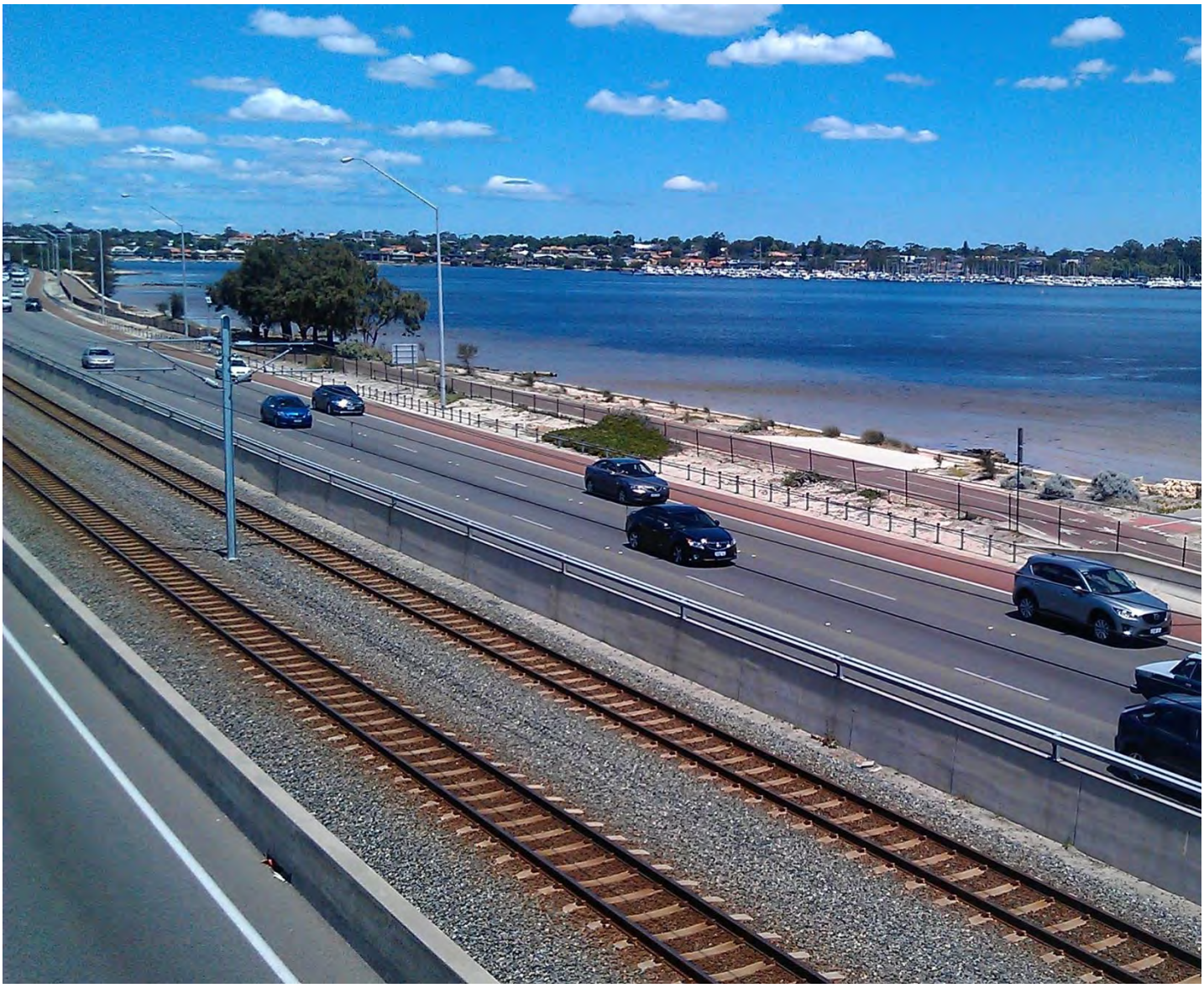

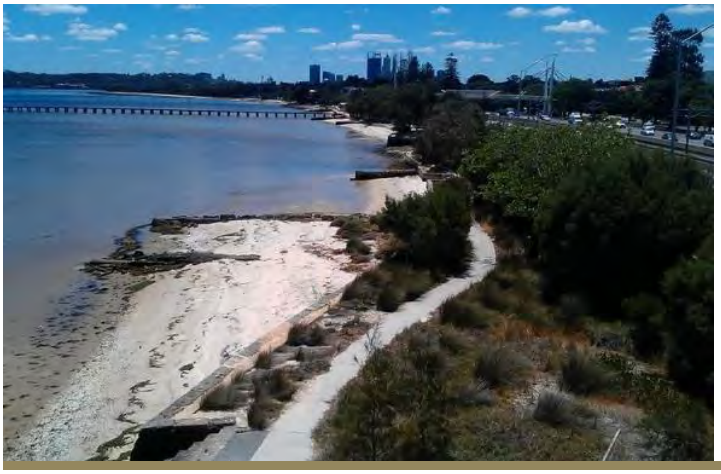

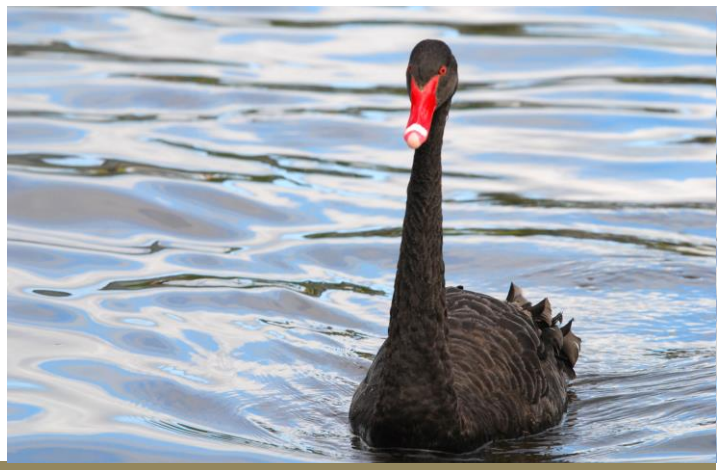

KWINANA FREEWAY FORESHORE MANAGEMENT PLAN-FINAL

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ACRONYMS AND ABBREVIATIONS

AHD	Australian Height Datum
ARI	Annual Return Interval
ASS	Acid Sulphate Soils
BAM Act	Biodiversity and Agriculture Management Act
CALM	Department of Conservation and Land Management (now DPaW)
CCAWG	Climate Change Assessment Working Group
City	City of South Perth
CSIRO	Commonwealth Science and Industrial Research Organisation
DAA	Department of Aboriginal Affairs
DAFWA	Department of Agriculture and Food Western Australia
DDA	Disability Discrimination Act
DIA	Department of Indigenous Affairs (now DAA)
DFES	Department of Fire and Emergency Services
DPaW	Department of Parks and Wildlife
DEC	Department of Environment and Conservation (now DPaW)
DoE	Department of Environment
DoT	Department of Transport
DoW	Department of Water
DTM	Digital Terrain Model
ENSO	El Nino Southern Oscillation
EWCP	Environmental Weed Census and Prioritisation
EWSWA	Environmental Weed Strategy Western Australia
FESA	Fire and Emergency Services Authority (now DFES)
FMP	Foreshore Management Plan
GIS	Geographical Information Systems
GPT	Gross Pollutant Trap

HAT	Highest Astronomical Tide
ICMM	International Council on Mine Closure and Metals
IPCC	Intergovernmental Panel on Climate Change
KFF	Kwinana Freeway Foreshore
KFFMP	Kwinana Freeway Foreshore Management Plan
KFFMG	Kwinana Freeway Foreshore Management Group
LiDar	Laser Imaging, Detection and Ranging
LGIS	Local Government Insurance Services
MOU	Memorandum of Understanding
MRWA	Main Roads Western Australia
MSDS	Material Safety Data Sheet
PSP	Principal Shared Path
RCP	Representative Concentration Pathways (Emissions Modelling Scenarios)
SPCC	South Perth City Council (now City of South Perth)
SW	South West
Trust	Swan River Trust
UCL	Unallocated Crown land
WAPC	Western Australian Planning Commission
WFMP	Western Foreshore Management Plan
WONS	Weeds of National Significance
WSUD	Water Sensitive Urban Design
WWC	World Wildlife Commission

SUMMARY

The Kwinana Freeway Foreshore (KFF) is the narrow linear foreshore which runs along the western edge of the Kwinana Freeway from the Narrows Bridge to Mount Henry Bridge. The KFF forms the eastern boundary of the large basin of the Swan Estuary known as Melville Water and provides one of Perth's major north-south transport links including road, rail, cyclist and pedestrian over the Narrows Bridge. It is an important section of land as it provides significant functions in terms of recreation, ecosystem, services, visual amenity and major transport corridors. The City of South Perth (the City) has adopted the Western Foreshore Management Plan (WFMP) finalised in 1993. Revisions of the plan were undertaken in 2003 and 2007 however none of these revised plans were finalised or adopted by the City.

The foreshore management plan needs to be revisited in order to incorporate a number of new proposed social and recreational developments within the area. In addition issues affecting the shoreline currently and within the next 30 years are different to what they were in 1993, particularly with respect to the levels of erosion along the foreshore and the increased awareness of the possible effects of climate change. The plan will also be extended from the 1993 WFMP to include the foreshore region between Canning Bridge and Mount Henry Bridge, which is one of the City's main areas for biodiversity conservation. The purpose of the revised plan is to provide guidance for the social, cultural, environmental and physical elements of the foreshore over the next 20 to 30 years.

Ownership and stakeholder management

Since the previous management plan was developed for this KFF, the City and Main Roads Western Australia (MRWA) have undertaken a project to identify the ownership of all major foreshore protection and drainage assets along the KFF. This was finalised in the development of a Memorandum of Understanding between the City and MRWA titled *Maintenance of Principal Shared Paths, Walls and other aspects of the Kwinana Freeway Foreshore*. All aspects of maintenance or replacement along the KFF should be undertaken in accordance with the ownership set out within this document.

The Department of Parks and Wildlife (DPaW) also have an interest with a section of Class A reserve that exists along the foreshore known as Milyu Nature Reserve and the Swan Estuary Marine Park.

