Copenhagen is a leader in flood management. They even have a term for it “Cloudburst”, which describes the flood events that can have a devastating impact on this low lying, coastal city.

The City of Copenhagen, as part of its climate change plan, is working towards being prepared for expected extreme weather events. This process began in after the climate summit, COP15, in Copenhagen in December 2009; on 25 August 2011, the City Council adopted the Copenhagen Climate Adaptation Plan. This plan sets the framework for the implementation of climate adaptive measures in the City Administration area.

However, before the City of Copenhagen Cloudburst Management Plan was published in 2012 there were no mitigation measures in place to deal with extreme rainfall events like the ones experienced in 2010 and again in 2011.

Flooding causes numerous problems and extreme rainfall events present challenges that vary according to location and cannot be managed using a single, one size fits all solution. For this reason, there is a need for coordinated and consolidated action combining the solutions appropriate for each area.

The City of Copenhagen Cloudburst Management Plan outlines the methods, priorities, and infrastructure recommended to help adapt to climate change, including extreme rainfall.

Concurrently with the initiatives to protect Copenhagen against flooding resulting from extreme rainfall events, work is going on to protect the city against storm surges where sea water is forced inland. Work is also going on to find new ways for the city to exploit rainwater is a resource we need to take great care of.

Copenhagen has a stormwater management system common in Northern Europe, but rare in Australia: a combined sewer network that conveys both stormwater and wastewater. However, the lessons from Copenhagen are still useful for Fishermans Bend. In particular, the collaborative approach between agencies, the management of water in low lying areas influenced by a high water table and the potential to use green areas to manage stormwater can be applied at Fishermans Bend.

The integration of stormwater management into the public realm, means that there is an opportunity for the stormwater to become a resource, improving the liveability of the area and making Fishermans Bend a more attractive place to work.

The Cloudburst Management Plan has been coordinated with Københavns Energi (Copenhagen Energy), the City of Frederiksberg, and Frederiksberg Forsyning (Frederiksberg utility company), since all rainfall water falling in Frederiksberg during an extreme rainfall event has to be led to either a sewage treatment plant or into the sea via the City of Copenhagen.

Furthermore, collaboration has been initiated with neighbouring local authorities who lead surface water and waste water through the city to the common sewage treatment plants or to common water courses and lakes.

To make the city more resilient to flooding will require action by at least three players: property owners, the utility company, and the City Administration.

- Property owners are, responsible for flood-proofing their properties on private soil. This might involve protecting basements, ground level adjustments and raising the sides of light wells.
- The utility company is responsible for ensuring that drainage systems meet the service levels.
- The City Administration is, in its capacity of urban planning authority and owner of the utility company, responsible for ensuring that the adaptive measures will be incorporated into the municipal master plans and implemented.

It will take many years for the initiatives and projects stipulated by the Cloudburst Management Plan to be implemented. There is a need, therefore, to have an emergency response plan in place to mitigate the worst damage from an extreme event until the city’s resilience to extreme weather events has been secured.

Motivations for Adaptation
The City of Copenhagen has experienced heavy rainfall events in 2010 and 2011. The latter resulted in cost damages of $US 0.9-1.3 billion. Climate change studies show that the city can expect heavier rainfall events and the hydraulic models project future flooding.

Goals for Adaptation
The City of Copenhagen has decided to secure the city for an extreme rain event with a return period of 100-years in 2115, but allowing 10 cm of water on the surface. The popular term for these extreme rain events in Denmark is Cloudbursts, which is the name used in the master plans developed for the city.

The design standard for separate storm water drainage is 10-year event. Rainfall is expected to increase with 30% over the course of 100 years. These additional 30% are planned to be accommodated in green surface solutions.

Analysis Behind Strategies and Plans
Copenhagen has focused on advanced hydraulic models that estimate the scope, depth and dynamics of the water flows at different return periods and for different scenarios between today and in 100 years combined with GIS analysis of the existing terrain.

The city has combined these analysis with extensive mapping of existing opportunities and constraints in the urban environment as well as planned projects.
Figure 97 Flood management, Copenhagen
The Copenhagen Cloudburst management plan has interlinked levee areas and blue green infrastructure to achieve flood management.
Source: Ramboll

Figure 98 Hans Tavsens Park, Copenhagen
As part of the Copenhagen Cloudburst plan, Hans Tavsens Park at Inner Nørrebro will act as a rainwater catchment basin during cloudbursts. The excess rainwater will be led via two streets into Peblinge Lake, and on the way, the water will be purified biologically by the city park greenery on two adjacent streets.
Source: SLA Architects
Estimated damage to buildings, infrastructure and services in a do-nothing scenario was used to prioritize the different water catchments in Copenhagen based on a score of economic risk, feasibility and synergy effects.

Level of Service Adopted
It is not feasible to protect Copenhagen against extreme rainfall events covering the entire scale of severity. Regardless of how comprehensive the systems implemented, there will always be the uncertainty that an intense rainfall event will produce even bigger quantities of water. Besides, it would be disproportionately expensive to protect the city against events which, statistically, only occur extremely rarely. There is a need, however, to define an acceptable water level during floods resulting from an extreme rainfall event.

Today, it is a common and widespread practice that sewer discharge at ground level is acceptable once every 10 years as a maximum. Sewer companies are not required to protect basements against flooding.

Cloudburst Management Plan recommends that these levels are raised significantly for Copenhagen.

To adjust investments to the benefits they provide, new risk dimensioning criteria must be determined. This is to be understood as the costs incurred by flood damage in a certain area multiplied by the probability of a recurrence in the same area.

Cloudburst Management Plan analyses show that the risk of water entering basement windows in Copenhagen is negligible when water levels are kept at approximately 10 cm on roadways. Furthermore, it is quite a manageable task to adapt roads and kerb stones and also to prevent water from entering basement entrances.

