Wivenhoe:

A Dam Designed to Fail

and Decimate Brisbane

Figure 1: Wivenhoe Dam with Fuse Plugs at left and gates at right.

With a Solution

So That Won't Happen

by

Ken Shaw

4 April 2011

2. Questions for the Commission

One question for the Commission is what to do about floods like that which has just happened to Brisbane, and how to prevent them.

But the larger question for the Commission is how to protect Brisbane from looking like Grantham as a result of a cataclysmic **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe.

Such a flood would not be like the Brisbane Flood of January 2011.

It would flow at 10 times the speed of the Brisbane Flood of January 2011, and would arrive in a wall of water many metres high. A wall of water which would smash everything in its path.

That's why the word "flood" is not an adequate description.

I'm calling it a **Dam-Burst-Tsunami-Flood-Wave.**

The failure of Wivenhoe is not something which will never happen.

As Wivenhoe is currently designed, it will fail one day.

The question is not if, but when?

How many lives would be lost if we do nothing?

What are we going to do to prevent that?

3. Table of Contents

4. Introduction

Wivenhoe is a dangerous dam which is designed to fail. We hope that it won't, but we know that it will. The question is: when?

Wivenhoe has a clay core and an earth wall. It has no structure which could survive overtopping which would collapse the wall leading to tsunami like flooding downstream.

China's Banqiao Dam overtopped and failed in 1975 with an estimated 171,000 fatalities, 26,000 from drowning.

Wivenhoe is built in an earthquake zone. There was an earthquake of magnitude 4.4 near Mt Glorious in 1960, and of magnitude 4.0 near Gatton in 1988. The Wivenhoe wall is in a direct line between Mt Glorious and Gatton. Earthquakes have collapsed dams elsewhere. Would a large earthquake threaten the Wivenhoe wall?

The Hume Weir, built on the Murray River, has dimensions of a similar order to Wivenhoe's. Monitoring of the Hume Dam wall in the early 1990s revealed that the water pressure and leakage had caused the dam to move on its foundations slightly, leading to concerns that the dam was heading for collapse.

In January 2011, a deluge at Toowoomba and upstream from Grantham caused torrential runoff with dozens of lives lost.

That deluge followed persistent rain over a considerable period, with several results. Firstly, almost 100% of the rainfall was converted to runoff. Secondly, the runoff was at a very high rate. Thirdly, the fast runoff of water gathered the water already running off ahead of it in an avalanche with a snowball effect that accelerated the runoff in front of it creating torrential runoff in excess of the runoff from the deluge itself.

This **Accelerator/Avalanche/Snowball Effect** is a very dangerous phenomenon as we saw at Toowoomba and Grantham. It is a particularly dangerous effect if the possibility of its occurrence is not allowed for in the management of Wivenhoe.

On the Tuesday 11th January, there were of the order of a million megalitres of water in the catchment, but not yet in Wivenhoe. If a short sharp deluge accelerated that water into Wivenhoe in an avalanche with a snowball effect, then the Wivenhoe outlets (the gates and fuse plugs combined) would not have been able to cope with the inflow. The dam, already nearly full, would have quickly overflowed and collapsed.

So what can we do? Some catchments like Moggill Creek lend themselves to the construction of levee banks with flood gates and flood pumps. But the most significant thing we can do is to make Wivenhoe safe by concreting the outer skin of the wall.

5. Wivenhoe is a dangerous dam

Wivenhoe is a dangerous dam.

It is designed so that it will fail if it is over-topped by flood-water.

The consequences of its failure would be catastrophic for all downstream communities.

Wivenhoe is designed to be over-topped by runoff when that runoff exceeds the Flood Capacity of the dam. When that happens, the earthen dam wall will fail, and a tsunami like wave of water of gigantic proportions will destroy Brisbane as we know it in an epic disaster which will put hundreds of thousands of lives at risk.

Wikipedia refers to over-topping dam failures as follows.

http://www.engpedia.com/index.php/Causes_of_Earth_Dam_Failure

1. Over-topping Failures

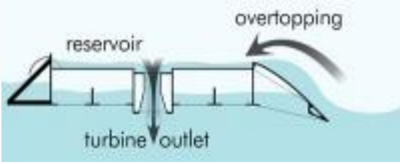


Figure 2: Diagram of over-topping dam

Over Topping of Dams

Over topping failures result from the erosive action of water on the embankment. Erosion is due to un-controlled flow of water over, around, and adjacent to the dam. Earth embankments are not designed to be over-topped and therefore are particularly susceptible to erosion. Once erosion has begun during over-topping, it is almost impossible to stop.

It is because of the knowledge of the danger of over-topping and collapse that there was the massive release of water from Wivenhoe in January 2011, causing extensive flooding to Brisbane and other downstream communities. But that flooding would be minor compared with that which would follow a failure of the wall.

Wivenhoe has a clay core and an earthen wall which is lined on the outside with rocks. Unlike Somerset Dam which has a concrete wall, Wivenhoe has no structure which could withstand the force of water flowing over its wall. If over-topped by flood-water, the Wivenhoe wall would quickly erode and fail, releasing the contents of a full Wivenhoe to flow down the Brisbane River at torrential speed.

There would be a Toowoomba-Grantham style of flood on a massively greater scale.

That event is due to happen infrequently; once in many thousands of years.

When will Wivenhoe fail? No-one knows. But it could happen next year, or the year after, or the year after that. No-one knows when it will happen. But everyone knowledgeable about the design of Wivenhoe knows that it is due to happen eventually. Wivenhoe was built with a design that ensures it will eventually fail in an extreme event.

In an attempt to reduce the likelihood of the failure of Wivenhoe, a few years ago, three fuse plugs were installed. But the fuse plugs won't prevent the failure of Wivenhoe; they will merely make it less likely.

One of the main criteria in relation to the selection of the fuse plug solution was cost. But the risk to the people who live downstream from Wivenhoe is too great to settle for second rate solutions just because they are cheap.

We have already seen how difficult it was to manage Wivenhoe in January 2011. Matters for judgement and human error by over-worked and stressed people have been retained as main elements in the management of Wivenhoe.

In January 2011, much of the theoretical flood capacity could not be used. Much of the Wivenhoe flood capacity was used to save the wall from overtopping, and the fuse plugs from an uncontrolled release; thereby rendering that flood capacity useless to save downstream communities from the flooding which ensued as a result. We are still learning about the management of Wivenhoe, and it is not an easy task. It is based on estimates of weather conditions and of rates of runoff: sciences which are still developing their skills and learning from recent events by trial and error.

The management of Wivenhoe relies on communications which may fail during extremely tempestuous cyclonic weather. It also relies on power and mechanical operation of the gates, which may also fail in the extreme conditions which may apply. What backup do we have if there is a power or mechanical failure; if communications towers and power towers are down; or if there is a failure of leadership under crisis conditions?

The management of Wivenhoe also relies on human operations from a control room located in the Wivenhoe wall; a control room manned by brave people who may panic in an event which may seem to become life-threatening.

I suspect that the overtopping of the wall of Wivenhoe would be emotionally similar to the sinking of the Titanic to those in the control room. Would you want to be there? How would you react? People do under pressure what they have done under practice; and they need realistic practice which is very difficult to simulate following years of fine days during droughts.

Elsewhere in this report, I argue that a short sharp deluge like that which hit Toowoomba and Grantham would have overwhelmed the wall in January 2011. That is because there was so much water in the catchment on its way to Wivenhoe; and that water would have been accelerated into Wivenhoe by a deluge. The acceleration would have produced a volume of inflow far greater than the combined outflow capacity of the gates and the fuse plugs. The wall would have overtopped and collapsed.

Figure 3: Wivenhoe dangerously full on Monday 10 January 2011

Figure 4: Wivenhoe in January 2011. The gates are at the right, and the fuse plugs near the top centre of picture

6. The Mysteries of Wivenhoe Dam

By the Honourable Bruce Flegg MLA: the Member for Moggill

Wivenhoe Dam on

Wednesday, 12 January 2011 at 08:46 am

Figure 5: Wivenhoe on Wednesday 12 January 2011 at 8:46 am

This haunting photo of Wivenhoe Dam wall taken on Wednesday 12th January shows the water level nearing the very top of the dam wall.

Many local constituents have expressed a view or asked questions about the flood component of Wivenhoe Dam.

Some of the answers are not as simple as what has been said publicly.

Essentially the operation of Wivenhoe Dam is that it holds around 1.15 million megalitres of water supply for Brisbane that at the dam wall comes to a depth of 67 metres. The government has claimed that it can hold an additional 1.45 million megalitres above that level in what is called the 'flood component' before the dam is unable to hold any further water.

However a decision taken around five years ago means that the official statements about the flood component are in fact incorrect. According to the official line Wivenhoe should be able to hold a maximum of about 225% that is a 100% for the drinking component and around 1¼ times as much in the flood component.

But the decision taken five years ago to construct what are referred to as 'fuse plugs' means that instead of raising the wall of the dam to cope with extreme events three structures were put in place in the wall at different heights that would mean if the dam reached a particular height at the wall the fuse plug an opening filled with rock and gravel would wash out and result in an uncontrolled release of water.

The idea of the fuse plugs was that in incredibly extreme events they would wash out and protect the dam wall. The first of the fuse plugs washes out when the water at the wall of the dam reaches 75.7 metres and there are two further fuse plugs that wash out at any higher levels.

This meant that the operators of the dam were under instruction not to allow the fuse plugs to wash out but to in fact release water into the flooded Brisbane River when the height at the dam wall reached 74.85 metres.

The result of the construction that was done about five years ago is that around 300,000 megalitres of the flood component of the dam was removed.

The often quoted figure that the flood component is 1.45 million megalitres is in fact exaggerated by 300,000 megalitres or around 20%.

This means that when trying to protect Brisbane from flood instead of having a total capacity of 225% the capacity of Wivenhoe Dam five years ago was reduced to around 200% approximately the level seen in the photograph.

At this point operators of the dam lose the discretion to hold back additional water.

Not being an engineer I would certainly not comment on whether the fuse plugs that were never envisaged as part of the original construction of the dam as a flood mitigation dam was in fact necessary to protect the integrity of the dam but I am told that had the decision been made to raise the level of the wall and place the fuse plugs so that the dam was still able to hold the intended 1.45 million megalitres of flood mitigation capacity that rather than cutting down the height of the existing wall then significantly more water could have been held back during the Brisbane flood.

I am sure these matters will be referred by interested parties to the upcoming inquiry but readers will of course know that it is not expected to report until 2012

7. The Three Wivenhoe Fuse Plugs:

Between February 2003 and September 2005, a 165-metre (541 ft) wide auxiliary spillway with a three-bay fuse plug was installed on the western portion of the Wivenhoe dam to further mitigate flooding.

Each of the three fuse plugs is set at a slightly different level. The fuse plugs are intended to fail (i.e. to erode as water flows over them) so that they prevent/delay overtopping of the main Wivenhoe Dam wall.

Electrical fuses are well understood. They fail and stop the flow of electrical current. Electrical fuses are expendable and thereby save a much more valuable piece of equipment.

Wivenhoe's fuses are slightly different: they don't stop the flow, but they divert some of it. If the flow exceeds the capacity of the fuse plugs, then water will still flow over the wall, destroying it.

If it were safe for water to flow over the main wall, we wouldn't have needed the fuse plugs.

Prior to building the fuse plugs, water now destined for the fuse plugs would have flowed over the main wall, which would have collapsed earlier than now in an extreme flood event.

The fuse plugs are designed to fail, and are built for that purpose using an earthen core which is rock lined. The fuse plugs collapse progressively; the middle fuse plug is fails first.

Figure 6: The 3 Wivenhoe Fuse Plugs. Notice the different heights. The Brisbane Valley Highway is at left, the gates at far right.

If the gates cannot handle the volume of water coming into the dam, water will flow over the fuse plugs, and the flow will erode the fuse plugs which will collapse.

If the fuse plugs and the gates cannot handle the volume of water coming into the dam, then water will flow over the main Wivenhoe wall. In that event, the main wall would fail, because, like the fuse plugs, the main wall is built from an earthen wall which is rock lined.

The main wall of Wivenhoe is no more capable of surviving being over-topped than the fuse plugs are. The fuse plugs and the main wall are both built from earth which will erode. The main wall of Wivenhoe has been designed so that it will fail if flood water flows over it.

Somerset Dam, upstream of Wivenhoe, is made of concrete, and is designed to be safely overtopped - in stark contrast with Wivenhoe which is designed so that it will collapse if it is over-topped. That's why it is correct to state: **Wivenhoe is designed to fail**.

Figure 7: The Wivenhoe Fuse Plugs prior to the 2011 flood

Figure 8: The Wivenhoe Fuse Plugs getting close to over-topping

Figure 9: Fuse plugs with water on the way down. See the high water mark on the pillars of the Brisbane Valley Highway.

8. A Haunting Picture of Wivenhoe

The picture hereunder (also on the following page on a larger scale for easier study) is of Wivenhoe Dam at 8:40 am on Wednesday 12 January 2011. Imagine if we had an extreme event with torrential rain and massive winds during a category 5 cyclone with trees, powerlines, power poles, power towers, and phone towers down. Imagine the worst weather you can think of persisting for day after day in the Wivenhoe catchment.

Figure 10: Wivenhoe on Wednesday 12 January 2011 at 8:46 am

What do you think would happen at Wivenhoe in those circumstances? Do you think it might overflow? Imagine what would happen if Wivenhoe overflows, if the wall erodes and collapses, and the Wivenhoe Lake floods downstream, inundating Brisbane and other downstream communities.

There is a precedent. In China, in 1975, the Banqiao Dam collapsed with loss of life estimated at 171,000, of whom 26,000 died from drowning, the others from epidemics and famine resulting from the massive disruption which followed the massive flood.

Figure 11: Wivenhoe on Wednesday 12 January 2011 at 8:46 am: Imagine the wall over-topping and eroding, and the Lake bursting downstream: A Dam-Burst-Tsunami-Flood-Wave

9. Banqiao Dam's Collapse & 171,000 Fatalities

The following is an edited excerpt of a Wikipedia entry about the failure of the Banqiao Dam. The full Wikipedia article about the Banqiao Dam, is in the Appendix B of this report and is found at http://en.wikipedia.org/wiki/Banqiao_Dam

*The **Banqiao Reservoir Dam** is a dam on the **River Ru** in Zhumadian Prefecture, Henan province, China. It infamously failed in 1975, causing more casualties than any other dam failure in history, and was subsequently rebuilt.*

*The Banqiao dam and **Shimantan Reservoir Dam** are among 62 dams in Zhumadian Prefecture of China's Henan Province that failed catastrophically or were intentionally destroyed in 1975 during Typhoon Nina.*

The dam failure killed an estimated 171,000 people, 26,000 from drowning, and the others from other causes including epidemic and famine.

Figure 12: The collapsed Banqiao Dam after flood-water over-topped and eroded the earthen wall

History

Figure 13: The location of Banqiao Dam

The Banqiao dam was begun in April 1951 on the Ru River with the help of Soviet consultants as part of a project to control flooding and to generate electricity. It was a response to severe flooding in the Huai River Basin in 1949 and 1950. The dam was completed on June 1952. Because of the absence of hydrology data, the design standard was lower than the standard. After the 1954 Huai River great flood, the upstream reservoirs including Banqiao were extended, constructed and consolidated. Banqiao Dam was increased in height by three meters. The dam crest level was 116.34 meters above sea level and the crest level of the wave protection wall was 117.64 meter above sea level. The total capacity of the reservoir was 492 million m^3, with 375 million m^3 reserved for flood storage. The dam was made of clay and was 24.5 metres high. The maximum discharge of the reservoir was 1,742 m^3/s.

Cracks in the dam and sluice gates appeared after completion due to construction and engineering errors. They were repaired with the advice from Soviet engineers and the new design, dubbed the iron dam, was considered unbreakable.

1975 Flood

The Dam was designed to survive a once-in-1000-years flood (300 mm of rainfall per day). In August 1975, however, a once-in-2000-years flood occurred, and poured more than a year's rainfall in 24 hours (new records were set, at 189.5 mm rainfall per hour and 1060 mm per day, exceeding the average annual precipitation of about 800 mm), which weather forecasts failed to predict, produced by the collision of Super Typhoon Nina and a cold front. Communication to the dam was largely lost due to the collapse of buildings under heavy rain and wire failures. On August 6, a request to open the dam was rejected, because of the existing flood in downstream areas. On August 7, however, the request was accepted, but the telegrams failed to reach the dam.

The sluice gates were not able to handle the overflow of water, partially due to sedimentation blockage. On August 7 at 21:30, the People's Liberation Army Unit 34450 (namely the 2nd Artillery Division in residence at Queshan county), which was deployed on the Banqiao Dam, sent the first dam failure warning via telegraph. On August 8, 0:30, the smaller Shimantan Dam, which was designed to survive a 1-in-500-year flood, failed to handle more than twice its capacity and broke upstream, only 10 minutes after Unit 34450 sent a request that would open the Banqiao Dam. A half hour later, at 1:00, water at the Banqiao crested 117.94 level above sea level, which was 0.3 meter higher than the wave protection wall on the dam, and it too failed. This precipitated the failure of 62 dams in total. The runoff of Banqiao Dam was 13,000 m³ per second inflow vs. 78,800 m³ per second outflow, and 701 million tons of water was released in 6 hours, while 1.6 billion tons of water was released in 5.5 hours at upriver Shimantan Dam, and 15.7 billion tons of water was released in total.

The resulting flood waters caused a large wave, which was 10 kilometres wide and between 3 and 7 meters high in Suiping, to rush downwards into the plains below at nearly 50 kilometres per hour, almost wipe out an area 55 kilometres long and 15 kilometres wide, and create temporary lakes as large as 12,000 square kilometres . Seven county seats, namely Suiping, Xiping, Ru'nan, Pingyu, Xincai, Luohe, Linquan, were inundated, as were thousands of square kilometres of countryside and countless communities. Evacuation orders had not been fully delivered because of weather conditions and poor communications. Telegraphs failed, signal flares fired by Unit 34450 were misunderstood, telephones were rare, and some messengers were caught by the flood. While only 827 out of 6,000 people died in the evacuated community of Shahedian just below Banqiao Dam, half of a total of 36,000 people died in the unevacuated Wencheng commune of Suipin County next to Shahedian, and the Daowencheng Commune was wiped from the map, killing all 9,600 citizens. Although a large number of people were reported lost at first, many of them returned home later. Tens of thousands of them were carried by the water to *downriver provinces and many others fled from their homes. It has been reported that around 90,000 - 230,000 people were killed as a result of the dam breaking.*

The Jingguang Railway, a major artery from Beijing to Guangzhou, was cut off for 18 days, as were other crucial communications lines. Although 42,618 People's Liberation Army troops were deployed for disaster relief, all communication to and from the cities was cut off. Nine days later there were still over a million people trapped by the waters, relying on airdrops of food and unreachable to disaster relief. Epidemics and famine devastated the trapped survivors. The damage of the Zhumadian area was estimated to be about USD $513 million). The Zhumadian government appealed to the whole nation for help, and received more than USD $44 million in donations.

After the flood, a summit of National Flood Prevention and Reservoir Security at Zhengzhou, Henan was held by the Department of Water Conservancy and Electricity, and a nationwide reservoir security examination was performed after this meeting.

Casualties

According to the Hydrology Department of Henan Province, in the province, approximately 26,000 people died from flooding and another 145,000 died during subsequent epidemics and famine. Unofficial estimates of the number of people killed by the disaster have run as high as 230,000 people. The death toll of this disaster was declassified in 2005.

Contrast between Banqiao and Wivenhoe

Specifications	Banqiao	Wivenhoe
construction	Clay	Clay core, earth wall
Water Capacity million ML	492	1,150
Flood Capacity million ML	375	1,450
Total Capacity million ML	**867**	**2,600**

10. A Banqiao Dam Retrospective (30 years Later)

The following is an article which appeared in the English version of the People's Daily Online on 1 October 2005. The original is at: http://english.people.com.cn/200510/01/eng20051001_211892.html

After 30 years, secrets, lessons of China's worst dams burst accident surface

A B

Though 30 years have passed, remorse, sighs and sympathy were common feelings among attendees who convened a seminar in this capital city of central Henan Province to commemorate an accident that had long been ignored nationwide.

A miserable story about China's most devastating dams bursts that caused thousands of lives in the province in August 1975 was unfolded by 150 officials, meteorologists, hydrologists from China, the United States and Italy at the seminar on Sept. 15, only three days after China announced to declassify its natural disaster death tolls.

HORRIBLE MEMORIES

On Aug. 7, 1975, just a day before the tragedy, almost nobody in Zhumadian, a city about 1,000 km south of Beijing in Henan, were aware that a catastrophe was looming.

A pouring rain following the third typhoon that battered China that year soaked the area with then about 7 million population, swollen more than 100 medium or small reservoirs with a rainfall recorded at 1,060 millimetres in 24 hours near the typhoon centre.

"When the rain continued, the days were like nights as rain fell like arrows," survivors were quoted as saying by official records. "The mountains were covered all over by dead sparrows after the rain."

The 24.5-meter dam of Banqiao Reservoir which took over the most rain from the typhoon first breached at wee hours of Aug. 8, releasing within six hours 700 million cubic meters of floods that wiped Daowencheng Commune downstream immediately from the map, killing all 9,600 citizens.

"The blare of the dam burst sounded like the sky was collapsing and the earth was cracking," survivors recalled. "Houses and trees disappeared all in a instant. Numerous corpses and bodies of cattle floated in water amid people's wailing for help."

To worsen the situation, the dams of the city's other 61 reservoirs collapsed one after another within a short period, unleashing about 6 billion cubic meters of floods to an area of about 10,000 square kilometres.

Official statistics recorded 30 years after the dams bursts show more than 26,000 people were killed in the floods, the life of more than 10 million people was affected and all communication to and from the city were cut off. But some meteorologists and researchers said the figure might be even bigger.

