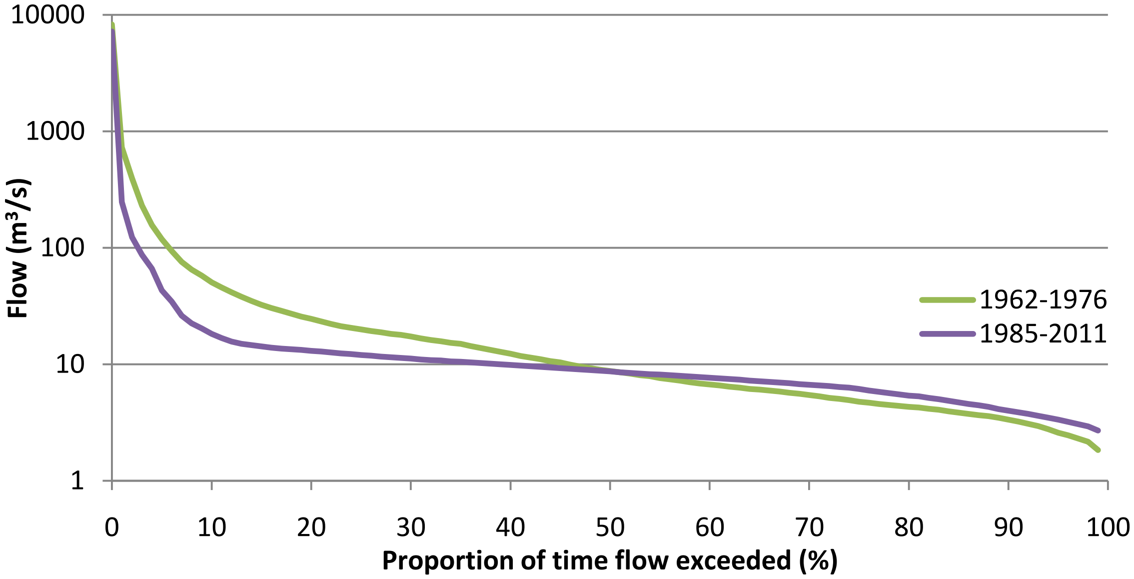

Figure 1: Flow duration curves for Savages Crossing, pre (1962-1976) and post (1985-2011) Wivenhoe Dam.

Outline of report

4. In the following sections, background is provided on the variety and timing of responses to dam closures that have been observed in affected river reaches. That information provides a backdrop to consideration of releases from impoundment and their geomorphological effectiveness in the mid-Brisbane River. Following that is a theoretical consideration of riverbank mass failure mechanisms and the extent to which they are affected by fluctuations in river stage. These considerations frame a view of the effect of the regulated drawdown on the mid-Brisbane River's banks in January 2011.

2. Effects of river regulation on channel form

5. Leopold and Maddock (1953) provided geomorphological evidence for the existence of quasi-equilibrium states between channel morphology (width, depth and slope) and the independent variables of discharge and sediment load. In natural rivers, discharge and sediment load constantly vary so that changes in channel morphology are balanced in a range about average energy conditions. Disruption of the pre-existing balance between the hydrologic regime, channel morphology and sediment load can be expected to have far-reaching and long term effects on the form of downstream channels (Petts and Gurnell, 2005). From the variety of responses to altered flow regimes that have been documented in the literature, it is fair to say that downstream channel morphology responds in a complex manner through time and space to the single trigger of dam closure (Petts, 1979; Benn and Erskine, 1994).

6. Indeed, as Knighton (1988) correctly points out, it is very difficult to draw any broadly applicable conclusions from a particular regulated river with its individual release policy and catchment characteristics. Moreover, past investigations into the downstream effects of reservoirs have rarely considered channel adjustments that might occur downstream from the confluence of the first major tributary, although there is evidence that the changes are quite significant (Andrews, 1986). In general terms, the greatest changes are found in the first 5 km below a dam (Williams and Wolman, 1984) with changes complete within a timeframe that may range from 10 to more than 500 years (Petts, 1984).

7. According to Church (1995) the initial effect of dam closure is degradation downstream from the wall because the entrained sediment is no longer replaced by material arriving from upstream. Depending on the relative erodibility of the streambed and banks, the degradation may be accompanied by either narrowing or widening of the channel. However, empirical relationships between channel form, discharge and sediment load presented by Schumm (1969) suggest that local channel degradation is only the most immediate morphological impact of altered hydrology. Over the long term, river regulation often initiates the complete readjustment of channel morphology throughout the length of a river system. Petts (1979) argued that the magnitude and nature of adjustment ultimately depends upon the degree of flow alteration, the sediment load, the resistance of the channel perimeter, and the supply of water and sediment from tributary sources.

