PROTECTING BRISBANE CENTRAL DISTRICT– CASE STUDY IN FUTURE FLOOD READINESS

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ABSTRACT

Flood prevention in Brisbane, Australia, is paramount to a sense of security for those living in close proximity to the Brisbane River.

Flooding along the Brisbane River has the potential to be devastating, as documented following previous flood events. The central business district is located 15 kilometres (km) from the mouth of the Brisbane River, where it is in close proximity to an area of known flood risk.

On January 13, 2011, major flooding occurred throughout most of the Brisbane River catchment, most severely in Toowoomba and the Lockyer Creek catchment, where 23 people drowned, as well as in the Bremer River catchment and in Brisbane. Insurers received some 56,200 claims with payouts totalling US$1.93 billion, but devastation resulting from the flood swept far beyond physical losses.

In all, more than 15,000 properties were inundated in metropolitan Brisbane, with approximately 3,600 homes evacuated and more than 200,000 people affected. Commercial losses of approximately $3.02 billion were reported across the mining, agriculture, and tourism sectors. More than 19,000 kilometres of roads were damaged, around 28 percent of the Queensland rail network damaged, and three major ports significantly affected. An estimated 28,000 homes would need to be rebuilt, while vast numbers of dwellings would require extensive repairs.

During the January 2011 flood, some parts of Brisbane were affected by water that came up from the river through the drainage networks and into the city's streets, a problem referred to as backflow flooding.

Backflow devices are one of many flood mitigation tools and strategies that Brisbane's city council is considering to help protect the city from the impacts of future flooding.

KEYWORDS

Brisbane, Flooding, Rain, Flood prevention, Mitigation, Protection, Backflow prevention devices

PRESENTER PROFILE

The Author, Kerry Olsson, has worked in the stormwater segment for 9 years worldwide. She has been involved in projects in USA, England, New Zealand and Australia primarily working with councils to ensure their infrastructure is future-proof in terms of flood prevention caused by back flow in stormwater systems.

The Presenter, James Logan, has been in the New Zealand water and wastewater industry for 20 years. Now with a focus on stormwater and wastewater drainage systems, he has seen the extraordinary results that the WaStop has delivered in communities around New Zealand.

1 INTRODUCTION

Brisbane CBD is a thriving, modern, trendy area popular with companies, families and students alike. Brisbane's metropolitan area has a population of 2.3 million and is in the southeast corner of Queensland. The central business district is situated inside a bend of the Brisbane River, about 15 kilometres (9 miles) from its mouth at Moreton Bay. Today, Brisbane is well known for its distinct Queenslander architecture which forms much of the city's built heritage. It also receives attention for its damaging flood events, most notably in 1974 and 2011.

2 BACKGROUND

2.1 BRISBANE

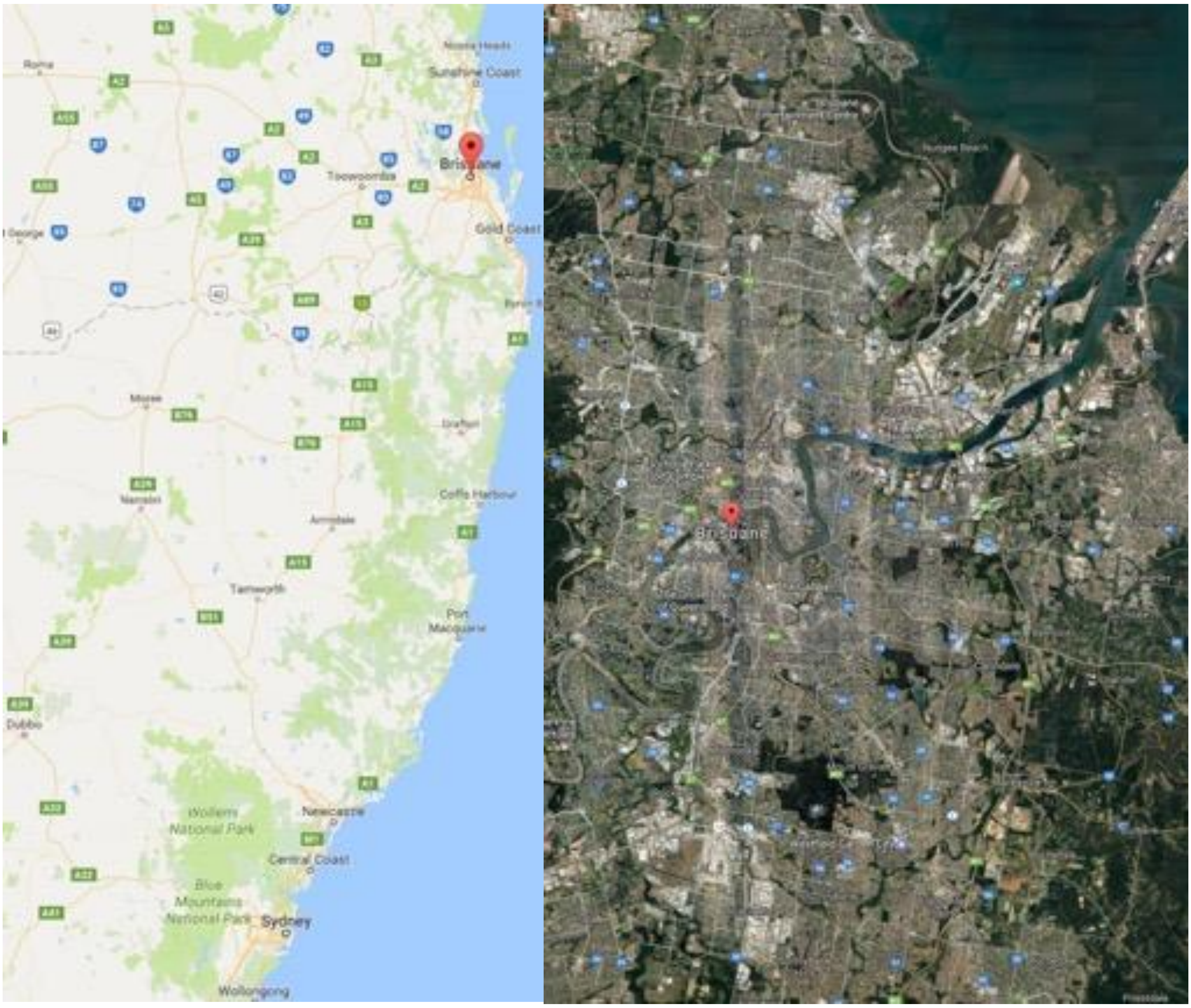
Brisbane is the capital and most populous city in the Australian state of Queensland, and the third most populous city in Australia. Brisbane's metropolitan area has a population of 2.3 million, and the South East Queensland urban conurbation, centred on Brisbane, encompasses a population of more than 3.4 million.