"The number may be revised some day in future," said Wang Yanrong, an official with Henan Province Department of Water Resources who has studied the province's flood disaster death tolls for years. "It depends on further and more thorough study of related files, documents and our data."

CHAIN-REACTING FAILURES

Though such appalling images of the dams burst, however, were not publicized during that time when Chinese leaders considered natural disaster death tolls a state secret, *an investigation by central government soon after the floods found a series of "unexpected failures" led to the nightmare.*

Xinhua learned that only a rainfall of 100 millimetres was forecast by the Beijing-based Central Meteorological Observatory forecast before the 1975 typhoon because no meteorologists in China then could reach an accurate prediction "given their scientific knowledge".

Water resources researchers said the design of those reservoirs and the guiding principles to contain the mighty Huaihe River should be blamed for such a calamity.

"The problem was not only the weather forecast," said Li Zechun, who first arrived at the scene as a weather forecaster after the floods 30 years ago and now an Academician of the Chinese Academy of Engineering Sciences, "that tragedy was a man-made calamity rather than a natural one."

Li said the water storage for irrigation function of a reservoir was overemphasized amid reservoir construction heat in the late 1959s despite warnings by some scientists that much of a reservoir's flood control was ignored.

The Banqiao Reservoir, which first collapsed, for example, was designed with only a capacity of 492 million cubic meters but it had to accommodate more than 697 million cubic metres of floods then.

The absence of an early-warning system or evacuation plan then also made the flooded areas quickly descended into chaos, Li said.

LIVE WITH FUTURE FLOODS

Since floods and drought are a fact of life for much of China, academics said, Chinese should be prepared for any devastating floods in the future.

"Henan still has an arduous task in flood control in future," said Kong Haijiang, a researcher with Henan Province Meteorological Observatory.

Kong estimated that a landfall of typhoon might cause a regional torrential rain similar to that in 1975. "We need to be prepared."

Other new threats in future floods have already emerged, said Li Zechun, the academician, such as the fast development of chemical industry in reservoir areas.

"Once the chemical plants are flooded, the contamination to the environment is immeasurable," Li said, "we have already witnessed such results in New Orleans from Hurricane Katrina."

Li said to prepare for future floods, a data base consisting of meteorological, hydrological, environmental protection, forestry and agricultural departments should be established first to form a uniform environment monitoring networks.

At the same time, Li said, the best way to prevent and control natural disasters was to have an early-warning system with a safe communication system.

"Had the communication in the reservoir areas not been cut off in 1975, " he said, "more lives would have had been saved in downstream."

Source: Xinhua

11. The Johnston Flood

Resulting from the South Fork Dam's Collapse

The **Johnstown Flood** (or **Great Flood of 1889** as it became known locally) occurred on May 31, 1889. It was the result of the catastrophic failure of the South Fork Dam situated 14 miles (23 km) upstream of the town of Johnstown, Pennsylvania, USA, made worse by several days of extremely heavy rainfall. The dam's failure unleashed a torrent of 20 million tons of water (4.8 billion U.S. gallons; 18.2 million cubic meters; 18.2 billion litres). The flood killed over 2,200 people[1] and caused US$17 million of damage.

South Fork Dam and Lake Conemaugh

High above the city, the South Fork Dam was built by the Commonwealth of Pennsylvania between 1838 and 1853,

Lake Conemaugh was 450 feet (140 m) in elevation above Johnstown. The lake was about 2 miles (3.2 km) long, approximately 1 mile (1.6 km) wide, and 60 feet (18 m) deep near the dam. The lake had a perimeter of 7 miles (11 km) to hold 20 million tons of water. When the water was at its highest point in the spring, the lake covered over 400 acres (160 ha).

The dam was 72 feet (22 m) high and 931 feet (284 m) long.,

The Great Flood of 1889

On May 28, 1889, a storm formed over Nebraska and Kansas, moving east. When the storm struck the Johnstown-South Fork area two days later it was the worst downpour that had ever been recorded in that part of the country. The U.S. Army Signal Corps estimated that 6 to 10 inches (150 to 250 mm) of rain fell in 24 hours over the entire region.

At around 3:10 p.m. (15:10) on the afternoon of May 31, 1889 , the South Fork Dam burst, allowing the 20 million tons of Lake Conemaugh to cascade down the Little Conemaugh River. It took about 40 minutes for the entire lake to drain of the water. The first town to be hit by the flood was the small town of South Fork. Fortunately, the town was on high ground and most of the people ran farther up the nearby hills when they saw the dam literally spill over. Despite 20 to 30 houses being destroyed or washed away, only four people were killed.

On its way downstream towards Johnstown, the crest picked up debris, such as trees, houses, and animals. At the Conemaugh Viaduct, an 78-foot (24 m) high railroad bridge, the flood temporarily was stopped when debris jammed against the stone bridge's arch. But after around seven minutes, the viaduct collapsed, allowing the flood to resume its course. Because of this, the force of the surge gained renewed impetus, resulting in a stronger force hitting Johnstown than otherwise would have been expected. The small town of Mineral Point, one mile (1.6 km) below the Conemaugh Viaduct, was hit with this renewed force. About 30 families lived on the village's single street. After the flood, only a bare rock remained. About 16 people were killed.

The village of East Conemaugh was next to be hit by the flood. One witness on high ground near the town described the water as almost obscured by debris, resembling "a huge hill rolling over and over". Locomotive engineer John Hess, sitting in his locomotive, heard the rumbling of the approaching flood and, correctly assuming what it was, tried to warn people by tying down the train whistle and racing toward the town by riding backwards to warn the residents ahead of the wave. His warning saved many people who were able to get to high ground. But at least 50 people died, including about 25 passengers stranded on trains in the town. Hess himself miraculously survived despite the flood picking up his locomotive and tossing it aside.

Of Woodvale's 1,100 residents, 314 died in the flood.

Some 57 minutes after the South Fork Dam collapsed, the flood hit Johnstown. The inhabitants of Johnstown were caught by surprise as the wall of water and debris bore down on the village, traveling at 64 km/h and reaching a height of 18 metres in places. Some, realizing the danger, tried to escape by running towards high ground. But most people were hit by the surging floodwater. Many people were crushed by pieces of debris, and others became caught in barbed wire from the wire factory upstream. Those who sought safety in attics, or managed to stay afloat on pieces of floating debris, waited hours for help to arrive.

The total death toll was 2,209, making the disaster the largest loss of civilian life in the United States at the time.

Ninety-nine entire families died in the Johnstown deluge, including 396 children. 124 women and 198 men were left without their spouses, 98 children lost both parents. 777 victims (1 of every 3 bodies found) were never identified.

It was the worst flood to hit the U.S. in the 19th century. 1,600 homes were destroyed, $17 million in property damage was done, and 4 square miles (10 km^2) of downtown Johnstown were completely destroyed. Clean-up operations continued for years.

12. The Teton Dam's Collapse

Teton Dam

From Wikipedia: http://en.wikipedia.org/wiki/Teton_Dam

Figure14: The collapsing Teton Dam

The **Teton Dam** was a federally built earthen dam on the Teton River in southeastern Idaho, set between Fremont and Madison Counties, USA which when filling for the first time suffered a catastrophic failure on June 5, 1976. The collapse of the dam resulted in the deaths of 11 people[1] and 13,000 head of cattle. The dam cost about USD $100 million to build, and the federal government paid over $300 million in claims related to the dam failure. Total damage estimates have ranged up to $2 billion. The dam has not been rebuilt.

The dam was completed in November of 1975 and no seepage was noted on the dam itself before the date of the collapse. However, on June 3, 1976 workers found two small springs had opened up downstream.

The collapse and flood

At the time of the collapse, spring runoff had almost filled the new reservoir to capacity, with a maximum depth of 240 feet (73 m). Water began seeping from the dam on the Thursday before the collapse, an event not unexpected for an earthen dam. The only structure that had been initially prepared for releasing water were the emergency outlet works, which could carry just 850 cubic feet per second (24 m^3/s). Although the reservoir was still rising over 4 feet (1.2 m) per day, the main outlet works and spillway gates were not yet in service. The spillway gates were cordoned off by steel walls while they were being painted.

On Saturday, June 5, 1976, at 7:30 a.m., a muddy leak appeared, suggesting sediment was in the water, but engineers did not believe there was a problem. By 9:30 a.m. the downstream face of the dam had developed a wet spot erupting water at 20 to 30 cubic feet per second (0.57 to 0.85 m^3/s) and embankment material began to wash out. Crews with bulldozers were sent to plug the leak, but were unsuccessful. Local media appeared at the site, and at 11:15 officials told the county sheriff's office to evacuate downstream residents. Work crews were forced to flee on foot as the widening gap, now over the size of a swimming pool, swallowed their equipment. The operators of two bulldozers caught in the eroding embankment were pulled to safety with ropes.

At 11:55 a.m. Mountain Daylight Time (UTC-6:00), the crest of the dam sagged and collapsed into the reservoir; two minutes later the remainder of the right-bank third of the main dam wall disintegrated. Over 2,000,000 cubic feet per second (57,000 m^3/s) of sediment filled water emptied through the breach into the remaining 6 miles (9.7 km) of the Teton River canyon, after which the flood spread out and shallowed on the Snake River Plain. By 8:00 p.m. that evening, the reservoir had completely emptied, although over two-thirds of the dam wall remained standing.

Deaths, damage and property claims

Teton Canyon comes to an end approximately six miles below the dam site, where the river flows into the Snake River Plain. When the dam failed, the freed waters struck several communities immediately downstream, particularly Wilford at the terminus of the canyon, Sugar City, Salem, Hibbard and Rexburg. Thousands of homes and businesses were destroyed. The small agricultural communities of Wilford and Sugar City were wiped from the river bank. Five of the fourteen deaths attributed to the flood occurred in Wilford. The similar community of Teton City, on the south bank of the river, is sited on a modest elevation and was largely spared. One Teton resident was fishing on the river at the time of the dam failure and was drowned.

One estimate placed damage to Hibbard and Rexburg area, with a population of about 10,000, at 80 percent of existing structures. The Snake River flows through the industrial, commercial and residential districts of north Rexburg. A significant reason for the massive damage in the community was the location of a large commercial lumber yard directly upstream. When the flood waters hit, thousands of board feet of timber snapped from their moorings, caught fire from leaking gas, and were swept downstream. The force of the logs and cut lumber, and the subsequent fires, practically destroyed the city.

The flood waters traveled west along the route of the south fork of the Snake, around the Menan Buttes, significantly damaging the community of Roberts. The city of Idaho Falls, even further down on the flood plain, had time to prepare. At the older American Falls Dam downstream, engineers increased discharge by less than 5% before the flood arrived. That dam held, and the flood was effectively over, but tens of thousands of acres of land near the river were stripped of fertile topsoil.

After the dam's collapse, debris clean up began immediately and took the rest of the summer. Rebuilding of damaged property continued for several years. Within a week after the disaster, President Gerald Ford requested a $200 million appropriation for initial payments for damages, without assigning responsibility for Teton Dam’s failure.

The Bureau of Reclamation set up claims offices in Rexburg, Idaho Falls, and Blackfoot. By January 4, 1977, disaster victims filed over 4,800 claims totalling $194 million. By that date, the Federal government paid 3,813 of those claims, $93.5 million. Originally scheduled to end in July 1978, the Claims Program continued into the 1980s. At the end of the Claims Program in January 1987, the Federal government had paid 7,563 claims for a total amount of $322 million.

13. Vital Questions Must Be Answered

Hedley Thomas, writing in the ***Australian*** on February 11, 2011 stated in relation to the abovementioned report:

A decade ago, with Queensland in an El Nino-caused drought, a handful of dam engineers produced an expert report on Brisbane's Wivenhoe Dam and the potential peril for those living downriver in the event of a catastrophic collapse.

"The population at risk within a distance that would result in less than three hours' warning of a dam failure is between 57,000 and 244,000, depending on the time of day and nature of the breach," *said the paper, entitled* ***Flood Passing Capacity Upgrade Considerations for Wivenhoe Dam****.*

Today, with Queensland at the mercy of La Nina-caused floods, there are vitally important matters requiring scrutiny by the Floods Commission of Inquiry, which is led by Supreme Court judge Cate Holmes.

The tragic deaths in the Lockyer Valley and Toowoomba will be exhaustively and sensitively examined, along with land-use planning, the Bureau of Meteorology's capacity to give timely warning of flash flooding, and the devastation caused across vast regions of the state.

However, the "population at risk" from a dam that is a flood-mitigation tool, a great reservoir for urban water supply and a key piece of Queensland's political furniture needs to be reassured that those responsible for the dam have the policies and competence to operate it safely.

This may be one of the reasons an international expert on dams, Phil Cummins, was selected by the Queensland government to assist Holmes and her senior counsel, Peter Callaghan SC, in an inquiry they pledge will be immune from political interference.

Already, thanks to the openness of Premier Anna Bligh, we know the dam "came very close to an uncontrolled release" during the peak of the run-off of the extreme levels of rain that fell across 7000 square kilometres of catchment, which does not include the Lockyer Valley.

As Bligh said gravely on the evening of January 14 after Brisbane was heavily flooded: "Of course we were worried . . . you would much rather be in control of the dam than it being in control of itself."

Now that the city and its flooded low-lying suburbs are dry again, fundamental questions for the inquiry revolve on investigating why control of this massive and potentially deadly infrastructure was almost lost.

Residents need to understand why the dam's operator, SEQWater, permitted it to lose its critical storage capacity in the days and hours before they were overtaken by crisis, necessitating a sudden, extreme and enormous release of water that caused much of the Brisbane River flood.

And why the Queensland government preferred to save funds by keeping the dam at full supply level even as the weather bureau issued increasingly serious warnings about extreme rain, as the Lord Mayor of Brisbane was cancelling his annual leave because he foresaw a major flood.

And why the pleas and warnings from people living below the dam went unheeded.

Reassuringly, Callaghan gives the impression he will brook no bureaucratic or political stonewalling in the quest for answers.

This is good news for the "population at risk".

"Flood Passing Capacity Upgrade Considerations for Wivenhoe Dam"

For more analysis about the lives at risk and the property damage anticipated by an overtopping and collapse of the Wivenhoe wall, please refer to the analysis by Messrs Crichton, Grant, Williams, & Ford in a paper entitled "***Flood Passing Capacity Upgrade Considerations for Wivenhoe Dam***" to be found at http://www.ancold.org.au/papers/2001-14.pdf

Please note that the abovementioned paper preceded the construction of the fuse plugs.

14. Distinguishing Between "Lives at Risk" and "Estimated Fatalities"

Please note that there is a significant difference between "**lives at risk**" and "**estimated fatalities**". If you are downstream of the Wivenhoe wall when it collapses, your life would be at risk, but you may not lose your life.

Some will lose their lives, some won't.

To understand methodology used in estimating fatalities, please refer to a September 1999 report about that matter published by the U.S. Department of Interior Bureau of Reclamation Dam Safety Office, and authored by Wayne J Graham entitled "***A Procedure for Estimating Loss of life Caused by Dam Failure***" found at http://www.usbr.gov/ssle/damsafety/Risk/Estimating%20life%20loss.pdf

That report shows that fatalities are fewer than the population at risk, and states:

Risk assessments and other dam safety studies often require that an estimate be made of the number of fatalities that would result from dam failure. To assist in this effort, an extensive evaluation of dam failures and the factors that contributed to loss of life was conducted.

Every U.S. dam failure that resulted in more than 50 fatalities and every dam failure that occurred after 1960 resulting in any fatalities was investigated with regard to warning, population at risk (PAR) and number of fatalities.

These dam failure data are used to provide a historical perspective of the risk associated with the U.S. dam inventory.

Loss of life resulting from dam failure is highly influenced by three factors:
1)The number of people occupying the dam failure flood plain,
2)The amount of warning that is provided to the people exposed to dangerous flooding and
3)The severity of the flooding.

The procedure for estimating loss of life due to dam failure relies heavily on data obtained from U.S. dam failures. The procedure is composed of 7 steps:
1) Determine dam failure scenarios to evaluate.
2) Determine time categories for which loss of life estimates are needed.
3) Determine when dam failure warnings would be initiated.
4) Determine area flooded for each dam failure scenario.
5) Estimate the number of people at risk for each dam failure scenario and time category.
6) Apply empirically-based equations or methods for estimating the number of fatalities.
7) Evaluate uncertainty.

It is clear that in the event of a cataclysmic **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe, there would be considerable and unacceptable loss of life downstream of Wivenhoe. Dozens of people drowned in the Lockyer Valley floods where the population at risk was only a tiny fraction of the population downstream from Wivenhoe. The force of the water in the Locker Valley was only a tiny fraction of that which would occur from a cataclysmic **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe.

15. If Wivenhoe had Failed on the Night of Tuesday 11 Jan 2011

In his abovementioned report "***A Procedure for Estimating Loss of life Caused by Dam Failure***", Wayne Graham states that one of the important factors in reducing fatalities is warning time. Mr Graham states:

> *Loss of life resulting from dam failure is highly influenced by three factors:*
>
> *1) The number of people occupying the dam failure flood plain,*
>
> *2) The amount of warning that is provided to the people exposed to dangerous flooding and*
>
> *3) The severity of the flooding.*

The Chinese authorities make a similar statement in the Banqiao Dam Retrospective in which the report states:

> *At the same time, Li said, the best way to prevent and control natural disasters was to have an early-warning system with a safe communication system.*
>
> *"Had the communication in the reservoir areas not been cut off in 1975, " he said, "more lives would have had been saved in downstream."*

If Wivenhoe had failed on the night of Tuesday 11 January 2011 as a result a Toowoomba/Grantham type of Deluge across the Wivenhoe catchment resulting in a **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe, what warning would downstream communities have had?

According to a report dated 22 January 2011 in *The Australian* by Hedley Thomas (found at http://www.theaustralian.com.au/in-depth/queensland-floods/the-great-avoidable-flood-an-inquirys-challenge/story-fn7iwx3v-1225992644199) communications within SEQ Water on the evening of 11 January were difficult, and one person who was a vital link in the communication chain was asleep at a critical time.

The abovementioned comment is not made in criticism of the person involved whom I have heard is widely admired and warmly regarded for his dedication to the task and the massive hours worked without sleep; rather it is a reflection on the systems in operation, and the adverse consequences which may have flowed from them in an extreme event which for which we were not fully prepared. In turn, this is the first major flood event since Wivenhoe was completed, and it is to be expected that we are still learning about the best management methods. I'm intending to be analytical rather than critical, and to analyse the past to help us be better prepared in the future.

I suspect that the warning time would have been insufficient to prevent massive loss of life resulting from the tsunami like flood-wave travelling many metres high at the order of 60 kilometres per hour and reaching Brisbane within 3 hours after the Dam's collapse.

Did we have emergency services ready to alert the population at risk? Were we ready to have vehicles (Police, SES, Fire) passing through every street with sirens blaring? Did we have personnel in every locality ready to adopt a leadership role, people who knew what to do? Had the population at risk been alerted to the fact that in certain scenarios their lives would be at risk? Have they been alerted now?

Practice makes Perfect

As a community we practice fire drills. Have we had any flood drills?

There is a military catechism: ***People do under pressure what they do under practice. And if they don't practice, that's what they do under pressure: nothing!***

Preparedness

The Canberra Times reported on 12 Jan, 2011 08:08 AM
(www.canberratimes.com.au/news/national/national/general/spooked-brisbane-waits-for-the...)

"A WAVE of dread spread across Brisbane as the city braced for devastating floods.
...

"About 40 people were taking refuge in Royal National Association Showgrounds in Brisbane, the only one of four evacuation centres that was open in the city last night.
"Other evacuation centres have been established at the 13,500-capacity Brisbane Entertainment Centre, the 52,500-seat Suncorp Stadium and the Brisbane Convention and Exhibition Centre."

In the end, the Royal National Association Showgrounds was the main evacuation centre, and both Suncorp Stadium and the Brisbane Convention and Exhibition Centre were flooded.

Brisbane's degree of preparedness can be measured by announcements of evacuation centres which were themselves flooded shortly after the announcements.

The consequences of unpreparedness and lack of warnings

The Toowoomba/Grantham experiences give us an insight into what may have happened in Brisbane in the event of a **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe. But the actual event would have been on a scale which would have been thousands a of times more severe than what happened at Toowoomba and Grantham.

Wayne Graham states that one of the important factors in reducing fatalities is warning time.

In the event of a **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe, the outcome in terms of fatalities in Brisbane would have been made worse because of a lack of warnings and preparedness.

This is in contrast to the extensive warnings which were given in relation to Cyclone Yasi.

Preparedness issues are under discussion in Eugene in Oregon State in the US

Similar issues relating to preparedness are under discussion in Eugene in Oregon State in the US.

Please refer to Appendix E which discusses the issues relating to possible flood or earthquake caused dam collapse in the Eugene area.

The following has been copied from the first page of Appendix E.

Perhaps the most serious disaster threat faced by the Eugene area is the potential for catastrophic failure of dams during a large flood or earthquake. The only disaster that would be worse is some sort of national or global cataclysm (nuclear war or pandemic), scenarios that would not be limited to our region.

If a 40 foot wall of water swept through the Eugene - Springfield area, the aftermath would resemble a mix of the inundation zones from the 2004 Indian Ocean tsunami and the impact of Hurricane Katrina upon the City of New Orleans. If the dam failures would caused by a large earthquake, it is likely that this would be the end of the Eugene metropolitan region. The combination of bridge collapses, destruction of many buildings and the sudden, severe flood from the dam failures would make the area "resemble Hiroshima" -- as one City Councillor has privately expressed.