As per the *Swan and Canning Rivers Management Act 2006*, the Swan River Trust (Trust) is the main government agency responsible for the planning, protection and management functions in respect to the Swan and Canning Riverpark. The Trust aims to protect and enhance riverbanks and shorelines to mitigate threats to foreshore values.

The City, MRWA, the Trust and DPaW have formed a working group to coordinate maintenance and any other activities which affect the KFF. This group meets monthly in order to keep other stakeholders informed of activities and to coordinate longer term plans within each organisation. The working group is known as the Kwinana Freeway Foreshore Management Group (KFFMG).

Stakeholders manage their assets along the foreshore by undertaking maintenance, capital replacement, revegetation programs and other activities as required to provide an expected level of service to the community and environment. The City, MRWA, the Trust, and DPaW provide monetary funding, officer time and resources and equipment resources to maintaining the ecological, coastal protection and amenity values of the foreshore.

There are some land tenure discrepancies along the foreshore, with some assets sitting within other stakeholders land tenures, particularly the location of the Principal Shared Path (PSP) and Kwinana Freeway overpasses. Currently this is managed by letters of agreement.

History

The shoreline is a location of significance for both Indigenous and European settlers. The shoreline consisted of a wide sandy beach with shallows which made it a popular hunting and fishing location for aboriginals and a popular swimming and holiday location up until the 1950's. A bridge to link the north and south shorelines across the Narrows had been discussed for many years and was finally constructed as the Narrows Bridge and Kwinana Freeway in 1959. The construction of the Kwinana Freeway was achieved by large amounts of reclamation of the river foreshore, which has altered the dynamics of the foreshore forever. Dredging works to construct the freeway and reclaim the foreshore occurred pre 1953, 1958-1960 and again over the period 1969-1972 with the widening of the Kwinana Freeway. No remnant vegetation exists between Canning Bridge and the Narrows, with all vegetation (including Milyu Nature Reserve) being planted subsequent to the foreshore reclamation in the 1950's. MRWA made a commitment to landscape the foreshore as part of the initial Kwinana Freeway project (Ecologia 2003). Recently MRWA have committed significant funding to the revegetation of the Milyu Nature Reserve in order to enhance the density of the vegetation through the area and also increase the resilience of the area against foreshore erosion.

Erosion

As part of the reclamation works for the Kwinana Freeway, the foreshore was supposed to have been nourished on a regular basis (Damara 2014). This additional renourishment has not occurred except for an exercise during the 1970's which was associated with another widening of the Kwinana Freeway. As a result, the highly modified shoreline has continued to experience largely event based erosion during significant winter storm events. Due to the reclaimed profile of the foreshore, with a steeper upper bank and shallow terrace, the shoreline has a limited ability to naturally accrete and recover after a large erosion event. This has resulted in a gradual recession of the shoreline and sand in the study area.

In general, the foreshore consists of the waterway of the Swan River, a sandy foreshore, a vegetated section or a coastal protection structure, the PSP, the Kwinana Freeway and Mandurah Rail Line and the eastern boundary is formed by Melville Parade and the suburb of Como. The sandy foreshore used to provide a buffer to a number of riverwall and other protection structures. Originally a number of the walls were built to a lower standard as they were only inundated occasionally during extreme events. The continued erosion of the sandy foreshore along this shoreline has reached a critical point in threatening higher value assets in a number of locations. This has resulted in a number of preventative maintenance tasks by the City and MRWA, such as the addition of toe scour rock to prevent the undermining of the structures, the repointing of the structures to improve durability and prevent failure of the wall structures and increasing the crest height of some structures to reduce overtopping volumes. Erosion in areas with no formal protection structure has seen the PSP being threatened. This has required the construction of a geotextile sand container groyne along a section of foreshore between Comer Street and South Terrace. MRWA are also funding a planting program within Milyu to increase the density of vegetation and improve the foreshore's durability against erosion during higher water level events whilst still retaining the ecological values of the Milyu Reserve.

The widening of the Kwinana Freeway and erosion of the shoreline has resulted in a number of pinch point locations where infrastructure is at risk. Riverwalls that previously had beaches in front of the wall now are permanently inundated in all but the lowest tides of the year. This results in the following effects:

- Loss of a number of sandy beach areas along the foreshore.
- Increased maintenance of the walling due to increased inundation and wave loading.
- Shorten the service life of many items of infrastructure along the shoreline.
- Scouring at the toe of the walling requiring scour protection.
- Increased overtopping rates – resulting in increased flooding and spray onto the PSP and Kwinana Freeway.
- Additional structures required in multiple locations to prevent damage to infrastructure assets.

A long term approach to the shoreline, whether it be large scale renourishment or protection with hard structures is required from the stakeholders to enable a number of foreshore and landscaping options to be implemented. The Trust has completed a study titled "*Feasibility Study of Options for Beach Renourishment Swan and Canning Rivers*". This study has investigated the options for beach nourishment in order to reinstate a sandy foreshore in a number of locations. The reinstatement of a sandy foreshore provides a number of benefits and would reduce the requirement for infrastructure upgrades in a number of locations to deal with the increased levels of overtopping and spray impacting the Kwinana Freeway as a result of increasing mean sea levels. It would also reduce increased frequency of maintenance and maintain the service life of current items of infrastructure. Should additional beach nourishment not occur, there are additional sections of foreshore which will require hard structures to be put into place within the next 10 years and possibly on a timeframe of the next five years has extensive storm events causing further erosion.

A section of foreshore at particular risk is the section of foreshore between Comer Street and South Terrace. It is thought that a portion of the sand feed into the Milyu Nature Reserve originates in this section of foreshore. Recent recession of the area appears to be the initial indicator for a reduced sediment feed from the offshore sand bars and the southern sections of foreshore. DPaW and MRWA have commenced a foreshore monitoring survey on a twice yearly basis to start providing some quantitative numbers to the shoreline movements along this stretch. It is expected that the sand feed from this section will further reduce due to the placement of structures to minimize the threat to the PSP. It is expected that increased erosion trends will become evident within the Milyu foreshore area and the ability of the foreshore to recover after an erosion event will be reduced further.

Decisions on the management approach to the foreshore are required in the immediate short term regardless of any future impacts of climate change as the recession of the reclaimed shoreline in conjunction with the widening of the Kwinana freeway and associated infrastructure westwards has reached a pivotal point, particularly for the section between Comer Street and South Terrace.

Climate Change

The adaptation of the KFF to climate change is one of the key priorities for the Stakeholders. The City is committed to climate change adaptation and has undertaken a Climate Change Risk Assessment (LGIS 2010) while also integrating climate change adaptation principles across the City's divisions. MRWA have also undertaken preliminary studies into the WA road network to identify sections that may be at risk due to a rise in sea level. This report indicated that the Kwinana Freeway was one of the States major transport routes at risk from inundation (MRWA 2011).

A number of studies have utilised combinations of extreme events and water level increases at the end of a 100 year timeframe in order to illustrate that the low lying relief of many estuarine areas are vulnerable to increases in sea level rises. The timeline requested for this management plan is of the order of 20 - 30 years, which would be approximately 2044.

It is certain that a mean sea level increase of approximately +0.9 m by 2110 will cause significant issues along the KFF. By 2110, it is expected that highest astronomical tide would be of the order of +1.45 m AHD. This is very close to the current predictions by the Department of Water for a current 100 year Annual Return Interval (ARI) storm surge event for the lower Swan Estuary. Due to the low relief levels from the reclaimed shoreline, flooding would break out across Mill Point Road and affect the northern bound lanes of the freeway at Scott Street, Judd Street, Lyall Street, Henley Street and Edgewater Street. The PSP would largely be inundated from Mt Henry Bridge to Canning Bridge. This increased inundation would have a multitude of impacts including social and environmental. The increased inundation would affect significant areas of remnant vegetation at Cloisters and the Spit.

The current shoreline is in a very different state to what it was only 50 years ago, let alone what it looked like 100 years ago. Undertaking significant change at the present time in order to accommodate climate change for 2110 would have little cost effectiveness, particularly when the service life of the majority of the infrastructure is such that it will require to be replaced at least once or twice before 2110. The approach to accommodate sea level rise progressively over the lifetime of structures is consistent with methodologies outlined by the Trust in assessing the vulnerability of foreshore areas to sea level rise in their technical advisory paper titled *"Potential Impacts of Climate Change on the Swan and Canning Rivers" (Trust 2007).*

In line with mean sea level rises adopted for coastal planning by Western Australian Planning Commission for the next 100 years (DoT 2010), a mean sea level increase of approximately +0.15 m above current levels would be expected by 2045. This increase is of a similar magnitude to many of the natural range of tidal processes of the area including changes in the seasonal tidal cycles, seasonal changes in the Leeuwin Current, inter annual changes to the El Niño–Southern Oscillation (ENSO) cycles and the 18.6 year lunar cycle. The 18.6 year lunar cycle for diurnal tides had a peak in 2007, with declining tidal peaks expected until 2017 (Eliot 2010). As the increase in mean sea level over the next 30 years is within the typical range of a number of tidal influencing factors, impacts from climate change induced mean sea level rise is not expected to significantly become evident within this timeframe. Increases will be masked to a degree by the natural variability of the ocean levels off Fremantle. Significant impacts of climate change would likely commence in the following 30 years (from 2045 to 2075) when the mean sea level rise is predicted to accelerate and increase an additional 0.3 m over this 30 year timeframe above 2045 water levels.

It has been shown that increased mean sea levels (such as during a La Nina ENSO phase) correspond with an increased frequency of inundation at higher levels. The impacts of increased mean sea levels during these periods are predominantly seen on sandy shorelines with increased erosion on upper banks, such has occurred since 2008 with the recession of the shoreline along Comer Street to South Terrace. Impacts on hard infrastructure items (such as riverwalls and revetments) in good condition during these periods are minimal. Infrastructure items in poor condition are more likely to experience significant damage or failure as they are already operating at a reduced capacity. Ecological impacts are also seen with vegetation at lower levels becoming stressed due to the longer periods of inundation, or the root mass being exposed due to the erosion of the upper bank sections. As noted however, this is within the range of the natural variability of annual mean sea levels.