Although approximately 10 cm of water on roadways is likely to reduce traffic movement during and after an extreme rainfall event, it will still be practicable to get through by car, by bicycle, and on foot. This is why acceptable flood water levels will be set at approximately 10 cm on roadways.

This level will facilitate keeping the water on the roads thereby using these as drainage routes in the case of high-intensity rain. Also, from an economic perspective, this will be a sustainable flood water level which is illustrated in the following section.

Cloudburst Solutions
Copenhagen combines subterranean solutions (larger sewerage pipes) with surface solutions (cloudburst roads, retention roads, green infrastructure). The surface solutions consist of more than 300 smaller projects. Some of the projects are already implemented and others are currently being implemented.

The city created the designs using consultants to do detailed masterplans for seven catchment areas. The process was created by following an iterative process, where the plans were developed during workshops with several city agencies, utility companies, local stakeholders and experts. The city held several meetings together with the local council groups of neighbourhoods, getting their input, creating amendments, and designing solutions that would support the development of that particular neighbourhood.

Reviewed Literature
- 2009: City of Copenhagen. Climate Plan (draft)
- 2011: City of Copenhagen. Copenhagen Climate Adaptation Plan
- 2012: City of Copenhagen. Copenhagen Cloudburst Plan
- 2012: COWI. Cloudburst Plan and Strategy
- 2015: City of Copenhagen. The Climate Change Adaptation and Investment Statement, part I and II

Figure 99 Saint Annes Place, Copenhagen
The area surrounding Sankt Anne Plads is flood prone and therefore a high priority area in the Copenhagen Cloudburst Plan.
Source: Schonherr Architects

Figure 100 Saint Annes Place, Copenhagen
The street and square have been transformed into a city space with effective, flexible and simple flood protection for the area.
Source: Schonherr Architects

Figure 101 Waterfront, Copenhagen
Incorporation of a seawall into the waterfront at the Copenhagen harbour, downstream of Sankt Anne Plads.
Source: Realdania
New York City faces increasing risks from the impacts of global climate change.

Recent storms, including heavy rain events and coastal flooding, demonstrate that the city’s water and wastewater system has risks from extreme weather that must be addressed through implementation of further climate adaptation interventions. Heavy rainfall events ("cloudbursts") can inundate urban areas and potentially cause severe damage.

The New York City Department of Environmental Protection (DEP) has started to develop innovative solutions to heavy rainfall and associated physical and societal impacts by conducting the Cloudburst Resiliency Planning Study, focusing on a pilot area in Southeast Queens.

The purpose of this project is to provide insight on ways to advance climate resiliency projects and traditional stormwater solutions to mitigate inland flooding and accommodate future increase in rainfall intensity through integration with ongoing urban planning and development. This executive summary describes the process and findings from the Cloudburst Resiliency Planning Study carried out by Ramboll in 2016. The methodology builds upon Ramboll’s experience and city-to-city collaboration regarding cloudburst solutions development for the City of Copenhagen.

DEP is seeking to address intense rainfall through integration of traditional underground drainage infrastructure with above-ground solutions into ongoing urban infrastructure planning. The focus is to enhance stormwater management through storage and surface flow conveyance, whilst creating inspiring urban areas with co-benefits for the citizens, local businesses, and the city.

The Cloudburst Resiliency Planning Study analyses best-available data related to New York City rainfall, recommends methodologies for incorporating findings into ongoing resiliency planning initiatives, and identifies best practices for considering climate change in future neighbourhood-specific planning studies. As an outcome of the study, opportunities for intervention are identified within the designated study area to provide retention and conveyance for extreme conditions, while also offering community and environmental benefits in normal conditions.

The study is designed around two main pillars: Integrated Planning (IP) and Blue-Green Infrastructure (BGI). In trying to understand the potential of integrated planning of BGI in NYC, the following questions were used to guide the study:

Integrated Planning (IP) comprises a system of interlinked actions which seeks to bring about a lasting improvement in the economic, physical, social, and environmental conditions of a city or an area. In IP, all policies and projects are considered in relation to one another.

Creating liveable urban environments encompasses a wide range of interrelated aspects of city life from governance, economy and planning to physical infrastructure, sustainable buildings, climate adaptation and environment. An integrated and balanced approach to these elements enables cities to develop and prosper sustainably, and thus, IP is becoming an inherent part of urban planning.

By applying IP to cloudburst management and planning, budgets may be combined across city agencies and stakeholders to increase available funds and provide buy-in for agencies and stakeholders. IP may also foster increased cooperation and capacity building across the city and promote movement from traditional step-by-step, silo planning to more inclusive and interdisciplinary approaches across all agencies involved.

Blue-Green Infrastructure (BGI) connects urban hydrological functions (blue) with vegetation systems (green) and offers valuable solutions for urban areas facing the challenges of climate change. BGI generates social and environmental value for the local area, and may often reduce the need for traditional grey infrastructure.

BGI is often used in isolation or implemented in a spatially dispersed manner. A cloudburst masterplan refers to a network of mainly BGI projects that provides an additional buffer on top of the storm sewer network.
Motivations for Adaptation
The risk to New York City from global climate change is severe. This has been brought into relief by recent storms which have included heavy rain events and coastal flooding. These storms demonstrated that the city’s water and wastewater system were at risk from extreme weather events.

The NYC Department of Environmental Protection (DEP) undertook a planning study to manage these risks. The study focussed on pilot area in Southeast Queens.

Goals for Adaptation
The New York City Department of Environmental Protection is seeking to address intense rainfall through integration of traditional underground drainage infrastructure with above-ground solutions into ongoing urban infrastructure planning. The focus is to enhance stormwater management through storage and surface flow conveyance, whilst creating inspiring urban areas with co-benefits for the citizens, local businesses, and the city.

Analysis Behind Strategies and Plans
In the Initial Analysis phase, background data such as land-use, terrain, infrastructure, and reports of flooding were mapped. By overlaying GIS data, problem and opportunity areas were communicated visually.