At a minimum, emergency response and awareness of these threats are desperately needed. Inundation maps need to be made public so that citizens would know how far - and which directions - to flee in the event of disaster. The State of Oregon posts tsunami inundation maps for coastal communities on its website, and posts signs on Highway 101 to indicate the danger zones. There is no technical, legal, political, financial or security excuse to keep similar information secret from the taxpayers of Eugene, Springfield and nearby communities -- since this knowledge would be the most important factor for minimizing casualties should this event occur. How far away from the river people would have to go is unknown to the average person. Would vertical evacuation in downtown Eugene be sufficient (going to the top of a parking garage or one of the taller buildings)? Widespread awareness of these facts could spur regional and federal government actions to address the problems by either strengthening or removing the dangerous dams.

16. Dam Safety:

Preventing the Failure of Wivenhoe

SEQ Water's 2005-06 Annual Report

In its 2005-06 Annual Report, SEQ Water states at page 18, under the Heading of "**Dam Safety**":

Construction of the auxiliary spillway for Wivenhoe Dam was completed in September 2005. This $70million project ensures that Wivenhoe Dam can withstand an extreme flood event.

In the same report, SEQ Water states at page 30, under the heading "**The Future**"

SEQ Water will maintain a strong position by adapting to a broad range of trends including:

- ***Climate Change - the need to respond quickly to mitigate the impact of climate change***

On page 62 of the same report, SEQ Water states on page 62 under the heading of "**Operations and Dam Safety**"

In August 2005, the Wivenhoe Alliance completed the project to upgrade the flood passing capacity of Wivenhoe Dam to handle a 1 in 100,000 year flood event. The works will protect the communities of South East Queensland against extreme flood events. The project consisted of a three-section fuse plug spillway, a new concrete bridge carrying the Brisbane Valley Highway over the dam, and post-tensioning works on the existing spillway to upgrade its capacity.

Comment on SEQ Water's 2005-06 Annual Report

By way of comment, I think it is fair to state that ***This $70million project ensures that Wivenhoe Dam can withstand <u>an</u> extreme flood event.*** The underlining of "***<u>an</u>***" is mine. But withstanding ***<u>an</u> extreme flood event*** does not mean that Wivenhoe can withstand ***<u>every</u> extreme flood event***.

In recognition that Wivenhoe cannot withstand ***<u>every</u>*** extreme flood event, SEQ Water's Report states on page 62, that the upgrade enabled ***Wivenhoe Dam to handle a 1 in 100,000 year flood event.***

That means that Wivenhoe has a failure rate of once in 100,000 years. Such assessments are not precise. They are a matter of statistics and judgement. Such assessments are revised from time to time in the light of new information. Perhaps the failure interval will be revised as a result of the recent Flood Event. Perhaps Climate Change and Global Warming will lead to a revision of the failure rate.

The SEQ Water report refers to Climate Change. Climate Change scientists warn of more intense cyclones, and of rising ocean and river levels. As climate changes, so too does the failure rate of Wivenhoe. What will the failure rate of Wivenhoe be estimated to be after taking into account the worst possible impacts of Climate Change?

The Wivenhoe failure rating means that over a period of many thousands of years, we can expect Wivenhoe to fail. That is, despite releasing water at the maximum rate, and the operation of the Fuse Plugs, we can expect Wivenhoe to fail. In that event, the earthen wall will quickly erode under the force of the over-topping water, and collapse, releasing the Wivenhoe Lake uncontrollably in a **Dam-Burst-Tsunami-Flood-Wave** surge which will dwarf the Grantham flood.

Whatever the appropriate figure happens to be, I think that it is fair to say:

1 In any particular year, Wivenhoe is likely to be safe; i.e. it should not fail.

2 In any particular year, Wivenhoe might not be safe; i.e. it might fail.

3 Wivenhoe may fail in any year, we don't necessarily have to wait thousands of years.

4 Given sufficient time, Wivenhoe is certain to fail.

5 Unlikely events are dangerous because their rarity leads to complacency. Because they are unlikely to happen we may ignore them until they happen. Unlikelihood lulls us into taking dangerous risks.

6 The failure of Wivenhoe would be so catastrophic that we need to prevent it, no matter how remote its likelihood.

7 The Fuse Plugs were built because the failure of Wivenhoe would be catastrophic.

8 The Fuse Plugs were not the best solution, they were a cost effective compromise. For example, the Fuse Plugs could have been made twice as long.

9 While the uncontrolled release of water from the Fuse Plugs is preferable to the collapse of the Wivenhoe wall, the uncontrolled release from the Fuse Plugs creates terrible consequences in the downstream communities. That prospect was so abhorrent in January 2011, that the very large controlled releases through the gates which flooded Brisbane were preferred by our leaders once they were informed of the consequences of the ***protection*** provided by the Fuse Plugs.

10 Therefore the following statement (reproduced from page 62 of the abovementioned SEQ Water Report) must be seen as an analysis of a choice between evils.

The works will protect the communities of South East Queensland against extreme flood events.

11 In this context there are three evils as follows:

A. The **controlled releases** which flooded Brisbane at a cost of billions of dollars and one life;

B. The abhorrent **uncontrolled releases** resulting from a collapse of the Fuse Plugs which would have created floods much worse than the controlled releases; and

C. The **cataclysmic releases** which would unfold from an over-topping of the Wivenhoe wall, the erosion of the wall, and the **Dam-Burst-Tsunami-Flood-Wave** which would destroy Brisbane and other downstream communities as we know them.

13 Many in ***the communities of South East Queensland*** would not regard the Fuse Plugs as providing ***protection.*** But it is all relative. The uncontrolled release from the Fuse Plugs, although much worse than the January 2011 Floods which followed the controlled release, are much less damaging than the catastrophic consequences of the **Dam-Burst-Tsunami-Flood-Wave.**

14 In the January 2011 Flood Event, ***the communities of South East Queensland*** never got to receive the "benefits" of the ***protection*** provided by the Fuse Plugs.

15 Our leaders were so shocked and frightened by the "benefits" of that ***protection*** that they decided they would rather create a major flood of downstream communities instead.

16 There are hundreds of thousands of Queenslanders who are aghast at what happened to them as a result of the January 2011 Floods.

17 If those Queenslanders realised that the January 2011 Floods were preferable to the ***protection*** provided by the Fuse Plugs, then they would be terrified by the ***protection*** and would want something better.

18 You get a sense of how dangerous a dam Wivenhoe is, when you accept that the January 2011 Floods were preferable to the ***protection*** provided by the Fuse Plugs, which in turn is preferable to the collapse of the Wivenhoe wall.

19 If Wivenhoe does fail, it would impose a cataclysmic **Dam-Burst-Tsunami-Flood-Wave** on Brisbane with unacceptable loss of life, and unimaginable property destruction.

20 As we now realise, Wivenhoe Dam is a two edged sword: **A Damocles' Sword** hanging over Brisbane.

21 It is commonplace to insure against unlikely events. Most people insure homes and cars.

22 In Public Governance, there are principles involved: particularly the Precautionary Principle.

23 The Precautionary Principle, and common sense, dictate that we should not accept the level of ***protection*** provided by the Fuse Plugs.

Questions for the Commission

The larger question for the Commission is not what to do about floods like that which has just happened to Brisbane, and how to prevent them. The larger question is how to protect Brisbane from looking like Grantham as a result of a cataclysmic **Dam-Burst-Tsunami-Flood-Wave** following the failure of Wivenhoe. The failure of Wivenhoe is not something which will never happen.

As Wivenhoe is currently designed, it will fail. The question is not if, but when? And at what cost?

What are we going to do to prevent that?

17. SEQ Water's Flood Operation Manual & January 2011 Flood Report

In the Conclusions of its Executive Summary of its January 2011 Flood Event Report on the operation of Somerset Dam and Wivenhoe Dam SEQ Water states:

Conclusions

The significant conclusions drawn from the information contained in this Report include:

- During the January 2011 Flood Event, Somerset Dam and Wivenhoe Dam were operated in accordance with *The Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam (Revision 7)*.

- The data collection and flood modelling systems used to support decisions made during the Event performed well and assisted informed decision-making, in accordance with the Manual.

- BoM rainfall forecasts did not support the additional release of flood water early in the Event.

- During the Event, Seqwater followed the Department of Environment and Resource Management's draft Communications Protocol, which was compiled after the October 2010 flood event. This Protocol was developed to ensure effective communication between local, State and Commonwealth agencies impacted by the release of flood water from the Dams.

- The January 2011 Flood Event was a very large and rare flood event. The combined effects of Somerset Dam and Wivenhoe Dam did reduce flood damage downstream, however it was not possible to fully mitigate the impacts of the Event without putting the safety of the Dams at risk.

- Studies associated with the design and operation of Wivenhoe Dam dating back to 1971 indicate a flood of the magnitude of the January 2011 Flood Event would be expected to result in urban damage below Moggill.

- The combined effects of Somerset Dam and Wivenhoe Dam provided clear and significant flood mitigation benefits during the January 2011 Flood Event.

Comment on the Conclusions:

1 If during the January 2011 Flood Event, Somerset Dam and Wivenhoe Dam were operated in accordance with *The Manual of Operational Procedures for Flood Mitigation at Wivenhoe Dam and Somerset Dam (Revision 7)*, as claimed in the first Conclusion above, then the Manual needs revising so that the flooding which occurred does not recur.

18. Does Wivenhoe Satisfy Flood Guidelines?

Rory Callinan reported in The Australian on January 13, 2011 at 12:00AM

Engineers reduce dam flow

THE massive volume of water gushing out of Wivenhoe Dam was being carefully reduced yesterday, as flood engineers managed to lower dam levels enough to start effectively managing flood levels again in the Brisbane River.

The development came as the dam's operator, South East Queensland Water Corporation, declined to comment on what action it had taken in response to a 2007 report that noted the giant dam did not satisfy Australian National Committee on Large Dams (ANCOLD) guidelines on acceptable flood capacity.

On Tuesday night, water releases from the dam rose as high as 645,000 megalitres, up nearly 30 per cent on the amount being released earlier in the day -- a course of action SEQW justified as being necessary for "the safe management of the dam".

The releases followed the dam almost reaching maximum capacity, classified by the corporation as being 200 per cent.

A government source said that, at the peak of 190 per cent full, the depth of water at the dam wall was just over 74 metres, about 60cm below the point at which water would start to go over a secondary spillway or fuse plug embankment -- a situation that would have meant a surge of water and a loss of control of the flow.

The massive releases have meant the dam, built as part of a flood mitigation strategy following the 1974 flood, was not effectively controlling water flows to the Brisbane River.

Premier Anna Bligh yesterday defended Wivenhoe's performance and suggested no dam could have stopped the amount of water that came into the catchment.

"Obviously at the end of this event, we will do a significant review of Wivenhoe's capacity," Ms Bligh said.

"Dams can help mitigate and minimise some of the impact that might have happened without them, but a dam cannot stop the sort of flood that is coming across the plains, the Lockyer Valley and the catchment area into the Wivenhoe system."

The Australian has learned that in 2007 a feasibility study was conducted into improving the dam's storage capacity and it noted that neither Somerset Dam nor Wivenhoe Dam "currently satisfied the Australian National Committee on Large Dams (ANCOLD) guidelines on Acceptable Flood Capacity (2003)". Somerset Dam controls waterways above Wivenhoe Dam and is currently near capacity.

ANCOLD guidelines require dams such as Wivenhoe to be able to withstand a probable maximum flood -- a situation where the dam receives the maximum possible precipitation. The Provision of Contingency Storage in Wivenhoe and Somerset Dams report recommended a number of options to increase the dam's storage capacity, at costs ranging from $5 million to more than $200m.

An SEQW spokesman said yesterday that experts were too busy to respond to questions about whether recommendations in the report had been acted on.

Climate Change and Guidelines

One of the difficulties in relation to Wivenhoe's satisfying Guidelines is Climate Change.

Climate Change has been stated by CSIRO scientists to lead to tropical cyclones becoming more and more intense as the ocean warms. In addition, if warm water creeps south with Global Warming, then cyclones may occur south of their previous occurrence. Furthermore, if ocean levels rise, then so too will River levels, and the extent of flooding would be expected to increase.

As a result of Climate Change, a dam which previously satisfied the Guidelines may not do so now.

And a dam which now satisfies the Guidelines now, may not do so in the future.

Managing Wivenhoe's compliance with Guidelines during Climate Change would be a difficult task; akin to kicking a football towards moving goalposts.

19. A Week to Remember: Wivenhoe Dam's Role in the Flood

For details of the chronology of the January Floods, please refer to report of the Australian entitled: ***A Week to Remember: Wivenhoe Dam's Role in the Flood,*** found at http://resources.news.com.au/files/2011/03/18/1226023/976281-aus-news-file-wivenhoe-timeline.pdf

The report is also included at larger scale in Appendix A of this report.

The report shows how close Wivenhoe came to being 100% full.

This event occurred during reasonably mild weather, but it stressed the management of Wivenhoe.

Imagine if we had an extreme event with torrential rain and massive winds during a cyclone with trees, powerlines, power poles and towers down, and phone towers down.

Imagine the worst weather you can think of persisting for day after day in the Wivenhoe catchment.

What do you think would happen at Wivenhoe in those circumstances?

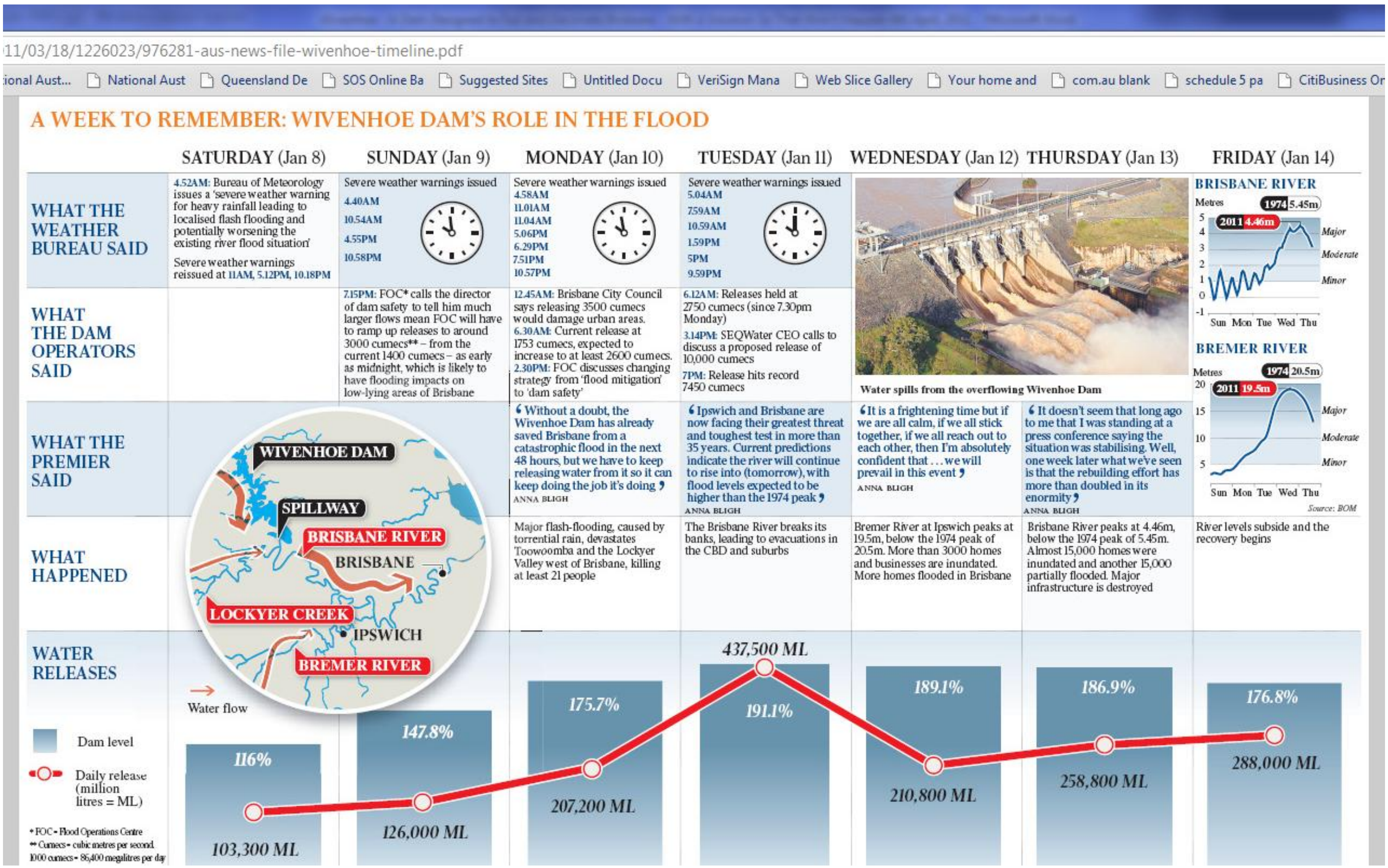


Figure 15: A Week to Remember

20. There's Always a Bigger Flood Coming

For a history of flooding in the Brisbane and Bremer Rivers, please refer to http://www.bom.gov.au/hydro/flood/qld/fld_history/brisbane_history.shtml

This history only goes back 170 years, and commences with the following reference:

1824	***John Oxley, early explorer, mentioned evidence of an inundation which he discovered on 19 September 1824 in an area north of the junction of the Bremer with the Brisbane : "the starboard bank an elevated flat of rich land, declining to a point where had evidently by its sandy shore and pebbly surface, been at some time washed by an inundation; a flood would be too weak an expression to use for a collection of water rising to the full height (full fifty feet) which the appearance of the shore here renders possible." (Ref 2)***

As we have seen in the Global Warming debates, we don't yet understand the cycles of climate change, or how long or large those cycles are.

We can see from the graph below that Brisbane River floods vary in severity and frequency, and that flood years seem to follow drought years with some sort of cycles.

No one knows how large the largest flood may be. We know that the 1840s and 1890s floods dwarfed what anyone now alive has seen.

Will "Climate change" lead to larger floods? How big a flood could occur? What will that do? No one knows. So abundant caution is the responsible course.

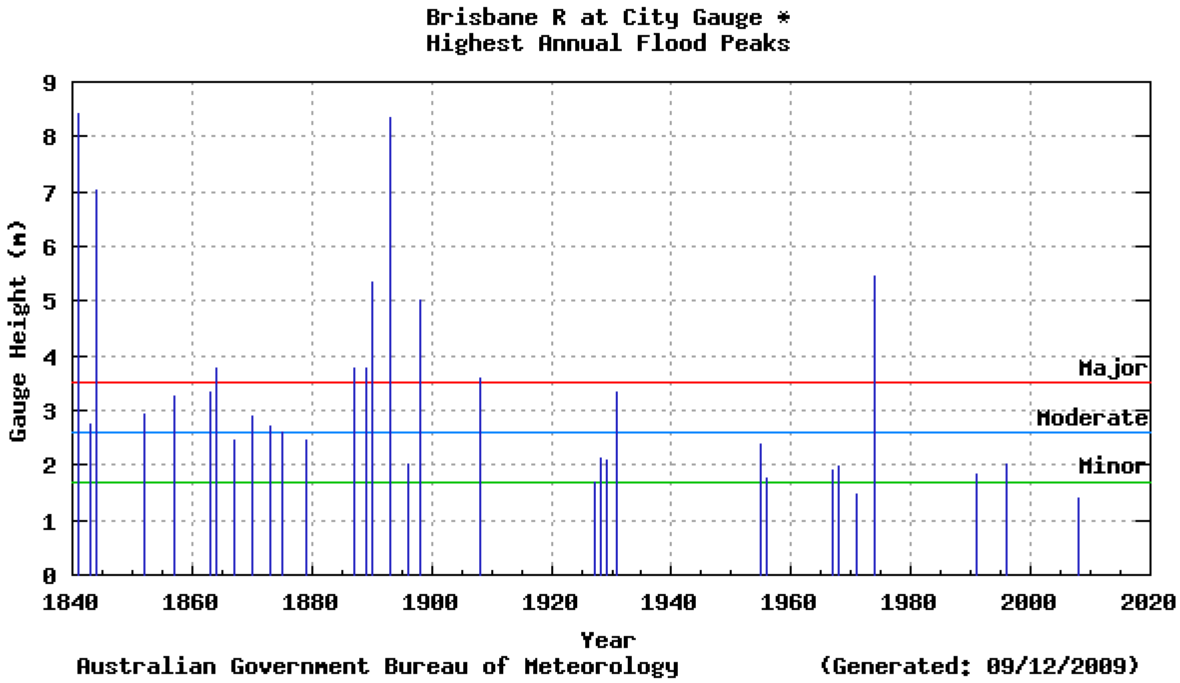


Figure 16: Brisbane River Flood Levels

Study the future by studying the past

That expectation of larger floods than the one just experienced is borne out by studying the many large floods of which we are aware (see the chart above) including two in the 1840s (1 over 8 metres the other over 7 metres), three in the 1890s (1 over 8 metres, the other 2 over 5 metres) and 1974 (over 5 metres).

There is anecdotal evidence of the aborigines showing Oxley debris in trees from a 12 metre flood prior to 1825.

We have only been collecting records for 170 years. We can anticipate that there will be larger floods than any of which we have evidence, given enough time.

How does SEQWater plan to manage an 8 metre flood? How does SEQWater plan to manage a 12 metre flood?

How much of Wivenhoe's flood compartment will be available to protect downstream communities in such large floods? I doubt if there would be any capacity for downstream flood mitigation at the peak of the flood, because the focus would be on Dam safety.

The following excerpt from the Flood History of Brisbane, shows how severe the 1893 floods were.