Many of the structures built along the foreshore since the late 1990's have accommodated an allowance for climate change where possible of at least 0.1 to 0.4 m, therefore there is no need to significantly alter these structures. Options for accommodating mean sea level rise for the next 20 to 30 years would be to retrofit an additional crown wall to reduce levels of overtopping or to increase the height of the structure when it is rebuilt. This has been undertaken in recent years by MRWA and the City.

MRWA recently replaced a smooth sloping revetment with a rubble mound revetment and crown wall in order to reduce wave run up levels, wave generated spray and inundation effects onto the PSP and Freeway. Other options include the installation of small block walls along the sides of the PSP in areas where a sandy or vegetated foreshore exists. This may reduce the inundation of the PSP, however will likely increase the inundation of the vegetated area.

A similar option is to provide some sort of inundation barrier along the edge of the Kwinana Freeway and allow the PSP to be inundated. This is already been undertaken by MRWA in some locations with the installation of small limestone block retaining walls along the eastern side of the PSP. It would also be possible to use a slipform concrete wall to act as both an inundation and safety barrier for the northbound freeway lanes, similar to the concrete walls protecting the Mandurah Rail line. These relatively simple measures outlined above would accommodate the majority of sea level rise effects over the next 50 years.

An alternative pedestrian and cycling route along the eastern side of the freeway may be required to cater for periods when the PSP is inundated.

Increasing the height of the foreshore structures provides solutions for inundation and wave overtopping from marine surge events, however the larger issue over the coming 50 years will be the performance of the stormwater drainage network. Marine backflow up the stormwater network, restricting the drainage of overland flow water from the eastern side of the South Perth and Como area is expected to pose issues for nuisance flooding of the adjacent Melville Parade and the Freeway. Many of the drainage outfalls are severely degraded and suffering from significant levels of siltation. Even without catering for improvements to the drainage network to accommodate an increased mean sea level, significant refurbishment is required along the majority of the drainage elements on the KFF.

There is limited opportunity with the drainage network to increase the capacity on the eastern side of the Kwinana Freeway. Due to the tight spatial constraints of the area, there are limited areas for additional storage. Under pavement storage techniques will be of limited use as they would be below the groundwater level. Some capacity can be obtained by reducing the backflow of marine waters and increasing the capacity of the road storage. Within the timeframe of this management plan, detailed studies regarding the capacity of the drainage network are required to commence the planning implementation for future mean sea level rises from 2045 beyond and to allow for the refurbishment of the existing outfalls.

Current Works

The City and MRWA have undertaken an annual maintenance regime since 2011 in order to maintain the integrity and extend the service life of the current river wall infrastructure. This approach, although given the short timeframe of implementation, has been successful with the refurbishment of two major sloping revetments able to be deferred due to stabilization of the condition of the structures. A program to provide a methodology to investigate the drainage network has been commenced by MRWA, however a number of constraints with the Kwinana Freeway and Mandurah Railway make the task difficult.

Biological Environment

The northern foreshore area serves an important site for many Trans equatorial migratory birds. Some of the major foraging and roosting areas for these birds areas actually occur outside of the nature reserve sites. Recommendations on the maintenance of sandy foreshores in these areas outside of the nature reserve areas are made in order to conserve and enhance the wading and beach areas to continue to provide habitat for these conservation significant species. This will be important in the nature reserve areas of the Groynes, Milyu and south of Canning Bridge.

Very little actual natural vegetation remains in the study area. Over a third (38.6%) of the study area has been cleared and landscaped. Some pockets of remnant vegetation communities still occur in the southern half of KFF between Canning and Mt Henry varying from Completely Degraded to Very Good condition. The Ecoscape (2014) *KFFMP Planting Guide Spread Sheet* provides a range of recommended local native species for revegetating and soft landscaping the study area, along with revegetation methods, domains and plant characteristics.

A total of 96 weed species are known or thought to occur in the study area. Of these, 34 species were determined to be High Priority to control. A range of control options was provided in the Ecoscape (2014) *KFFMP Weed Management Spread Sheet*, targeting their life form and optimal control times.

Social Environment

KFF has both Indigenous and European cultural significance. The site is adjacent to the sacred home of the Rainbow Serpent and is a registered Aboriginal camping ground heritage site. Being close to the City centre, KFF has played a role in Perth's early history. There is much potential to develop a Wayfinding and Interpretation Plan to promote the study area's unique history.

Community education and involvement, including local school and youth groups is critical for the long-term conservation of the site's environmental and cultural values. Creating a strategy to involve these groups will assist in developing a sense of ownership within the community, will empower people and will encourage them to devote their own resources to appropriate care and management.

Major developments proposed for the area within the next 20 to 30 years consist of the Canning Bridge Precinct and also at Richardson Park. There is significant potential at the Canning Bridge site to improve the social use of the area. Given the constraints of the KFF, other opportunities for commercial or social developments are limited, however there would also be opportunities at the northern end of the foreshore at the Jet Ski car park and recreation area.

The study area accommodates wide variety of on and off-shore recreational activities for the local community and commuters; however the main activity, particularly over the last 5 years has been the growth in cycling along the PSP. Information from the Department of Transport indicate that cycling movements at the Kwinana Freeway PSP Narrows Bridge traffic counter have increased from 235,935 in 2008 to 873,082 movements in 2013. This represents an approximate 4 fold increase in the number of cycling movements along the PSP since 2008.

The existing facilities and amenities are in various states of condition and style, and are subject to vandalism depending on their location. As with most complex user groups there are conflicts; the primary conflict in KFF is the actual and potential conflicts on the PSP between cyclists and walkers, particularly walkers with unrestrained dogs and commuter cyclists riding in groups. Dog walking along the foreshore and particularly along the shallow water is one recreational activity that is going to be impacted by erosion of the foreshore.

Increased incidents of overtopping and inundation of the PSP will also reduce the amenity of walking or cycling along the PSP, although numbers of recreational users are significantly reduced during these events anyway. Increased usage of the PSP may also start presenting conflicts with the use of the Sea Scouts building on the KFF, particularly vehicles trying to access and then exit onto the freeway. This issue will be further complicated if the emergency lane of the freeway is utilised as a fourth lane.

Due to the location of the foreshore and the limited points of both vehicular and pedestrian access across the freeway, it is difficult to determine what activities and access types are available along the PSP and from overpasses. Some of the overpasses were built prior to any standards for universal access. These restrict the ability of people with mobility issues to access the foreshore.

Access Restrictions

Public vehicular access is limited to the Jet Ski car park near the Narrows and Gentilli Way on the Canning River. Vehicle access along the KFF is particularly constrained, especially for larger vehicles and trucks. This restricted access for large trucks adds significantly to the cost of doing any major works along the foreshore. MRWA have taken measures to improve access by the addition of a service vehicle gate adjacent to South Terrace.

The movements of maintenance vehicles along the PSP presents a risk between cyclists, pedestrians and maintenance vehicles, although MRWA have taken measures to reduce this by undertaking widening

modifications to the PSP to allow for clearer sight lines and increased passing room. The City has also established several hard stand areas to allow for vehicles or laydown areas to be situated off the main path.

Possible modifications to the Kwinana Freeway to utilise the emergency lane as a fourth lane of traffic may pose a risk for maintenance vehicles, particularly when the vehicles are required to exit into traffic. It is also significantly more difficult when undertaking works for approval to close an active running lane of the freeway rather than the emergency lane. Therefore the conversion of the emergency lane to a running lane may result in more restrictions and additional costs to works along the KFF.

Conclusions

A number of difficulties and potential opportunities exist along the KFF for the next 30 years. These issues range over the short to medium (next 5 to 10 years) to long term (strategic, 10 years +) planning periods. Some of these issues require significant funding and investigation within the short term to enable medium term solutions to be implemented in time. Delaying some of the works required, particularly decisions with respect to the possible beach nourishment of the foreshore impact the viability and cost benefit of the solutions.

Beach nourishment along the KFF is of particular importance to the decisions affecting the other infrastructure assets. Should the foreshore be renourished, then maintenance requirements on a number of river walls etc. can be reduced and the service life of a number of existing assets will likely be able to be extended by minor maintenance only. If beach nourishment is not decided to be implemented then it is expected that a number of assets will experience a higher rate of deterioration and increased maintenance, a number of assets will also likely require replacement to a more durable marine structure standard and some sections of foreshore will required new structures to be built to prevent erosion to the PSP.

Sea level rises beyond the 30 year timeframe will begin to have a greater impact on inundation of the Kwinana Freeway, foreshore assets and nuisance flooding from the stormwater system.

If the estimates of a mean sea level increase of +0.9 m by 2110 are correct, then many low lying areas around the Swan and Canning River foreshores will require some sort of adaptation or accommodation. These issues are on a much larger scale than this management plan developed for the KFF and it is recommended that they be dealt with on an overall region level by the state government. It is also not economical to be trying to accommodate these 100 year projected mean sea levels in the current day. Many items of infrastructure will require to be replaced at least once (and likely twice) over this period. The replacement of these items of infrastructure provides the opportunity to retrofit or accommodate additional allowances for climate change into the new structure. For example, increasing crest levels of structures when being replaced is a practice already undertaken by the City and MRWA along the KFF.

Inundation occurring from an increasing mean sea level over the 30 year term of this plan is expected to be minor, although frequency will likely increase. The greatest impacts are likely to occur with respect to inundation of the PSP and nuisance flooding from backing up in the stormwater drainage network. The addition of small retaining walls along the rear of the PSP or a slip form concrete barrier to replace the existing wire rope fence would be suitable methods to minimise the inundation impacts along the foreshore on the Kwinana Freeway within this timeframe.

Many of the outlets of the stormwater drainage network are severely degraded, although the actual pipework upstream of the outlet may be in good condition. The damaged outlets result in significant levels of siltation of the pipe network. Improving the drainage outlets to minimise siltation and reduce the backflow of marine storm surge up the pipe network will add some capacity to the stormwater network. This practice of adding some sort of backflow device has been adopted within other Australian states, particularly in cyclone prone areas that are subject to high storm surge levels.