In conjunction, New York undertook advanced hydraulic modelling to estimate flooding issues. This included an understanding of the depth and dynamics of the water flows at different return periods and for different scenarios between today and in 100 years combined with GIS analysis of the existing terrain.

The city combined these analyses with extensive mapping of existing opportunities and constraints in the urban environment as well as planned projects.

A cost benefit approach was undertaken that examined damage to buildings, infrastructure and services. A do-nothing scenario was used to compare and prioritize projects based on a score of economic risk, feasibility and links to existing sites.

Level of Service Adopted
The level of service adopted for New York was a major part of the decision making section of the strategy for this project. It was discussed during the workshop process and a conclusion has yet to be reached. A safety level of a 100-year storm for extreme rain events was adopted.

Cloudburst Solutions
A number of solutions were developed, they included the South Jamaica Houses Pilot Project which integrated a conceptual water management plan into existing plans for transport, the college and bike paths.

A generic road profile was also designed in order to illustrate the potential of cloudburst roads. The design suggested a bike lane and rain gardens in the side of the road for retention. A green roundabout can also retain large volumes of water and help ease the transit through the area and replace full stop crossings.

A pumping station at St. Albans was also designed, although it was outside the study area. Three proposals were developed to reduce the stormwater volumes in the pumping station service area.

First, a design to handle a 100-year storm through mainly blue green infrastructure, thereby replacing the need for the pump. For a lower design criteria of a 10-year storm, a smaller blue green infrastructure solution was developed. Lastly, a design to upgrade the pump to a 10-year storm connected to limited BGI was proposed. The combination of pumps and blue green infrastructure in this manner is highly relevant to the site at Fishermans Bend.

Key Findings
he estimated capital investment costs show that it is possible to reduce risks using BGI for a similar budget as traditional stormwater infrastructure. However, in order to not over- or under- estimate dimensions for the master plan, research should go into finding the optimum safety level for cloudburst management through BGI. Oversizing can be unnecessarily expensive in terms of capital investment costs, while undersizing might prove relatively expensive, yet less effective in reducing risk costs.

The dynamics and outputs from the workshops show, that it is possible to increase cooperation across city agencies and stakeholders and maximise output of invested money through intellectual property. Involved stakeholders show high interest in participating in cloudburst management, and a general desire for increased cooperation across agencies.

While many barriers remain as to applying new methodologies at a higher level, stakeholders express optimism and willingness to overcome these challenges, leaving much potential and momentum for decision-makers to act.

Reviewed Literature
• Ramboll. Cloudburst Resiliency in New York. 20216
Figure 103 South Jamaica Houses, New York
Visualization of area in South Jamaica Houses in its current state

Figure 104 South Jamaica Houses, New York
Visualization of areas in South Jamaica Houses with cloudburst detention

Figure 105 Samuel Huntington School, New York
Sketch of how Samuel Huntington School could be transformed to include Blue-Green Infrastructure elements based on Google Street View

Figure 106 Nr. 12 155th Street, New York
Sketch of how 155th Street could be transformed to include Blue-Green Infrastructure elements based on Google Street View

Figure 107 Merrick St Boulevard, New York
Sketch of how Merrick Boulevard could be transformed to include Blue-Green Infrastructure elements based on Google Street View
Rotterdam has been undertaking flood management for its entire history. It’s latest plans build on this knowledge and implement new ideas and technology.

Rotterdam is in many ways the marine gateway western Europe. In addition to its trading advantages, this site means that it is also a vulnerable location to floods as most of the city’s neighbourhoods are located below sea level.

Urban development because of population growth have increased flood risks over the last 50 years by a factor of 7. This is in addition to increased sea levels and rainfall that is predicted with climate change.

Due to its location, Rotterdam has a long history of managing flood risk. And the Dutch are recognised internationally for their coordinated and country wide flood management system.

Most of Rotterdam’s residential areas are protected by levees, however the newer port areas lie outside of the levee system. This is to allow ships to enter the harbour as part of its normal functioning as a port.

To aid in flood protection, over the last 100 years, more than 10,000 hectares of land have been elevated several metres using fill around the port area.

Historic flooding has driven flood protection in the Netherlands. For example, a storm surge in 1953 led to the formation of the “Delta Works”, that incorporated new levees and storm surge barriers. One of the main aspects of this plan was the protection of Rotterdam from extreme storm surges.

And the Maeslant Storm Surge Barrier was developed as a result. This seals off the port area in the case of an extreme event, but stays open during normal conditions to allow free access to the older port areas as well as the inland shipping canals behind the barrier.

Expected casualties as a result of flooding in Rotterdam is regarded as an important indicator of vulnerability. This is expected to increase not only through increased population exposure, but also through increased storm surges due to climate change.

The expected population growth in South Holland is of particular concern due to population growth, +50% in the areas that could be hit by flooding, compared to +33% for the area as a whole. This is so significant that it is expected to have a real impact on mortality rates in coming years.

In addition to potential fatalities, a large number of Holland’s assets are located in this region. The estimated cost of flooding is in the order of tens of billions of euros. There are also effects on commerce in the area. For example, a flood in 1995 of the Ruhr valley in Germany caused an associated cost of 200 million euro in Rotterdam due to loss of business alone.

The factors of risk and consequence at Rotterdam has mean that a concerted effort has been made to prepare for future flooding.
This chapter sketches an integral vision of a climate proof Rotterdam in which adaptive measures combating various climate change effects can be combined. Descriptions from six Rotterdam perspectives illustrate which measures will be effective in different parts of the city and how these adaptive measures will contribute to improving the environment, society, the economy and the ecology.