3/2/1893	*Lower part of Brisbane submerged, and water still on the rise; the "Elamang" and the gunboat "Paluma' were carried by the flood into the Botanical Gardens, and the "Natone" on to the Eagle Farm flats.*
4/2/1893	*Disastrous floods in the Brisbane River; 8 feet of water in Edward Street at the Courier building. Numbers of houses at Ipswich and Brisbane washed down the rivers.* ***Seven men drowned through the flooding*** *of the Eclipse Colliery at North Ipswich. Telegraphic and railway communication in the north and west interrupted.*
5/2/1893	*The Indooroopilly railway bridge washed away by the flood. Heaviest floods known in Brisbane and suburbs.*
6/2/1893	*The lower part of South Brisbane completely submerged. The flood rose 23'9" above the mean spring tides and 10 feet above flood mark of 1890; north end of the Victoria Bridge destroyed.*
7/2/1893	*Flood waters subsiding. Sydney mail train flood bound at Goodna, unable to either proceed or return.*
13/2/1893	*Second flood for the year in the Brisbane River.*
16/2/1893	*More rain in the south east districts; another rise in the Brisbane; further floods predicted.*
17/2/1893	*A third flood occurred in the Brisbane River for the year.*
18/2/1893	*The 'Elamang" floated off from the Botanical Gardens. Business at a standstill in Brisbane. Ipswich and other towns.* ***Several deaths by drowning reported****.*
19/2/1893	*The gunboat "Paluma" safely floated off the Gardens, and the "Natone" off Eagle Farm flats. Another span of the Indooroopilly railway bridge carried away. The third flood reached its maximum height at 12 noon, viz. 10 inches below the first flood.*
21/2/1893	*Flood waters subsiding.*
11/6/1893	*Flood waters of the Brisbane River still rising.*
10/6/1893	*A fresh in the Brisbane River.*
12/6/1893	*Flood at Brisbane reached a height of 10 feet 10 inches above low water or 1'4" above the level of the flood of 1887; water stationary at 10 am.*

21. Climate Change:

Although the previous section refers to studying the future by studying the past, Climate Change may cause us to revise our findings. These sections are inserted to illustrate the complexity involved.

SEQ Water's Annual Report refers to Climate Change: "***the need to respond quickly to mitigate the impact of climate change***".

Climate science has been attempting to understand the cycles of nature and of weather. Climate changes from day to night, and during the seasons of the year. Many cycles are emerging with various periodicities and predominance. The matter is extremely complex, and interactive.

Some cycles include the following which may have complex interacting influences on one another:

1 Tides: Once or twice a day
2 King Tides: Less frequently
3 Winter and summer: Every year
4 The Madden–Julian oscillation (MJO): Every 30 to 90 days; with cycles lasting 30 to 60 days
5 La Nina, El Nino: Cycles varying between months and years
6 Droughts and Floods: Alternating every decade or so
7 Sunspots: Every eleven years (and which may be influenced by earth's magnetic field)
8 Earth's magnetic field reversal: Average interval of approximately 200,000 to 300,000 years

Many, but not all, scientists believe in Anthropogenic Global Warming (i.e. GW caused by human activity). Other scientists assert that global warming, is part of the normal cycles of nature. Perhaps GW is a combination of both. There is much disagreement on what is happening and why. There are many theories which can only be proven or disproven over long periods of time, and the measurements of change are indiscernible on a yearly basis. There is emotion mixed with science.

However, there is agreement on one matter: the earth is warmer now than it was 100 years ago.

That warmth, and the possibility/likelihood of a continuing uptrend in warming, has a very great significance for Queensland. The significance is that tropical cyclones are generated when the ocean surface temperatures exceeds a critical temperature (of 27^0C). As the ocean warms, the locations which are warm enough to generate tropical cyclones will move south, closer to Wivenhoe.

At a recent climatologist conference in Cairns, CSIRO personnel presented papers asserting that Queensland will receive fewer but more intense cyclones as the ocean warms from Climate Change.

So Queensland may experience more intense and more southerly cyclones than previously.

That is very bad news for the forecast failure rate of Wivenhoe, because intense tropical cyclones are one of the threats which may lead to the over-topping and collapse of Wivenhoe.

How much more intense might those cyclones be? What daily rainfall and peak rate of rainfall and runoff might apply? How much will the old figures need to be changed? How much more likely is Wivenhoe to overtop and collapse than previously? And what should we do about it?

22. La Nina, El Nino, the Madden–Julian Oscillation, Sunspots, & Earth's Magnetic Field

La Niña

From Wikipedia: http://en.wikipedia.org/wiki/La_Ni%C3%B1a

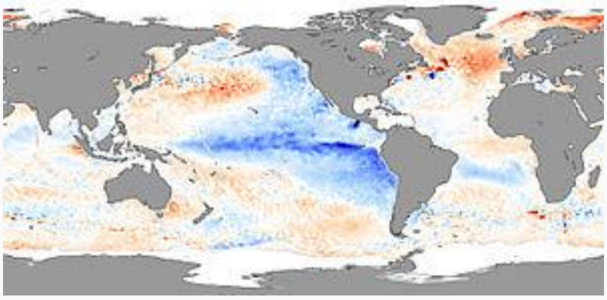


Figure 17: Sea surface temperature anomalies in November 2007 showing La Niña conditions

La Niña is a coupled ocean-atmosphere phenomenon that is the counterpart of El Niñoas part of the broader El Niño-Southern Oscillation climate pattern. During a period of La Niña, the sea surface temperature across the equatorial Eastern Central Pacific Ocean will be lower than normal by 3–5 °C. In the United States, an episode of La Niña is defined as a period of at least 5 months of La Niña conditions.

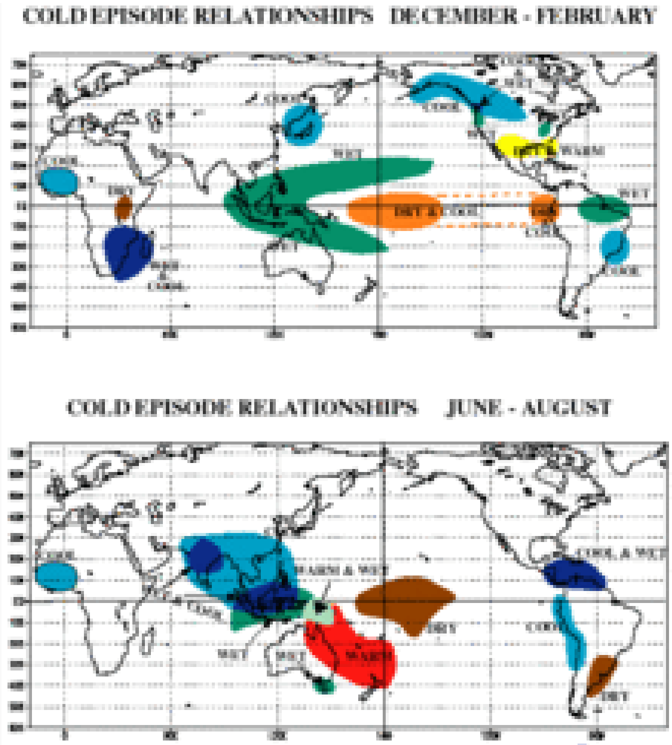


Figure18: Regional impacts of La Niña.

La Niña, sometimes informally called "anti-El Niño", is the opposite of El Niño, where the latter corresponds instead to a higher sea surface temperature by a deviation of at least 0.5 °C, and its effects are often the reverse of those of El Niño. El Niño is famous due to its potentially catastrophic impact on the weather along both the Chilean, Peruvian and Australian coasts, among others. La Niña is often preceded by a strong El Niño.

The results of La Niña are mostly the opposite of those of El Niño, for example, El Niño would cause a wet period in the Midwestern U.S., while La Niña would typically cause a dry period in this area. At the other side of the Pacific La Niña can cause heavy rains. For India, an El Niño is often a cause for concern because of its adverse impact on the south-west monsoon; this happened in 2009.

A La Niña, on the other hand, is often beneficial for the monsoon, especially in the latter half. The La Niña that appeared in the Pacific in 2010 probably helped last year's south-west monsoon end on the favourable note. But then, it also contributed to the deluge in Australia, which resulted in one of that country's worst natural disasters with large parts of State of Queensland either under water from floods of 'biblical proportions' or being battered by Tropical Cyclones, including that of category 5 Tropical Cyclone Yasi. It wreaked similar havoc in south-eastern Brazil and played a part in the heavy rains and consequent flooding that have affected Sri Lanka.

"La Niña" events between 1950 and 2011.

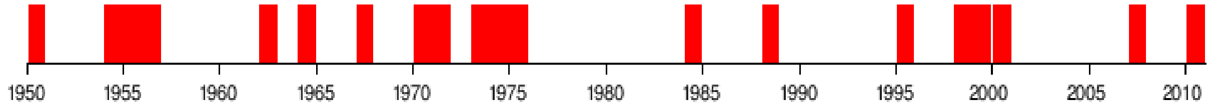


Figure 19: La Nina cycles between 1950 and 2011

El Niño-Southern Oscillation

From Wikipedia: http://en.wikipedia.org/wiki/El_Ni%C3%B1o-Southern_Oscillation

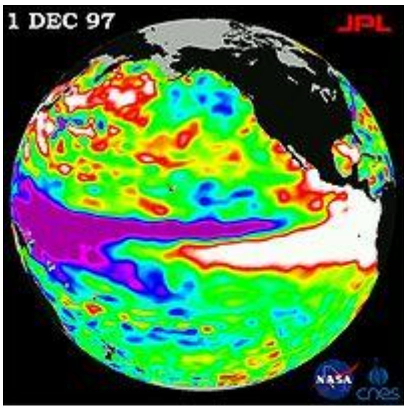


Figure 20: The 1997 El Niño observed by **TOPEX/Poseidon**. The white areas off the tropical coasts of South and North America indicate the pool of warm water.

El Niño/La Niña-Southern Oscillation, or **ENSO**, is a quasiperiodic climate pattern that occurs across the tropical Pacific Ocean with on average five year intervals. It is characterized by variations in the temperature of the surface of the tropical eastern Pacific Ocean—warming or cooling known as *El Niño* and *La Niña* respectively—and air surface pressure in the tropical western Pacific—the *Southern Oscillation*. The two variations are coupled: the warm oceanic phase, El Niño, accompanies high air surface pressure in the western Pacific, while the cold phase, La Niña, accompanies low air surface pressure in the western Pacific.[2][3] Mechanisms that cause the oscillation remain under study.

ENSO causes extreme weather (such as floods and droughts) in many regions of the world. Developing countries dependent upon agriculture and fishing, particularly those bordering the Pacific Ocean, are the most affected. In popular usage, the El Niño-Southern Oscillation is often called just "El Niño". El Niño is Spanish for "the boy" and refers to the Christ child, because periodic warming in the Pacific near South America is usually noticed around Christmas.[4] The expression of ENSO is potentially subject to dramatic changes as a result of global warming, and is a target for research in this regard.

Madden–Julian Oscillation

From Wikipedia: http://en.wikipedia.org/wiki/Madden%E2%80%93Julian_oscillation

The **Madden–Julian oscillation (MJO)** is the largest element of the intraseasonal (30–90 days) variability in the tropical atmosphere. It is a large-scale coupling between atmospheric circulation and tropical deep convection [1] [2]. Rather than being a standing pattern (like ENSO) it is a traveling pattern, propagating eastwards at approximately 4 to 8 m/s, through the atmosphere above the warm parts of the Indian and Pacific oceans. This overall circulation pattern manifests itself in various ways, most clearly as anomalous rainfall. This was discovered by Roland Madden and Paul Julian (again the comparison with ENSO is instructive, since their local effects on Peruvian fisheries were discovered long before the global structure of the pattern was recognized).

The MJO is characterized by an eastward progression of large regions of both enhanced and suppressed tropical rainfall, observed mainly over the Indian Ocean and Pacific Ocean. The anomalous rainfall is usually first evident over the western Indian Ocean, and remains evident as it propagates over the very warm ocean waters of the western and central tropical Pacific. This pattern of tropical rainfall then generally becomes nondescript as it moves over the cooler ocean waters of the eastern Pacific (except over the region of warmer water off the west coast of Central America) but occasionally reappears at low amplitude over the tropical Atlantic and higher amplitude over the Indian Ocean. The wet phase of enhanced convection and precipitation is followed by a dry phase where thunderstorm activity is suppressed. Each cycle lasts approximately 30–60 days. Because of this pattern, The MJO is also known as the **30–60 day oscillation**, **30–60 day wave**, or **intraseasonal oscillation.**

Sunspots

From Wikipedia: http://en.wikipedia.org/wiki/Sunspot

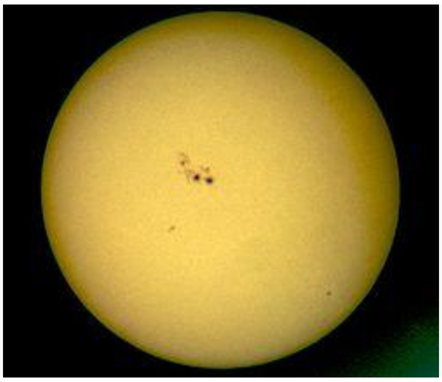


Figure 21: Sunspots imaged on 22 June 2004

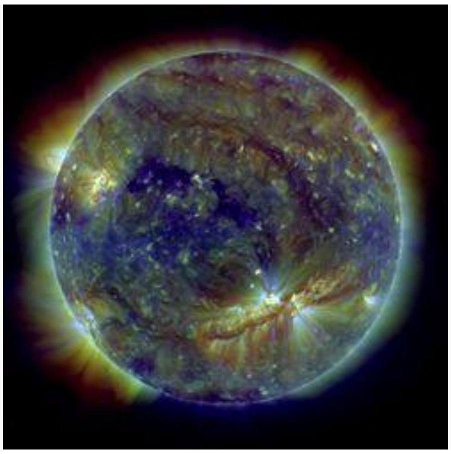


Figure 22: A view of the coronal structure above a different sunspot seen in October 2010

Sunspots are temporary phenomena on the photosphere of the Sun that appear visibly as dark spots compared to surrounding regions. They are caused by intense magnetic activity, which inhibits convection by an effect comparable to the eddy current brake, forming areas of reduced surface temperature. Although they are at temperatures of roughly 3,000–4,500 K (2,727–4,227 °C), the contrast with the surrounding material at about 5,780 K leaves them clearly visible as dark spots, as the intensity of a heated black body (closely approximated by the photosphere) is a function of temperature to the fourth power. If the sunspot were isolated from the surrounding photosphere it would be brighter than an electric arc. Sunspots expand and contract as they move across the surface of the Sun and can be as large as 80,000 kilometers (49,710 mi) in diameter, making the larger ones visible from Earth without the aid of atelescope. They may also travel at relative speeds ("proper motions") of a few hundred m/s when they first emerge onto the solar photosphere.

Manifesting intense magnetic activity, sunspots host secondary phenomena such as coronal loops and reconnection events. Most solar flares and coronal mass ejections originate in magnetically active regions around visible sunspot groupings. Similar phenomena indirectly observed on stars are commonly called starspots and both light and dark spots have been measured.

Sunspot variation

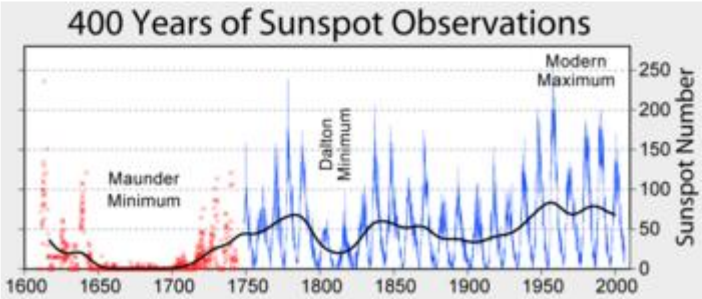


Figure 23: 400 year sunspot history

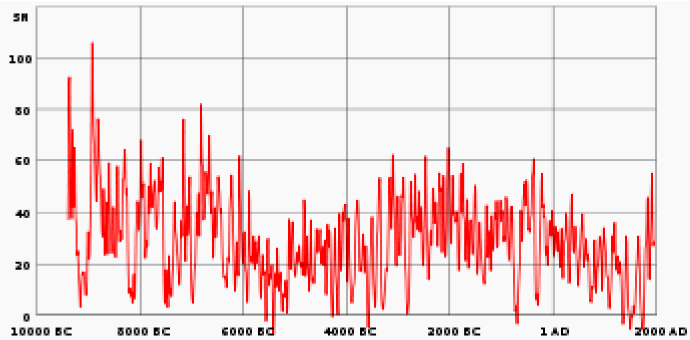


Figure 24: 11,000 year sunspot reconstruction

Sunspot populations quickly rise and more slowly fall on an irregular cycle of 11 years, although significant variations in the number of sunspots attending the 11-year period are known over longer spans of time. For example, from 1900 to the 1960s the solar maxima trend of sunspot count has been upward; from the 1960s to the present, it has diminished somewhat.[3] Over the last decades the Sun has had a markedly high average level of sunspot activity; it was last similarly active over 8,000 years ago.[4]

The number of sunspots correlates with the intensity of solar radiation over the period since 1979, when satellite measurements of absolute radiative flux became available. Since sunspots are darker than the surrounding photosphere it might be expected that more sunspots would lead to less solar radiation and a decreased solar constant. However, the surrounding margins of sunspots are brighter than the average, and so are hotter; overall, more sunspots increase the sun's solar constant or brightness. The variation caused by the sunspot cycle to solar output is relatively small, on the order of 0.1% of the solar constant (a peak-to-trough range of 1.3 $W.m^{-2}$ compared to 1366 $W.m^{-2}$ for the average solar constant).[5][6] Sunspots were rarely observed during the Maunder Minimum in the second part of the 17th century (approximately from 1645 to 1715). This coincides with the middle (and coldest) part of a period of cooling known as the Little Ice Age.

There may be a resonant gravitational link between a photospheric tidal forceexerted by the planets and the sunspot cycle.

Earth's magnetic field

From Wikipedia, the free encyclopedia

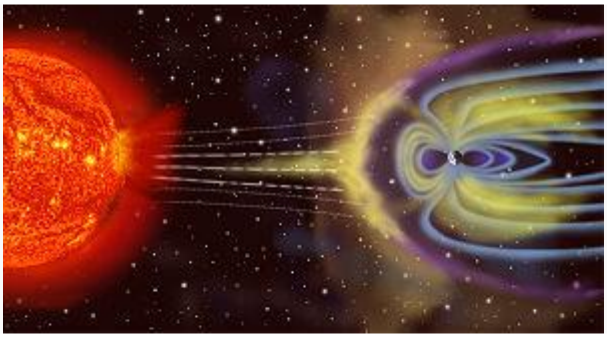


Figure 25: The magnetosphere shields the surface of the Earth from the charged particles of the solar wind and is generated by electric currents located in many different parts of the Earth. It is compressed on the day (Sun) side due to the force of the arriving particles, and extended on the night side. (Image not to scale.)

Earth's magnetic field (and the **surface magnetic field**) is approximately amagnetic dipole, with the magnetic field South pole near the Earth's geographic north pole (see Magnetic North Pole) and the other magnetic field N pole near the Earth's geographic south pole (see Magnetic South Pole). This makes the compass usable for navigation. The cause of the field can be explained by dynamo theory. A magnetic fieldextends infinitely, though it weakens with distance from its source. The Earth's magnetic field, also called the **geomagnetic field**, which effectively extends several tens of thousands of kilometres into space, forms the Earth's magnetosphere. A paleomagnetic study of Australian red dacite and pillow basalt has estimated the magnetic field to be at least 3.5 billion years old.

Importance

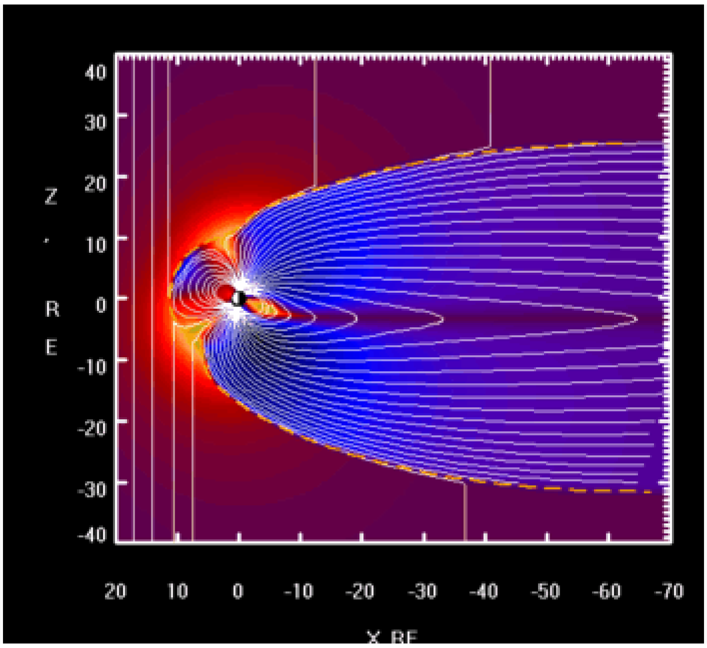


Figure 26: Simulation of the interaction between Earth's magnetic field and the interplanetary magnetic field.

The Earth is largely protected from the solar wind, a stream of energetic charged particles emanating from the Sun, by its magnetic field, which deflects most of the charged particles. Some of the charged particles from the solar wind are *trapped* in the Van Allen radiation belt. A smaller number of particles from the solar wind manage to travel, as though on an electromagnetic energy transmission line, to the Earth's upper atmosphere and ionosphere in the auroral zones. The only time the solar wind is observable on the Earth is when it is strong enough to produce phenomena such as the aurora andgeomagnetic storms. Bright auroras strongly heat the ionosphere, causing its plasma to expand into the magnetosphere, increasing the size of the plasmageosphere, and causing escape of atmospheric matter into the solar wind.Geomagnetic storms result when the pressure of plasmas contained inside the magnetosphere is sufficiently large to inflate and thereby distort the geomagnetic field.