Remnant vegetation along the KFF is limited to the Canning River areas of Cloisters and Mt Henry. These areas are limited in their ability to adapt to rising foreshore levels given that they are not able to retreat. With rising levels the foreshore edges of these area will become increasing inundated over the next 100 years. Mt Henry spit is vulnerable to changes in predominant wind directions and is also subject to effects from passing vessel wakes and flood events on the Canning River. There has been the recession of the point and the edge vegetation along this stretch will be continually under pressure. The City has successfully provided some soft protection to the more protected shoreline of the Cloisters and Infill sections.

The PSP along this stretch will also become inundated more frequently, as the relief levels are quite low along this section, particularly the sections of Infill and Cloisters. Efforts for increasing the density of the vegetation are recommended to concentrate on the centre section of the spit and progress outwards.

A number of studies and capital upgrade programs are required to be implemented in the short term to enable the successful management of the KFF area. These are in response to current issues brought about by discontinuity of previous works and a number of asset items reaching the end of their service life. This is without further consideration of future effects from climate change mean sea level increases. Major items identified within this plan indicate that the foreshore and PSP are likely to initially feel the impact of increasing water levels over the next 30 years before any significant issues with the Kwinana Freeway. The majority of issues for the Kwinana Freeway within this management plan will be associated with drainage and a significantly reduced drainage capacity.

The following items are identified for major action. These are the key recommendations:

- Maintain outcomes from the 1993 Management Plan, particularly the Kwinana Freeway Management Group and the maintenance of a Section 18 Aboriginal Heritage Approval for the City's foreshore to promote ease of implementation of projects, quick responses to issues and long term project planning.
- The City, MRWA and DPaW should liaise with the Trust to determine the feasibility of a undertaking a major beach nourishment project along the KFF as per the Trust's report "*Feasibility Study of Options for Beach Renourishment Swan and Canning Rivers*". This beach nourishment project would act to minimise future maintenance costs of, improve the service life of and reduce capital improvement requirements to existing structures along the KFF as well as reduce the need for additional structural solutions along the foreshore.
- Investigate the drainage network and undertake capital upgrades of the outlets in order to reduce siltation of the pipe network and reduce marine backflow up the network, particularly the areas shown to flood on the eastern side of the Kwinana Freeway.
- Investigate the installation of a slipform concrete barrier in several spots to reduce inundation of the Kwinana Freeway in extreme weather events and maintain emergency vehicle access. This will be sufficient along lower areas of the Kwinana Freeway to reduce inundation of the Kwinana Freeway in a 100 year ARI event.
- Undertake a capital program to increase crest height of structures where wave overtopping and spray onto the freeway is of concern.
- Formalise an alternative PSP route along the foreshore from Mt Henry Bridge to the Narrows, particularly the underpass sections at Canning Bridge which are the lowest sections of the PSP. This could investigate the provision of a commuting bike lane along The Esplanade in Mount Pleasant or establishing a PSP along the eastern side of the Kwinana Freeway.
- Undertake revegetation works to improve the durability of the existing remnant vegetation areas of the Spit and Cloisters.
- Continue revegetation works at Milyu to improve the durability of the vegetation against increases in mean sea level.
- Prioritise species that are tolerant to inundation for replanting of the KFF area.

- Identify other areas that would be suitable for the establishment of natural vegetation areas to offset future losses associated with increasing mean sea level rise in the coming 100 years.
- Investigate opportunities to shift the Sea Scout Hall at the end of the service life of the current building. There are opportunities to incorporate a new Sea Scouts building into the Canning Bridge Development or a new facility relocated to the Jet Ski car Park area where vehicle access may be easier.
- DPaW to continue shoreline monitoring along Milyu to provide a quantifiable dataset of shoreline movements.
- MRWA to establish an expected "level of service" for the Kwinana Freeway in order to provide a set of criteria to dictate design modifications to reduce overtopping and inundation.
- Plan for more frequent inundation of the PSP. Utilise the PSP as a scour protection apron for the Kwinana Freeway. The western edge of the PSP may require strengthening (deeper front footing) in the future to reduce the scouring effects of wave rundown.

Recommendations

A total of 112 recommendations were made in this report, which are summarised in **Appendix One**.

1.0 INTRODUCTION

1.1 GENERAL INTRODUCTION

The Kwinana Freeway Foreshore (KFF) is the narrow linear foreshore which runs along the western edge of the Kwinana Freeway from the Narrows Bridge to Mount Henry Bridge, incorporating foreshore sections of both the Swan and Canning Rivers. It is an important section of land as it provides significant functions in terms of recreation, ecosystem services, visual amenity and major transport corridors including road, rail and pedestrian.

The City of South Perth (City) has previously prepared a foreshore management plan for the area in 1993 titled the *Western Foreshore Management Plan* (WFMP). Revisions of the plan were undertaken in 2003 and 2007 however none of these revised plans were finalised or adopted by the City.

Given its location on the eastern boundary of Melville Water, the length of foreshore from Canning Bridge to the Narrows is subject to reasonable wind and wave action generated across the fetch of Melville Waters.

The foreshore has a long Aboriginal and European history, however the location of the majority of the current foreshore is essentially artificial. The current foreshore location is a direct result of locating and the construction of the Kwinana freeway along the South Perth foreshore between the 1950 to the 1970's. Dredge spoil was salvaged from the adjoining riverbed and deposited along the foreshore as part of a land reclamation activity for the Kwinana Freeway. Shoreline dynamics were affected by the change and subsequent management actions such as the construction of groynes, revetments and seawalls have been undertaken to stabilise the reclaimed foreshore.

Since the previous management plan was developed for the KFF, the City and Main Roads Western Australia (MRWA) have undertaken a project to identify the ownership of all major foreshore protection and drainage assets along the KFF. This was finalised in the development of a Memorandum of Understanding between the City and MRWA titled *Maintenance of Principal Shared Paths, Walls and other aspects of the Kwinana Freeway Foreshore*. All aspects of maintenance or replacement along the KFF are undertaken in accordance with the ownership set out within this document. The Department of Parks and Wildlife (DPaW) also have an interest along the section of Class A reserve that exists along the foreshore known as Milyu Nature Reserve and the Swan Estuary Marine Park.

As per the *Swan and Canning Rivers Management Act 2006*, the Swan River Trust (Trust) is the main government agency responsible for the planning, protection and management functions in respect to the Swan and Canning waterways, riverbanks and associated land. The Trust aims to ensure the maintenance of ecological and community benefits and amenity for the river foreshores. The Trust is active in partnering with the City, MRWA and DPaW along the KFF.

As per one of the outcomes of the 1993 WFMP, a working group comprising of the City, MRWA, the Trust and DPaW has been formed to coordinate maintenance and any other activities which affect the KFF. This group meets monthly in order to keep other stakeholders informed of activities and to coordinate longer term plans within each organisation. The working group is known as the Kwinana Freeway Foreshore Management Group (KFFMG).

Funding of assets along the foreshore including maintenance activities, capital replacement, revegetation programs and other activities are undertaken by the stakeholders. The City, MRWA, the Trust, and DPaW

provide monetary funding, officer time and resources and equipment resources to maintaining the ecological, coastal protection and amenity values of the foreshore.

Since its inception the KFF has undergone changes though both the engineering and landscape means. Some of the features of the foreshore reserve include:

- Recreation hubs,
- Pedestrian and cycle ways,
- Nature reserves,
- Visual amenity, and
- Cultural values.

The current 1993 WFMP requires to be revisited in order to incorporate a number of new proposed social and recreational developments within the area. In addition, issues affecting the shoreline currently and within the next 30 years are different to what they were in 1993, particularly with respect to the levels of erosion along the foreshore and the increased awareness of the possible effects of climate change. The extent of the plan will also be extended from the 1993 extent to include the foreshore region between Canning Bridge and Mount Henry Bridge, which is one of the City's main areas for biodiversity conservation. The purpose of the revised plan is to provide guidance for the social, cultural, environmental and physical elements of the foreshore over the next 20-30 years.

1.2 NEEDS FOR THE STUDY

The primary objective of the Brief was to review the 1993 WFMP and develop a new Kwinana Freeway Foreshore Management Plan (KFFMP) for the KFF between the Narrows Bridge and the Mt Henry Bridge. The City is currently participating in two important groups which provide advice on current and future issues associated with the foreshore management, the Kwinana Freeway Foreshore Management Group (KFFMG) and a Climate Change Risk Assessment Working Group (CCAWG). Hence there are existing communication and technical structures which will provide input into the formulation of the Management Plan and enable its implementation through time.

As part of the development of the new foreshore management plan a number of key tasks were undertaken, these included:

- Consultation with key stakeholders – through the KFFMG and City Environment Coordinator.
- Reviewing previous report and documents.
- Undertaking site familiarisation analysis to determine the main issues, areas of concern, recreation, infrastructure and conservation assets and erosion issues.
- Examining the available data and models of sea level rise and determining if gaps exist and how the climate change adaptation options under different scenarios can be best interpreted.
- Determining options for managing the major infrastructure assets (i.e. Kwinana Freeway and Principal Shared Path (PSP) and other infrastructure asset such as stormwater drainage under different climate change, storm surge and erosion scenarios.
- Undertaking a holistic approach to the foreshore in terms of its assets, their protection, conservation, recreation and community and cultural values, particularly under climate change induced sea level changes in the short and long term.
- Developing a Management Plan which is strategic and consistent with the Trust's guidelines and has high acceptance with key stakeholders.

1.3 AIM AND OBJECTIVES

The aim of the KFFMP is to review and update the previous management plans of the study area into an overall document that will meet the KFFMG's needs.

The specific objectives of the KFFMP are to:

- Establish consistency with the following documents:
  - Swan River Trust (2012b) *Guidelines for Developing Foreshore Management Plans in the Swan Canning River Park*
  - CALM (1999b) *Swan Estuary Marine Park and Adjacent Nature Reserves Management Plan 1999-2009.*
- Assess available sea level rise data (modelling) for the Swan and Canning Rivers system and identify gaps in data.
- Provide adequate interpretation of available sea level rise data and integrate current sea level rise modelling data into the report to reflect various sea level rise scenarios in order to offer appropriate climate change adaptation options.
- Provide recommendations to the KFFMG on proposed strategies to alleviate any gaps
- Outline management options for erosion control and the impacts of climate change with a focus on KFF asset and infrastructure protection (e.g. Kwinana Freeway and the PSP) based on various sea level rise scenarios (e.g. low, medium and high).
- Provide recommendations for stormwater drainage asset management including functionality, and response to predicted sea level rise.
- Address the key stakeholders' current and future issues related to foreshore erosion, conservation, recreation and infrastructure protection.