8. Sherrerd and Erskine (1991) characterised the downstream effects of dams in terms of three orders of impacts. First-order impacts determine the magnitude of river response and include the effects of dams on such environmental processes as streamflows and sediment loads. Second-order impacts refer to the changes in channel form resulting from the first-

order impacts. Third-order impacts include the effects of the morphological changes upon channel ecology. Feedback processes stabilise channel morphology after a complex response has been initiated by dam closure. Bench and bar formation, as well as vegetation encroachment, promote long-term changes leading to river metamorphosis.

Mid-Brisbane River

9. The purpose of the foregoing is to highlight the need to consider the broader geomorphological adjustment trajectory when evaluating channel change following occurrence of a particular flood.

10. Accordingly, it is considered that there is no general correlation between the rate of releases and geomorphological efficacy. The effect of any discharge from the dam on downstream channel adjustment would vary markedly from one point to another downstream, or vary markedly through time during the period of transition from one state of quasi-equilibrium to another. Because of this variation through time and space, each of the three descriptive variables of floods needs to be considered. It is not just the magnitude of a flow that dictates geomorphological efficacy, a flood's frequency and duration are also prime considerations.

11. The greater the flood's magnitude, the greater the area of inundation and the greater the shear stress exerted by the flow on inundated surfaces. During normal floods, the discharge of any given release rate from the dam will be augmented (to greater, or lesser, degrees) by inflows from unregulated tributaries. The longer the duration of the flood, the more time that surfaces are inundated and exposed to potential reworking by the flow. Again, flow duration can be augmented by asynchronous flows arriving from tributaries. The less frequent the flood, the more time there is between events (of similar size) for the channel to recover from the last flood. The importance of this relaxation period will vary through the adjustment period following dam closure.

12. Importantly, the effects of any flow on channel adjustment is moderated by the vegetation growing on the channel's margin, or riparian zone (Abernethy, 1999). To this end, and as observed in an earlier related report (SKM, 2011), the generally degraded condition of the mid-Brisbane River's riparian zone was probably a higher-order contributing factor to the wholesale bank erosion of the mid-Brisbane, than was the flood itself. Certainly, had the flood occurred in a naturally vegetated catchment, its impacts would have been far reduced.

3. Bank erosion processes

13. For descriptive purposes, and process interpretation in the field, it is useful to consider bank erosion in terms of three broad categories:
    a) subaerial preparation of bank sediments;
    b) direct fluvial scour; and
    c) mass failure under gravity.

    In lowland floodplain reaches, such as those found below Wivenhoe Dam, riverbanks generally erode by a cyclical combination of processes from all three categories.

14. Subaerial processes act externally to the river and operate on exposed riverbanks regardless of the presence of moving water in the channel. In contrast, fluvial scour is entirely associated with channel flow hydraulics. Mass failure is usually triggered when a critical stability condition is exceeded, either by reduction of the internal strength of the bank (via subaerial processes) or a change in profile geometry (via fluvial scour). The rate at which material is transported away, or scoured, from a particular site ultimately controls the rate of bank retreat sustained over time (Thorne, 1982; Alonso and Combs, 1990).

15. These processes have been the focus of numerous studies over the years and were presented in summary in SKM (2011). Repeated here, though, is a longer account of the processes that give rise to mass failure and their interaction with recharge and discharge of water to and from the river banks.

Mass failure

16. Theories of slope stability state that a bank will collapse under its own weight if, for any assumed failure mechanism, the stress exerted by the weight of the bank material exceeds the internal strength of the bank material to resist that stress. The stability of a bank section is usually evaluated to determine its factor of safety (F_s), with respect to mass failure. The safety of the bank is generally expressed (after Sidle *et al*., 1985) as the ratio of the stresses resisting failure to the stresses required to bring the bank into a state of limiting equilibrium along a given failure surface:

$$F_s = \frac{s}{\tau} \qquad (1)$$

    where s is the shear strength of the soil and τ is the shear stress acting along the failure surface. The driving stresses result from the downslope component of weight of the bank material. A safety factor of one would indicate imminent or incipient failure.

17. In its simplest form the shear strength of a soil is described by the Mohr-Coulomb equation:

$$s = c + \sigma \tan\phi \,, \qquad (2)$$

where c is the soil cohesion, σ is the total stress normal to the shear plane and $\tan\phi$ is the coefficient of internal friction. When water is present in the soil, and steady downslope seepage conditions prevail, the total normal stress is replaced by an effective stress ($\sigma - u$) where u is the pore-water pressure (see review by Fredlund, 1987). The shear strength is described by:

$$s = c' + (\sigma - u)\tan\phi' ; \qquad (3)$$

the primes on c and ϕ denote effective stress.

18. Equation (3) indicates that in poorly drained banks, positive pore-water pressure weakens a bank by reducing its effective strength (Bradford and Piest, 1977; 1980; Simons and Li, 1982). However, the influence of bank geotechnical properties, with respect to mass failure, is a complicated topic and the simple form of Equation (3) belies the complexity of geotechnical research (see Fang, 1997).