The solar wind is responsible for the overall shape of Earth's magnetosphere, and fluctuations in its speed, density, direction, and entrained magnetic field strongly affect Earth's local space environment. For example, the levels of ionizing radiation and radio interference can vary by factors of hundreds to thousands; and the shape and location of the magnetopause and bow shock wave upstream of it can change by several Earth radii, exposinggeosynchronous satellites to the direct solar wind. These phenomena are collectively called space weather. The mechanism of atmospheric stripping is caused by gas being caught in bubbles of magnetic field, which are ripped off by solar winds.[3] Variations in the magnetic field strength have been correlated to rainfall variation within the tropics.[4]

Magnetic field reversals

Based upon the study of lava flows of basalt throughout the world, it has been proposed that the Earth's magnetic field reverses at intervals, ranging from tens of thousands to many millions of years, with an average interval of approximately 200,000 to 300,000 years.[15][16] However, the last such event, called the Brunhes–Matuyama reversal, is observed to have occurred some 780,000 years ago.

There is no clear theory as to how the geomagnetic reversals might have occurred. Some scientists have produced models for the core of the Earth wherein the magnetic field is only quasi-stable and the poles can spontaneously migrate from one orientation to the other over the course of a few hundred to a few thousand years. Other scientists propose that the geodynamo first turns itself off, either spontaneously or through some external action like a comet impact, and then restarts itself with the magnetic "North" pole pointing either North or South. External events are not likely to be routine causes of magnetic field reversals due to the lack of a correlation between the age of impact craters and the timing of reversals. Regardless of the cause, when the magnetic pole flips from one hemisphere to the other this is known as a reversal, whereas temporary dipole tilt variations that take the dipole axis across the equator and then back to the original polarity are known as excursions.

Studies of lava flows on Steens Mountain, Oregon, indicate that the magnetic field could have shifted at a rate of up to 6 degrees per day at some time in Earth's history, which significantly challenges the popular understanding of how the Earth's magnetic field works.

23. Cyclones

Queensland is cyclone prone. It has been hammered by hundreds of cyclones in the last 100 years as shown in the chart below which tracks cyclones from 1906 to 2006.

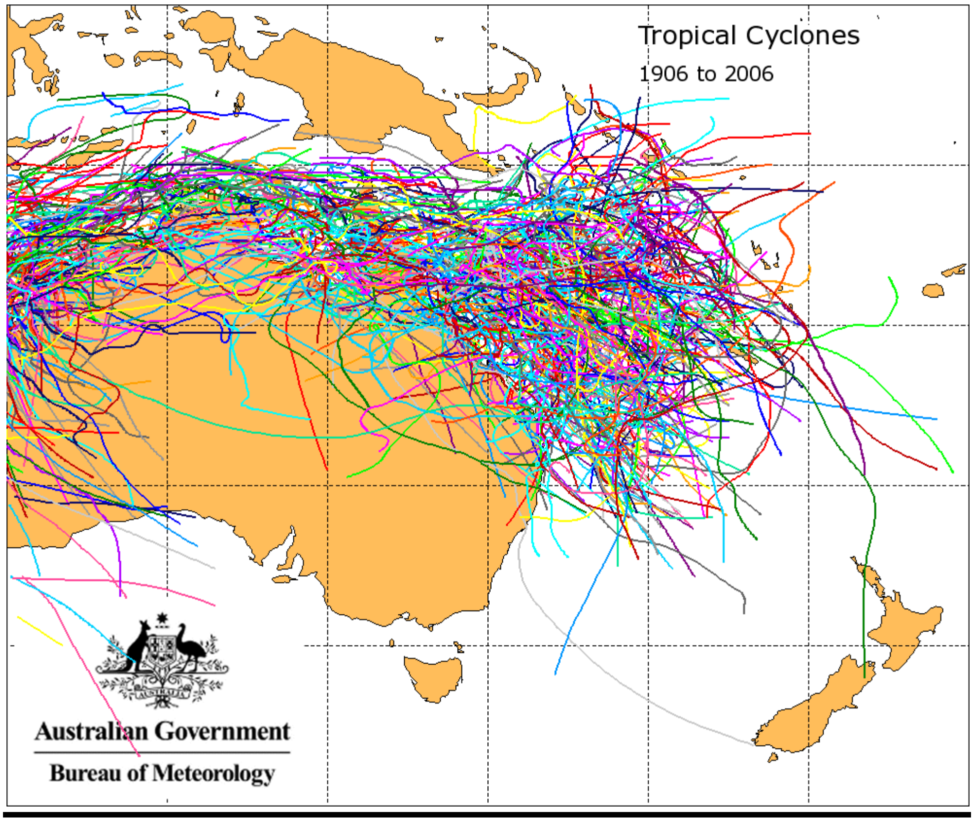


Figure 27: Queensland Cyclones from 1906 to 2006

Generally cyclones are more frequent and more severe in North Queensland, but Southern Queensland is not immune from cyclones, or the floods of remnant rain depressions after cyclones.

According to Wikipedia, Queensland has experienced at least 12 recorded category 5 cyclones in the last 100 years. What would happen if a Category 5 Cyclone flooded the Wivenhoe catchment?

Many cyclones have travelled within 200 kilometres of Wivenhoe. No-one can guarantee that the Wivenhoe catchment won't experience a category 5 cyclone next year, or the year after that, or within our lifetimes.

We have recently seen the impact of Category 5 Tropical Cyclone **Yasi** on North Queensland.

But Queensland has experienced worse cyclones than Yasi. The world's largest recorded Tsunami, over 14 metres high, occurred in North Queensland in 1899 at Bathurst Bay as a result of **Category 5 Cyclone Mahina** which wiped out the pearling fleet with over 400 deaths and only a few survivors.

Because of the significance of a Category 5 cyclone flooding Wivenhoe, I have reproduced the Wikipedia article about Cyclone Mahina. Although Wivenhoe is immune from receiving a storm surge, it is not more immune from experiencing extreme cyclonic weather with flooding rains.

24 Cyclone Mahina

The following article is edited from Wikipedia where the full article can be found at: http://en.wikipedia.org/wiki/Cyclone_Mahina

Cyclone Mahina struck Bathurst Bay, Australia and the surrounding region with a devastating storm surge on 4 March 1899, killing over 400 people, the largest death toll of any natural disaster in Australian history.

Intensity

Tropical cyclone Mahina hit on 4 March 1899. It was a Category 5 cyclone, the most powerful of the tropical cyclone severity categories. In addition, Mahina was perhaps one of the most intense cyclones ever observed in the Southern Hemisphere and almost certainly the most intense cyclone ever observed off the East Coast of Australia in recorded history. Mahina was named by Government Meteorologist for Queensland Clement Wragge, a pioneer of naming such storms.

The centre pressure, standardized for temperature, was calculated as 914 mb (hPa).

In comparison tropical cyclone Tracy which devastated Darwin in 1974 had a central pressure of 950 hPa. Barometric pressure this low at mean sea level is also a likely cause and strong indicator of why cyclone Mahina created such an intense, phenomenal and claimed world record height storm surge of the likes not seen since.

Impact

Within an hour, the Thursday Island based pearling fleet anchored in the bay or nearby, was either driven onto the shore or onto the Great Barrier Reef or sunk at their anchorages. Four schooners and the manned Channel Rock lightship were lost. A further two schooners were wrecked but later refloated. Of the luggers, 54 were lost and a further 12 were wrecked but refloated. Over 30 survivors of the wrecked vessels were later rescued from the shore however over 307 were killed, mostly immigrant non-European crew members.

A storm surge, variously reported as either 13 metres or 48 feet (14.6 meters) high, swept inland for about 5 kilometers, destroying anything that was left of the Bathurst Bay pearling fleet along with the settlement. Eyewitness Constable J. M. Kenny reported that a 48 ft (14.6 m) storm surge swept over their camp at Barrow Point atop a 40 ft (12 m) high ridge and reached 3 miles (5 km) inland, the largest storm surge ever recorded.

The cyclone continued southwest over Cape York Peninsula, emerging over the Gulf of Carpentaria before doubling back and dissipating on 10 March.

Over 100 Indigenous Australians died, including some who were caught by the back surge and swept into the sea while trying to help shipwrecked men. Thousands of fish and some sharks and dolphins were found up to several kilometres inland and rocks were embedded in trees. On Flinders Island (Queensland) dolphins were found 15.2 metres up on the cliffs.

25 The Frequency and Intensity of Cyclones

At a recent climatologist conference in Cairns, CSIRO personnel presented papers asserting that Queensland will receive fewer but more intense cyclones as the water warms from Climate Change.

So we may experience **more intense** and **more southerly** cyclones than previously. That is very bad news for the forecast failure rate of Wivenhoe, because tropical cyclones are one of the threats which may lead to the over-topping and collapse of Wivenhoe.

How much more intense might those cyclones be? What daily rainfall and peak rate of rainfall might apply? How much will the old figures need to be changed? How much more likely is Wivenhoe to overtop and collapse than previously? And what should we do about it?

As a result of the Precautionary Principle, we must plan for the worst. SEQ Water states that it will respond quickly to climate change.

Intensity of Cyclones

On 5 April 2011, *The Australian* reported CSIRO research about cyclones as follows.

http://www.theaustralian.com.au/national-affairs/fewer-more-intense-cyclones-on-the-way-csiro/story-fn59niix-1226033652833

In the wake of Cyclone Yasi, Greens deputy leader Christine Milne warned: "This is a tragedy, but it is a tragedy of climate change. The scientists have been saying we are going to experience more extreme weather events, that their intensity is going to increase, (and) their frequency."

The Australian obtained 12 scientific papers prepared for the Department of Climate Change under a project entitled "Projecting Future Climate and its Extremes". The department refused to release a further 19 papers because they were yet to be peer-reviewed.

One paper, by CSIRO researcher Debbie Abbs, found rising temperatures could dramatically reduce the frequency of tropical cyclones.

"Climate change projections using this modelling system show a strong tendency for a decrease in TC numbers in the Australian region, especially in the region of current preferred occurrence," the paper says.

"On average for the period 2051-2090 relative to 1971-2000, the simulations show an approximately 50 per cent decrease in occurrence for the Australian region, a small decrease (0.3 days) in the duration of a given TC, and a southward movement of 100km in the genesis and decay regions."

The study did not examine the likely intensity of cyclones, but Dr Abbs, an atmospheric research scientist, told The Australian that cyclones in the Australian region were expected to become more destructive as a result of climate change.

"There's a greater risk they will occur in the more extreme category," she said.

Frequency of Cyclones

The two charts below show Queensland's cyclone activity in two periods of 50 years: from 1906 to 1956, and from 1956 to 2006. The charts show a greater frequency of cyclones in the later period.

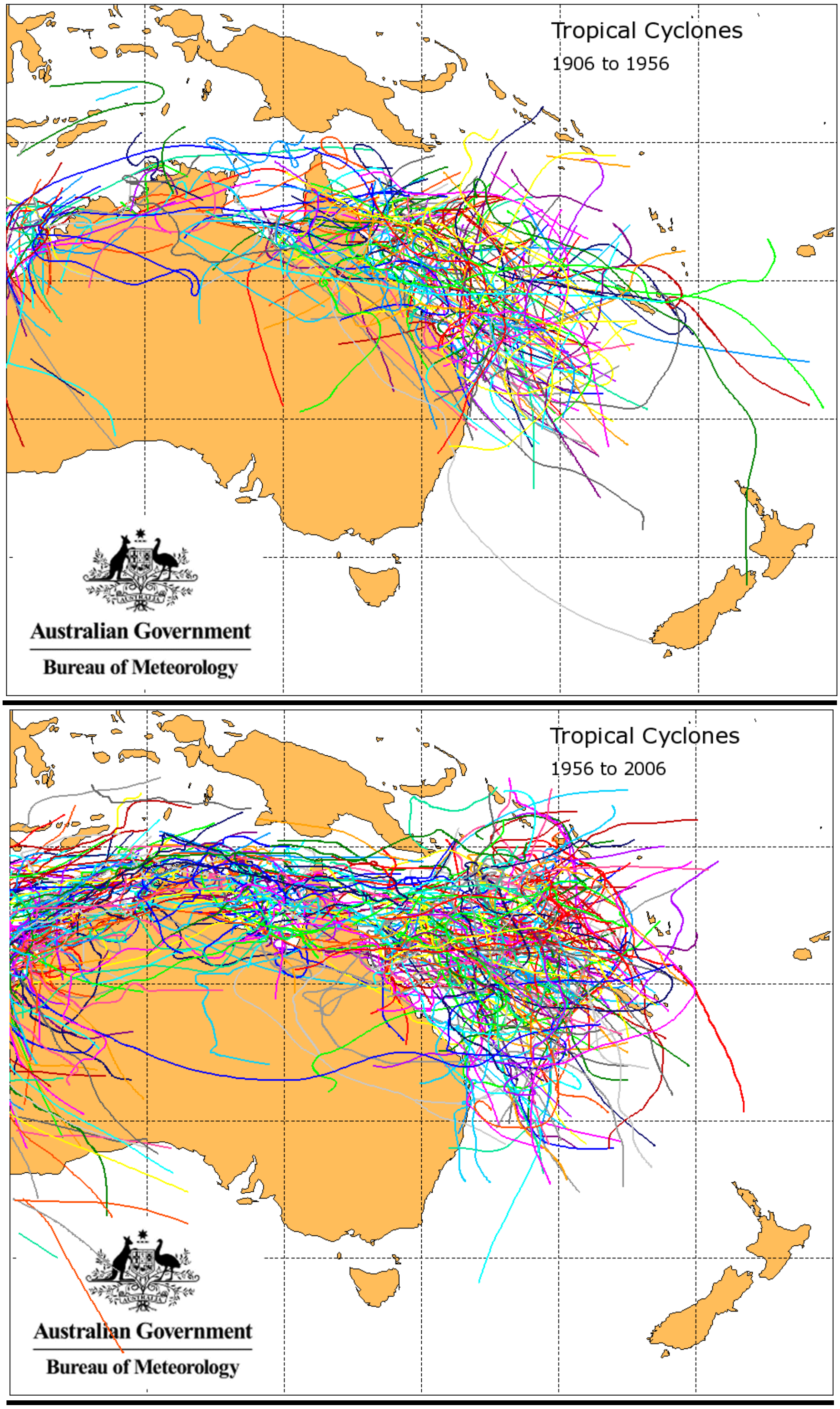


Figure 28: Contrast between Queensland cyclonic in the 50 years before and after 1956.

26 Cyclones at Wivenhoe

As we know from the January 2011 floods at Wivenhoe, it is not just cyclones which cause floods. Rain depressions can have the same effect. Some rain depressions are degraded cyclone remnants.

Cyclone

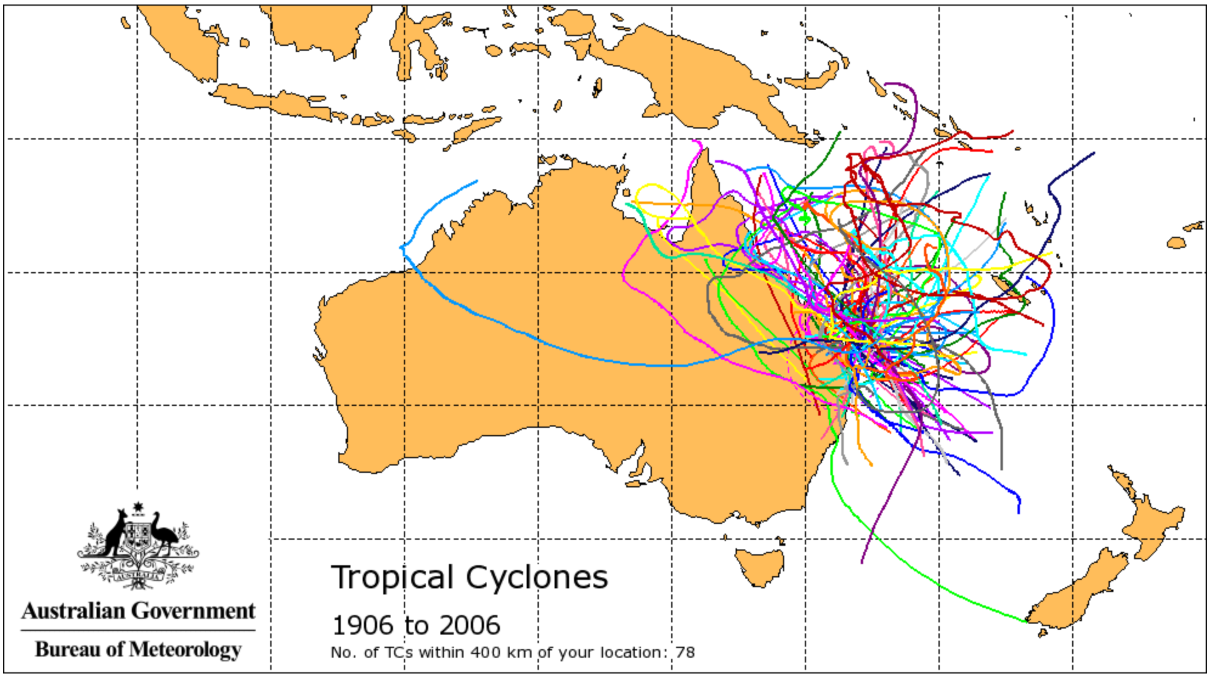


Figure 29: Countless cyclones within 400 km of Wivenhoe between 1906 and 2006. These can produce rain at Wivenhoe.

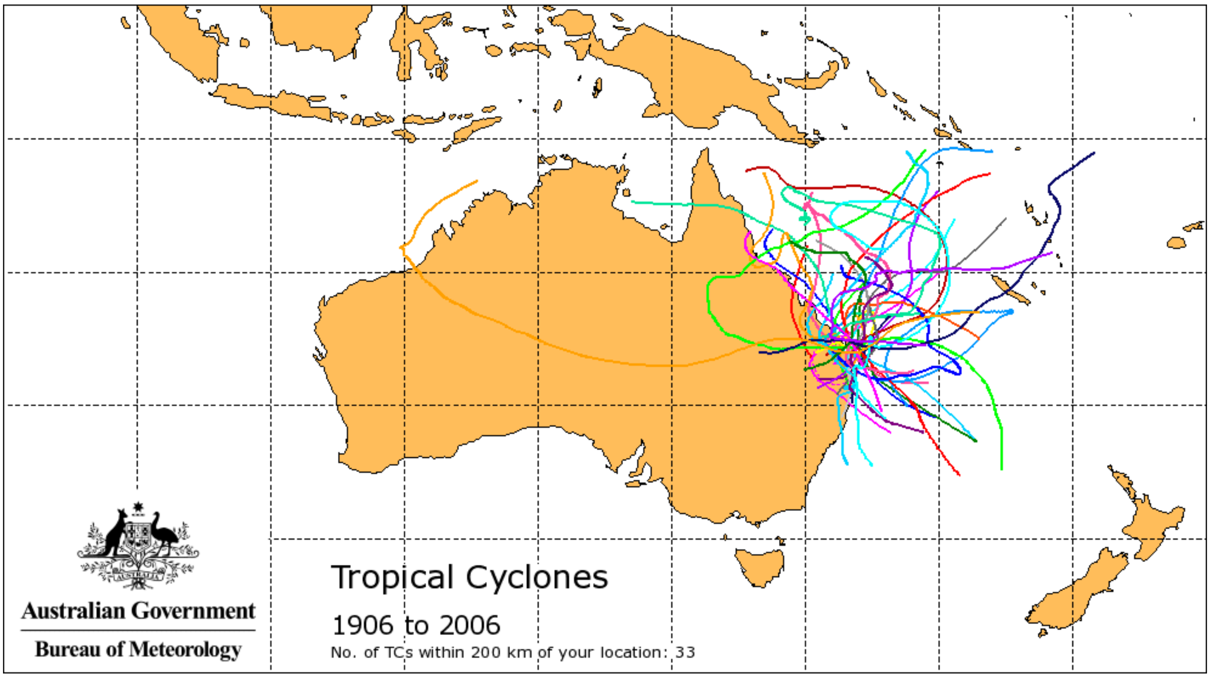


Figure 30: Dozens of cyclones within 200 km of Wivenhoe between 1906 and 2006

The charts hereunder show a dozen cyclones which came within 100 kilometres of Kilcoy, which is close to the rainfall epicentre of Wivenhoe, and three which came within 50 kilometres. The Wivenhoe catchment covers 7,020 square kilometres, and has a radius approximately 100 kilometres