1.4 LOCATION

The study area is the long strip of foreshore running parallel along the western edge of the Kwinana Freeway from the Narrows Bridge at the northern extent south to Mt Henry Bridge. The foreshore is approximately 8.5 km in length and covers sections of both the Swan River estuary and the Canning River. The Canning River joins the Swan River at Canning Bridge. The KFF forms the eastern boundary of a wide estuarine basin known as Melville Water. The setting of the KFF and its extents can be seen in Figure 1.

Along the foreshore, the cross section is generally as follows from the waterway across to the eastern boundary of the Kwinana Freeway:

- Swan or Canning River Waterway
- Section of foreshore or protection structure (such as river wall or similar)
- Principal Shared Path (recreational and commuter use)
- Kwinana Freeway Western Northbound Lanes
- Perth to Mandurah Train Line
- Kwinana Freeway Eastern Southbound Lanes
- Melville Parade
- Suburbs of Como & South Perth.

In areas where no protection structure exists, any recession of the foreshore begins to put pressure onto the PSP and Kwinana Freeway. Where a protection structure exists, it is vital to keep the asset in a good condition to minimise the risk of failure and possible disruption to the PSP. The PSP forms a good buffer to the erosion of the western lanes of the Kwinana Freeway. The Perth to Mandurah Rail Line is well protected by concrete slip form retaining walls from inundation.

Figure 1: Location of Study Area

From North to South, the study area is adjacent to the following main recreation areas; Richardson Park, Royal Perth Golf Club, Comer Reserve, Olives Reserve and Aquinas College.

1.5 METHODS

1.5.1 Desktop Review

A large number of documents and plans were reviewed as part of this study. A list of the more important documents reviewed for the works are detailed below:

- Main Roads Western Australia & City of South Perth (2012) *Memorandum of Understanding for the maintenance of Principal Shared Paths and other aspects of the Kwinana Freeway Foreshore*.
- Ecologia (2003) *Draft Western Foreshore Management Plan*
- Ecoscape (2002) *Mt Henry Peninsula Foreshore Management Plan*
- CALM (1999) *Swan Estuary Marine Park and Adjacent Nature Reserves Management Plan 1999 – 2009*
- Department of Water/ URS (2013) *Assessment of Swan And Canning River Tidal and Storm Surge Water Levels .*
- Damara WA (2013) *Feasibility Study of Options for Beach Renourishment, Swan and Canning Rivers.*
- Department of Transport (2010) *Sea Level Change in Western Australia: Application to Coastal Planning.*
- Main Roads WA (2004) *Waterways Report Swan River Flooding Perth Area (RN 467)*
- Swan River Trust (2010) *Climate Change Risk Assessment Project*
- Swan River Trust River (2012a) *Draft Protection Strategy for the Swan Canning Riverpark*
- Swan River Trust (2012b) *Guidelines for Developing Foreshore Management Plans in the Swan Canning River Park.*
- Natural Areas Consulting (2013) *Milyu Revegetation Plan*
- Syrinx (2013) *Mount Henry Spit Restoration Plan.*

The data from the desktop review was analysed to:

- Determine any gaps in information,
- Interpret sea level rise data to reflect various sea rise scenarios,
- Develop management options for managing the following existing and potential impacts,
- Examine hydrological, including sea level rise, flooding and stormwater drainage,
- Determine environmental issues, including vegetation, weeds, native fauna, pest fauna, and diseases,
- Determine social issues, including recreation, visual amenity, fire and future projects (e.g. Canning Bridge Precinct development),
- Determine and map foreshore restoration priority areas,
- Develop suitable landscape and rehabilitation treatments for sections of the foreshore and remnant vegetation; and
- Development management of newly included study areas, including Cloisters, Infill and Mount Henry Spit.

1.5.2 Fieldwork

The study area was traversed and the following items examined:

- Infrastructure
  - Type and condition.
  - Stormwater drainage.
  - Recreation use.
- Vegetation and environment
  - General domains (e.g. foreshore, transition, upland, landscaping).

General vegetation condition, using the Keighery (1994) *Bushland Condition* Scale (Table 1)

  - Vegetation description (dominant native flora).
  - Dominant and common weed species.
  - Signs and locations of foreshore erosion and accretion.
  - Signs and location of any observed pest fauna and diseases.
  - Existing shoreline condition.
- Social values, including heritage, development and recreation.
- Any other observed impacts.

Table 1: Keighery (1994) Bushland Condition Scale

Condition	Description
Pristine	No obvious signs of disturbance
Excellent	Vegetation structure intact, disturbance only affecting individual species and weeds are non-aggressive species
Very Good	Vegetation structure altered, obvious signs of disturbance e.g. repeated fires, aggressive weeds, dieback, logging and grazing.
Good	Vegetation structure altered, obvious signs of disturbance. Retains basic vegetation structure or ability to regenerate it. The presence of very aggressive weeds at high density, partial clearing, dieback, logging and grazing.
Degraded	Basic vegetation structure severely impacted by disturbance. Requires intensive management. The presence of very aggressive weeds at high density, partial clearing, dieback, logging and grazing.
Completely Degraded	Vegetation structure is no longer intact and the area is completely or almost completely without native flora. 'Parkland Cleared'.

1.5.3 Domain Rehabilitation Model

The Rehabilitation Domain Model (Mikli & Kaesehagen 2009) was used, which was based on the International Council on Mine Closure and Metals (ICMM 2008) *Domain Model*.

Areas to be revegetated can be divided into Domains with restoration goals, according to their site characteristics (e.g. soil characteristics and topography) and End Land Use (e.g. visual screen, fauna habitat, resembles original vegetation). Treatments can then be designed for each domain to use or overcome site characteristics to reach their rehabilitation goal. Key performance indicators (KPI) are then developed to assess whether the Treatments are achieving the rehabilitation goals. This rehabilitation domain approach is summarised in Figure 2.

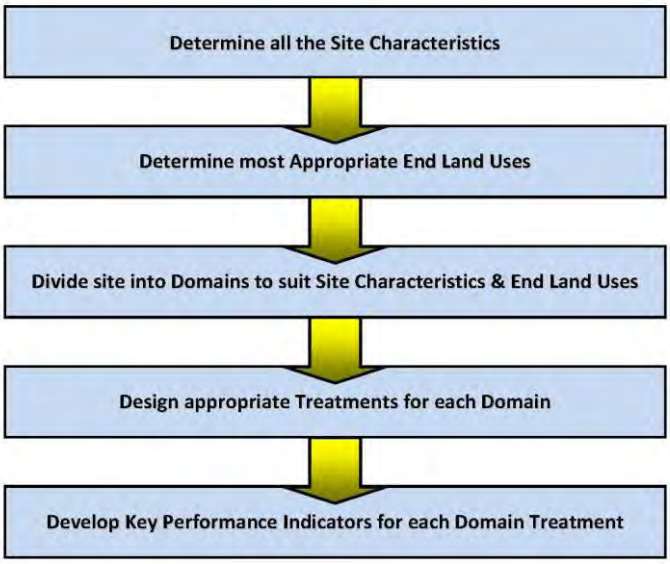

Figure 2: Rehabilitation Domain Model outline

1.5.4 Stakeholders

The Kwinana Freeway Foreshore Management Group (KFFMG) comprises representatives for the following bodies:

- City of South Perth (City)
- Main Roads Western Australia (MRWA)
- Swan River Trust (Trust)
- Department of Parks and Wildlife (DPaW).

2.0 EXISTING MANAGEMENT PLAN

2.1 REVIEW OF OUTCOMES

32 outcomes were listed within the 1993 Western Foreshore Management Plan for the KFF from the Narrows to Canning Bridge. These were as detailed in Table 2.

The section of foreshore from Cloisters to the Spit is covered under the City's Mt Henry Peninsula Management Plan prepared in 2003. This management plan is still relevant to the areas of Cloisters, Infill and Spit.

Table 2: **Recommendations from 1993 Western Foreshore Management Plan**

No.	Recommendation	Status
	Waterway Management	
1	Allocate funding for additional testing materials, seek assistance and advice from WWC to encourage more local schools to be involved in Ribbons of Blue Water Quality monitoring scheme with the City of South Perth.	Program lacks commitment and has been stopped. Water quality monitoring undertaken by SERCUL. Local schools also undertake water quality testing via Schools Nature Nurturing Program & Millennium Kids.
2	Monitor water quality in storm drains.	See comments on Item No 1. Trust monitor water quality offshore from Western Foreshore.
3	Use walling, preferably sloped, as solution to erosion threat on foreshore, plant local native vegetation for additional protection against erosion.	Completed where appropriate.
4	Repair all damaged or eroded groynes and remove all groyne debris.	Outstanding.
5	Incorporate oil and grease traps in all storm water drains. Where nutrient levels are high, custom design and incorporate biological filters.	Outstanding.
6	Request Royal Perth Golf Club to establish a nutrient irrigation management plan to minimise fertiliser use and nutrient leaching from Royal Perth Golf Course.	RPGC are following best practice turf management which includes soil and leaf analysis to minimise over fertilising.
7	Include a requirement to minimise water and fertiliser use on Royal Perth Golf Course in future lease agreements.	.Not implemented, relying on RPGC to follow best practice.
8	Review current turf management practices on all reserves in the City of South Perth.	City is applying best practice water use by metering all groundwater bores and monitoring irrigated water use via a centralised control system and weather station. Leaf and soil analysis are also routinely carried out to ensure over fertilising does not occur.
	Landscaping	
9	Review and modify the MRWA landscape plan (adopted by MRWA, SPCC and Trust in 1989) in accordance with recommendations in this plan.	Status Unknown.
10	Group trees to retain and frame views and to provide shade and shelter.	Ongoing.
11	Select shade trees from species lists provided and plant in recreational areas: Narrows, Como, Scouts.	Ongoing.
12	Plant low maintenance areas according to newly agreed landscape plan (1993): Groynes, Palms, Skinny, Scouts, N Canning, S Canning.	Ongoing.
13	Monitor veldtgrass each year. Employ licensed herbicide operator and bush regenerator to control with Fusilade. Obtain permits from Health Dept WA and Trust.	Ongoing.
14	Provide access to each section of the foreshore for maintenance purposes.	MRWA installed new gate South Tce. Other areas of foreshore accessible via City or MRWA gates.
	Fauna Management	
15	Retain dead tree limbs for fauna habitats. Create additional bird habitats with local native species plantings.	Ongoing.
16	Gazette "no dog" area north of Milyu, erect signs.	Completed.
17	Identify appropriate limits for dog beaches; Gazette these areas, erect dog control signs.	Completed.
18	Place dog poo bins at each end of and every access point to dog recreation areas and at the start of each footbridge.	Completed.