19. Failure usually occurs during ‘worst case’ conditions when the strength of the bank materials is minimised and their weight is maximised (Thorne *et al*., 1988). The literature argues consistently that worst case conditions are associated with drawdown in the channel. At such times, positive pore-water pressures may be produced which weaken riverbanks.

Pore-water pressure

20. Exfiltrating seepage, following periods of high channel flow and/or heavy precipitation, has been linked to widespread bank instability on the Ohio River in the United States in a series of papers by Hagerty and others (e.g. Hagerty, 1991). Seepage of water through the bank leads to leaching and softening or, in extreme cases, pipe erosion (Twidale, 1964). Even where the seepage force is not great enough to result in pipe erosion, exfiltration reduces the shear strength of bank material and reduces its resistance to fluvial scour. Excessive moisture also has implications for a bank’s mass stability through increased pore-water pressure.

21. Under normal low-flow conditions, the pore-water pressure of bank material above the water table is negative. The presence of negative pore-water pressures, or suction, in unsaturated portions of streambanks contributes to an apparent strength of the material that can be visualised as either a friction angle or a component of cohesion (Fredlund, 1987). For example, non-cohesive material can behave like a weakly cohesive soil in these circumstances, maintaining a bank angle that exceeds the friction angle. Slope stability analyses incorporating the effect of soil suction have been the subject of recent detailed research (see Fredlund and Rahardjo, 1993), and are now being applied to riverbank stability problems (Casagli *et al*., 1997; Simon and Curini, 1998; Casagli *et al*., 1999).

22. Banks discharge water back to the channel during drawdown. The special conditions of drawdown have been the object of a considerable literature (e.g. Morgenstern, 1963; Burgi and Karaki, 1971; Gill, 1990; Borja and Kishnani, 1992). Bishop (1954) and Skempton (1954) investigated effective stresses in an earth dam during rapid drawdown. However, the stability problems of natural riverbanks differ from embankment dams in that the natural setting is extremely variable with heterogeneous sediments and complex geometries (Chugh, 1983; Simon *et al*., 2000). In any case, variations in pore pressures during and after flow events, which are the most critical periods in terms of bank stability, are complex and difficult to predict (Rinaldi *et al*., 2004). Various authors have observed that bank failures are likely to occur during drawdown following a high stage, when the bank material is still in or near a saturated condition and the confining pressure of the river decreases to zero (Twidale, 1964; Thorne, 1982; Rinaldi *et al*., 2004). However, predicting the occurrence of bank failures is confounded by our inability to account for the complex interactions between pore water pressures within the bank and the confining pressure of the river in bank stability analyses.

23. Freeze and Cherry (1979) report that extensive laboratory and field tests indicate a range in the hydraulic conductivity of alluvial material of more than three orders of magnitude. The variations reflect the difference in grain-size distributions in individual strata; the bedded character of fluvial deposits imparts a strong anisotropy to the system (Freeze and Cherry, 1979). Variations in hydraulic conductivity can greatly modify groundwater flow, effective-stress fields, and slope stability (Reid, 1997). The greater the hydraulic conductivity of a bank profile, the more able it is to drain freely during drawdown.

Mid-Brisbane River

24. As noted in paragraph 1), the Commission asked for commentary on the "*likely impact on riverbank erosion, slumping and instability of a more gradual drawdown [of river stage below] Wivenhoe Dam from 9pm on 11 January 2011*". It is difficult to comment generally on likely impacts as the sedimentological characteristics of riverbanks vary enormously even over short distances (Abernethy and Bresnehan, 2001). However, the general principles of drawdown are instructive.

25. For drawdown failure conditions to be set up, the flood must:
    a) be of sufficient magnitude to wet the higher portions of the bank profile (where the greater the magnitude of the flow, the higher the water surface elevation);
    b) be of sufficient duration to allow the wetting front to move into the bank, beyond potential failure planes (where the duration maintains a high water surface elevation); and
    c) recede (where the water surface elevation lowers) more quickly than the bank is able to drain.

26. As noted in SKM (2011), a number of failures were observed along the mid-Brisbane River. Whilst the drawdown following the extended drain-down phase of the release was slower than comparable natural rates, the sustained higher flows during this phase extended the period of inundation of the lower bank portions. It may be that during this phase of the January releases, there was sufficient time for the wetting front to saturate the bank profile beyond potential failure planes and that the subsequent drawdown (albeit slower than natural) did not allow some bank sections to drain, giving rise to their subsequent failure.

27. Without a more considered investigation, involving field testing of bank properties, it is not possible to elucidate the critical values for those parameters and to advise on the likely impact of a more gradual drawdown. The key parameters here are: height of river stage, duration of stage, drawdown rate, and bank hydraulic conductivity. But clearly, the longer the stage is maintained at higher elevations, the slower the drawdown needs to be, to avoid mass failures of the banks.