The Brisbane central business district stands on the original European settlement and is situated inside a bend of the Brisbane River, about 15 kilometres (9 miles) from its mouth at Moreton Bay. The metropolitan area extends in all directions along the floodplain of the Brisbane River Valley between Moreton Bay and the Great Dividing Range, sprawling across several of Australia's most populous local government areas (LGAs), most centrally the City of Brisbane, which is by far the most populous LGA in the nation.

One of the oldest cities in Australia, Brisbane was founded upon the ancient homelands of the indigenous Turrbal and Jagera peoples. Named after the Brisbane River on which it is located – which in turn was named after Scotsman Sir Thomas Brisbane, the Governor of New South Wales from 1821 to 1825 – the area was chosen as a place for secondary offenders from the Sydney Colony.

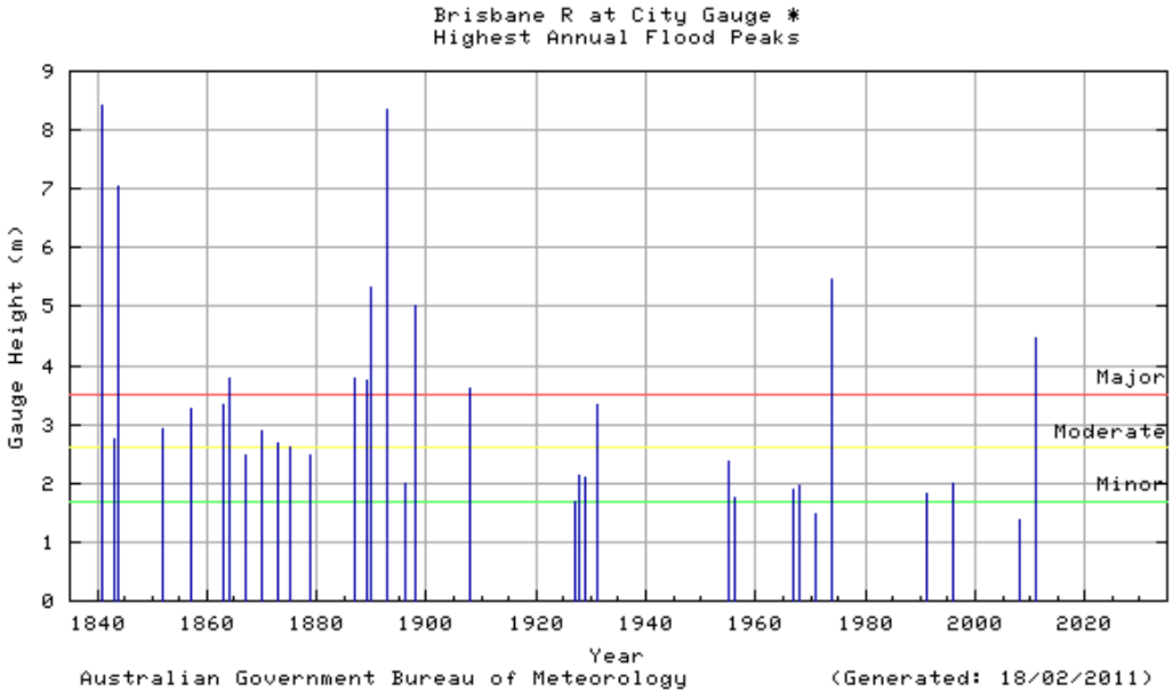
The city was marred by the Australian frontier wars between 1843 and 1855, and development was partly set back by the Great Fire of Brisbane, and the Great Brisbane Flood of 1893.

Today, Brisbane is well known for its distinct Queenslander architecture which forms much of the city's built heritage. It also receives attention for its damaging flood events, most notably in 1974 and 2011. The city is a popular tourist destination, serving as a gateway to the state of Queensland, particularly to the Gold Coast and the Sunshine Coast, popular resort areas immediately south and north of Brisbane, respectively.



2.2 HISTORY OF FLOODING IN BRISBANE

Flooding along the Brisbane River has the potential to be devastating, as documented following previous flood events. The central business district is located 15 kilometres (km) from the mouth of the Brisbane River, where it is in close proximity to an area of known flood risk. For much of the river's length, its banks are relatively high but topped by a broad plain. The river's meandering course prevents upstream floodwaters from being quickly discharged into Moreton Bay. Therefore, higher than normal flows cause river levels to rise rapidly, and once the top of the banks are breached, the floodwaters can spread over wide areas of the city.



Seven major flood peaks have been recorded at the Brisbane gauge since records began in 1841. A major flood peak of 4.46 metres (6th highest) was recorded at 3:00am on Thursday the 13th of January 2011. This is the largest flood peak recorded since the January 1974 flood when the Brisbane River reached 5.45 metres. Higher levels are possible in Brisbane with two floods (8.35 metres and 8.09 metres) being recorded two weeks apart in February 1893 and higher still in the record flood of January 1841 at 8.43 metres.