No.	Recommendation	Status
19	Erect signs along the PSP to direct: pedestrians and cyclists to keep left; cyclists to ring bells.	Completed.
20	Investigate sound barrier between Como Beach and Freeway.	Installed.
	Facilities	
21	Install repair the following facilities: Narrows – seats; Palms – log fence at north end; Scouts – Resurface path to scout hall, remove steel pillar; make path to north beach, picnic shelters in northern area; Cloisters – Limestone surface on boat ramp.	Ongoing Maintenance items.
	Prawning	
22	Erect Signs at approaches to foreshore areas where prawning is popular to remind prawners that fires are illegal.	Recreational Prawning significantly reduce due to low stock numbers.
23	Assess the effectiveness of the prawn boiler at Cloisters Reserve. If effective, install at other sites.	
24	Direct Rangers to monitor prawners on the foreshore and ensure that they; do not light fires, remove debris, return aquatic life to the river.	
25	Assist Trust in undertaking survey of prawners.	Trust continuing effort to restock river with Prawns. Trust *"Prawn Watch"* program.
	PSP	
26	Modify intersection of Cale Street footbridge path and PSP in Scout zone to ensure that users are directed along PSP or toward northern end of foreshore and not through Sea Scouts area.	PSP alignment seems appropriate.
	Information	
27	Initiate formation of Friends Groups to encourage community and school involvement in foreshore regeneration and care.	City actively engaged with Community.
28	Prepare pamphlets in conjunction with Trust with information about the foreshore environment.	City and Trust distribute education material online.
	Signs	
29	Erect information sign at North Canning to describe shoreline reclamation for Freeway construction.	Not undertaken.
30	Design, word and locate signs according to guidelines in the CALM sign manual.	Not undertaken.
31	Form & Maintain Western Foreshore Steering Committee with representatives of SPCC, MRWA, local community, local vegetation expert, Aboriginal interests. Committee to: Coordinate and monitor implementation of this plan, report progress to SPCC and MRWA annually until maintenance works are completed; thereafter to report to SPCC.	Completed and ongoing Kwinana Freeway Foreshore Management Group.
32	Draft Maintenance agreement between SPCC and MRWA detailing; Works to be completed by MRWA before handover of responsibility for maintenance to SPCC; areas to remain responsibility of MRWA, time frame for completion of works.	Completed MOU with City and MRWA.

The major items on the list from the 1993 plan that have been completed are the establishment of the Kwinana Freeway Foreshore Management Group (KFFMG) with representatives of the City, MRWA, DPaW and the Trust meeting monthly to coordinate activities and works along the KFF. The KFFMG has also established a Memorandum of Understanding for maintenance activities along the KFF. The MOU clearly sets out the ownership of assets and defined responsibilities, which has made the progression of a number of items significantly smoother.

The City, MRWA and the Trust are also actively contributing to the vegetation of the shoreline with local species and in particular along the sections of Milyu Reserve. The City is also managing its remnant bushland areas of Cloisters and Mt Henry.

A number of the items identified within the 1993 WFMP have still not been acted on. It is noted that the drainage and shoreline management groynes along the foreshore were identified as requiring significant maintenance in 1993. 20 years later and these items have still not been addressed. Works to address the groynes and drainage outlets has recently commenced, although whether they are reconstructed as groynes or as outfall structures only is highly dependent upon a decision as to whether beach nourishment will occur to restore the previous reclaimed shoreline position.

Many of the other elements identified within the 1993 WFMP are minor in nature and are addressed by the City's ongoing maintenance or landscaping tasks. Other items are not now relevant, such as items to address recreational prawning as there has been a dramatic decrease in this recreational activity due to a

decline in prawn stocks in the river. Additional increases in weed and blowfish numbers have made drag netting for prawns less of an enjoyable recreational activity. It is noted that the Trust is currently undertaking a program of restocking the Swan River with prawns to hopefully increase the stock numbers, the program is called "*the Trust Prawn Watch Initiative*".

The City also revised the foreshore management plan in 2003, however this revision of the 1993 WFMP was never formally adopted by the City. The final draft of the 2003 WFMP provided 61 recommendations, 32 of which were adopted from the 1993 WFMP. Additional management items noted within the 2003 draft WFMP are listed in Table 3.

It is noted that the majority of major items listed have been addressed and that some major items, such as the use of beach nourishment and offshore headlands to provide protection are still options to be addressed for the future of the foreshore. Other items within the recommendations listed are generally of a minor nature and some are not relevant to the area anymore. It is noted that it is preferred to limit the amount of signage along the foreshore, as in addition to providing information for the public, they provide the City with additional assets to maintain and also protect from vandalism or graffiti. Methods of informing and educating the public have also migrated to online and social media rather than with signage and pamphlet or letter drops.

Table 3: List of Recommendations from the 2003 Draft Management Plan

2003 draft WFMP Item No.	Recommendation	Status
1	Encourage Trust to extend water sampling to include the Western Foreshore.	Trust undertakes monitoring of waterway, although limited sites in Melville Water.
8	Perth Urban Rail Development should undertake rigorous routine water sampling for pollutants subsequent to drain construction.	Completed.
11	Construct offshore groynes parallel to the existing shoreline at Groynes and Skinny.	Construction of offshore groynes is still a possible option to reduce wave impacts on foreshore.
12	Repair seawall in front of ablution block at Como Beach and renourish the beach at this point. Redesign seawall to extend north around play equipment.	Complete.
13	Renourish beaches at North Milyu, Como Beach and just south of Scouts in early Autumn (April).	Only minor renourishment at Como Beach.
16	Create ecoscapes in the underutilised North and South Canning Zones.	This item will be superseded by the Canning Bridge Precinct plan.
17	Improve facilities, weed control and rubbish removal in Groynes, Palms and Skinny.	Ongoing.
21	Increase capacity for propagation of seedlings in Council Nursery and initiate plant salt and drought conditioning regime.	Completed and ongoing.
22	Ensure revegetation sites are properly prepared.	Ongoing.
23	Ensure that planting is only undertaken where and when the resources are available for follow up maintenance, including hand weeding.	Ongoing.
25	Ensure that weeding is undertaken as per management guidelines.	Ongoing.
27	Create additional bird habitats with local native species plantings.	Ongoing.
28	Propose the planting of Harsh Hakea between bush and shoreline either end of Milyu Reserve.	DPaW have prepared a revegetation plan for Milyu – ongoing.
29	Repair or replace signage relating to migratory birds.	Complete.
31	Create a barrier of Harsh Hakea to separate PSP from bird roosting beaches.	Ongoing.
32	Department of Infrastructure to fund 3 year bird monitoring program to assess the influence of personal watercraft.	Study undertaken.
33	Meet with CALM to discuss options for Fox control.	Status Unknown.
35	Develop information signage about the impact pets have on the environment and responsible pet management.	Unlikely to proceed.
38	Promote public awareness of the benefits of keeping cats indoors as much as possible and particularly at night.	Status Unknown.
39	Encourage local residents to respond to fire authorities by contacting authorities. Provide a list of contact numbers in case of emergencies and forward to residents with their rates notices.	Status Unknown.

2003 draft WFMP Item No.	Recommendation	Status
40	City Rangers should ensure that patrols of the foreshore are incorporated into their regular schedule.	Council Staff Monitor.
42	Plan to maintain adequate access routes for rubbish removal.	Ongoing.
43	Council Staff attend the foreshore after storms to remove storm debris from shoreline.	Ongoing.
44	Consider the necessity for works offshore and if necessary initiate aboriginal consultation through a reputable Ethnographic consultant.	Possible Future Option.
46	Restructure PSP as per AustRoads Part 14. Recommendations for the creation of cycle paths.	MRWA have widened PSP.
49	Playground with retaining wall is a hazard and should be covered with compressed rubber.	City maintained as sand.
50	Install and repair picnic shelters in the northern section of the Scouts Zone.	Area has been revegetated.
51	Incorporate seats, BBQ, and revegetation area in the northern section of the Scouts Zone.	Area has been revegetated.
54	Western foreshore should be included in a regular patrol schedule for fisheries.	Unlikely to occur.
56	Increase community awareness of environment with pamphlets in conjunction with Trust offering information about foreshore environments.	Trust media campaigns and website ongoing.
59	Design, word and locate signs according to guidelines in the CALM sign manual and guidelines provided by AustRoads.	Ongoing as necessary.
60	Establish a register of qualified and competent contractors for all facets of foreshore construction and maintenance.	Completed, City has panel contracts in place for foreshore maintenance works.

A number of items for the Mt Henry Peninsula Management Plan relate to the section of foreshore from Cloisters through to the Spit. This plan has 115 general recommendations and 48 specific recommendations for the zones from Cloisters to the Spit.

Many of the general recommendations overlap that of the previous 1993 WFMP and other recommendations noted in the 2003 drafts. Items relevant to the areas of Cloisters, Infill and the Spit are shown in Table 5.