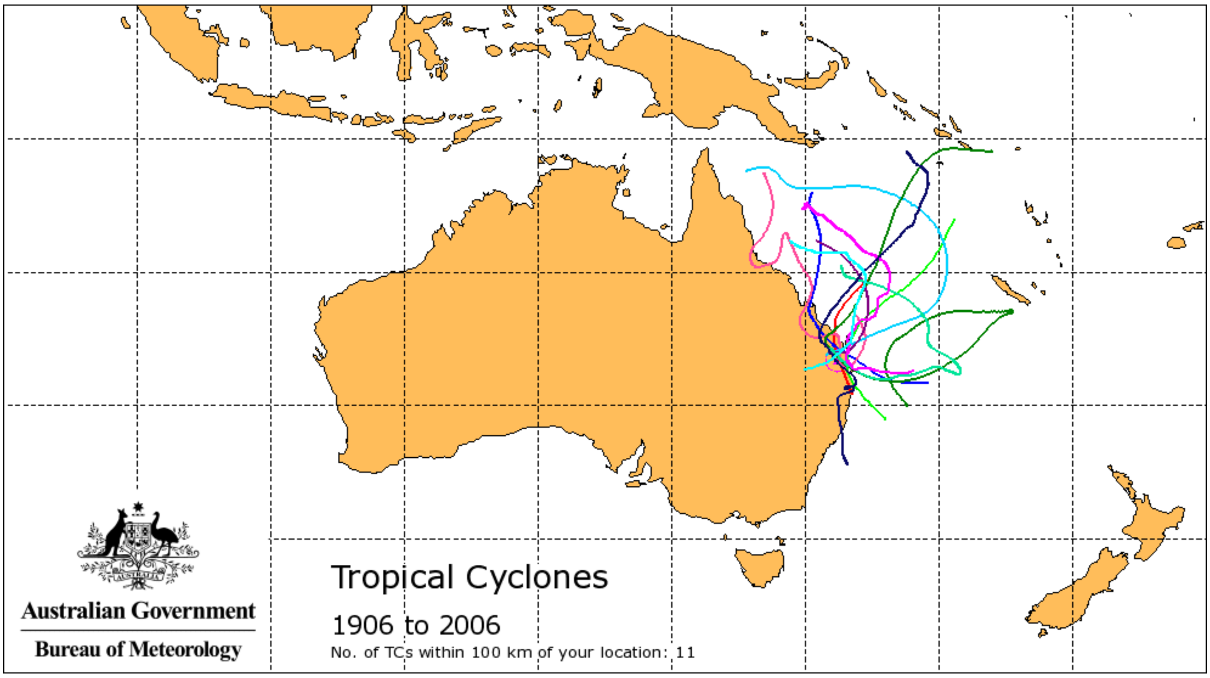


Figure 31: A dozen cyclones within 100 km of Wivenhoe between 1906 and 2006

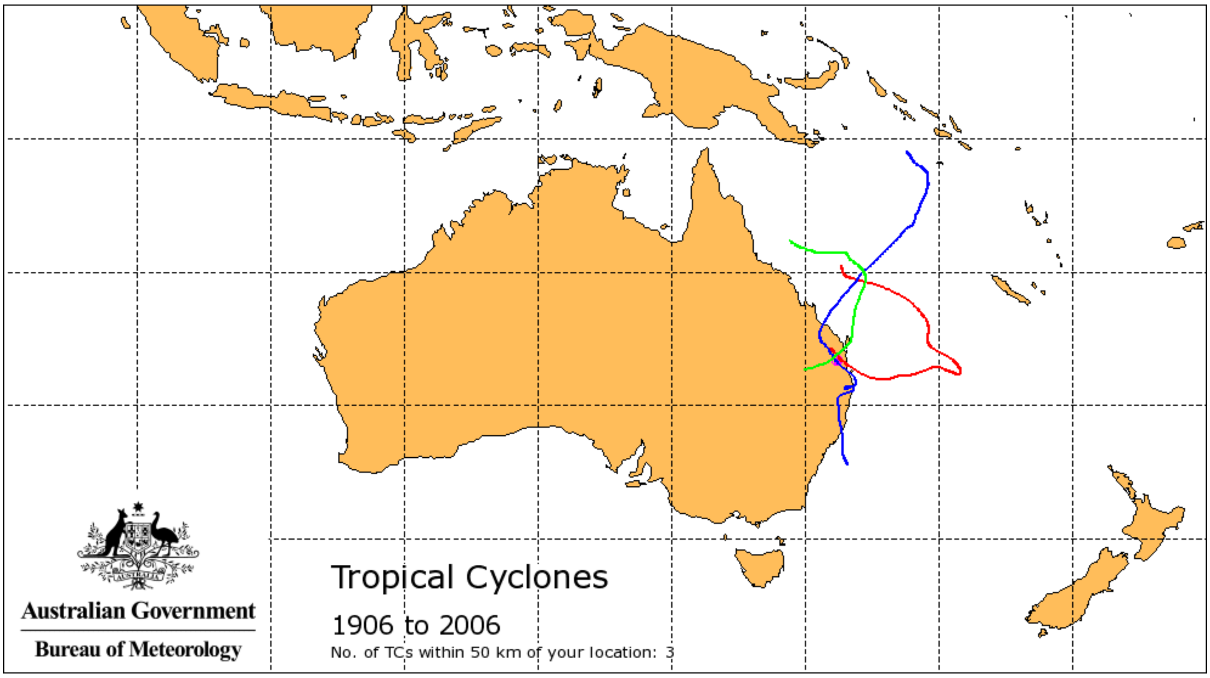


Figure 32: Cyclone activity within 50 km of Wivenhoe between 1906 and 2006

The 3 cyclones within 50 km were all in the early 1970s: Dora in Feb 1971; Emily in April 1972; Wanda in January 1974

27. Wivenhoe is Built in an Earthquake Zone

I wonder if the designers of the Wivenhoe Dam factored in the impact of an earthquake on the wall which has a clay core and is a rock lined earthen embankment.

There was a magnitude 4.0 earthquake near Gatton in 1988, a magnitude 4.4 near Mt Glorious (not far from the Wivenhoe wall) on 17 November 1960, a magnitude 4.4 near Monto on 16 January 2004, a magnitude 5.4 near Bundaberg in 1935, a magnitude of at least 6 near Lady Elliot Island on 7 June 1918.

It may be the case that a large earthquake would threaten the Wivenhoe wall.

Most people don't expect an earthquake to damage the Wivenhoe wall. The people of Newcastle in 1989, Christchurch in 2010, and Japan in 2011 didn't expect their earthquakes either.

No-one can know whether or not an earthquake will damage the Wivenhoe wall.

Qld earthquake risk real reports Daniel Hurst

in the Brisbane Times on April 24, 2009

http://www.brisbanetimes.com.au/queensland/qld-earthquake-risk-real-20090424-ahbe.html

A Queensland seismologist has warned the state should prepare for damaging earthquakes as strong as magnitude 6 in the future, despite widespread public perceptions the risk is low.

Central Queensland Seismology Research Group leader Mike Turnbull said his pleas for greater funding to help his ground monitoring work had fallen on deaf ears - even though Central Queensland had experienced strong earthquakes in the past including a magnitude 6 quake in 1918.

The scale of this earthquake - which caused property damage in Rockhampton, Bundaberg and Gladstone - is nearly as high as the devastating 6.3 quake that struck in Italy early this month, killing hundreds of people and leaving thousands homeless.

Diagram: Implied fault lines in the area west of Bundaberg
Brisbane is considered to have a lower earthquake risk, but the region has experienced earthquakes in the past.

The Emergency Management Australia disaster database shows a 4.4 magnitude quake hit Mount Glorious, 20 kilometres north-west of Brisbane, on November 17, 1960, causing some damage in the Lockyer Valley region.

Houses sustained damage when a magnitude 4 earthquake struck near Gatton in 1988.

Mr Turnbull told brisbanetimes.com.au the state's greatest earthquake risk was in Central Queensland. He said he was particularly worried about potential earthquakes along a fault line just 30 kilometres west of Bundaberg - the origin of a quake at least 5.4 in magnitude in 1935.

The Central Queensland University researcher has operated a monitoring station at his home in the Gin Gin area since 2004. Mr Turnbull said he had detected more than 100 earthquakes in this time, including a magnitude 4.4 quake that struck 30km east of Monto on January 16, 2004.

"It was felt quite strongly over a radius of 70 kilometres," he said.

"We can expect to have a magnitude four earthquake in this region every two years ... and we can expect to have at least one magnitude six earthquake in any 120 year period.

"We've had them in the past, we're going to have them again, we just don't know when exactly."

James Cook University School of Earth Sciences associate professor Tom Blenkinsop said the predictions sounded reasonable, based on the limited data available.

Dr Blenkinsop said earthquakes occurred in Australia even though the nation did not sit on a tectonic plate boundary. The nearest boundary passed through Papua New Guinea to the north, into the Pacific Ocean and south to New Zealand.

Australia experienced "intraplate earthquakes" along fault lines dating back millions of years when parts of the country were on or near plate boundaries, Dr Blenkinsop said.

"These earthquakes go off and they catch people by surprise because they're unanticipated," he said.

Mr Turnbull said he had received barely any funding for his monitoring work, even though the smaller quakes could provide a better picture of fault lines and potential earthquake locations.

Mr Turnbull said a three-year experiment to identify active faults west of Bundaberg would cost about $300,000.

He claimed scientists, engineers, state and local governments and insurers "would be falling over themselves" to identify active earthquake faults if South East Queensland - rather than Central Queensland - had experienced two major earthquakes in the last 100 years.

Mr Turnbull said the "Great Queensland Earthquake" that struck on June 7, 1918, originated near Lady Elliot Island and was felt as far west as Charleville, as far north as Mackay and as far south as Lismore.

He said the 1918 quake, which was now listed in the Emergency Management Australia database as a magnitude 6, had often been identified in literature as a magnitude 6.2 and even as 6.3 in University of Queensland literature in 2006.

"It caused minor structural damage in Rockhampton and Bundaberg, toppling chimneys for example, and caused mild panic in Rockhampton where people were reported to have run into the streets screaming," he said.

Geoscience Australia says the nation experiences about 200 earthquakes of magnitude 3.0 or more every year. It says on its website that a potentially disastrous earthquake of magnitude 6 or more occurs every five years in Australia.

Thirteen people died when a 5.6 magnitude earthquake struck Newcastle, in New South Wales, on December 28, 1989.

The quake damaged more than 35,000 homes, leaving an estimated damage bill of $4 billion

28. Earthquakes in Australia

There have been a number of significant earthquakes in Australia. We have recently witnessed the results of severe earthquakes in Christchurch and Japan. In 1989 there was a major earthquake in Newcastle with 13 fatalities.

A full list of earthquakes in Australia is found at:

http://en.wikipedia.org/wiki/List_of_earthquakes_in_Australia

The following list of major Australian earthquakes includes three earthquakes in South-east Queensland.

List of earthquakes in Australia

The list hereunder has been edited from Wikipedia

Location	Date	Magnitude	Damage	Notes & References
Gayndah, Queensland	28 August 1883	5.9	Caused major damage in the Gayndah region.	
Bundaberg - Rockhampton, Queensland	7 June 1918	6	Caused "serious damage" to Rockhampton, Bundaberg and Gladstone. An offshore earthquake.	Offshore earthquake
Gayndah, Queensland	12 April 1935	5.4	Caused considerable damage to the town of Gayndah. One fatality.	
Newcastle, New South Wales	28 December 1989	5.6	13 fatalities, 160 people hospitalised, 300,000 people affected. 50,000 homes damaged, 300 buildings demolished. Damage estimated at $4 billion.	To date the most destructive earthquake recorded in Australia, damaging over 50,000 buildings and shutting down the Newcastle CBD for two weeks. Effects of the earthquake were felt over 200,000 square kilometres up to 800 kilometres away.

Questions

1	Is Wivenhoe in an earthquake zone?	Yes, see above
2	Could an earthquake damage Wivenhoe's wall?	No-one can guarantee that it won't.
3	Have earthquakes caused dam collapse?	Yes, see below3

29. Earthquakes which have collapsed Dams

For a discussion on the connection between dams and earthquakes, please refer to an article at: http://www.seis.com.au/Basics/Dams.html part of which is reproduced hereunder.

Dams & Earthquakes

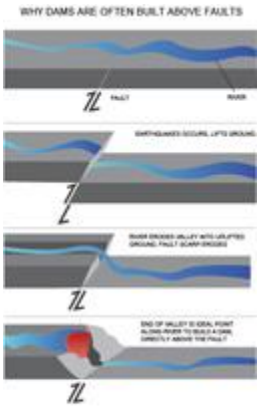
Introduction

People involved in the design, construction and operation of large dams are normally particularly sensitive to earthquakes.
This is because of four factors:

1. **Dams are often built in active earthquake areas**
2. **Reservoirs can trigger earthquakes**
3. **Some water supply structures are susceptible to earthquake motion**.
   Embankments and outlet towers respond to earthquake vibrations. Shaking an unstable slope that has been weakened after saturation by rises in ground water levels may produce a landslide into the reservoir.
4. **The consequence of a dam or water supply failure is high**.
   The effects of a dam failure on people and structures downstream are dramatic and obvious. A more likely example of earthquake damage would be loss of control of the water supply.

The first two points will be examined in more detail.

Why are Dams Often Built in Active Earthquake Areas? *Click to view PDF*



- Dams are usually built in valleys
- Valleys exist because active erosion is taking place
- Active erosion implies there has been recent uplift
- Under compressional tectonic force, reverse or thrust faults produce uplift
- Reverse or thrust faults dip under the upthrown block
- Therefore, many dams have an active fault dipping under them

ReservoirTriggered Earthquakes

Large new reservoirs can trigger earthquakes. This is due to either:

- change in stress because of the weight of water, or more commonly by
- increased groundwater pore pressure decreasing the effective strength of the rock under the reservoir.

For triggered earthquakes to occur, both mechanisms require that the area is already under considerable tectonic stress.

Internet searches of earthquake induced dam failures include:

Earthquakes can certainly cause damage to dams but complete failure of a large dam due to earthquake damage appears to be very rare. The Lower San Fernando Dam in California, USA did fail during a (magnitude 6.6) earthquake in 1971 which caused the fill in the dam wall to liquefy resulting in the collapse of the upstream part of the dam. A disastrous flood was only prevented because the reservoir level happened to be low at the time of the earthquake and no water escaped downstream.

Santa Barbara, California
1925 June 29 14:42 UTC
Magnitude 6.8

This destructive earthquake caused property damage estimated at $8 million and killed 13 people. Most of the damage occurred at Santa Barbara and nearby towns along the coast, but the earthquake caused moderate damage at many points north of the Santa Ynez mountains, in the Santa Ynez and Santa Maria River valleys. North of Santa Barbara, the earth dam of the Sheffield Reservoir was destroyed, but the water released caused little damage.

China Earthquakes More Peril: Dam and Reservoir Collapse

By CSC staff

The 7.8 earthquake that shook Sichuan Province in the afternoon of May 12, 2008 killing an estimated 50,000, is posing a continuing threat as the untold damage to hydropower stations and reservoir dams upstream on the Min River (the Minjiang) becomes apparent. The Minjiang is a tributary of the Yangtze River.

"We're ready to go to the earthquake affected areas. The Ministry of Water may summon us at any time," Li Lei, professor at the Nanjing Hydraulic Research Institute, said to a China Business News reporter.

The National Development and Reform Commission has revealed the destruction caused to water facilities by the earthquake. By 5pm, May 13, safety problems had been discovered at 391 reservoirs, including two big ones, 28 medium ones and 361 small ones, in Sichuan and other four provinces.

The quake and its aftershocks were strong enough to cause damage to the foundation and body of the dams and reduce their bearing capacity. "Judging from the number of the dams destroyed, the damage is very serious," said Professor Li Lei.

Sichuan has about 7,000 dams in its system, 70% of which were built in 1950s or 1960s, which now needs to be consolidated.

30. The Hume Weir started moving down river

Lake Hume is an artificial lake in Australia formed by the Hume Weir east of Albury-Wodonga on the Murray River just downstream of its junction with the Mitta River. The small towns of Tallangatta, Bonegilla and Bellbridge are located on the shores of Lake Hume. It is often referred to as the Hume Weir, only named Lake Hume in the mid 1980s.

History: concerns that the dam was heading for collapse

Monitoring of the dam in the early 1990s revealed that the water pressure and leakage had caused the dam to move on its foundations slightly, leading to concerns that the dam was heading for collapse, threatening Albury-Wodonga and the entire Murray basin with it. Authorities denied any short-term threat. Traffic was banned from the spillway, and a large repair job commenced involving, in part, the construction of a secondary earth wall behind the original to take the strain.

The Wall

Figure 33: The Hume Weir's concrete gates in the foreground, and the earthen wall in the distance

The Hume Weir wall

The dam wall is constructed of rock covered with clay and other earth, with a concrete spillway. Designed to carry vehicular traffic, the dam wall is 51 metres high and 1,616 metres long, and at 100% capacity can hold 3,000,000 megalitres of water. Water is retained nearly 40 kilometres up both river valleys. Lake Hume holds approximately 5 times the volume of Sydney Harbour.

The Wivenhoe wall

Those familiar with the specifications of Wivenhoe will notice the similarities between the Hume Weir and Wivenhoe. Wivenhoe Dam consists of an earth and rock embankment 2.3 kilometres (1.4 mi) long and 50 metres (160 ft) high. It has a concrete spillway section on which five steel crest gates are installed. The dam's reservoir has a total storage capacity of 2.61 cubic kilometres (0.63 cu mi), of which 1.16 cubic kilometres (0.28 cu mi) is used for urban water storage.

Specifications	Hume	Wivenhoe
Height (metres) above stream bed	51	56
Length (metres)	1,616	2,300
Construction	earth wall	earth wall, rock lined, clay core
Total Capacity (Million ML)	3,000	2,600

31. Accelerator/Avalanche/Snowball Effect

We've all heard of the snowball effect. A snowball rolling down hill gathers snow and pace exponentially. And we've all heard of avalanches which are examples of an effect similar to the snowball effect.

Something similar happens with runoff. When water is flooding in from Peachester (at the very north-east of the Wivenhoe catchment), towards Wivenhoe, it starts trickling off trees and through grass and over soil and around rocks and sticks, and slowly makes its way to Wivenhoe via gullies then creeks then the Stanley River, then it flows out of Somerset Dam into the Brisbane River at the top of Wivenhoe. Its speed gradually increases as it goes further down the catchment, because it gets deeper. The more it concentrates, the deeper it gets, and the faster it flows.

For a certain rate of rainfall, water reaches an equilibrium rate of flow. We can find that a catchment which receives X mm of rain per hour will generate Y cubic metres per second of runoff.

However, if rainfall dramatically increases for a short period, the depth of the runoff also dramatically increases, and the rate of flow dramatically increases.

For example, let's assume in **Scenario A** that rain is falling at the rate of 1 mm per minute, which is 60 mm per hour.

Then let's assume in **Scenario B** that the rain falls at the rate of 8 mm per minute for 5 minutes (the Deluge) and then drops back to .3636 mm per minute for 55 minutes (the Trickle). That's also 60 mm per hour.

However, in Scenario B, the rate of rainfall during the Deluge is 8 times that of Scenario A, and the velocity of the runoff during the Deluge is many times that of Scenario A. The Deluge runoff not only runs off faster than in Scenario A, but the Deluge runoff accelerates all the water already moving in the landscape, and moves that water at the rate of the Deluge runoff.

This is of enormous consequence in saturated extensive catchments such as Wivenhoe's in January 2011. Perhaps conventional runoff modelling of 60 mm per hour would allow for steady state runoff. But Deluges would produce immensely faster runoff, not just from the Deluge, but from all the runoff water speeded up by the Deluge.

This torrential flow then catches up with all of the slow moving water ahead of it from previous rainfall and pushes the total body of water faster and faster and faster as the water gets deeper and deeper and deeper. The previously slow moving water in the system is all hurried-up and delivered together with the water from the Deluge.

There is resistance in the landscape to the flow of water: by grass, trees, rocks, soil, sticks, stones etc; but as the amount of water increases, the resistance becomes less important. The resistance of grass to a trickle is very significant, and slows water flow down appreciably. But at torrential rates, the resistance of cars and houses is negligible. Resistance drops inversely proportionally to rates of flow as water is flowing smoothly over water instead of being slowed by grass, and other landscape elements, and flow velocity increases dramatically.

It's a bit like an out-of-control semi-trailer hitting a line of cars in a traffic jam going down the Toowoomba Range: there is a cataclysmic snowball towards the bottom of the hill, not just of the semi-trailer, but of everything in its path.

Another analogy is that It's a bit like a home run in baseball. If you're the first batter, you only get one home run. But if the bases are loaded, you get 4 home runs. There's an avalanche during which the 4 runners arrive in quick succession. With runoff, instead of the runners arriving in succession, it's different. It's like a fast runner catching up to a runner in front; whereupon the combination causes both runners to go even faster than the faster runner of the two (deeper water flows faster). When the first two runners catch up on the next runner, the impact is exacerbated, and the three runners go even faster than before, etc.

At Toowoomba and Grantham, water moved very fast because there was a lot of it. The more there was, the faster it travelled, and the easier it was to overwhelm and destroy obstacles without slowing down. I believe that the **Accelerator/Avalanche/Snowball Effect** was on display in Toowoomba and Grantham.

The Toowoomba and Grantham floods occurred on Monday 10 January 2011. It is interesting to look up the rainfalls for the 24 hours to 9:00 am on Tuesday 11th:

Toowoomba: 117 mm   Helidon: 29 mm

These are not exceptional levels of rainfall compared to the average in the Wivenhoe catchment which was of the order of 110 mm that day and 153 mm the day before. So why was the Toowoomba rainfall so destructive? Why was the Helidon/Grantham rainfall so destructive? Because it fell quickly. The Toowoomba downpour was reported at 60 mm in an hour whereas the Wivenhoe catchment rainfall averaged of the order of 6.4 mm per hour to 9:00 am on Monday 10th and 4.5 mm per hour to 9:00 am on Tuesday 11th.

On Tuesday 11 January 2011, on my calculations, there was in excess of 1 million ML (perhaps up to 1.5 million ML: I have not had time to reconcile the final detailed figures) in the Wivenhoe/Somerset catchment, not yet in the Lakes.

If a catchment-wide Scenario B Deluge had accelerated that 1 million ML, plus the water from the Deluge of 280,000 ML (5 minutes @ 8 mm = 40mm x 7,000 hectares), then 1.28million ML would all arrive in Wivenhoe in a relatively short period and overwhelm the wall. If the 1.28 million ML of water arrived at Wivenhoe in 6 hours, that would be far too much for the release capacity of the gates and the fuse plugs. And because there was very little flood capacity at that stage, the Wivenhoe wall would quickly be over-topped and destroyed.

It is very important to managing Wivenhoe that the **Accelerator/Avalanche/Snowball Effect** is understood and taken into account. Without proper allowance of that **Effect, and of the amount of water in the catchment but not yet in the Lake,** Wivenhoe may be kept so full that a short sharp Deluge across the catchment could quickly overfill Wivenhoe leading to wall failure.