4. Summary

28. River regulation disrupts the equilibrium state that would otherwise exist between discharge, sediment load and channel morphology. Although the most apparent responses are found close to the dam structure, channel adjustment is complex and significant effects can be observed further downstream. Regulation may trigger the complete readjustment of a channel over the entire length of a river, with changes occurring over a period of up to 500 years. Within this complex response to dam closure, it is difficult (and inappropriate) to comment on the effects of an individual release. This is particularly true without considering other factors such as riparian degradation and the contribution of unregulated tributary flows.

29. A number of bank erosion processes act as the mechanisms for channel adjustment: subaerial preparation of bank sediments, fluvial scour and mass failure under gravity. Mass failure is the collapse of a bank under its own weight. In regulated rivers, this often occurs after rapid drawdown of the channel. Below Wivenhoe Dam, all three of these process groups act to destabilise and erode the riverbanks. Generally, the slower the drawdown of high stages, the less likely unstable bank conditions will arise. However, without further work, it is not possible to determine the critical stage duration/drawdown rate for the mid-Brisbane River.

5. References

Abernethy, B., 1999. *On the Role of Woody Vegetation in Riverbank Stability*. PhD Thesis. Civil Engineering, Monash University, Melbourne.

Abernethy, B. and S. Bresnehan, 2001. Downstream Poatina geomorphology assessment. In H. Locher (ed.) *Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro-Power Generation*. Hydro Tasmania, Hobart: Appendix 17.

Alonso, C.V. and S.T. Combs, 1990. Streambank erosion due to bed degradation - a model concept. *Transactions of the American Society of Agricultural Engineers*, 33(4): 1239-48.

Andrews, E.D., 1986. Downstream effects of Flaming Gorge Reservoir on the Green River, Colorado and Utah. *Geological Society of America Bulletin*, 97: 1012-23.

Benn, P.C. and W.D. Erskine, 1994. Complex channel response to flow regulation: Cudgegong River below Windamere Dam, Australia. *Applied Geography*, 14: 153-68.

Bishop, A.W., 1954. The use pore-pressure coefficients in practice. *Géotechnique*, 4: 148-52.

Borja, R.I. and S.S. Kishnani, 1992. Movements of slopes during rapid and slow drawdown. In R.B. Seed and R.W. Boulanger (eds.), *Stability and performance of slopes and embankments II: proceedings of a specialty conference, Berkeley, California*. American Society of Civil Engineers, Geotechnical special publication; No. 31, New York: 405-13.

Bradford, J.M. and R.F. Piest, 1977. Gully wall stability in loess-derived alluvium. *Soil Science Society of America Journal*, 41: 115-22.

Bradford, J.M. and R.F. Piest, 1980. Erosional development of valley-bottom gullies in the upper midwestern United States. In D.R. Coates and J.D. Vitek (eds.), *Thresholds in Geomorphology*. Allen and Unwin, Boston: 75-101.

Burgi, P.H. and S. Karaki, 1971. Seepage effect on channel bank stability. *Journal of the Irrigation and Drainage Division, ASCE*, 97(1): 59-72.

Casagli, N., A. Curini, A. Gargini, M. Rinaldi and A. Simon, 1997. Effects of pore pressure on the stability of streambanks: preliminary results from the Sieve River, Italy. In S.S.Y. Wang, E.J. Langendoen and F.D. Shields (eds.), *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*: 243-8.

Casagli, N., M. Rinaldi, A. Gargini and A. Curini, 1999. Pore water pressure and streambank stability: results from a monitoring site on the Sieve River, Italy. *Earth Surface Processes and Landforms*, 24(12): 1095-114.

Chugh, A.K., 1983. Slope stability analysis of riverbanks. *Canadian Geotechnical Journal*, 20: 335-43.

Church, M., 1995. Geomorphic response to river flow regulation: case studies and time-scales. *Regulated Rivers: Research and Management*, 11: 3-22.

Fang, H., 1997. *Introduction to Environmental Geotechnology*. CRC Press, Boca Raton.

Fredlund, D.G., 1987. Slope stability analysis incorporating the effect of soil suction. In M.G. Anderson and K.S. Richards (eds.), *Slope Stability*. Wiley, Chichester: 113-44.

Fredlund, D.G. and H. Rahardjo, 1993. *Soil Mechanics for Unsaturated Soils*. John Wiley & Sons, New York.

Freeze, R.A. and J.A. Cherry, 1979. *Groundwater*. Prentice Hall, Englewood Cliffs.

Gill, B.C., 1990. *Riverbank Slumping Due to Groundwater Discharge at Darcy's Bend on the Goulbourn River*. Investigations Report No. 1990/47, Investigations Branch, Tatura.

Hagerty, D.J., 1991. Piping/sapping erosion. I Basic considerations. *Journal of Hydraulic Engineering*, 117(8): 991-1008.

Knighton, A.D., 1988. The impact of the Parangana Dam on the River Mersey, Tasmania. *Geomorphology*, 1: 122-237.

Leopold, L.B. and T. Maddock, 1953. The hydraulic geometry of stream channels and some physiographic implications. *United States Geological Survey Professional Paper*, 252.