Table 4: Recommendations for Cloisters, Infill and Spit from Mt Henry Management Plan

2003 MHMP Item No.	Recommendation	Status
	Vesting and Lease of Land	
G1.1	City should initiate transfer of vesting of Cloisters Reserve (R21288) from DOLA to City.	Noted.
G1.2	Vacant crown land (VCL) on the western foreshore outside the needs of the freeway should be rezoned Parks and Recreation and vested in the City.	Completed.
G1.3	The 0.48 ha section of VCL should be annexed to Cloisters Reserve (R21288).	Completed.
G1.4	In the event that all or any of freehold property P003383 should be sold, the feasibility of public acquisition and reservation should be assessed.	Noted.
G1.5	Form a steering committee to implement management plan recommendations.	Complete for Western Foreshore.
G1.6	Ensure high levels of communication between stakeholders to achieve common goals and interests.	Achieved through KFFMG.
G1.7	Where possible share resources to achieve cost effective solutions.	Achieved through KFFMG.
	Management of Physical Environment	
G2.1	Undertake impact assessment of engineering options before implementation of erosion control measures at Edgewater Overpass.	Constructed by MRWA.
G2.2	Carry out sediment movement modelling to accurately assess requirements and dimensions of engineering options at Edgewater Overpass.	Works Completed.
G2.3	Choose engineering option for erosion control at Edgewater Overpass based on impact assessment and sediment movement modelling.	Works Completed.
G2.4	Revegetate eroded section of the Spit with native rushes and paperbarks extending from existing sections of good vegetation on the flanks of the Spit.	Management Plan in place.
G2.11	Undertake detailed inspections and if necessary repair all drains within the study area.	Outstanding.
G2.12	Undertake weed control measures around all drains within the study area.	Ongoing.

2003 MHMP Item No.	Recommendation	Status
G2.14	Undertake regular water quality sampling and analysis to ensure that nutrient levels of water entering the wetlands and river is acceptable. Should include peak flows, nutrient levels, pH and dissolved oxygen levels.	Water quality monitoring undertaken by SERCUL. Local schools also undertake wq testing via Schools Nature Nurturing Program & Millenium Kids.
G2.17	Use water sensitive design principles and best management practice for proposed future freeway alterations.	MRWA to address.
	Vegetation Management	
G3.1	Continue to support two specialised trained staff to work in bushland regeneration and maintenance on the foreshore.	City Environment Staff.
G3.3	Continue revegetation of the foreshore using local plant species.	Ongoing City and DPaW/MRWA.
G3.4	Remove inappropriate trees and shrubs planted during the construction of the freeway and PSP and along the foreshore of Aquinas College and replace with local species.	Ongoing.
G3.5	Continue ongoing weed control measures.	Ongoing.
G3.6	Formalise weed management strategies based on the general approaches to weed control.	Ongoing.
G3.9	Facilitate community involvement in resource led weed control projects.	Ongoing.
G3.16	Continue to collect local seed and cuttings for propagation at the Council Nursery.	Ongoing.
G3.23	Maintain and periodically update a comprehensive Fire “Management and Response Plan according to FESA guidelines.	Status Unknown.
G3.24	Continue the ongoing control of grassy weeds.	Ongoing.
G3.25	Undertake fuel reduction measures periodically.	Ongoing – see item 3.24.
	Fauna Management	
G4.6	Undertake comprehensive feral animal control program.	Ongoing.
G4.11	Install signage at key access points warning dog owners to keep their dogs leashed.	Complete.
G4.13	Continue ‘Pindone’ rabbit baiting within the study area.	Status Unknown.
	Heritage Management	
G5.1	Proposed developments should be carried out with Aboriginal consultation and should avoid disturbance to the riverbed or embankments.	City obtained a Section 18 approval for works along its foreshores.
G5.2	Hard based paths should be restricted to the existing PSP. Other paths should be surfaced with mulch or timber to prevent erosion.	Addressed as appropriate.
	Recreation and Infrastructure Management	
G6.1	Investigate feasibility of routing power and water from Canning Bridge or under freeway to Cloisters Reserve.	Outstanding. Likely to be addressed as part of Canning Bridge Precinct development.
G6.2	Install facilities and amenities at Cloisters Reserve including picnic tables, benches play equipment, bins, toilet, bike racks and water facilities.	Outstanding.
G6.3	Investigate feasibility of lighting at Cloisters Reserve.	Outstanding.
G6.4	Install seating at Strategic points along the Western Foreshore.	Complete.
G6.5	Investigate feasibility of providing water fountains at strategic locations.	Some water points installed. Ongoing.
G6.8	Resurface freeway using low noise surfacing.	Unlikely to proceed.
G6.9	Erect screening vegetation where it does not pose a hazard to freeway users or detract from the visual quality to motorists.	Ongoing.
G6.12	Assess access points for ease of use by disabled people and ensure all future constructions allow for universal access.	Ongoing.
G6.16	Install bicycle speed limit signs at Cloisters Car-Park and Mt Henry Bridge.	Unlikely to be policed, therefore unlikely to occur.
G6.17	Investigate feasibility of widening PSP in places to reduce conflicts between cyclists and pedestrians.	MRWA widened PSP.
	Public Awareness	
G7.1	Assess current level of signage and remove extraneous signs.	Ongoing.
G7.2	Ensure signs are uniform and complement the environment while still being visible.	Ongoing.
G7.3	Ensure signs are uniform and complement the environment while still being visible.	Ongoing.
	Maintenance	
G8.1	Undertake regular inspections of infrastructure and repair or replace where necessary.	Ongoing.
G8.3	To discourage vandals, repair all damaged facilities immediately after any act of vandalism or graffiti.	Ongoing.
G8.9	Investigate the feasibility of providing a locked gate at the entrance to Gentilli Way overpass.	Unlikely to occur.

2.2 REVIEW OF CLIMATE CHANGE REPORTS

The City is committed to climate change adaptation and has undertaken a Climate Change Risk Assessment (LGIS 2010) while also integrating climate change adaptation principles across the City's divisions. The City also has a Climate Change Strategy which outlines the City's sustainability plans for the period 2010- 2015 in order to try and reduce the City's carbon footprint.

The Fifth Assessment Report released by the Intergovernmental Panel on Climate Change (IPCC 2014) indicate that they have increased their confidence in projections of mean sea level rise because of improved physical understanding of the components of sea level, the improved agreement of process based models with observations and the inclusion of ice sheet dynamical changes (IPCC 2014). Over the range of different emissions scenarios modelled, the estimate of global mean sea level rise to 2100 will be 0.26 to 0.98 m relative to 2005. The 'Likely' range (95% confidence interval) of the highest emissions scenario Representative Concentration Pathway (RCP) 8.5 is 0.45 to 0.82 m with a mean of 0.63m. The 'Likely' range of sea level rise for this RCP 8.5 scenario by 2065 is 0.22 to 0.38 with a mean of 0.30 m.

The policy for the allowance of sea level change in coastal planning adopted by the Western Australian Planning Commission (WAPC) uses a mean sea level increase of 0.9 m by 2110, which is still consistent with these latest reviews on mean sea level increases. The IPCC do make notes in their summary documents that the basis for higher projections of mean sea level rise has been considered, however there is currently insufficient evidence to evaluate the probability of these higher levels above the assessed likely range. There is low confidence in these higher projections and the reliability of the modelling methods used (IPCC 2014).

MRWA undertook a preliminary study into possible effects of climate change and mean sea level on the inundation of the roads around the state (MRWA 2011). This study indicated that the Kwinana Freeway was at risk of inundation by mean sea level increases of the order of 0.5 m and up to 1 m. The cell sizes of the maps shown do not appear to be fine enough to pick up the heights of the river wall structures and foreshore, as they indicate flooding across the Freeway in events as low as +0.7 m AHD, which is typical of an average winter cold front crossing during a higher tidal period. This level is achieved multiple times a year and no inundation effects affect the Kwinana Freeway or PSP. As such, the inundation maps within this brief preliminary study are likely to be conservative. Dependent upon the degree of wave and wind setup along the KFF, in general minimal flooding of the foreshore occurs until water levels at the Barrack or Fremantle gauges exceed +1.0 m AHD.

Studies on water levels along the KFF including flood and wind and wave setup were investigated for the construction of the Perth to Mandurah Rail Line (MRWA 2004). This study investigated the total water levels expected in a 100 and 500 year event along the Kwinana Freeway. Total water levels from a combined a 100 year storm surge and a 100 year peak flood flow down the Swan River were used to conservatively estimate a 100 year joint probability event (It is noted that the joint probability of these two events occurring together would result in an event with an ARI greater than the 100 year event).

These investigations utilised increases in mean sea level due to climate change of +0.6 m. This information was current at the time of the study and in line with the IPCC (2001) projections and advice provided by the State Coastal Planning Policy (SPP 2.6) and WAPC. The elevation of the rail line included effects of wave and wind setup along the Kwinana Freeway shoreline in addition to the static water level predicted by the 100 year storm surge and the 100 year peak river discharge for the Swan River. This provided the following total water levels along the Kwinana Freeway for the rail line.

Table 5: Wave heights at Kwinana Freeway Foreshore

Event	Location	100 Yr ARI	500 Yr ARI
2003	Como	1.94 m AHD	2.46 m AHD
2123	Como	2.49 m AHD	2.92 m AHD

The Perth to Mandurah rail line is well protected by a concrete slip form barrier along its length, which is approximately 1 m higher than the surrounding pavement level of the Kwinana Freeway. While the Kwinana Freeway itself may become inundated in some of these extreme events, the railway line is well protected from direct inundation. Some flooding may occur internally within the railway reserve due to stormwater backflow or direct rainfall.

MRWA noted within these studies that while it is important to understand the impacts of potential climate change out to approximately 2100, the majority of planning horizons are of the order of 20 to 30 years. MRWA have adopted internally an inclusion of a sea level rise of approximately 0.3 m within current road infrastructure solutions (MRWA 2011).

The University of Western Australia undertook some preliminary flood mapping to highlight the low lying nature of the Swan River Coastal Plain and possible effects of varying mean sea level rises (UWA 2012). Mean sea level rises reviewed in this study include +0.5 m, +1.0 m and +1.5 m. A sea level rise of +1.5 m is beyond the estimates of the IPCC (2014), with the most recent IPCC (2014) studies lowering the expected (95th percentile) upper range of climate change down to 0.82m, with a mean of 0.63m. The maps associated with the +1.5 m scenario are overly conservative for expected climate change to year 2110 and there are several inconsistencies throughout the report and the mapping.