Chapter 4 discusses the climate-related tasks facing Rotterdam and describes when and where the effects of climate change will become noticeable in the city. Chapter 5 describes the strategy and measures required for each of the climate tasks. Exemplary studies and projects illustrate the opportunities available while simultaneously solving some of the problems. The perspectives in this chapter are area-specific and for each ‘type of urban area’, a number of suitable combinations of robust and adaptive measures are proposed together with an illustration of the spatial characteristics involved. This chapter combines chapters 4 and 5 in six integral visions that act as guidelines for the implementation agenda for the Rotterdam Climate Change Adaptation Strategy.

Six types of urban area are identified: the port, Stadshavens, the outer-dike urban districts, the compact city centre, the inner-dike urban districts and the post-war suburbs with their parks and gardens.
Motivations for Adaptation
The City of Rotterdam is a delta city where nearly 80% of the city lies below sea level. The city is already well-protected by a complex system of dikes, dams and storm surge barriers. Rotterdam faces the challenges of water from both rising sea levels, rising water levels in rivers, rising groundwater levels and heavier rain events. An expected sea level rise of 1.9 ft (60 cm) will increase the probability of flooding in harbour areas from once every 50 years to an average of once every year.

Goals for Adaptation
The City of Rotterdam’s vulnerability of the drainage system becomes apparent during extreme rainfall. By the middle of this century, the type of shower that currently occurs once every five years will on average occur once a year. The goal is to work with water to create an attractive, economically strong and climate proof city. The “waterproof city” is robust and resilient (grey and blue-green) with a mix of paving and vegetation. Most areas are already protected from storm events with return periods ranging from a 4,000-year event to 10,000 years.

Analysis Behind Strategies and Plans
Rotterdam launched its “Rotterdam Climate Change Adaptation Strategy” in 2013 which is based on climate change scenarios for future precipitation rates, GIS analyses identifying areas with insufficient water storage capacity below and on terrain, and vulnerable urban areas in the city centre.

The strategy also shows damage analyses with calculated cost of doing nothing.

Level of Service Adopted
A service level of 1 in every 2 years was adopted.

Cloudburst Solutions
Rotterdam has made use of different green infrastructure solutions such as water squares, underground water storage and bioswales.

Since 2010 Rotterdam has completed several green infrastructure projects and in 2014 the city had completed more than 185,000 m2 of green roofs.

The city has established new water storage facilities and water squares and has started two Climate Proof City Pilot Projects for two districts in the city.

Reviewed Literature
- 2010: City of Rotterdam. Rotterdam Climate Proof: Adaptation Programme 2010
- 2011: City of Rotterdam. Vasthouden van regenwater in de oenbare ruimte van Rotterdam
- 2013: Connecting Delta Cities. Resilient Cities and Climate Adaptation Strategies
- 2013: City of Rotterdam. Rotterdam Climate Change Adaptation Strategy
- 2014: Rebel Group. CBA. Rotterdam Climate Adaptation Strategy. Case: Bergpolder Zuid
- 2016: Connecting Delta Cities. Deltacities.com
The climate is changing, and sea levels will continue to rise, at least for the time being. This is especially significant to Rotterdam. Extreme weather conditions will become ever more likely, such as longer dry periods in particular, the frequency and severity of the wetter and the rainfall increasingly extreme. During hotter summers, on average, our winters will become milder. The Netherlands will be subject to increasingly wetter winters.

Rotterdam: The consequences of climate change that will affect Rotterdam and the climate

- Higher river discharges from the river
- Lower river discharges from the sea
- More intensive rainfall from above (precipitation)
- Longer dry periods from below (groundwater)

Rotterdam is one such vulnerable delta city. Located in the delta of the rivers Rhine and Meuse, Rotterdam is mostly well below sea level, with the lowest outer-dike areas. Within the dikes, the inner-dike city of Rotterdam is well below sea level with open links to the sea and is influenced by the tide. Via the Nieuwe Waterweg (New Waterway), the city is connected to the sea and is vulnerable to sea surges.

An ingenious but vulnerable system keeps our city safe and dry (and sometimes wet). The lower-lying polders are well-protected by a system of canals and surge barrier. The city keeps the water levels in the polder dry. Pumping stations run by the water boards regulate the water levels and keep the lower-lying polders at Zeeuwse Level, an agreed ordnance measurement that is almost 0.5 m lower than the NAP the National Amsterdam Level. The outer-dike city districts and harbours are generally constructed on higher ground and are therefore still well above sea level and thus protected from flooding.

Pump stations. The outer-dike city districts and harbours are generally constructed on higher ground and are therefore still well above sea level and thus protected from flooding. However, it is also a complex, inflexible system. If anything should go wrong, the damage to people and property in the lower-lying and wetter areas could be catastrophic. A combination of measures are taken to ensure the safety of the city: robust dikes and barriers such as the Maeslant storm surge barrier. The city keeps the water levels in the polder dry. Pumping stations run by the water boards regulate the water levels and keep the lower-lying polders at Zeeuwse Level, an agreed ordnance measurement that is almost 0.5 m lower than the NAP the National Amsterdam Level. The outer-dike city districts and harbours are generally constructed on higher ground and are therefore still well above sea level and thus protected from flooding.

For this reason, Rotterdam, like many other delta cities, has open links to the sea and is influenced by the tide. Much of Rotterdam, including the main port, lies in the countryside. An ingenious system keeps our city safe and dry (and sometimes wet). The lower-lying polders are well-protected by a system of canals and surge barrier. The city keeps the water levels in the polder dry. Pumping stations run by the water boards regulate the water levels and keep the lower-lying polders at Zeeuwse Level, an agreed ordnance measurement that is almost 0.5 m lower than the NAP the National Amsterdam Level. The outer-dike city districts and harbours are generally constructed on higher ground and are therefore still well above sea level and thus protected from flooding.