2.3 FLOODING IN 2011

The city of Toowoomba, in the Darling Downs, was hit by flash flooding after more than 160 millimetres (6.3 in) of rain fell in 36 hours to 10 January 2011; this event caused four deaths in a matter of hours. Cars were washed away. Toowoomba sits on the watershed of the Great Dividing Range, some 700 metres (2,300 ft) above sea level. A three-week period where it had rained on all but three days had left the soil around Toowoomba super saturated and when a line of storms hit the city on 10 January, the resulting torrential rain rapidly ran off down gullies and streets. The central business district of the city sits in a small valley where two small water courses—East Creek and West Creek—meet to form Gowrie Creek. Unable to cope with the volume of water heading toward them, the creeks burst their banks, pushing a devastating wall of water through the city centre. (Fraserq, 2011) This water then headed west - not towards the Lockyer Valley which was also experiencing extreme rainfall that fell on eastern facing slopes. (Graham, 2011)

The surge passed through the Lockyer Valley town of Withcott, where the force of the water pushed cars into shops and forced the evacuation of hundreds of people. The scene was described by an onlooker as "like Cyclone Tracy has gone through it ... If you dropped an atom bomb on it, you couldn't tell the difference." (Johnson, 2011). Nearby Helidon had several homes and farms flooded but did not break the main creek bank and enter the town. It was cut off from all sides by destroyed roads. Granthamwas also devastated by the surge of water. Houses were left crumpled by what Premier of Queensland Anna Bligh described as an "inland tsunami". According to local media, the flood waters had reached a height of 7 or 8 m (23 or 26 ft.) by the time it struck Grantham. (Grantham is a town left in tatters, 2011)The peak discharge rate around Withcott and Grantham where Lockyer Creek is joined by Gatton Creek, was estimated to be 3,500 m³ second. (Flooding In The Brisbane River Catchment, 2011). At least 100 people were evacuated to the Helidon Community Hall. (Jamieson, 2011) . Nine people were confirmed dead, and many more feared dead among 66 reported missing. The body of one victim washed away at Grantham was recovered 80 kilometres (50 mi) downstream and Queensland Police Commissioner Bob Atkinson warned that some bodies may never be found. (Fergusson & Schulz, 2011). Nearby Gatton saw voluntary evacuations as the Lockyer Creek rose to a record height of 18.92 metres (62.1 ft.), exceeding the previous record set in the 1893 Queensland floods. (Torrential rain raises alarm for Toowoombra, Maryborough, Gympie, Wide Bay, Kingaroy, Cooloola and Brisbane. , 2011)

Three people from Grantham listed as missing were officially declared dead by the Coroner on 5 June 2012. (Flood victims' family demands judicial inquiry, 2012)

2.4 FLOODING AND TIDAL IMPLICATIONS

Evident in Figure 1 above are two peaks—a minor peak at 5:00 pm on Wednesday 12th January (4.30 m) and then later at 3:00 am on Thursday 13th January, when the river reached 4.46 m. Given a "major flood" at the Brisbane City gauge is defined as a gauge height of 3.50 m or greater, Brisbane City experienced a major flood from 10:00 am on Wednesday 12th January until 6:00 pm on Thursday 13th January, a period of 32 hours. This 32-hour period at the City gauge spanned three high tides:

14:15 Wednesday 12th January

02:34 Thursday 13th January

14:54 Thursday 13th January

The major peak of 4.46 mAHD at the City gauge corresponded almost exactly with the high tide at 2:34 am on 13th January. The minor peak of 4.30 mAHD at 17:03 Wednesday 12th January (Figure 1) probably represents the highest river flows. Brisbane felt the full force of these.

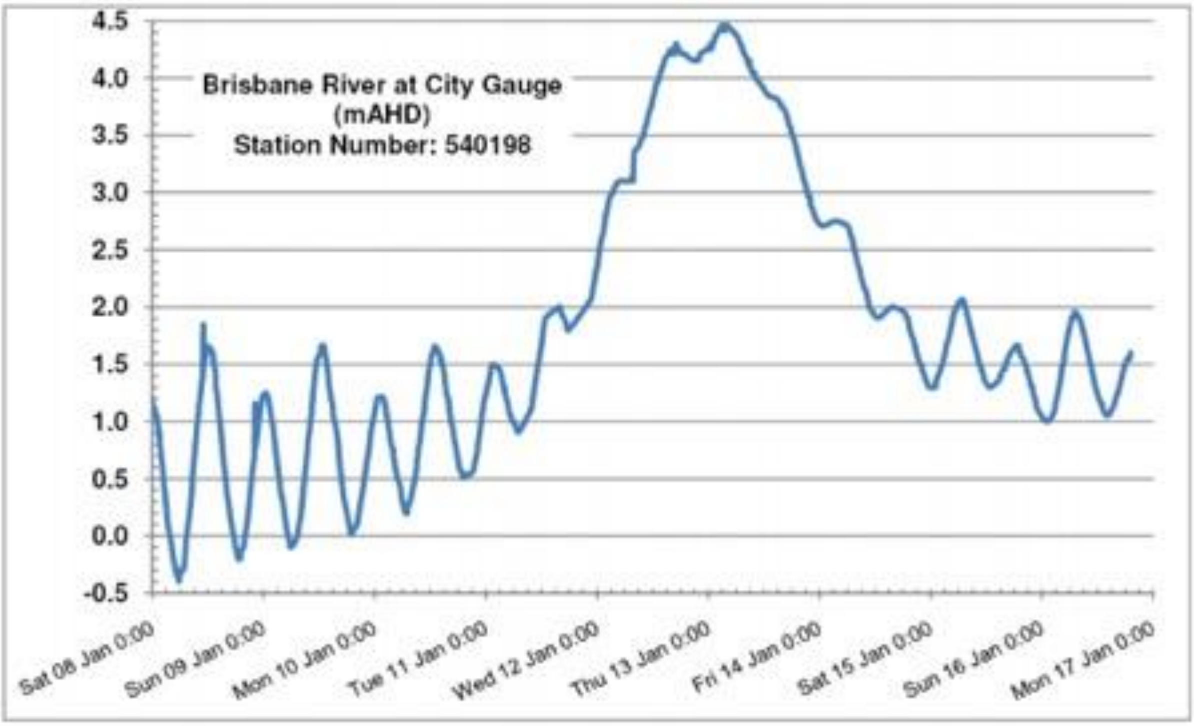


Figure 1

2.5 CAUSES OF THE 2011 FLOODING EVENT

The second half of 2010 and early 2011 was characterized by one of the four strongest La Niña events since 1900 (Honert & McAneney, 2011) (Figure 2). Strong La Niña events are often associated with extreme rainfall and widespread flooding in eastern Australia.