I believe that we were only a Deluge away from the Wivenhoe wall collapsing during the Flood in January 2011.

32. SEQ Water Report: the Anomaly

I suspect from reading section 8.9 of the SEQWater Flood Report, particularly page 147, that SEQWater may not have factored in the **Accelerator/Avalanche/Snowball Effect** which would produce an alternative explanation instead of the 1/2,000 year rainfall imputed to solve the problems explained on pages 146 and 147 of SEQWater's Report. The SEQWater comments suggest that there may be problems with their modelling. Perhaps SEQWater hasn't allowed for the **Accelerator/Avalanche/Snowball Effect.** That effect is of massive importance in managing Wivenhoe.

Please refer particularly to the excerpt from SEQWater's report highlighted in gold hereunder to appreciate the difficulty SEQWater are having with their modelling:

*"It was then **necessary to scale this rainfall up by a factor of two to match the rapid lake level rises**. This factored Mt Glorious rainfall data had an average intensity of 68mm/hr, which exceeds an annual recurrence interval of 1 in 2,000 years and may be well into the extreme category" (the use of bold type and underlining is mine).*

SEQWater state in Section 8.9 (I have removed the graphs):

8.9 Impact of intense rainfall occurring on Tuesday 11 January 2011

As discussed in Section 6, heavy, localised, intense rainfall around the Wivenhoe lake area commenced in the early hours of Tuesday 11 January 2011 and continued into the afternoon.

This rainfall was recorded in the rain gauges to the east and south of Lake Wivenhoe (around Mt Glorious and Lowood), however, it was not recorded in gauges to the north and west of Wivenhoe Dam. There is a large, unmonitored area between these gauges, which covers a large component of the Lake area. For modelling purposes, this area is treated as impervious and generates 100% runoff. Radar images at the time indicated rain was falling continuously in this area over the period. Rainfall totals in the 12 hours to 15:00 ranged from 410mm at Mt Glorious on the eastern side of the lake, to only 32mm at Rosentretters on the western side of Lake Wivenhoe.

The real time modelling undertaken with the available recorded rainfall data did not reproduce the rapid rise in Lake level recorded that afternoon. This inferred very heavy rain fell within and around the Wivenhoe Dam Lake area immediately upstream of the Dam. This suggestion was tested using the Seqwater Unified River Basin Simulator (URBS) model using the following methodology.

The recorded Mt Glorious rainfall was transposed to a dummy station at the centre of the Lake and, for the period of heavy rainfall, scaled up the URBS model re-run, and the resultant flows imported into the gate operations spreadsheet. The modelled water levels were then compared with the recorded water levels.

Figure 8.9.1 below shows the impact of the scaled rainfall on the modelled upper Brisbane River inflow to Wivenhoe Dam. The peak of the inflow is both much higher and earlier with the transposed dummy rainfall station than without.

In order to reproduce the recorded Wivenhoe Dam levels, it was necessary to scale the rainfall of the transposed Mt Glorious data by a factor of two for the period between 03:00 to and 15:00 on Tuesday 11 January 2011, indicating the significance of the heavy rainfall in the ungauged area immediately upstream of the Dam.

IFD analysis of the rainfall record at Mt Glorious shows the 12 hours to 15:00 on Tuesday 11 January 2011 had an average intensity of 33.9mm/hr and was in the range 1 in 500 to 1 in 1,000 AEP, between the large and rare categories.

To model the rapid rise of the recorded Wivenhoe Dam levels between 03:00 to 15:00 on Tuesday 11 January 2011, the Mt Glorious rainfall data was repositioned to the ungauged area immediately upstream of the Dam, where the BoM radar indicated was the centre of the heavy rainfall during that period. It was then necessary to scale this rainfall up by a factor of two to match the rapid lake level rises. This factored Mt Glorious rainfall data had an average intensity of 68mm/hr, which exceeds an annual recurrence interval of 1 in 2,000 years and may be well into the extreme category. Rainfall of this intensity and duration over the Wivenhoe Dam lake area at such a critical stage of a Flood Event was unprecedented. The resulting runoff could not be contained without transition to Strategy W4, as discussed in Section 2 and Section 10.

Michael O'Brien: "Brisbane Flooding January 2011: An Avoidable Disaster"

Michael O'Brien comments on SEQWater's report as follows in his report "***Brisbane Flooding January 2011: An Avoidable Disaster***", found at:

http://resources.news.com.au/files/2011/03/22/1226025/997481-aus-news-file-obrien-report-replace.pdf

There are two possible explanations: -

- *That this period of 8 hours was the period of highest rainfall in the Wivenhoe catchment, or*
- *The manual gauge board was reading high and the dam level was not increasing at the rate shown by the gauge board. In this case the calculated inflow rates would then be lower than the currently estimated values.*

Further detailed analysis of this period is essential because: -

- *This is a critical period for gaining a proper understanding of the impact of the releases from Wivenhoe on the flood in Brisbane.*

- *If correct, the elevated rainfall over this period would represent the most severe inflows to the dam and would be expected to significantly impact on future event forecasting. As noted by SEQWater this would require a rainfall event with an ARI of 2000 years.*

Another possible explanation of the Anomaly

I suspect that the anomaly referred to by both SEQWater and Michael O'Brien may be solved by further analysis of the **Accelerator/Avalanche/Snowball Effect.**

It is very important to managing Wivenhoe that the **Accelerator/Avalanche/Snowball Effect** is understood and taken into account. Without proper allowance of that **Effect, and of the amount of water in the catchment but not yet in the Lake,** Wivenhoe may be kept so full that a short sharp Deluge across the catchment could quickly overfill Wivenhoe leading to wall failure.

It seems to me to be vital to factor into the Wivenhoe Management Manual the possibility of a Deluge which could very quickly change the water levels in the Lake. Such a Deluge could trigger a Strategy W4 almost instantaneously, and therefore the possibility of that event should be taken into account in the Manual of Operational Procedures. The possibility of such an event would trigger a W4 Strategy much earlier than otherwise.

I believe that we were only a Deluge away from the Wivenhoe wall collapsing during the Flood Event in January 2011.

I believe that if on the afternoon of Tuesday 11th the Wivenhoe catchment had received the 60 mm cloudburst that hit Toowoomba the day before, the Wivenhoe dam wall would have failed. Wivenhoe was nearly full then, and couldn't cope with much more.

33. How likely is a Deluge at Wivenhoe?

A relevant question pursuant to this analysis is: "How likely were we to get rainfall of 60 mm in an hour across the Wivenhoe catchment?"

The Wivenhoe catchment has an area of 7,020 square kilometres, and has a wide range of rainfall characteristics. As a result, the likelihood of high rainfall is normally greater in the east of the catchment than in the west.

That's what happened in January 2011: the heaviest falls were in the east of the catchment. If the falls in the east of the catchment as experienced at Mt Glorious had fallen across the catchment, Wivenhoe would have been at crisis point.

To give an example of the likelihood of 60 mm per hour at Kilcoy, we can research through the Bureau of Meteorology's extensive online data.

That question is addressed by the BoM at an Intensity-Frequency-Duration rainfall site (the IFD site) at http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

The results of inputs to that site of the coordinates of Kilcoy (26/59/00 South & 152/30/00 East) are copied below.

Kilcoy is due north of the Wivenhoe wall and is close to the rainfall weighted epicentre of the Wivenhoe catchment.

The IFD site shows that a rainfall of 60 mm in an hour at Toowoomba has an average frequency of about 40 years; and at Kilcoy, of about 10 years (for 58.8 mm in an hour). I dare say that during the rainfall events that we were experiencing, the chance of such a rainfall event was higher than on any "normal" day.

More alarmingly, for Kilcoy, we can see from the IFD Table that rainfall at that intensity of 58.8 mm per hour for 20 minutes occurs every year on average. The relevance of the intensity relates to the mobilization of the water already ahead of the Deluge via the **Accelerator/Avalanche/Snowball Effect** so that a relatively short sharp Deluge can mobilize a far greater quantity of water.

This is the first major flood we've had since Wivenhoe was built, and it is clear that we are still learning how the Wivenhoe catchment behaves, and learning how to manage the Dam.

When we have high rainfall, all of the Wivenhoe flood compartment may need to be used merely to save the dam wall from collapse, with none available to mitigate the type of flooding which Brisbane recently experienced which may be necessary to prevent far worse cataclysmic Grantham tsunami type flooding of Brisbane if the Dam wall fails.

Welcome to the IFD Program Page 1 of 1

Home | About Us | Contacts | Careers | Help | Feedback |

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Home | IFD Table | IFD Chart | Coefficients | ARI | Print IFD table | Help IFD table

Intensity-Frequency-Duration Table

Location: 26.975S 152.500E NEAR.. Kilcoy Issued: 16/2/2011

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	104	134	170	192	223	264	296
6Mins	97.0	125	159	179	208	246	276
10Mins	79.4	102	130	147	170	201	226
20Mins	58.8	75.7	95.7	108	125	148	166
30Mins	47.9	61.7	78.0	88.0	102	120	135
1Hr	31.8	41.0	52.0	58.8	68.0	80.6	90.5
2Hrs	19.7	25.4	32.6	37.0	43.0	51.1	57.6
3Hrs	14.5	18.8	24.3	27.7	32.3	38.6	43.6
6Hrs	8.53	11.1	14.5	16.7	19.6	23.6	26.9
12Hrs	5.12	6.71	8.85	10.2	12.1	14.7	16.7
24Hrs	3.20	4.18	5.56	6.44	7.62	9.26	10.6
48Hrs	2.00	2.61	3.47	4.02	4.76	5.78	6.61
72Hrs	1.44	1.89	2.51	2.92	3.46	4.21	4.83

(Raw data: 42.46, 6.8, 1.93, 77.76, 13.84, 3.99, skew=0.26, F2=4.38, F50=17.26) © Australian Government, Bureau of Meteorology

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http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml 16/02/2011

Figure 34: IFD rainfall data for Kilcoy (near the rainfall epicentre of the Wivenhoe catchment)

Welcome to the IFD Program

Page 1 of 1

Home | About Us | Contacts | Careers | Help | Feedback |

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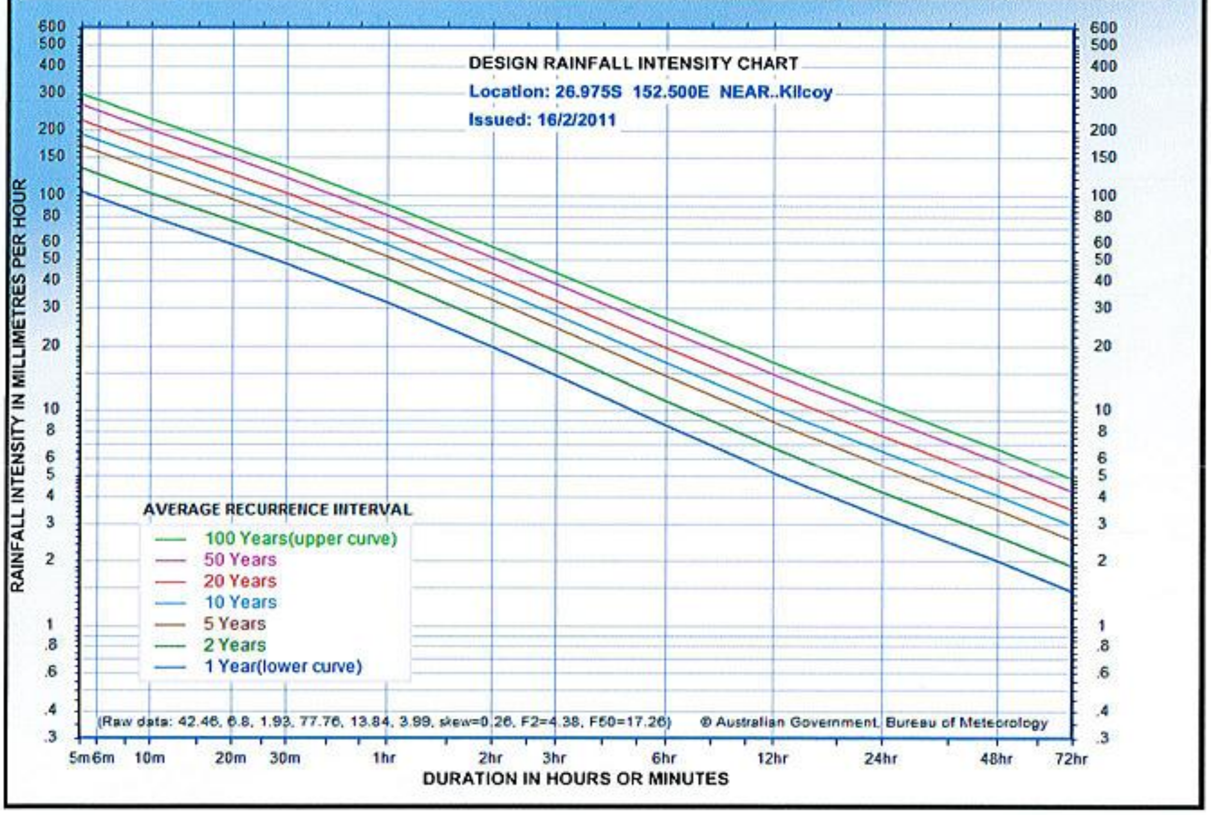
Home | IFD Table | IFD Chart | Coefficients | ARI | Print IFD chart | Help IFD chart



Home | About Us | Contacts | Careers | Search | Site Map | Help | Feedback
Weather & Warnings | Climate Information | Water Information | Radar | RSS | Learn About Meteorology

Figure 35: IFD rainfall graphs for Kilcoy (near the rainfall epicentre of the Wivenhoe catchment)

34. Levees & Flood Gates & Flood Pumps

Many communities throughout Australia have successfully used levee banks to protect property from floods.

Where levee banks are built on creeks, both flood gates and flood pumps are needed.

The Geography of Brisbane's Creeks

There are many creeks in Brisbane with a wide variety of geography. Some lend themselves to levee banks more than others.

Moggill Creek

Moggill Creek lends itself to the construction of levee banks between two knolls near the river bank. Flood gates (of steel seated in waterproof gaskets housed in concrete) can be installed in the levee to allow the gates to swing outwards to allow outbound water to flow to the river, but not vice versa. In the event that the Creek and the River are running simultaneously, a battery of diesel powered high volume flood pumps can provide a backup when the gates are closed.

Thereby, Moggill Creek can be flood proofed, at least against a 12,000 cubic metre per second (cumec) river flood in accordance with the flood map as published by the Bureau of Meteorology.

Other Creeks

Most of Brisbane's creeks lend themselves to this approach, but not all to the same extent.

For example, it would be easy to protect Oxley Creek and the Rocklea Markets from a 2011 level flood, but not so easy in respect of a 12,000 cumec flood.

It is then a difficult decision as to what to do. The cost for minor works provides reasonable protection against minor floods, but not major ones. Yet the expectation arising from the works is that the land will be invulnerable to flooding, and that would not be the case.

Increased Rates and Land Tax will help fund Works

As a result of those Flood Control Levee Bank Works, "Valuer-General's" property values of affected property would increase considerably, perhaps doubling for some properties, thereby raising Rate revenue and Land Tax. These sources of revenue can assist with the financing of the works.

35. Plan of Moggill Creek in a 12,000 m^3/s flood

See the 2 knolls near the Brisbane River bank. Flooded land is shown in gold. Knolls are white.

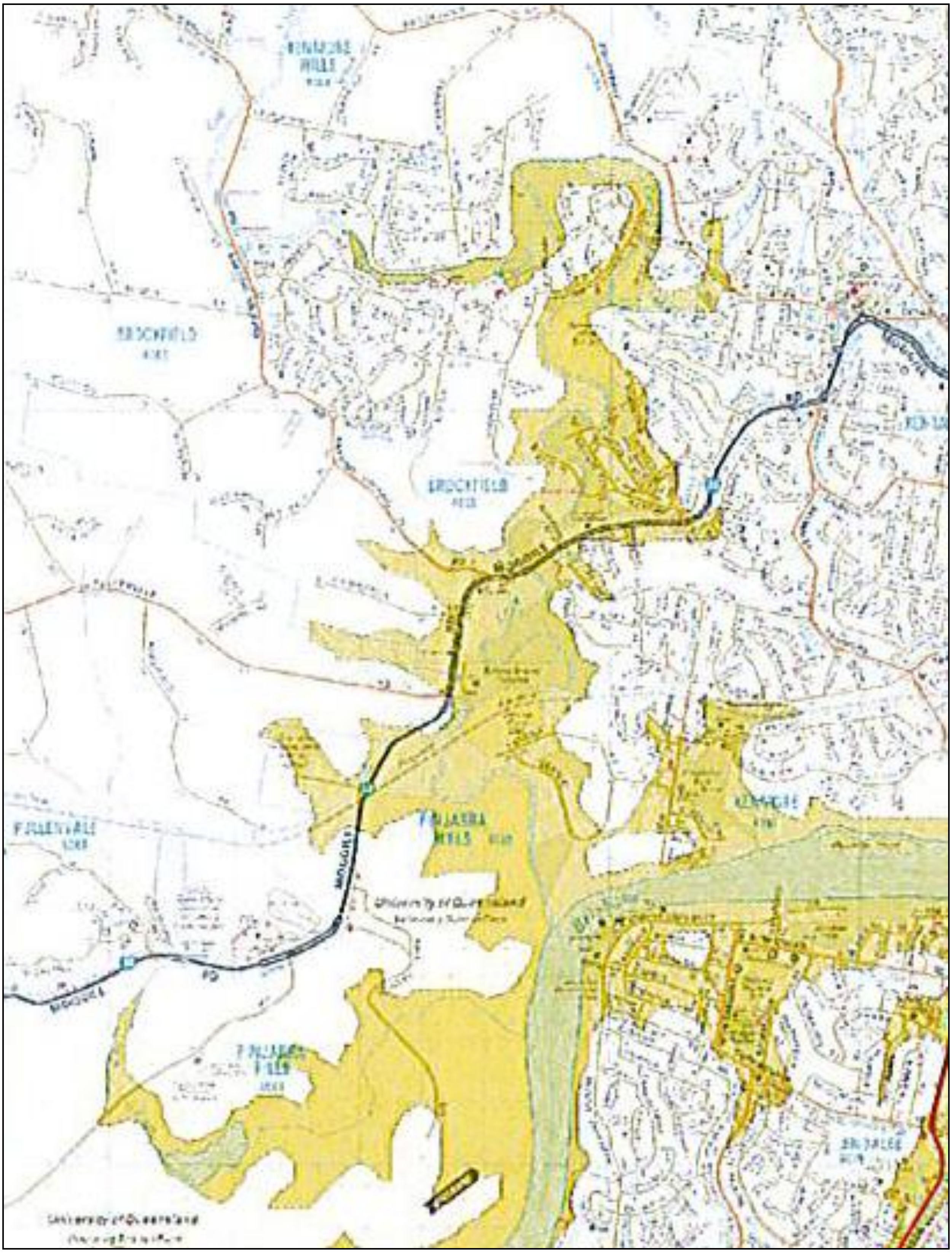


Figure 36: Moggill Creek has 2 knolls near the Brisbane River. The knolls can be connected by a levee with flood gates & pumps

36. Concrete the outer skin of the Wivenhoe wall

We deserve a safe solution to the Wivenhoe problem.

That solution is to concrete the outer skin of the Wivenhoe wall.

In Table 1, to make a start on cost estimates, I have set out some parameters which estimate the cost of concreting the Wivenhoe wall at between $300 million and $700 million.

In Table 2, I list some of the advantages flowing from the concreting of the outer skin of the Wivenhoe wall.

Wivenhoe is built above rock which provides a base into which a concrete wall can be anchored. That concrete wall would allow the dam to be safely overtopped.

That situation would allow the fuse plugs to be closed up, thereby increasing the flood capacity. In addition, because the wall could be safely overtopped, the entire flood capacity could be used to mitigate downstream flooding.

Earthen dam walls usually fail from the outside bottom upwards. They progressively cut back and up from turbulence at the outside bottom of the wall until the cutting reaches the top whereupon the breach quickly widens and the wall collapses.

The solution is to create a massive concrete anchor in bedrock near the outside bottom of the wall, and concrete the road and the outside skin of the wall (the inside is irrelevant) fully anchored into rock along the length of the wall, supported by piles, and strengthened by horizontal and vertical beams. This then allows the dam to be safely overtopped.

There is then no danger of overtopping, or from movement or pressure of the water inside.

There are real issues in that respect with all earthen walls particularly relating to how well they are keyed into bedrock at the heart of the wall.

See the Wikipedia article about the Hume Weir "***Monitoring of the dam in the early 1990s revealed that the water pressure and leakage had caused the dam to move on its foundations slightly, leading to concerns that the dam was heading for collapse, threatening Albury-Wodonga and the entire Murray basin with it. Authorities denied any short-term threat. Traffic was banned from the spillway, and a large repair job commenced involving, in part, the construction of a secondary earth wall behind the original to take the strain***."

The cost of concreting the outside skin of the Wivenhoe wall is petty cash compared with the cost of the failure of Wivenhoe.

The extent of the rock can be seen near the Wivenhoe gates.

Figure 37: The extent of the rock can be seen near the Wivenhoe gates

The height of the Wivenhoe wall varies significantly

Figure 38: The height of the Wivenhoe wall varies significantly

Table 1: Cost of concreting the outer wall of Wivenhoe (plus the road & an apron at the foot of the wall; plus beams & piles)

The cost range is estimated at between $300 million & $700 million as follows.