Morgenstern, N.R., 1963. Stability charts for earth slopes during rapid drawdown. *Géotechnique*, 13(2): 121-31.

Petts, G.E., 1979. Complex response of river channel morphology subsequent to reservoir construction. *Progress in Physical Geography*, 3: 329-62.

Petts, G.E., 1984. *Impounded Rivers*. Wiley, Chichester.

Petts, G.E. and A.M. Gurnell, 2005. Dams and geomorphology: research progress and future directions. *Geomorphology*, 71: 27-47.

Reid, M.E., 1997. Slope instability caused by small variations in hydraulic conductivity. *Journal of Geotechnical and Geoenvironmental Engineering*, 123(8): 717-25.

Rinaldi, M., N. Casagli, S. Dapporto and A. Gargini, 2004. Monitoring and modelling of pore water pressure changes and riverbank stability during flow events. *Earth Surface Processes and Landforms*, 29(2): 237-54.

Schumm, S.A., 1969. River metamorphosis. *Journal of the Hydraulics Division, ASCE*, 95(HY1): 255-73.

Sherrard, J.J. and W.D. Erskine, 1991. Complex response of a sand-bed stream to upstream impoundment. *Regulated Rivers: Research and Management*, 6: 53-70.

Shields, F.D., A. Simon and L.J. Steffen, 2000. Reservoir effects on downstream river channel migration. *Environmental Conservation*, 27(1): 54-66.

Sidle, R.C., A.J. Pearce and C.L. O'Loughlin, 1985. Hillslope Stability and Land Use. *American Geophysical Union Water Research Monograph*, 11: 140.

Simon, A. and A. Curini, 1998. Pore pressure and bank stability: the influence of matric suction. In S.R. Abt, J. Young-Pezeshk and C.C. Watson (eds.), *Water Engineering '98: Proceedings of the International Water Resources Engineering Conference, Memphis*. American Society of Civil Engineers: 358-63.

Simon, A., A. Curini, S.E. Darby and E.J. Langendoen, 2000. Bank and near-bank processes in an incised channel. *Geomorphology*, 35(3-4): 193-217.

Simons, D.B. and R.-M. Li, 1982. Bank erosion on regulated rivers. In R.D. Hey, J.C. Bathurst and C.R. Thorne (eds.), *Gravel-Bed Rivers: Fluvial Processes, Engineering and Management*. Wiley, Chichester: 717-47.

Skempton, A.W., 1954. The pore-pressure coefficients *A* and *B*. *Géotechnique*, 4: 143-7.

SKM, 2011. *Brisbane River flood, 2011: report on riverbank erosion*. Sinclair Knight Merz, Melbourne.

Thorne, C.R., 1982. Processes and mechanisms of riverbank erosion. In R.D. Hey, J.C. Bathurst and C.R. Thorne (eds.), *Gravel-Bed Rivers: Fluvial Processes, Engineering and Management*. Wiley, Chichester: 227-71.

Thorne, C.R., D.S. Biedenharn and P.G. Combs, 1988. Riverbank instability due to bed degradation. In S.R. Abt and J. Gessler (eds.), *Hydraulic Engineering: Proceedings of the 1988 National Conference on Hydraulic Engineering, Colorado Springs*. ASCE.

Twidale, C.R., 1964. Erosion of an alluvial bank at Birdwood, South Australia. *Zeitschrift für Geomorphologie*, 8: 184-211.

Williams, G.P. and M.G. Wolman, 1984. Downstream effects of dams on alluvial rivers. *United States Geological Survey Professional Paper*, P 1286: 83.

BA-2

Dr Bruce Abernethy

Qualifications

Doctor of Philosophy
Department of Civil Engineering
Monash University, 1999

Bachelor of Science (Honours Class 1)
School of Geography
University of New South Wales, 1994

Affiliations

Member of the River Basin Management Society

Fields of special competence

- Regional strategic planning
- Natural resource management planning
- Strategic sustainability planning
- Fluvial geomorphology
- Role of vegetation in river channel processes
- River bed and bank erosion
- Hillslope and gully erosion processes
- Environmental flows

Relevant experience

I have sixteen years experience in riverine investigations and catchment management. My career has exposed me to a broad range of catchment, waterway and floodplain management issues. My work has variously involved: fluvial investigations; river rehabilitation strategies; catchment sediment budgeting; investigations of the impacts from riverine quarrying; extraction site closure and rehabilitation; environmental flow assessments; regional planning; and strategic sustainability planning. Through this experience, I have developed a number of techniques to assess and report the social, economic and environmental requirements of contemporary natural resource management.

In addition to my technical roles, I have managed many multidisciplinary projects. My project management relies on my practical knowledge of natural and social processes combined with proactive risk management and successful community and stakeholder consultation.