Figure 109 Rotterdam Harbour, Netherlands
Source: Rotterdam Climate Initiative

Figure 112 Rotterdam Harbour, Netherlands
Source: Rotterdam Climate Initiative

Figure 110 Levee location, Rotterdam
Location of levee shown in blue.
Source: Ramboll

Figure 111 Rotterdam flood system
Conceptual layout of levee and flood management system.
Source: Rotterdam Climate Initiative
Motivations for Adaptation
Launceston (population 70,000) is a city with a portion of its CBD and major northern suburb, Invermay, is located at the confluence of the Tamar River estuary and the North and South Esk Rivers. This forms a natural floodplain. Much of Invermay is below the high tide level and is reliant upon levees to protect it from flooding. The levees are located as shown in Figure 117.

The Invermay area has been identified as a desirable inner city suburb with a potential for growth. It contains much of Launceston’s cultural centre, including Launceston’s Museum, Aurora Sports Stadium, and campuses of the University of Tasmania. The flood prone area of the CBD is a mixture of residential and commercial areas and is home to Boags Brewery and historic buildings associated with Launceston’s port.

Launceston has been subject to 35 significant floods since records began. The worst of these, in 1929, displaced 4000 residents and destroyed many buildings uninhabitable. Much of the lower CBD was also inundated during this flood. Two floods in 1852 and 1863 are recorded to be higher than the 1929 flood; however the 1929 flood had the most severe consequences.

Goals for Adaptation
The Flood Levee Project began in the 1960s however the need for a system of levees was identified after the devastating 1929 flood. After a review of the levees in 2010, the Launceston Flood Authority subsequently adopted the 95% 1 in 200 year AEP for the flood protection heights for the upgrade of the Launceston flood protection scheme.

Levee design
Earth levees were selected in areas where river bank stability would allow construction. Earth levees are preferred because they are considerably cheaper than reinforced concrete structures.

Earth levees were designed with batters ranging from 1:2 to 1:4 depending upon the location, serviceability standard and public use. They were generally covered with topsoil and lawns in low flow velocity locations, while in high flow locations rock beaching or geo-fabric protection was preferred prior to the application of topsoil.

Concrete levees were selected where the river banks could not support the mass of an earth levee or where there was insufficient space. Concrete levees were also used in areas to transition from an earth levee to an existing structure such as a bridge abutment.

Two types of flood gates were chosen for the flood protection scheme. They were steel sliding gates and a demountable proprietary system by “Bauer”.

Steel gates were designed where it was practicable to have the sliding panel and the demountable system was used for structures such as bridges where space was limited. Another advantage of the demountable system was that the majority of the bays could be erected leaving the final bay open for essential service vehicles or community evacuations only installing the ‘planks’ as the waters rise.

Length of levee
10 kilometres

Height of levee
Natural ground level ranged between 1.5 m AHD to 3.1 m AHD requiring the levee height to vary between 2.0 m to 3.5 m above ground level.

Flooding post construction
With Launceston experiencing severe flooding in June 2016, a cost benefit analysis was undertaken to assess the effectiveness of the system. It highlighted the benefits through avoided impacts of the flood levee mitigation program, against the cost of construction.

Findings show that the upgrading of the levee system, completed in 2014, resulted in avoiding losses of about $216 million (had the pre-existing levees failed), which is approximately four times the total investment in the new levee system. This investment in building the new levee system was found to be a sound economic decision based on the estimated costs at the time of decision making, alongside improved estimates of benefits from the study. The actual benefits of these mitigation works to the community extended beyond the direct benefits as assessed, to the intangible and indirect benefits that have not been included.
Figure 113 Location of levee, Launceston
Levee shown in blue.

Figure 114 Levee reference photo, Launceston
Source: The Examiner

Figure 115 Levee reference photo, Launceston
Source: Duggans Precast Cement

Figure 116 Levee reference photo, Launceston
Source: Tripadvisor
APPENDIX 4
SITE CONSTRAINTS SERVICES

Fishermans Bend has a significant number of services located across the site, notably:

- Potable water
- Sewer
- Electricity
- Gas

Flood management at the site will necessarily disrupt some of these services. In addition, as the site develops, the service locations will change.

The aim of The Fishermans Bend Plan is to avoid major services, which are shown in Figure 117. In particular, the gas main line that occurs on Buckhurst St, Cecil St and Boundary St.
Figure 117. Major service locations
Major service locations for Fishermans Bend
CONTAMINATED SOILS

Contaminated soils at Fishermans Bend and will need to be considered for the placement of flood management areas.

Overview
Fishermans Bend represents one of the most challenging urban renewal projects in Australia due to a long industrial history, land reclamation activities, complex underlying geology, and the current substantial private land ownership. Successful redevelopment requires the involvement of many agencies and stakeholders to find solutions for issues arising and to manage the integration of the Fishermans Bend District into the surrounding urban areas. To create alignment requires vision, planning and experience within the Victorian planning and regulatory environment throughout the lifespan of the redevelopment, which is anticipated to take 20 to 30 years.

Past and Present Land Use
Advanced manufacturing was the original focus of industry in the Precinct. The automotive industry led by GM Holden acted as a catalyst in the 1930s to develop unused land close to Melbourne city. The onset of World War II saw aerospace manufacturing move in beside automotive to learn mass production techniques. Post war industrial growth saw large industrial move in beside automotive and research, defence manufacturing and printing facilities. In addition, several areas of deep fill have been identified with the potential to intercept groundwater.

Land Reclamation and Filling History
The original landscape of the Employment Precinct was low lying, swampy land prone to flooding. Construction of the Coode Canal created the northern boundary of the Precinct which introduced flooding controls and began reclamation. Initially land along the Canal was reclaimed to create the extension of South Wharf and Lorimer Street. Extensive sand mining for construction within the Precinct and sale of washed sands resulted in several deep excavations. Following the end of sand mining in the 1950s and zoning to industrial land use, deep excavations were infilled, including the operation of the Port Melbourne municipal tip.