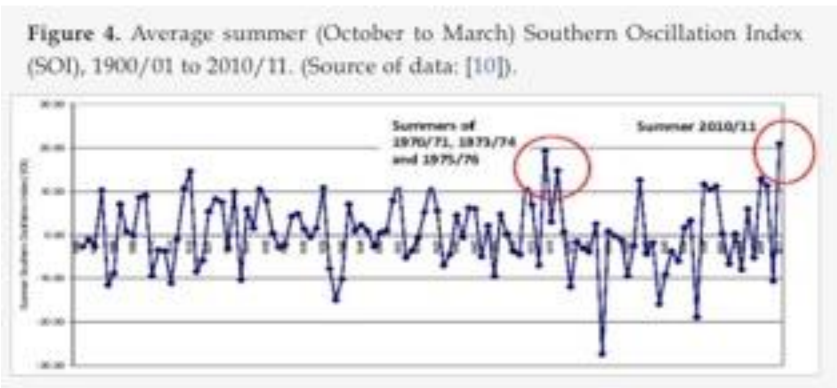


Figure 2

An extremely wet spring (September to November) meant that catchments were already saturated before the December 2010 and January 2011 rains. (Honert & McAneney, 2011) Figure 3 shows total rainfall across Australia for November 2010 to January 2011. During this period, rainfall in the 600 to 1,200 mm range was widespread along most of the Queensland coast. Some stations north and west of Brisbane exceeded 1,200 mm during this same period.

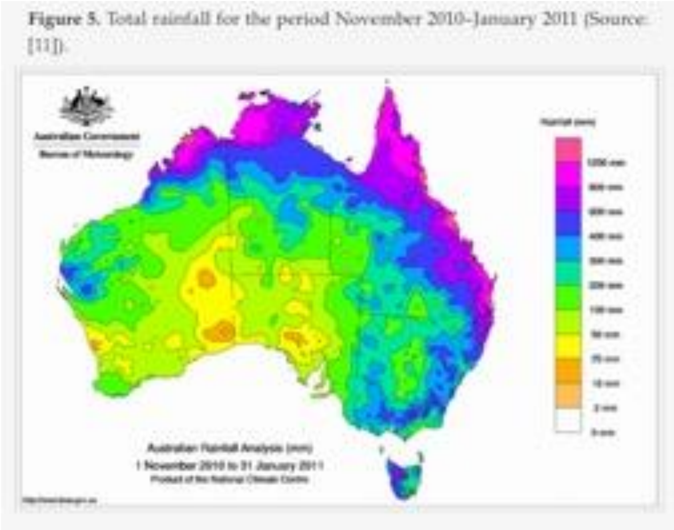


Figure 3

The flooding in southeast Queensland during the second week of January was caused by the interaction of a low-pressure system situated off the mid and south Queensland coasts, and upper level and monsoonal troughs (Honert & McAneney, 2011). Between Friday 7th January and Sunday 9th January the low-pressure system moved in a southerly direction from east of Mackay (800 km north west of Brisbane) to an area north east of Fraser Island, before moving closer to the coast on Monday 10th January. Early on Sunday 9th January the low-pressure system combined with an upper level trough to deliver heavy rains to southeast Queensland. This rainfall continued for much of the day.

The upper level trough dissipated early on Monday 10th January, but the low-pressure system intensified and moved north to combine with a southward moving monsoonal trough. Warm moist air delivered into this trough system by a high pressure system located off New Zealand led to very heavy rainfalls across the southeast corner of Queensland from the evening of Monday 10th until the late afternoon of Tuesday 11th January, with rainfall tailing off on Wednesday 12th (Honert & McAneney, 2011) . Direct rainfall for the period 9th–13th January into Wivenhoe and Somerset Dams was very heavy, with totals of 480 mm and 370 mm respectively.

The 10th–11th January rainfall led to very high water levels in the two dams. Levels in Somerset Dam peaked at 104.96 m AHD around 05:30 on Wednesday 12th January 2011. Water levels in Wivenhoe Dam peaked at 74.97 m AHD around 19:00 on Tuesday 11th January and remained above 74.9 m AHD for six hours from 18:00 on Tuesday 11th January (Honert & McAneney, 2011).

Downstream of the dams, areas in the lower Brisbane River catchment also experienced significant rainfall, decreasing towards the south and east. In the Lockyer Creek catchment total rainfalls of around 450 mm were recorded close to its downstream end, with intensities having an Average Return Interval (ARI) greater than 100-years for durations greater than 3 hours. In the Bremer River catchment, 420 mm was recorded near the northwestern limit. The lowest rainfalls across the lower reaches of the catchment were recorded in the southern and eastern suburbs of Brisbane (110–160 mm) (Honert & McAneney, 2011).