My corporate roles have included people, commercial and strategic management. I currently manage SKM's southeast Australian Water and Environment Operations. The business spans Victoria, Tasmania and the ACT and is comprised of some 300 engineers, scientists, planners and spatial analysts engaged in a variety of potable and wastewater engineering, surface water, groundwater and land management projects and environmental impact assessments.

Previously, I managed our New Zealand Water and Environment Operations. Before that, I managed our US Water and Environment Operations, where my role was to foster client relationships, build business and strengthen SKM's global alliance with our North American partners. Recently, I also lead SKM's global sustainability strategy. This role necessitated framing and implementing a range of initiatives to reduce the company's environmental footprint and oversee a change management process that introduced sustainability to all SKM project delivery. The execution of the strategy saw a number of profound changes in the company's operations and staff outlook.

Sinclair Knight Merz
November, 1999 to date

Manager – SE Australia Water and Environment Operations (June 2011 – date)

- Line management of 300 staff
- Commercial management
- Accountable for Profit and Loss
- Business development
- Strategic planning

Manager – NZ Water and Environment Operations (October 2009 – June 2011)

- Line management of 100 staff
- Commercial management (profit and loss)
- Business development/strategic planning

Manager – US Water and Environment Operations (January 2008 – October 2009)

- Business development
- Alliance management
- Commercial management
- Strategic planning

Manager – corporate sustainability strategy (May 2007 – January 2008)

- Responsible for formulation and delivery of the company's global sustainability strategy
- Framed and introduced initiatives to
    - reduce the company's environmental footprint
    - deliver our client's projects in a sustainable way
    - manage cultural change and staff communication

Manager – Catchment Planning (June 2004 – May 2007)

- Line management of 70 staff
- Commercial management
- Strategic planning

Geomorphologist/project manager (November 1999 – date)

- Geomorphology.
    - Investigation to assess potential channel change from proposed irrigation dam, Hurunui River, New Zealand.
    - Investigation to assess extreme sediment discharge (conveyed by the probable maximum flood) through Keepit Reservoir, Namoi River, New South Wales.
    - Assessment of Manilla Weir sedimentation, Namoi River, New South Wales.
    - Sand extraction site closure and rehabilitation plan – stable planform design, revegetation and environmental monitoring – Delatite River, Victoria and Buaraba Creek, Queensland.
    - Investigation of the downstream geomorphological effects of changed powerstation operations, Macquarie River, Tasmania.
    - Investigation of potential avulsion sites on the Goulburn River, Victoria.
    - Hillslope erosion control investigations, Victoria.
    - Investigation of the impact of changed flow on channel morphology in Murray River anabranches due to proposed groundwater interception scheme, Victoria.
    - Glenelg basin geomorphic categorisation, Victoria.
    - Assessing high conservation value in the Murrumbidgee catchment, New South Wales.

- River/estuary restoration.
  - Project manager and project geomorphologist for river restoration plans – Surrey River, Honeysuckle Creek, Moe River, Bruces Creek, Victoria.
  - Development of action plan to manage opening the Surrey River mouth during times of low flow, Victoria.
  - Development of Waituna Lagoon barrier breaching options to manage lagoon health, Southland, New Zealand.
- Catchment sediment budgets.
  Project Manager and project geomorphologist for sediment budget and geomorphological studies – upper Loddon River, Glenelg River, upper Barwon River and upper Hopkins River catchments, Victoria.
- Environmental flow determination.
  Project Manager and project geomorphologist for a variety of projects that determined the of environmental water requirements for the: Onkaparinga River, South Australia; Welcome River, Bluemans Creek, Tommahawk Creek, Tasmania; Wimmera River, Avoca River, Glenelg River, Macalister River, Lindsay River, Mullaroo Creek, Birches Creek, Campaspe River, Yarra River, Woori Yallock Creek, Ovens River, Broken Creek, Tarra River, Avon-Richardson River, Moorabool River, Sevens Creek, Wannon River and Lake Wallawalla, Victoria.
- Nutrient action plans.
  Project manager of nutrient action plans for the Loddon, Campaspe Avoca, Avon-Richardson Rivers, Victoria.
- Strategic sustainability.
  - Project manager of SKM corporate sustainability strategy, global. Responsible for formulation and delivery of the company’s global sustainability strategy, including framing and introducing initiatives to: reduce the company’s environmental footprint; deliver our client’s projects in a sustainable way; and manage cultural change and staff communication.
  - Project director of San Diego International Airport expansion – sustainability analysis, California. Objectively compared two existing expansion proposals with a third, sustainability focused alternative to evaluate major sustainability components.
  - Sustainability consultant for Columbus Solids Treatment and Disposal Master Plan, Ohio, USA. Provided knowledge and technical guidance during, facility tour, expert panel and concept confirmation conferences.
  - Sustainability consultant for Coquina Coast seawater desalinisation project, Florida, USA.
- Regional natural resource management.
  Conceived and managed the development of five-year regional natural resource management plans for the Wimmera and Glenelg Hopkins regions in Victoria; the Eyre Peninsula and Rangelands regions in South Australia; the Western Catchments region in Queensland; and the Cradle Coast, NRM North and NRM South regions in Tasmania.