In addition, the low lying topography of the area led to widespread shallow filling between 1 to 2 metres thick across much of the Precinct. Elevated areas of fill for landscaping occurred in Westgate Park during the 1980s and 1990s. A land reclamation and fill model has been provided which presents a spatial map with fill depths across the precincts.

Potential Land Use Contamination
Potential land use contamination across the precinct has been assessed based on a review readily available public information and professional judgement. For the purposes of this study, the degree of potential contamination was divided into three main and subjective contamination ranking categories of low, moderate and high. Areas with fill greater than 2 metres depth below ground level is likely to intercept the groundwater have been identified and classified based on fill history. Further investigations of each land parcel, either as a desktop review of site investigations or through collection of primary data, will be required to refine the contamination ranking and to quantify site specific potential contamination issues. Site rankings in part reflect the types of industry present, with the higher potential for land use contamination, associated with occupying industries such as aerospace manufacturing and research, defence research, automotive manufacturing and printing facilities. In addition, several areas of deep fill have been identified with the potential to intercept groundwater.

Table 5. Summary of site contamination issues.

<table>
<thead>
<tr>
<th>Potential Land Use Contamination</th>
<th>Definition</th>
<th>Low Density Residential/Kindergarten</th>
<th>High Density Residential</th>
<th>Recreational</th>
<th>Commercial/Industrial</th>
<th>Average Cost of Remediation (per hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA Soil and groundwater contamination is unlikely</td>
<td></td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>NA</td>
</tr>
<tr>
<td>Low Soil Contamination is Likely &amp; Groundwater Contamination is Possible. The information suggests that there may have been some activities on the site that have resulted in localised contamination of the land but the site is not likely to be a source site for groundwater impact.</td>
<td>Possible</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>Unlikely</td>
<td>&lt; $1 million</td>
<td></td>
</tr>
<tr>
<td>Medium Soil &amp; Groundwater Contamination is Likely. The information suggests that the site activities may have contaminated the land and/or groundwater. Some remediation of soil will potentially be required and there will be a potential need for groundwater remediation.</td>
<td>Possible with exceptions</td>
<td>Possible</td>
<td>Possible</td>
<td>Unlikely</td>
<td>$3 million</td>
<td></td>
</tr>
<tr>
<td>High Soil B/ or Groundwater Pollution. The information suggests that the site activities are likely to have caused pollution that would likely require soil remediation and/or active groundwater remediation.</td>
<td>Likely</td>
<td>Likely</td>
<td>Likely</td>
<td>Possible</td>
<td>&gt; $6 million</td>
<td></td>
</tr>
</tbody>
</table>

Documents Consulted


Figure 118. Fishermans potential site contamination
Groundwater

The shallow groundwater flow paths in fill and the Port Melbourne Sands across Fishermans Bend are in a northerly direction towards the Yarra River within the Employment Precinct and Lorimer Precinct, and in a southerly direction towards Hobsons Bay in the Wirraway, Sandridge and Montague Precincts.

A groundwater high/divide is apparent along the Westgate Freeway (approximately). Given the presence of a historical landfill/quarry in the southern portion of the Employment Precinct and the ground disturbance activities that would have occurred during construction of the Freeway, it is not unexpected to observe a groundwater high between the Employment Precinct and the precincts that lie south of the Westgate Freeway.

The groundwater height across the site will mean that infiltration may have to be limited.
Figure 119. Fishermans groundwater depth below AHD
Flow directions shown on map.
APPENDIX 5
PLANNING CONTEXT

Current Planning Context

Melbourne Water is a determining referral authority for any application for buildings and works within a Land Subject to Inundation Overlay (LSIO) or a Special Building Overlay (SBO) within the Melbourne and Port Phillip Planning Schemes.

The distinction between the overlays is as follows:

- A SBO identifies areas prone to overland flooding. The purpose of this overlay is to set appropriate conditions and floor levels to address any flood risk to developments.
- A LSIO applies to land affected by flooding associated with waterways and open drainage systems, these areas are commonly known as floodplains.

A determining referral authority has powers legally (under the Planning and Environment Act 1987) where any conditions placed on the development are binding. If Melbourne Water specify conditions (including finished floor levels of the building set at a Reduced Level to Australian Height Datum) the development must be approved subject to these conditions and floor levels.

A SBO2 co-refers to a Council local drainage system. The application may be informally referred to Melbourne Water for comment. The decision maker is not bound to incorporate these comments.

A LSIO applies to land affected by flooding associated with waterways and open drainage systems. The application may be informally referred to Melbourne Water for comment. The decision maker is not bound to incorporate these comments.

A SBO1 co-refers to a Council local drainage system and Melbourne Water comments.

Melbourne Water will provide written approval that your project is flood protected or meets Melbourne Water conditions to proceed with building permit application.

Melbourne Water guidelines are intended to be consistent with best practice principles, including Victoria’s 1 in 100 year AEP.

Planning Permit Process

The areas marked with the SBO (identified as the land within the Lorimer precinct, much of Montague, and over a limited proportion of land in Wirraway which is generally bound by Williamstown Road, Plummer Street and Salmon Street), a permit application must be referred to Melbourne Water for comment.

Building Permit Process

It is noted that building surveyors must consult with Melbourne Water prior to issuing a building permit to ensure that the proposed development design has considered the impacts of flooding and assets such as waterways or drains;

- A building permit application is referred if the proposed site is land liable to flooding and the land abuts a waterway or is within 20 metres of an asset or waterway (Regulation 806).
- Council or building surveyors are required to consult with Melbourne Water to obtain flood level information. This information will assist in the setting of floor levels to protect against flooding (Regulation 802).

Melbourne Water comments.

General comments regarding the overlay

In the Port Phillip Planning Scheme there is a distinction between the SBO, where the schedules relate to:

- SBO1 covers the Melbourne Water drainage system and nominates Melbourne Water as the Determining Referral Authority. All applications for development in this overlay are referred to Melbourne Water to assess and provide the appropriate permit conditions and floor levels.
- SBO2 covers the local drainage system and Council is the responsible authority for drainage. Council assesses all applications for development in this overlay and provides appropriate permit conditions and floor levels.