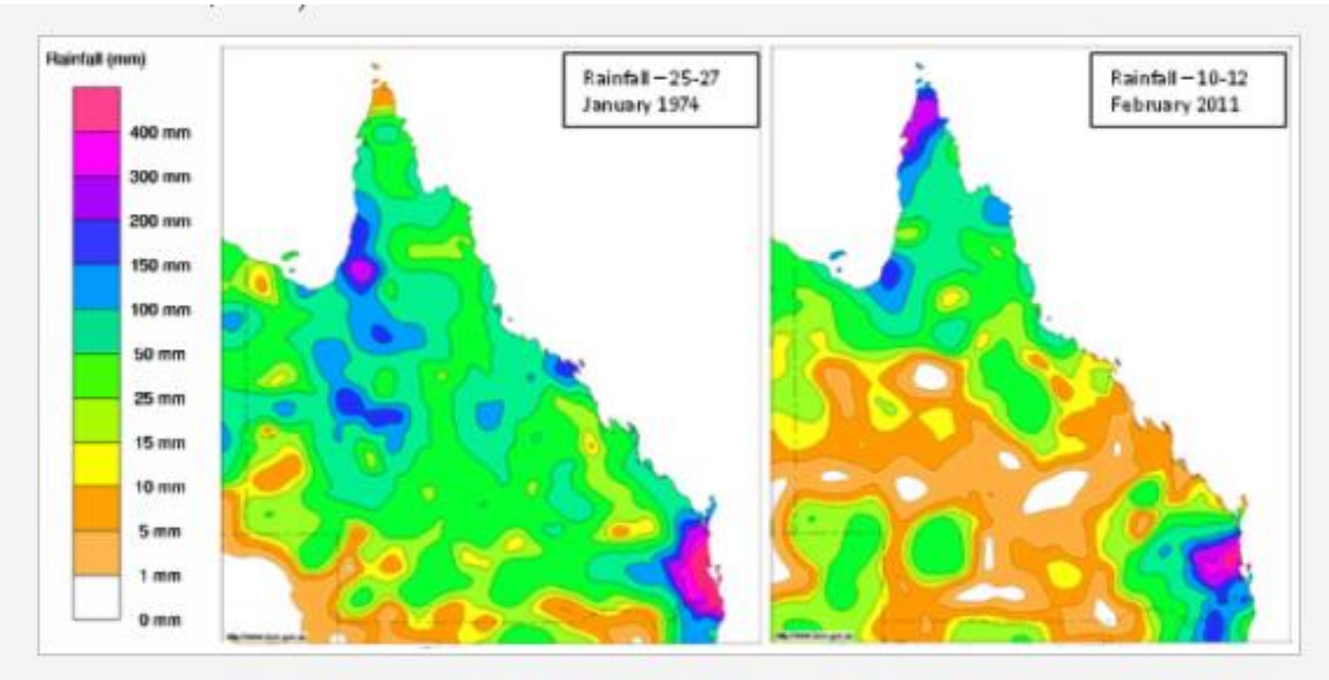


Figure 4

Figure 4 (Honert & McAneney, 2011) displays three-day rainfall totals from the period 10th–12th January 2011 and for the 25th–27th January 1974. Key points to emerge are:

(1) Peak rainfalls in 1974 were substantially heavier than those in 2011. A number of rainfall stations in southeast Queensland had three-day rainfall totals in excess of 1,000 mm in 1974 compared with a maximum of 648 mm recorded during the 2011 event. Over the Brisbane River catchment as a whole, the average three-day rainfall in 1974 was 349 mm, compared with 286 mm in 2011, and all four major sub-catchments were also wetter in 1974 than in 2011, although by small margins in the cases of the Bremer (442 mm *vs.* 417 mm) and Lockyer (331 mm *vs.*292 mm) sub-catchments (Honert & McAneney, 2011).

(2) The above observation also extends to metropolitan Brisbane where three-day and one-day totals of 600 mm and 314 mm in 1974 were significantly greater than the 166 mm and 111 mm recorded in 2011 (Honert & McAneney, 2011).

(3) In 1974 the heaviest rains in south east Queensland occurred close to the coast, whereas in 2011 the heaviest rainfalls spread further inland, particularly on the western fringe of the Brisbane River catchment and on the Great Dividing Range.

2.6 WATER RELEASE WIVENHOE DAM

Hydrologists appointed by the Insurance Council of Australia to investigate events leading to flood damage claims in Brisbane, Ipswich, Toowoomba and the Lockyer Valley consider the Brisbane flood event to be a "dam release flood." In other words, in their view release of water from the Wivenhoe Dam was a key contributor to the flooding downstream over the period 11th–12th January 2011 (Honert & McAneney, 2011). This does not imply fault, but merely acknowledges that the water that caused much of the damage came from dam releases. In what follows we briefly discuss this issue.

Seqwater operates the Wivenhoe and Somerset Dams in accordance with procedures contained in its operations manual (Honert & McAneney, 2011). The manual provides objectives and strategies to guide operational decision-making during a flood event, and lists its operational objectives, in descending order of importance, as:

(1) Ensuring the structural safety of the dams;

(2) Providing optimum protection of urbanised areas from inundation;

(3) Minimising disruption to rural life in the valleys of the Brisbane and Stanley Rivers;

(4) Retaining the storage at Full Supply Level (for water supply purposes) at the conclusion of the Flood Event;

(5) Minimising impacts to riparian flora and fauna during the drain down phase of the flood.

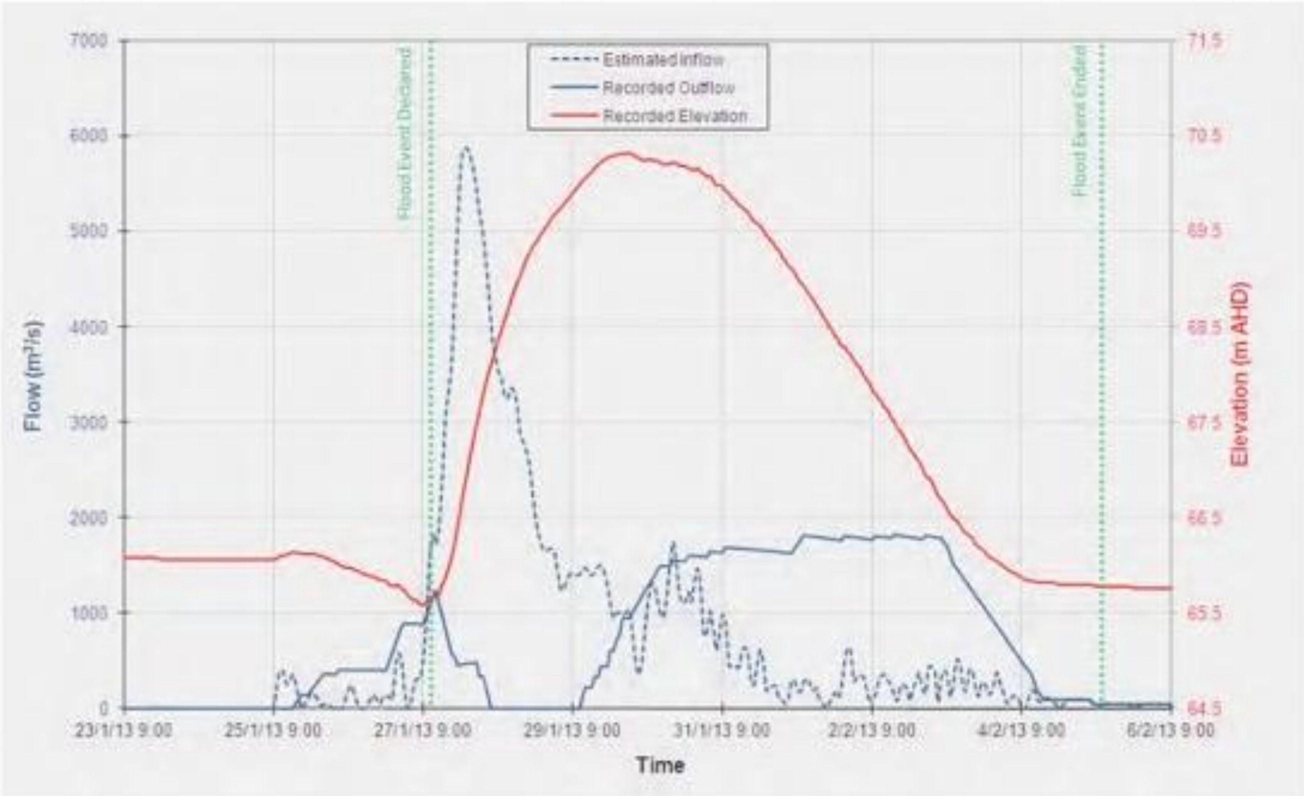
Apart from the obvious most important objective of ensuring the structural integrity of the dam itself, it can be seen that the dam is expected to serve two contradictory functions. On the one hand it serves as a buffer against drought, meaning that it is desirable to keep the dam as full as possible in case future rainfall is low (objective 4); on the other hand, the dam was specifically built to provide a buffer against floods, meaning it is desirable to keep it as empty as possible to maximize retention of flood waters (objectives 2, 3 and 5). Since keeping the dam full and empty are not simultaneously possible, Seqwater's engineers have to balance these conflicting objectives.