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January, 1999 – November, 1999
Post-Doctoral Research Fellow (University of Melbourne)

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March, 1995 – January, 1999
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Assistant Environmental Planner

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Papers and presentations

Abernethy, B., 1994. *Predicting the Headward Extent of Gully Erosion using Digital Terrain Analysis*. BSc Honours Thesis. School of Geography, University of New South Wales, Sydney.

Abernethy, B., 1999. *On the Role of Woody Vegetation in Riverbank Stability*. PhD Thesis. Civil Engineering, Monash University, Melbourne.

Abernethy, B. and S. Bresnehan, 2001. Downstream Poatina geomorphology assessment. In H. Locher (ed.) *Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro-Power Generation*. Hydro Tasmania, Hobart: Appendix 17.

Abernethy, B. and S. Bresnehan, 2003. Assessing downstream channel adjustment in response to hydro-electric powerstation operations [abstract]. In M. Thoms, G. Quinn, B. Gawne, A. Arthington, K. Walker, P. Cottingham, F. Dyer and R. Sinclair (eds.), *Ninth International Conference on River Research and Applications: the Nature of Variability in River Systems, Albury*. Cooperative Research Centre for Freshwater Ecology, Melbourne: 27.

Abernethy, B., R. Lett and H. Chaplin, 2006. Use of a predictive sediment budget to prioritise catchment management for improved water quality. In *Asia Water 2006: Addressing Water and Wastewater Challenges, an Asian Perspective*. Malaysian Water Association, Kuala Lumpur.

Abernethy, B., A.J. Markham, I.P. Prosser and T.M. Wansbrough, 2005. A sluggish recovery: the indelible marks of landuse change in the Loddon River catchment. In I.D. Rutherfurd, I. Wiszniewski, M.J. Askey-Doran and R. Glazik (eds.), *Proceedings of the Fourth Australian Stream Management Conference: Linking Rivers to Landscapes, Launceston*. Department of Primary Industries, Water and Environment, Hobart: 13-21.

Abernethy, B. and I.P. Prosser, 1996. Predicting the limits to gully erosion. In I.D. Rutherfurd and M. Walker (eds.), *Stream Management '96, Proceedings of the First National Conference on Stream Management in Australia, Merrijig*. Cooperative Research Centre for Catchment Hydrology, Melbourne: 63-8.

Abernethy, B. and I.D. Rutherfurd, 1996. Vegetation and bank stability in relation to changing channel scale. In I.D. Rutherfurd and M. Walker (eds.), *Stream Management '96, Proceedings of the First National Conference on Stream Management in Australia, Merrijig*. Cooperative Research Centre for Catchment Hydrology, Melbourne: 213-9.

Abernethy, B. and I.D. Rutherfurd, 1998. Pulling roots in Gippsland: the role of root reinforcement in riverbank stability [abstract]. In B. Bourman (ed.) *Eighth Australian and New Zealand Geomorphology Group Conference, Goolwa*: 1.

Abernethy, B. and I.D. Rutherfurd, 1998. The role of riparian tree roots in reinforcing riverbanks. *Eos Transactions, AGU*, 79(17): Spring Meeting Supplement, S157.

Abernethy, B. and I.D. Rutherfurd, 1998. Scale analysis of bank stability: targeting river reaches for riparian revegetation. In H.O. Hansen and B.L. Madsen (eds.), *River Restoration '96 - Session Lectures Proceedings. International Conference Arranged by the European Centre for River Restoration, 9-13 September, 1996, Silkeborg*. National Environmental Research Institute, Silkeborg: 50-6.

Abernethy, B. and I.D. Rutherfurd, 1998. Where along a river's length will vegetation most effectively stabilise stream banks? *Geomorphology*, 23(1): 55-75.

Abernethy, B. and I.D. Rutherfurd, 1999. *Guidelines for Stabilising Streambanks with Riparian Vegetation*. Technical Report 99/10. Cooperative Research Centre for Catchment Hydrology, Melbourne.

Abernethy, B. and I.D. Rutherfurd, 1999. Riverbank reinforcement by riparian roots. In I.D. Rutherfurd and R. Bartley (eds.), *Proceedings of the Second Australian Stream Management Conference: The Challenge of Rehabilitating Australian Streams, Adelaide*. Cooperative Research Centre for Catchment Hydrology, Melbourne: 1-7.

Abernethy, B. and I.D. Rutherfurd, 2000. Determining riparian zone widths to maintain riverbank stability [abstract]. In *Riversymposium: Third International River Management Symposium, Brisbane*: 59.

Abernethy, B. and I.D. Rutherfurd, 2000. Does the weight of riparian trees destabilise riverbanks? *Regulated Rivers: Research and Management*, 16(6): 565-76.