A LSIO applies to land affected by flooding associated with waterways and open drainage systems. The application may be informally referred to Melbourne Water for comment. The decision maker is not bound to incorporate these comments.

Melbourne Water comments.

The application may be informally referred to Melbourne Water for comment. The decision maker is not bound to incorporate these comments.

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Melbourne Water comments.

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Melbourne Water comments.

The application may be informally referred to Melbourne Water for comment. The decision maker is not bound to incorporate these comments.

Melbourne Water guidelines are intended to be consistent with best practice principles, including Victoria’s 1 in 100 year AEP.
Figure 121. Planning overlays

Location of Planning overlays at Fishermans Bend Site.
APPENDIX 6
DOCUMENTS CONSULTED

This shows a brief description and discussion of the relevance of the documents consulted.

Green Star Communities Guide For Local Government 2014

Water for Victoria Water Plan 2017

The Principles for Waterwise Cities 2016

State Environment Protection Policy (Waters of Victoria) 1988

Total Watermark Update 2014
Rainwater tanks combined with other measures

This guide is a resource for local governments to encourage community development projects in their local government areas (LGAs) that will enhance liveability, contribute to local economic prosperity and deliver sustainable outcomes.

This guide explains how councils can use the Green Star – Communities national framework and the Green Star – Communities rating tool to support and achieve better economic, social and environmental outcomes across the built environment.

- **Design**
- **Liveability**
- **Economic prosperity**
- **Environment**
- **Innovation**

**Discussion**

Undertaking a full rating of the proposed flood management plan is beyond the scope of this project. However, a preliminary analysis suggests that there is significant potential to increase the ratings of the current design in relationship to the categories of Urban Design and Liveability.

**Rating**

- **Existing drainage system**: "Major Improvement". There is potential to significantly improve the site according to the State Water Plan Principles, particularly regarding Climate Change, Waterway Health and Liveability.
- **Existing drainage system with rainwater tanks**: "Major Improvement". There is potential to significantly improve the site according to the State Water Plan Principles, particularly regarding Climate Change, Waterway Health and Liveability.
- **Rainwater tanks combined with other measures**: "Major Improvement". There is potential to significantly improve the site according to the State Water Plan Principles.

**State Water Plan: Water for Victoria**

**Description**

Water for Victoria is the Victorian Government’s adaptation response to the impacts of climate change on water resources and on the availability of water in the future.

- **Climate change**
- **Waterway and catchment health**
- **Water for agriculture**
- **Resilient and liveable cities and towns**
- **Recognising and managing Aboriginal values**
- **Recognising recreational values**
- **Water entitlements and planning**
- **Realising the potential of the grid and markets**
- **Jobs, economy and innovation**

The aim of the document is to ensure water security for all Victorians.

**Discussion**

Many of the topics covered in Water for Victoria are outside the scope of Fishermans Bend. However, many of the areas are covered and responded to well, such as climate change, resilience and the use of rainwater tanks as an alternate supply of water.

**Rating**

- **Existing drainage system**: "Major Improvement". There is potential to significantly improve the site according to the State Water Plan Principles, particularly regarding Climate Change, Waterway Health and Liveability.
- **Existing drainage system with rainwater tanks**: "Major Improvement". There is potential to significantly improve the site according to the State Water Plan Principles, particularly regarding Climate Change, Waterway Health and Liveability.
- **Rainwater tanks combined with other measures**: "Major Improvement". There is potential to significantly improve the site according to the State Water Plan Principles.

**International Water Association: Principles for Waterwise Cities**

**Description**

The IWA Principles for Water-Wise Cities assist leaders to develop and implement their vision for sustainable urban water, beyond equitable universal access to safe drinking water and sanitation. The Principles underlie resilient planning and design in cities. The ultimate goal of these Principles is to encourage collaborative action, underpinned by a shared vision, so that local governments, urban professionals, and individuals actively engage in addressing and finding solutions for managing all waters of the city.

Four principles are described to achieve a Waterwise City, they are:

1. Regenerative water services
2. Water sensitive urban design
3. Basin connected cities
4. Water-wise communities

**Discussion**

Of the four principles, there is opportunity to secure improvements in each category through the use of integrated urban spaces, increased infiltration and collection of stormwater for passive irrigation.

**Rating**

- **Existing drainage system**: "Major Improvement". There is potential to improve the rating according to water sensitive urban design, basin connected cities and water wise communities.
- **Existing drainage system with rainwater tanks**: "Major Improvement". There is potential to improve the rating according to water sensitive urban design, basin connected cities and water wise communities.
- **Rainwater tanks combined with other measures**: "Major Improvement". There is potential to improve the rating according to water sensitive urban design.

**State Environmental Protection Policies (Water for Victoria)**

**Description**

To secure a sustainable future for Victorians, there needs to be protection and rehabilitation of the aquatic habitats of our rivers, lakes, wetlands, estuaries, bays and oceans, and the social and economic values they support. To achieve this, there needs to be a continuous reduction of the impacts on surface water environments, by using land and water resources within their capabilities, and by avoiding and re-using wastes, particularly those generated from everyday activities.

This Policy provides a legal framework for State and local government agencies, businesses and communities to work together to protect and rehabilitate Victoria’s surface water environments. Importantly, it supports Victoria’s catchment and coastal management processes and associated community decision-making they support.

**Discussion**

The proposed flood management plan is not expected to breach this policy, further it is likely that the indicators described will be improved by this project. However, there is a chance to further improve the indicators that the SEPP measures in relation to current conditions.