In January 2011, Wivenhoe Dam was called upon to accommodate massive inflows made up of surface runoff from the upstream catchment area, releases from Somerset Dam and direct rainfall into the lake. The greater the volumes and rate of inflow, the less effective are dams in mitigating flood flows, and the more constrained are management options for dam operators. According to a Seqwater report into the January 2011 flood event (Honert & McAneney, 2011) operational decisions were made in accordance with the manual. Dam outflows were delayed until it was clear that no other option was available without risking the safety of the dams. Seqwater reported that:

Two distinct flood peaks entered Wivenhoe Dam during the flood event. The first flood into Wivenhoe Dam was similar in nature and magnitude to the comparable flood flows of the January 1974 event. The combined mitigation effect of Somerset and Wivenhoe Dams ensured that this first flood did not result in urban damage below Moggill (some 20 km upstream from Brisbane CBD), however achieving this result did cause significant filling of the dams' flood storage compartments. The second flood was also similar in nature and magnitude to the comparable flood flows of the January 1974 event. The flood compartments of the dams were filled to a high level by the first flood and there was not sufficient time to release this water prior to the second flood arriving. Accordingly, the second flood could not be completely contained without risking the safety of the dams. The resulting inflow of water into the Brisbane River, combined with floodwaters from Lockyer Creek, the Bremer River and the Lower Brisbane River resulted in significant urban damage. However, the extent of this damage was greatly reduced by the operation of the dams.

(Honert & McAneney, 2011)

The inflow of water into the Wivenhoe Dam, the outflows and the headwater elevation of the dam around the time of the 2011 flood are shown in Figure 8. The peak of the outflow from the dam (around 23:30 on 11th January) was approximately 40% lower than the peak of the inflows (at about 13:00 on the same day). Indeed, model estimates provided to Seqwater by Brisbane City Council indicate that without the mitigating effects of Wivenhoe the peak flood height measured at the City gauge near the Brisbane CBD would have been approximately 2.0 m higher than was actually experienced, and a further 14,000 properties impacted (Honert & McAneney, 2011).



Figur 5

Figure 5 shows that water releases commenced only at 15:00 Friday 7th January when Wivenhoe Dam was at 109.6% and Somerset at 110.9% of FSL, with a total of 153,000 mL already in flood storage. In the week from 06:30 Tuesday 4th January, when Wivenhoe Dam was at 102.1% and Somerset at 102.9% of FSL and Seqwater were required under the manual to declare a Flood Event, there were only 14 hours during which the release rates from Wivenhoe Dam exceeded inflows.

The balancing act between retaining as much water as possible and releasing water to make space for further significant inflows has been automated to some extent with the operations manual directing that the water release strategy chosen at any point in time will depend on the *actual* water level in the dam, as well as modelling predictions about future water levels. The latter are to be made using the best available *forecast* rainfall and stream flow information (Honert & McAneney, 2011). In the aftermath of the January 2011 flood, a senior Wivenhoe engineer has stated before the Commission of Inquiry (Honert & McAneney, 2011) that uncertainty in BoM rainfall forecasts and the paucity of rain gauges in the catchment immediately above the Wivenhoe Dam led them to conclude that the precipitation forecasts were not sufficiently reliable to form the basis for operational decision making (Honert & McAneney, 2011; Brisbane City Council, 2016; Brisbane City Council, 2016; Brisbane City Council, 2016; Brisbane City Council, 2016). Seqwater claim there were gaps in the information on which operational decisions needed to be made, despite them having available the best rain gauge of all - the dam itself!

2.7 DAMAGE CAUSED BY FLOODING

More than 15,000 properties were inundated in metropolitan Brisbane and some 3,600 homes evacuated. Across Queensland approximately 12,000 people were accommodated in 34 evacuation centres managed by the Red Cross. Altogether over 200,000 people were affected. Approximately 3,570 business premises were inundated, and commercial losses of approximately $4 billion were reported across the mining, agriculture and tourism sectors. Over 19,000 kilometres of roads were damaged, around 28 percent of the Queensland rail network damaged and three major ports significantly impacted. An estimated 28,000 homes would need to be rebuilt, while vast numbers of dwellings require extensive repairs. According to the Insurance Council of Australia, almost 56,200 claims were received by insurers, with an insured cost of $2.55 billion. (Honert R. v., 2011)

2.8 INVESTIGATIONS INTO BACKFLOW

The investigation into the feasibility of backflow devices along the length of the Brisbane River was completed in 2012.