Abernethy, B. and I.D. Rutherfurd, 2000. The effect of riparian tree roots on the mass-stability of riverbanks. *Earth Surface Processes and Landforms*, 25(9): 921-37.

Abernethy, B. and I.D. Rutherfurd, 2000. Stabilising streambanks with riparian vegetation. *Natural Resource Management*, 3(2): 2-9.

Abernethy, B. and I.D. Rutherfurd, 2001. The distribution and strength of riparian tree roots in relation to riverbank reinforcement. *Hydrological Processes*, 15(1): 63-79.

Abernethy, B., M. Shirley, J. Roberts, K. Lewin, M. Lake, K. Swingler, A. Sharpe and S. Treadwell, 2004. E-flows: from concept to implementation [Abstract]. In *Riversymposium: Seventh International River Management Symposium, Brisbane*.

Abernethy, B. and T.M. Wansbrough, 2001. Where does river rehabilitation fit in catchment management? In I.D. Rutherfurd, F. Sheldon, G. Brierley and C. Kenyon (eds.), *Proceedings of the Third Australian Stream Management Conference: The Value of Healthy Streams, Brisbane*. Cooperative Research Centre for Catchment Hydrology, Melbourne: 1-6.

Donnelly, L., M. Shirley and B. Abernethy, 2005. Application of the FLOWS Method to the determination of Environmental Water Requirements for the Welcome River in Tasmania. In I.D. Rutherfurd, I. Wiszniewski, M.J. Askey-Doran and R. Glazik (eds.), *Proceedings of the Fourth Australian Stream Management Conference: Linking Rivers to Landscapes, Launceston*. Department of Primary Industries, Water and Environment, Hobart: 185-91.

Fleming, N., B. Abernethy and C. Clifton, 2003. An asset-based approach to planning for investment in integrated natural resource management – raising the benchmark and setting future directions. In *Integrated Catchment Management Conference (ICaM 2003), Paramatta*. Australian Water Association.

Fleming, N., D. Young and B. Abernethy, 2002. *Integrating our management of natural resources: combining benefits and risks in planning and prioritising investments*. Sinclair Knight Merz, Melbourne.

Hill, P., H. Griffith, M. Shirley, N. Fleming, B. Abernethy and S. Gatti, 2003. Developing options for providing water for the environment in the Onkaparinga River Catchment. In *28th International Hydrology and Water Resources Symposium*. The Institution of Engineers, Australia.

Lett, R., B. Abernethy and H. Chaplin, 2007. Are all river reaches created equal? Identifying erosion hotspots for catchment management. In A.L. Wilson, R.L. Dehaan, R.J. Watts, K.J. Page, K.H. Bowmer and A. Curtis (eds.), Proceedings of the 5th Australian Stream Management Conference. Australian rivers: making a difference, Albury. Charles Sturt University, Thurgoona: 217-22.

Prosser, I.P. and B. Abernethy, 1996. Predicting the topographic limits to a gully network using a digital terrain model and process thresholds. *Water Resources Research*, 32(7): 2289-98.

Prosser, I.P. and B. Abernethy, 1999. Increased erosion hazard resulting from log-row construction during conversion to plantation forest. *Forest Ecology and Management*, 123: 145-55.

Rutherfurd, I.D. and B. Abernethy, 1999. Controlling stream erosion. In S. Lovett and P. Price (eds.), *Riparian Technical Guidelines Volume Two: On-ground Management Tools and Techniques*. Land and Water Resources Research and Development Corporation, Canberra: 33-48.

Rutherfurd, I.D., B. Abernethy and I.P. Prosser, 1999. Stream erosion. In S. Lovett and P. Price (eds.), *Riparian Technical Guidelines Volume One: Principles of Sound Management*. Land and Water Resources Research and Development Corporation, Canberra: 61-78.

Rutherfurd, I.D., T. Hoang, I.P. Prosser, B. Abernethy and N. Jayasuriya, 1996. The impact of gully networks on the time-to-peak and size of flood hydrographs. In *Water and the Environment: 23rd Hydrology and Water Resources Symposium, Hobart*. Institution of Australian Engineers, Canberra: 397-402.

Sandercock, P.J., A. Allgaier, B. Abernethy, A. Brooks, S. Treadwell, R. Morden and S. Lang, 2008. Influence of woody debris on channel hydraulics in the lower Avoca River. In *13th Australia and New Zealand Geomorphology Group Conference*, Queenstown, Tasmania.

Shirley, M., P.I. Hill, S. Hannon, B. Abernethy, H. Griffith and S. Gatti, 2002. Water for the Environment? Providing Environmental Flows in the Onkaparinga River. In *ANCOLD 2002 Conference on Dams, Adelaide*: 39-50.

Shirley, M.J., B. Abernethy, S. Hannon and T.M. Wansbrough, 2001. When the flow is too great: an environmental flow assessment of Mullaroo Creek, a River Murray anabranch [Abstract]. In *Riversymposium: Fourth International River Management Symposium, Brisbane*: 31.