**Rating**

- **Existing drainage system**: "Probable Improvement". There is potential to significantly improve the use of water for liveability at the site.
- **Existing drainage system with rainwater tanks**: "Major Improvement". There is potential to significantly improve the use of water for liveability at the site.
- **Rainwater tanks combined with other measures**: "Major Improvement". There is potential to significantly improve the use of water for liveability at the site.

**EcoCity Initiatives (City of Melbourne), Total Watermark - City as a Catchment**

**Description**

The vision of the City of Melbourne, put forward in this document is a healthy city in a healthy catchment. Seeing the city as a catchment means that there is a recognition of the important roles of natural and man-made catchments, including roads, roofs and impermeable surfaces. The aim of this document is to get the whole of Melbourne’s community – residents, workers and businesses alike, to think about water and its role in our future, to help create a healthy city in a healthy catchment.

There are four key areas of focus in the Total Watermark Strategy, they are:

- Climate change adaptation and flood
- Water for liveability
- Water for the environment
- Water use

**Discussion**

This project makes a positive contribution to all four of the key areas mentioned above. However, there is opportunity for improvement, especially in the use of water for liveability, by improving the integration of flood protection into green spaces.
DOCUMENTS CONSULTED

- Climate Change Adaptation Strategy Refresh 2017
- Victorian Floodplain Management Strategy 2016
- South East Water Urban Water Strategy 2017
- Yarra River Action Plan 2017
EcoCity Initiatives (City of Melbourne). Climate Adaptation Strategy

Description
The strategy details existing efforts and new actions to work towards a vision of a city that is adapting well to climate change.

The aim is that Melbourne prospers and thrives and continues to be a global leader in climate change adaptation.

Five goals will guide this plan:
- Goal 1: Enhance the natural environment and green spaces of our municipality.
- Goal 2: Shape our built form and urban renewal areas to withstand future climate change impacts.
- Goal 3: Strengthen the resilience of our inclusive, family friendly and culturally diverse community.
- Goal 4: Protect and enhance our economy.
- Goal 5: Continue to build Melbourne’s adaptation capabilities and expertise.

Discussion
Flooding is one of the major impacts of climate change. This flood management plan directly deals with this issue and takes into account likely future scenarios. However, there is scope to address the goals above that improves Fishermans Bends Response to climate change.

Rating
Existing drainage system
- "Major Improvement". There is potential to significantly improve the response by increasing the amount of green areas.

Existing drainage system with rainwater tanks
- "Major Improvement". There is potential to significantly improve the response by increasing the amount of green areas and at the same time improving the economy and liveability of the site.

Rainwater tanks combined with other measures
- "Major Improvement". There is potential to significantly improve the response by increasing the amount of green areas and at the same time improving the economy and liveability of the site.

South East East Water - Urban Water Strategy

Description
This document summarises South East Water’s Urban Water Strategy, which establishes our strategic water resource management directions and actions to 2065, to further support the creation of liveable communities and sustain our region’s geographic diversity.

It aligns with the State Government of Victoria’s Water for Victoria plan.

South East Water has identified five key actions to implement its plan, they are:
1. Manage water resources adaptively
2. Create water efficient communities
3. Deliver water efficient wastewater systems
4. Integrated water management solutions
5. Enhance climate change resilience
6. Create empowered and engaged communities

Rating
Existing drainage system
- "Major Improvement". There is potential to significantly improve the response through increased collection and supply of rainwater due to the installation of rainwater tanks as an alternative to potable water supply.

Existing drainage system with rainwater tanks
- "Suitable". There is unlikely to be major improvements in the collection and supply of rainwater due to the installation of rainwater tanks in this option.

Rainwater tanks combined with other measures
- "Suitable". There is unlikely to be major improvements in the collection and supply of rainwater due to the installation of rainwater tanks in this option.

Victorian Floodplain Management Strategy

Description
The Victorian Floodplain Management Strategy sets the direction for floodplain management in Victoria.


Rating
Existing drainage system
- "Probable Improvement". The main area of potential improvement is the allocation of areas for stormwater treatment.

Existing drainage system with rainwater tanks
- "Probable Improvement". The main area of potential improvement is the allocation of areas for stormwater treatment.

Rainwater tanks combined with other measures
- "Probable Improvement". The main area of potential improvement is the allocation of areas for stormwater treatment.

Yarra River Action Plan

Description
The Yarra Strategic Plan does not replace other policies and plans made under statutes such as the Planning and Environment Act, the Environment Protection Act and the Water Act. Instead, it aims to coordinate and harmonise the many existing plans, regulations and investment programs. It will identify priority actions and provide an overarching (strategic) whole-of-river-corridor context for localised planning of places along the river.

The Yarra Strategic Plan has four objectives:
1. A healthy river
2. The Great Yarra Parklands
3. A culturally diverse riverscape
4. Securing the Yarra Footprint
5. Modern Governance

Yarra River Action Plan

Description
This proposed flood management options directly addresses this document. In many cases this is the most important of the documents as flooding will cause the the greatest risk to people and infrastructure at the site.

Discussion
Due to the scope of this project, the area of the most impact will be on the health of the river, both through reduce peak runoff and decreased stormwater pollutants.

Rating
Existing drainage system
- "Major Improvement". There is potential to significantly improve the response through further mitigation of flooding on site.

Existing drainage system with rainwater tanks
- "Suitable". There is unlikely to be major improvements in flood protection due to additional measures, or improvements may be at the expense of the use of the site for other purposes.

Rainwater tanks combined with other measures
- "Suitable". There is unlikely to be major improvements in flood protection due to additional measures.
APPENDIX 7
REFERENCES

- ‘Baseline Groundwater Quality Assessment’. 2016. AECOM for EPA.
- ‘Desktop Study and Preliminary Regional Conceptual Site Model Fishermans Bend Urban Renewal Area’. 2015. AECOM for EPA.
- ‘Groundwater Monitoring Event Fishermans Bend Urban Renewal Area’. 2016. AECOM for EPA.

Figure 122. Coastline
Source: Ramboll