Average Wall Height metres	Average Road Width metres	Average Apron Width metres	Height plus Road plus Apron metres	Total Length in metres	Average Thickness of concrete metres	Concrete Volume in Cubic Metres	Cost per Cubic Metre	External Skin Cost $ millions	Surcharge for beams at 20% $ millions	Surcharge for piles 20% $ millions	Total Cost in $ millions	Total Cost rounded up $ millions	Cost Range in $ millions
25	10	10	45	2,300	2	207,000	$1,000	$207	$41	$41	$290	$300	low
30	10	15	55	2,300	2.5	316,250	$1,500	$474	$95	$95	$664	$700	high

Table 2: Benefits of concreting the outer wall of Wivenhoe (plus the road & an apron at the foot of the wall; plus beams & piles)

1	Allows the wall to be safely overtopped without causing the dam to collapse
2	Safety to downstream people
3	Safety to downstream property
4	Enables abandonment of fuse plugs, thereby increasing Flood Capacity
5	Allows full Flood capacity to be used, thereby increasing Flood capacity
6	Simplifies Dam management
7	Reduces the likelihood of 2011 type panic releases and damage to downstream properties
8	Insures against collapse or partial collapse from overtopping, thereby saving on repairs
9	Stabilizes against Hume Weir type downstream movement which may lead to collapse
10	Stabilizes against earthquake which may lead to collapse (Mt Glorious magnitude 4.4 in 19; Gatton 4.0 in 1988; up to 6.0 forecast)
11	Because of the above, improves downstream property values
12	Because property values increase, rate revenue and land tax increase
13	Rate and Land Tax revenue can help to amortise cost
14	Preventing floods like 2011 would provide satisfactory ROI

37. The Precautionary Principle

The Precautionary Principle would encourage us to do whatever we can to remove the massive risk currently facing downstream communities below Wivenhoe: i.e. to remove the risk of a **Dam-Burst-Tsunami-Flood-Wave.**

The following article is from Wikipedia. The full article is found at:
http://en.wikipedia.org/wiki/Precautionary_principle#Australia

The following article has been slightly edited from the full article.

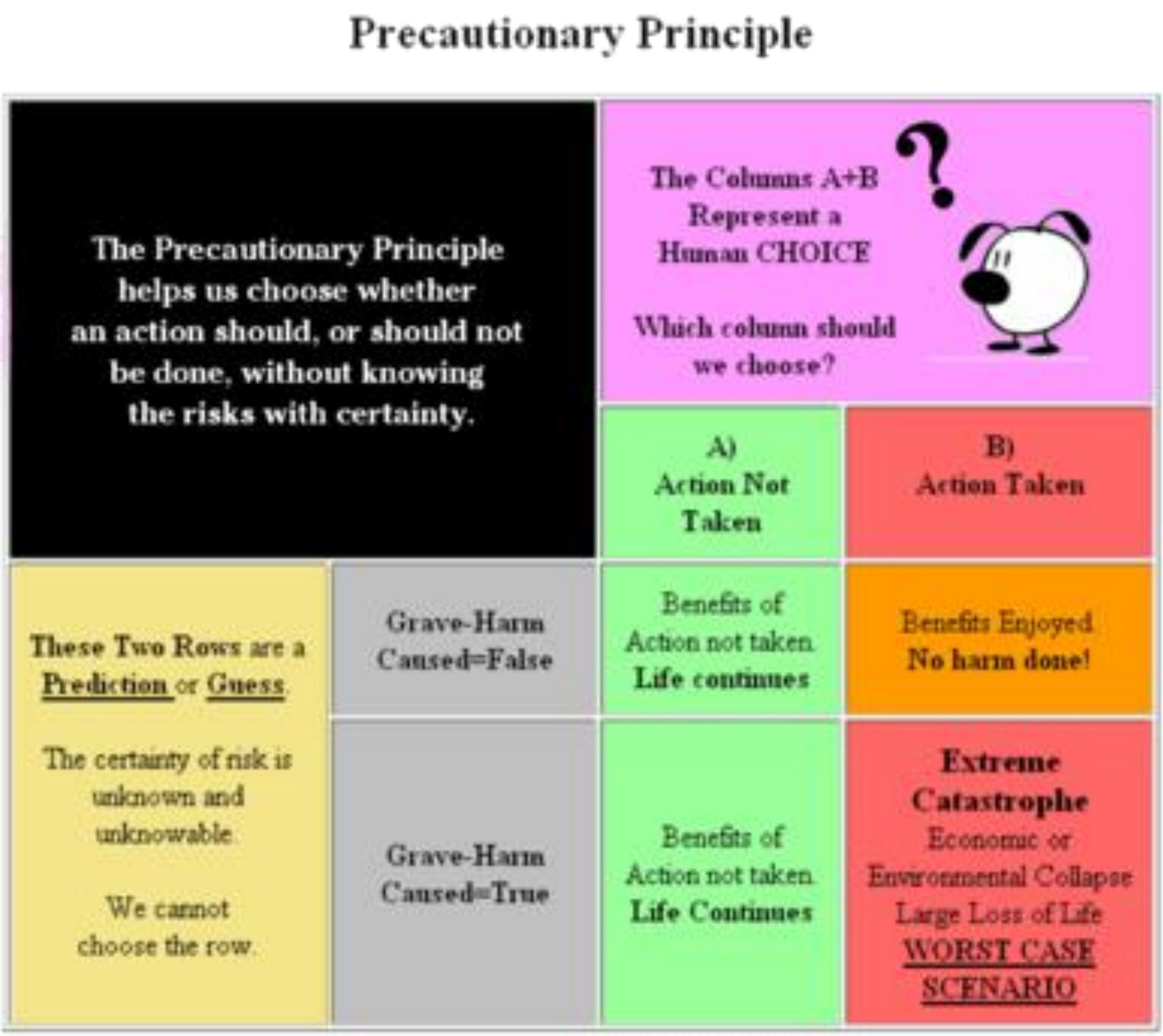


Figure 39: The Precautionary Principle Illustrated as a Decision Matrix

The **precautionary principle** or precautionary approach states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking the action.

This principle allows policy makers to make discretionary decisions in situations where there is the possibility of harm from taking a particular course or making a certain decision when extensive scientific knowledge on the matter is lacking. The principle implies that there is a social responsibility to protect the public from exposure to harm, when scientific investigation has found a plausible risk. These protections can be relaxed only if further scientific findings emerge that provide sound evidence that no harm will result.

In some legal systems, as in the law of the European Union, the application of the precautionary principle has been made a statutory requirement.

Formulations of the precautionary principle

Many definitions of the precautionary principle exist. Precaution may be defined as "*caution in advance*," "*caution practised in the context of uncertainty*," or *informed prudence*. All definitions have two key elements.

1. an expression of a need by decision-makers to anticipate harm before it occurs. Within this element lies an implicit reversal of the onus of proof: under the precautionary principle it is the responsibility of an activity proponent to establish that the proposed activity will not (or is very unlikely to) result in significant harm.
2. the establishment of an obligation, if the level of harm may be high, for action to prevent or minimise such harm even when the absence of scientific certainty makes it difficult to predict the likelihood of harm occurring, or the level of harm should it occur. The need for control measures increases with both the level of possible harm and the degree of uncertainty.

One of the primary foundations of the precautionary principle, and globally accepted definitions, results from the work of the Rio Conference, or "Earth Summit" in 1992. Principle #15 of the Rio Declaration notes:

"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

This definition is important for several reasons. First, it explains the idea that scientific uncertainty should not preclude preventative measures to protect the environment. Second, the use of "cost-effective" measures indicates that costs can be considered. This is different from a "no-regrets" approach, which ignores the costs of preventative action.

The 1998 Wingspread Statement on the Precautionary Principle summarizes the principle this way: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." (The Wingspread Conference on the Precautionary Principle was convened by the Science and Environmental Health Network).

The February 2, 2000 European Commission Communication on the Precautionary Principle notes: "The precautionary principle applies where scientific evidence is insufficient, inconclusive or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern that the potentially dangerous effects on the environment, human, animal or plant health may be inconsistent with the high level of protection chosen by the EU".

It is important to emphasize that, although this principle operates in the context of scientific uncertainty, it is considered by its proponents to be applicable only when, on the basis of the best scientific advice available, there is good reason to believe that harmful effects might occur.

The precautionary principle is most often applied in the context of the impact of human actions on the environment and human health, as both involve complex systems where the consequences of actions may be unpredictable.

As applied to environmental policy, the precautionary principle stipulates that for practices such as the release of radiation or toxins or massive deforestation the burden of proof lies with the advocates. Concerning potential risks to public health, examples of cases in which the precautionary principle has been advocated (but not always accepted) are: the commercialization of genetically modified foods, the use of growth hormones in cattle raising, measures to prevent the "mad cow" disease, health claims linked to phthalates in PVC toys, among many others.

An important element of the precautionary principle is that its most meaningful applications pertain to those that are potentially irreversible, for example where biodiversity may be reduced. With respect to bans on substances like mercury in thermometers, freon in refrigeration, or even carbon dioxide exhaust from automobile engines and power plants, it implies:

> ... a willingness to take action in advance of scientific proof [or] evidence of the need for the proposed action on the grounds that further delay will prove ultimately most costly to society and nature, and, in the longer term, selfish and unfair to future generations.

The concept includes an implicit ethical responsibility towards maintaining the integrity of natural systems, and acknowledges the fallibility of human understanding.

Some environmental commentators take a more stringent interpretation of the precautionary principle, stating that proponents of a new potentially harmful technology must show the new technology is without major harm before the new technology is used.

Origins and theory

The formal concept evolved out of the German socio-legal tradition in the 1930s, centering on the concept of good household management. In German the concept is *Vorsorgeprinzip*, which translates into English as *precaution principle*.

Many of the concepts underpinning the precautionary principle pre-date the term's inception. For example, the essence of the principle is captured in a number of cautionary aphorisms such as "**an ounce of prevention is worth a pound of cure**", "**better safe than sorry**", and "**look before you leap**". The precautionary principle may also be interpreted as the evolution of the ancient medical principle of "**first, do no harm**" to apply to institutions and institutional decision-making processes rather than individuals.

The precautionary principle is in some ways an expansion of the English common law concept of '**duty of care'** originating in the decisions of the judge Lord Esher in the late 1800s. According to Lord Esher: "***Whenever one person is by circumstances placed in such a position with regard to another that everyone of ordinary sense who did think, would at once recognise that if he did not use ordinary care and skill in his own conduct with regard to those circumstances, he would cause danger or injury to the person, or property of the other, a duty arises to use ordinary care and skill to avoid such danger***". This statement clearly contains elements of foresight and responsibility, but does not refer to a lack of certainty, as the word "would" is used rather than "might", or "could". The other important difference is that the duty of care applies only to people and property, not to the environment.

In economics, the precautionary principle has been analysed in terms of the effect on rational decision-making of the interaction of irreversibility and uncertainty. Authors such as Epstein (1980) and Arrow and Fischer (1974) show that irreversibility of possible future consequences creates a quasi-option effect which should induce a "risk-neutral" society to favour current decisions that allow for more flexibility in the future. Gollier et al. (2000) conclude that "more scientific uncertainty as to the distribution of a future risk– that is, a larger variability of beliefs– should induce Society to take stronger prevention measures today."

Application

The application of the precautionary principle is hampered by both lack of political will, as well as the wide range of interpretations placed on it. One study identified 14 different formulations of the principle in treaties and non-treaty declarations. R.B. Stewart (2002) reduced the precautionary principle to four basic versions:

1. Scientific uncertainty should not automatically preclude regulation of activities that pose a potential risk of significant harm (Non-Preclusion PP).
2. Regulatory controls should incorporate a margin of safety; activities should be limited below the level at which no adverse effect has been observed or predicted (Margin of Safety PP).
3. Activities that present an uncertain potential for significant harm should be subject to best technology available requirements to minimize the risk of harm unless the proponent of the activity shows that they present no appreciable risk of harm (BAT PP).
4. Activities that present an uncertain potential for significant harm should be prohibited unless the proponent of the activity shows that it presents no appreciable risk of harm (Prohibitory PP).

In deciding how to apply the principle, analysis may use a cost-benefit analysis that factors in both the opportunity cost of not acting, and the option value of waiting for further information before acting. One of the difficulties of the application of the principle in modern policy-making is that there is often an irreducible conflict between different interests, so that the debate necessarily involves politics.

38. Conclusions:

1 *Brisbane escaped a catastrophe because there was no deluge which would have collapsed the Wivenhoe wall on Tuesday 11 January 2011.*

2 *If a Deluge had have occurred, there would have been tens of thousands of lives lost by dawn on Wednesday 2011.*

3 *The Hume Weir, built in a similar manner to Wivenhoe became unstable in 1999.*

4 *Wivenhoe is built in a zone which has had earthquakes. Earthquakes have collapsed Dams in the past. No-one can guarantee that an earthquake will not cause the Wivenhoe wall to fail.*

5 *Many dams throughout the world have failed from either floods or earthquakes.*

6 *Queensland has cycles of droughts followed by extreme flooding weather.*

7 *Queensland receives tropical cyclones including category 5 cyclones.*

8 *Wivenhoe is not immune from tropical cyclones and may experience a Category 5 in future.*

9 *CSIRO is predicting more intense cyclones in future.*

10 *Climate Change and Global Warming are factors which need to be taken into account.*

11 *We may need to contend with higher river levels and more intense tropical cyclones from Climate Change.*

12 *SEQWATER is having difficulty explaining the rapid rise in the recorded level of Wivenhoe between 03:00 and 15;00 on Tuesday 11 January 2011.*

13 *SEQ Water may not have a complete understanding of the runoff characteristics of the Wivenhoe catchment and may not have allowed for the Accelerator /Avalanche/Snowball Effect.*

14 *That Effect is potentially catastrophic if it is not taken into account because the dam can overfill very quickly.*

15 *Managing Wivenhoe in a crisis is a very difficult task with unacceptable consequences of error or miscalculation or human error or failure of leadership or communications or machinery.*

16 *We need to find ways to reduce the risk which is currently posed by Wivenhoe.*

39. Recommendations:

1 *Concrete the outer skin of the Wivenhoe Wall as a result of which most of the following matters are not as important.*

2 *Move the Wivenhoe control room from the Wivenhoe Wall.*

3 *Ensure redundant methods of securing all communications, power, gate operation, etc., so that the operation of Wivenhoe is fail-safe.*

4 *Liaise with flight simulators to attempt to create realistic operator training.*

5 *Practice every scenario until operators know what to do without having to think out what to do under stressful conditions.*

6 *Ensure redundancy of personnel so that if one person falls ill, the operation continues uninterrupted during a crisis.*

7 *Build Levee Banks with flood gates and flood pumps at the mouth of Moggill Creek and on such other creeks as designs are found for.*

40. Bibliography

Banqiao Dam

- http://en.wikipedia.org/wiki/Typhoon_Nina_(1975)
- http://english.people.com.cn/200510/01/eng20051001_211892.html
- 75.8 30 anniversary of disastrous floods (Photo) _ _ Sina News.htm
- http://www.britannica.com/EBchecked/topic/1503368/Typhoon-Nina-Banqiao-dam-failure
- http://www.sjsu.edu/faculty/watkins/aug1975.htm

Brisbane/Bremer Flood History

- http://www.bom.gov.au/hydro/flood/qld/fld_history/brisbane_history.shtml

Bureau of Meteorology Rainfall IDF Data System

- http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

Cyclones

- http://en.wikipedia.org/wiki/Tropical_cyclone
- http://en.wikipedia.org/wiki/Cyclone_Mahina
- http://reg.bom.gov.au/cgi-bin/silo/cyclones.cgi?region=ause&syear=1906&eyear=2006&loc=0
- http://www.bom.gov.au/cyclone/history/eastern.shtml
- http://www.disasters.ema.gov.au/Browse%20Details/CategoryDetails.aspx?Entity=CategoryID
- http://www.theaustralian.com.au/national-affairs/fewer-more-intense-cyclones-on-the-way-csiro/story-fn59niix-1226033652833

Climate Change, La Nina, El Nino

- http://en.wikipedia.org/wiki/Earth's_magnetic_field#Magnetic_field_reversals
- http://en.wikipedia.org/wiki/Sunspot
- http://www.google.com.au/search?q=wiki+la+nina&rls=com.microsoft:en-au&ie=UTF-8&oe=UTF-
- 8&startIndex=&startPage=1&rlz=1I7SKPB_en&redir_esc=&ei=81qgTYm6F4iqcbWEkeEB
- http://en.wikipedia.org/wiki/El_Ni%C3%B1o-Southern_Oscillation
- http://en.wikipedia.org/wiki/Madden%E2%80%93Julian_oscillation
- http://en.wikipedia.org/wiki/La_Ni%C3%B1a

Dam Failure

- http://en.wikipedia.org/wiki/Dam_failure
- http://www.engpedia.com/index.php/Causes_of_Earth_Dam_Failure
- http://en.wikipedia.org/wiki/Category:Dam_disasters_in_the_United_States

Earthquakes

- http://www.brisbanetimes.com.au/queensland/qld-earthquake-risk-real-20090424-ahbe.html
- http://en.wikipedia.org/wiki/List_of_earthquakes_in_Australia
- http://www.disasters.ema.gov.au/Browse%20Details/CategoryDetails.aspx?Entity=CategoryID
- http://www.chinastakes.com/2008/5/china-earthquakes-more-peril-dam-and-reservoir-collapse.html
- http://www.seis.com.au/Basics/Dams.html

Floods

- http://www.disasters.ema.gov.au/Browse%20Details/CategoryDetails.aspx?Entity=CategoryID
- http://www.bom.gov.au/hydro/flood/qld/fld_history/brisbane_history.shtml

Fuse Plugs

- http://www.leightoncontractors.com.au/verve/_resources/wivenhoe-dam-alliance.pdf

Google Earth centred on Wivenhoe

- 
  GoogleEarth_Placemark.kmz

The Australian

- http://www.theaustralian.com.au/in-depth/queensland-floods/the-great-avoidable-flood-an-inquirys-challenge/story-fn7iwx3v-1225992644199
- http://www.theaustralian.com.au/news/nation/cheap-wivenhoe-dam-upgrade-reduced-its-capacity/story-e6frg6nf-1226000456000
- http://www.theaustralian.com.au/news/nation/engineers-reduce-dam-flow/story-e6frg6nf-1225986634232
- http://www.theaustralian.com.au/national-affairs/fewer-more-intense-cyclones-on-the-way-csiro/story-fn59niix-1226033652833

Hume Weir

- http://en.wikipedia.org/wiki/Lake_Hume

Loss of Life

- http://www.ancold.org.au/papers/2001-14.pdf
- http://www.usbr.gov/ssle/damsafety/Risk/Estimating%20life%20loss.pdf

Johnston Flood

- http://en.wikipedia.org/wiki/Johnstown_Flood

Mt Glorious & Kilcoy

- http://en.wikipedia.org/wiki/Mount_Glorious
- http://en.wikipedia.org/wiki/Kilcoy,_Queensland

Michael O'Brien's Report : Brisbane Flooding January 2011: An Avoidable Disaster

- http://resources.news.com.au/files/2011/03/22/1226025/997481-aus-news-file-obrien-report-replace.pdf

Photos and Videos and News of Floods

- http://www.crikey.com.au/2011/01/12/qld-floods-brisbane-ipswich-prepare-for-worst/
- http://www.dailymail.co.uk/news/article-1346684/Australia-floods-25-dead-dozens-missing-water-swallows-Brisbane.html
- http://www.news.com.au/breaking-news/floodrelief/queensland-floods-interactive-before-and-after-photos/story-fn7ik2te-1225987255127
- http://www.brisbanetimes.com.au/environment/weather/a-dam-and-a-prayer-20110111-19mt1.html
- www.canberratimes.com.au/news/national/national/general/spooked-brisbane-waits-for-the...

Precautionary Principle

- http://en.wikipedia.org/wiki/Precautionary_principle
- http://www.treasury.govt.nz/publications/research-policy/ppp/2006/06-06/05.htm
- http://www.mindfully.org/Precaution/Precautionary-Principle-Common-Sense.htm

Photos of Wivenhoe & elsewhere (hundreds of photos on Google)

- http://www.google.com.au/images?hl=en&biw=900&bih=515&q=pictures+of+Wivenhoe+dam&rlz=1R2SKPB_enAU395&wrapid=tlif130191719579311&um=1&ie=UTF-8&source=univ&sa=X&ei=Da6ZTc-lMojOvQOho8DpCw&ved=0CB0QsAQ

SEQ Water January 2011 Flood Event: Reprot on the Operation of Somerset Dam & Wivenhoe Dam

- http://www.derm.qld.gov.au/commission/documents/report.pdf

SEQ Water regarding Wivenhoe

- http://www.seqwater.com.au/public/sites/default/files/userfiles/file/pdfs/Wivenhoe%20Fact%20sheet.pdf

- http://www.seqwater.com.au/public/sites/default/files/userfiles/file/pdfs/Water_Grid_FS_Wivenhoe_Somerset_Dams.pdf

Severe Storms

- http://www.disasters.ema.gov.au/Browse%20Details/CategoryDetails.aspx?Entity=CategoryID

Sword of Damacles

- http://en.wikipedia.org/wiki/Damocles

The Mysteries of Wivenhoe: An article by the Honourable Bruce Flegg MLA, Member for Moggill

- http://moggill.net/hot-issues/28-2011-floods/2992-the-mysteries-of-wivenhoe-am.html

Teton Dam Collapse (including a video of its collapse)

- http://www.guitarsolos.com/videos-teton-dam-flood-[uQzCDJrnWBk].cfm
- http://en.wikipedia.org/wiki/Teton_Dam

Timeline of January Floods in the Brisbane River catchment

- http://resources.news.com.au/files/2011/03/18/1226023/976281-aus-news-file-wivenhoe-timeline.pdf

Videos of Wivenhoe (these are worth watching)

- http://wn.com/Wivenhoe_Dam

Wivenhoe Wiki

- http://en.wikipedia.org/wiki/Wivenhoe_Dam