The technical investigations were carried out in two stages:

Stage 1 - Pre-feasibility Investigation

- Pre-feasibility investigation for implementation of backflow prevention technology in the three case study areas of the CBD, Rosalie/Milton and New Farm
- A city-wide desktop review of other affected areas along the Brisbane River

Stage 2 - Technical Investigation

- Developing detailed designs for the implementation of backflow devices in the three case study areas of the CBD, Rosalie/Milton and New Farm. Construction is complete
- Investigations along the length of the Brisbane River to determine stormwater systems that contributed to backflow flooding in the January 2011 floods and that could be retrofitted with backflow devices

2.8.1 INSTALLATION OF BACKFLOW DEVICES

The installation of backflow devices on the pre-feasibility sites was completed in 2012.

Twelve further stormwater systems were identified as high priority sites for backflow device installation and the construction was completed in June 2014.

Future works: (remaining backflow devices) other feasible systems will be considered in Council’s future drainage program, which is subject to Council's annual budget and citywide priorities.

2.8.2 BACKFLOW SITES

Twelve stormwater systems were identified as high priority sites for backflow device installation. These 12 projects systems will provide benefit to approximately 80% of properties that were impacted by backflow flooding in January 2011 (Brisbane City Council, 2016)



2.9 IMPORTANT FACTORS IN DECISION ON BACKFLOW DEVICES

For the drainage systems identified as feasible for installation of back flow devices, the data for each system has been collated to produce a draft backflow management strategy, centred on calculation of a ‘Relative Cost Benefit Ratio’. High level likely installation costs were compared with benefits based on the damages potentially mitigated by back flow devices to produce the Relative Cost Benefit Ratio. While this ratio provides a guide to which systems provide the highest value, a number of factors will be considered by Council when deciding a priority for installation of back flow devices. These factors may include cost benefit analysis, the number of properties impacted by floods, the cost of installation, operational issues, previously programmed drainage network upgrades or critical infrastructure impacted by flood.

Particular attention has been given to:

- The head loss rating curve of the device (typically relating flow rate with head loss)

- The ability to install the device simply and effectively

- Whether the device is best installed at an outlet or at some point further upstream

- Reducing required monitoring and maintenance of the device

- The ability of the device to withstand high external pressures and high lateral velocities

- Suitability for installation in the intertidal zone

- Types of devices already installed within Brisbane City Council

- The procurement and installation cost of the device.

The chosen device for Bulimba was based on the above factors.

2.9.1 RELATIVE COST BENEFIT RATIO

The Cost Benefit Ratio was deemed positive given the other alternatives would have required major reconstruction of the outlet structure and 3-4 months in civils. Another 6 months was saved given that the valve sits inside the existing pipe and therefore there wasn't a requirement for statutory approval for working within the tidal zone.

Maintenance costs have been reduced by AUD$100,000 per year just in reduced de-silting operations.

2.9.2 HEADLOSS

WaStop has the lowest head loss on the market for gravity check valves. Testing conducted at Utah State University confirmed this and showed that the head loss with the valve was only slightly higher than the normal head loss of the system.

This was an important factor for Brisbane given that during flood events it is essential to release as much water as possible, as fast as possible, to reduce the risk of upstream flooding.

$$\Delta p_{f,minor_L} = \frac{K_L \rho V^2}{2} = \rho g h_{L,minor} \Rightarrow h_{l,minor} = K_L \frac{V^2}{2g} \qquad (1)$$

$\Delta p_{f,minor_L}$: $Pressure\ loss\ minor [Pa]$ $h_{l,\,minor}$: $Headloss\ (minor) [m_{H_2O}]$

K_L: $Loss\ coefficient\ [-]$ V: $Velocity\ in\ pipe\ \left[\frac{m}{s}\right]$ g: $9.81\ \left[\frac{m}{s^2}\right]$

The total head loss of a system being:

$$h_L = \left(\frac{fL}{D} + \sum K_L\right)\left(\frac{V^2}{2g}\right) \quad (2)$$

Here is an example of a head loss curve for the WaStop Valve compared to the head loss in the pipe system.

ASSUMPTIONS:

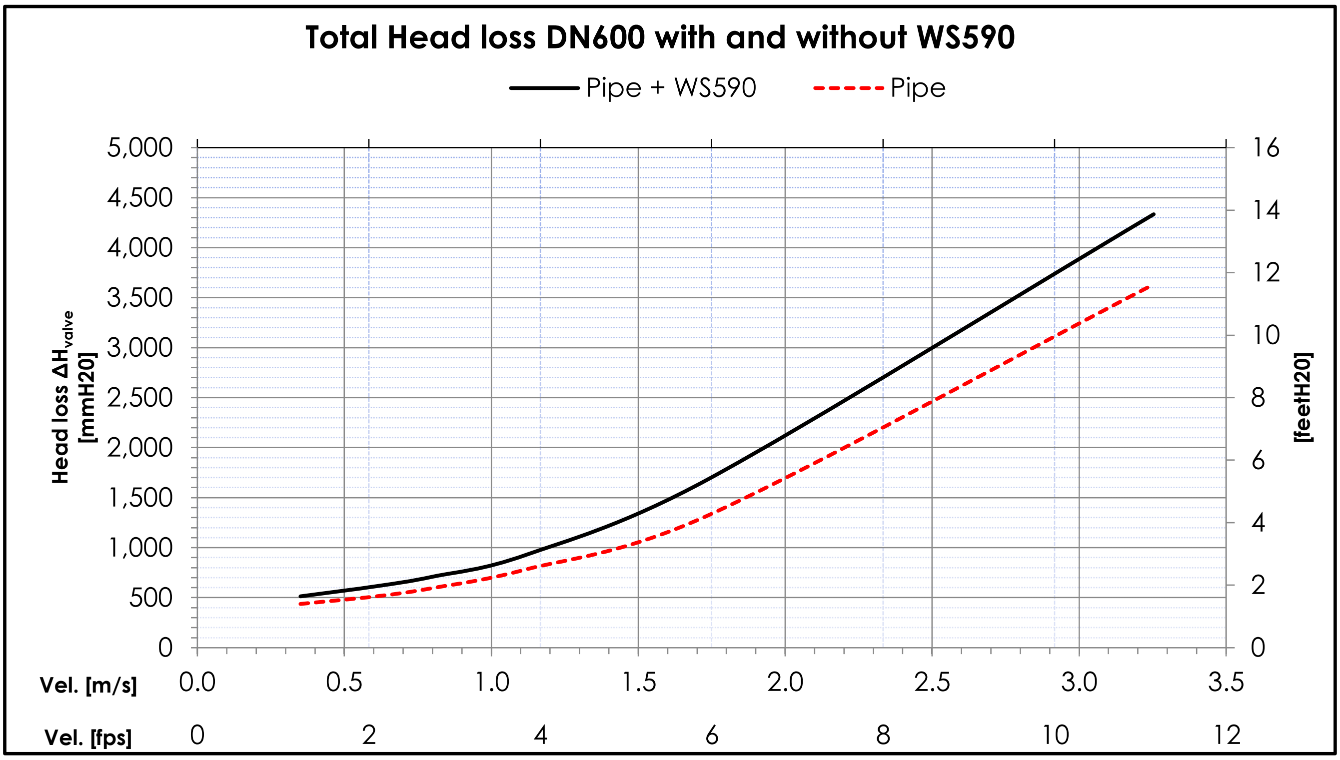
Pipe roughness $k = 2$ ($\epsilon = \frac{2}{600}$), pipe diameter 600mm (24'')

Discharge submerged, all the velocity potential is lost; $K_L = 1$ (without a Wastop)

Inlet to the piping system $K_L = 0.5$

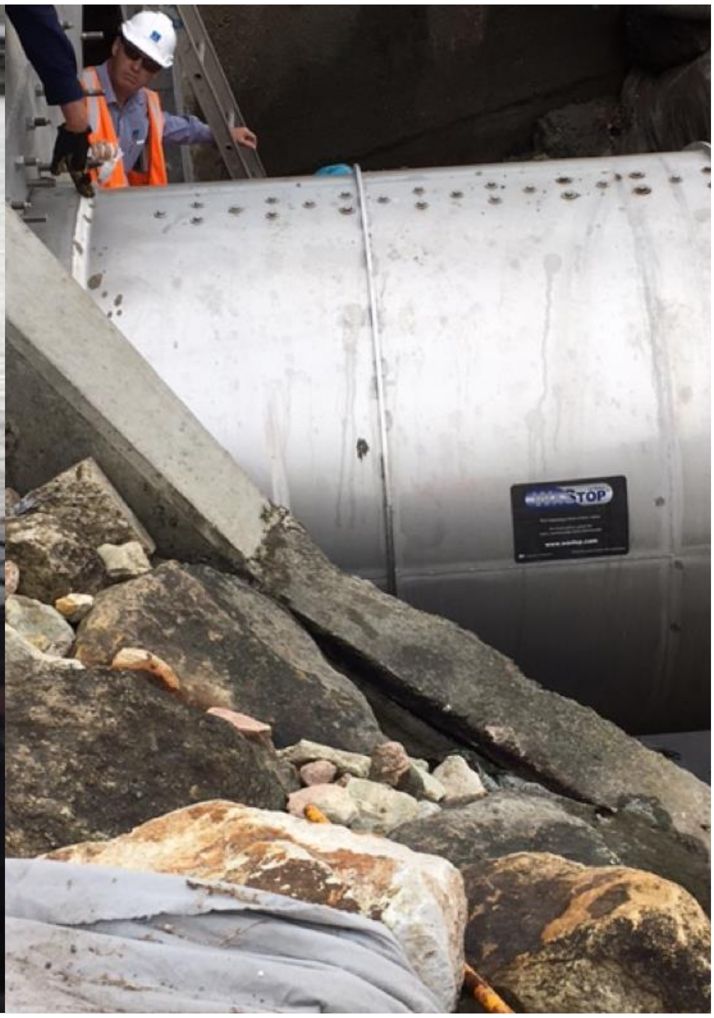
K_L values for the given flow rates for the outlet with a WaStop from a test done at the Utah State University Water Researched Laboratory.

Incline 4 ‰ (=0.4%)



2.9.3 SIMPLE EFFECTIVE INSTALLATION

Installation of WaStop is simple and effective. Simply sliding the valve into the pipe and bolting it into the headwall is all that is required. The valve is then operational.



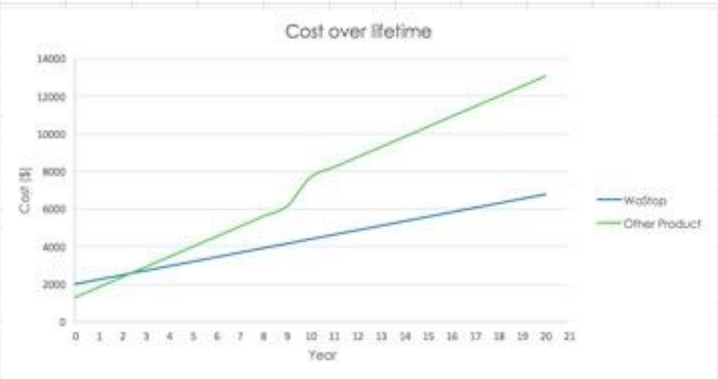
2.9.4 ABILITY TO WITHSTAND LATERAL AND TIDAL PRESSURE

Given that the valve sits inside the existing pipe the device is protected from lateral pressure and tidal debris

2.9.5 PROCUREMENT AND INSTALLATION COSTS

A quick calculation allows municipalities to estimate the life-cycle cost of different device options based on earlier collected data. With reduced maintenance budgets it is important to ensure that the ongoing maintenance is reduced as much as possible.

	WaStop	Other Product
Initial		
Purchasing cost	2000	1000
Installation		
-Headwall	0	300
-Rehabilitation of pipe	0	0
Maintenance		
-times / year	2	4
-hours / time	2	2
-cost / hour	60	60
Service Life		
Life span	20	10
Incidents		
times /10 years	0	3
cost /time	0	200
Sum 20 years	**6800**	**13100**
Break-even year	**3**	
Savings after 20 years	**6300**	



3 CONCLUSIONS

1. Brisbane is built on a floodplain and will flood again
2. Dam levels and water release impacts downstream areas particularly in tidal areas
3. Backflow devices are one method of protection

ACKNOWLEDGEMENTS

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