Based on the latest IPCC (2014) reports, the WAPC adopted mean sea level increase of +0.9 m by 2110 to be used in coastal planning within Western Australia is still relatively conservative.

3.0 STUDY AREA

3.1 SETTING

Perth is situated in the south western corner of Australia and is approximately 15 kilometres inland from the coastline. The town of Fremantle sits on the entrance of the Swan River to the Indian Ocean. The Swan River runs through a narrow section upstream for approximately 8.5 km before widening into a large basin known as Melville Water. Melville Water has average dimensions of approximately 6 km long by 3 km wide.

The KFF forms the eastern shoreline of this large basin and is aligned approximately north to south. The setting of the area can be seen in **Figure 3.**

Generally, tidal flows within the Swan – Canning river system are small and flood events are infrequent. The basin of Melville Water is in general dominated by combinations of wind induced wave and storm surge water levels rather than freshwater flood flows. Elements affecting the study area are described in detail in the following sections.

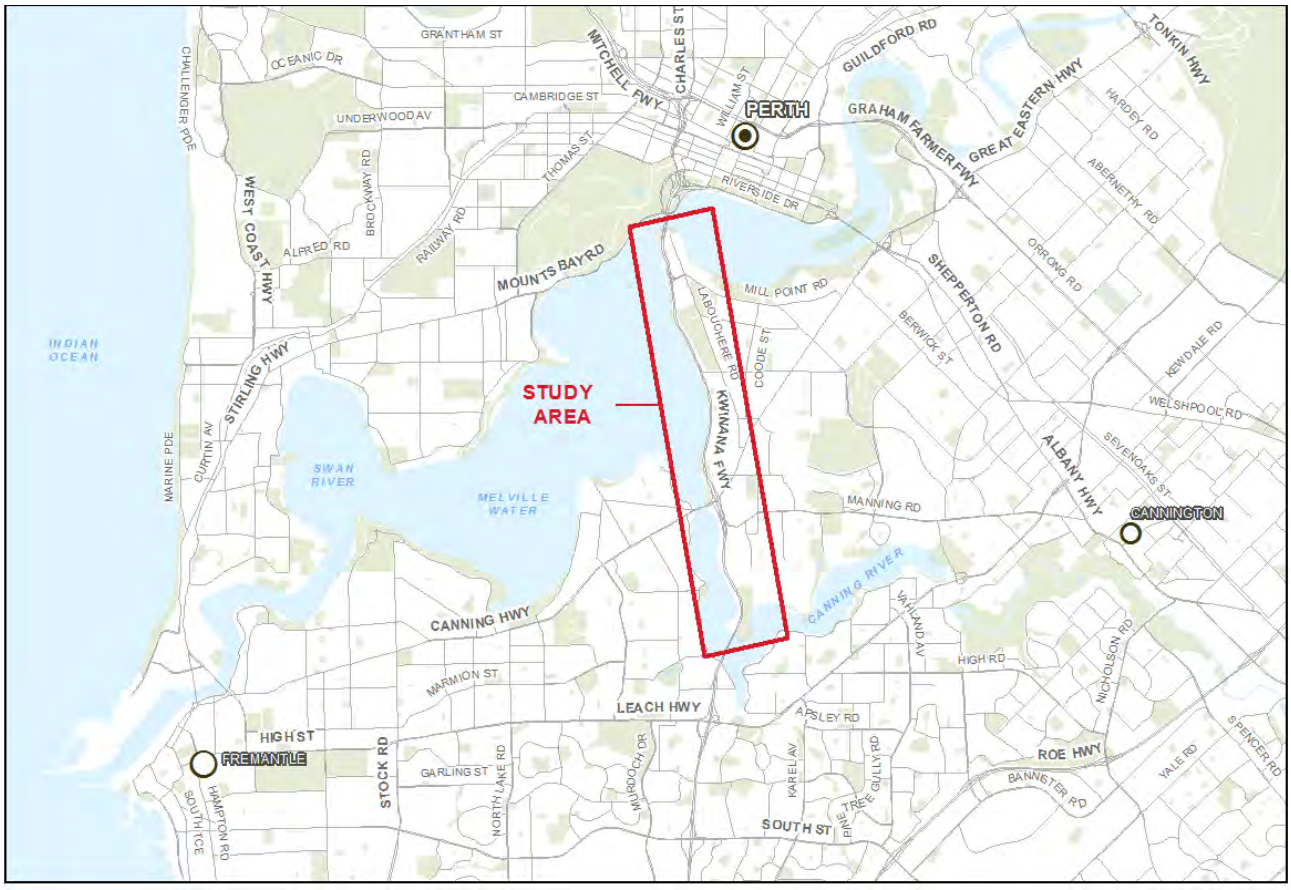

Figure 3: Swan River Extent from Fremantle to Perth City

3.2 PHYSICAL ENVIRONMENT

3.2.1 Climate

The study area is characterised by a mild Mediterranean type climate with hot dry summers and mild wet winters. The climate varies seasonally, with rainfall, temperature and winds following a well-defined annual cycle. The majority of the rainfall occurs in the winter months with 90% falling between April and October.

Historic temperature records from the Perth Metropolitan weather station, located approximately 2.1 km north of the study area, indicate that lowest temperatures are in July with an average daily minimum and maximum temperature of approximately 7.7 °C and 18.4 °C, respectively. The highest temperatures occur in February with an average daily minimum and maximum temperatures of 18.3 °C and 31.6 °C, respectively. The mean annual rainfall is 729.4 mm. Mean summer rainfall is minimal, between 8.5 and 16 mm. The amount of rainfall begins to increase in May and is highest in July with 146.4 mm, before beginning to decline in September (Figure 4).However, climate patterns have recently begun to slightly differ from these averages. Over the last five years the mean minimum and maximum temperature have increased by 0.3 °C and 0.6 °C respectively. Mean annual rainfall has decreased by 59.0 mm. In general, winter months have become slightly drier and summer months slightly wetter.

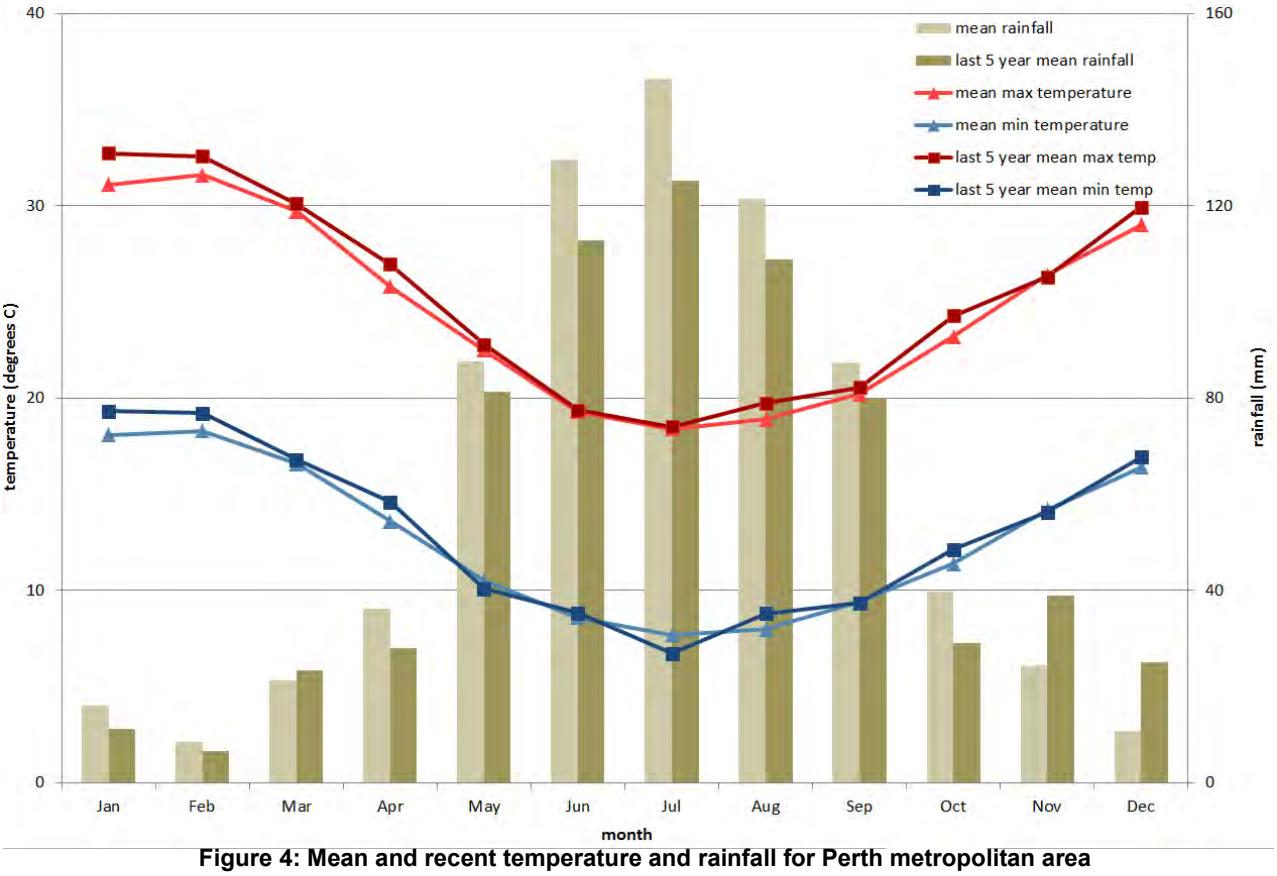

Figure 4: Mean and recent temperature and rainfall for Perth metropolitan area

3.2.2 Wind and Wave

The lower Swan Canning River system can be effectively separated into a number of distinct regions. These are the Entrance Channel (from Fremantle Harbour through Blackwall Reach to Point Walter), Freshwater Bay, Melville Water, Perth Water (between the Narrows and Causeway) and the Canning River (upstream of the Canning Bridge).

The lower estuarine environment of the Swan Canning is characterised by diurnal microtidal conditions, with an astronomical tidal range of approximately 1.0 m. The area is predominantly a wave dominated environment, with some areas of tidal current flow through the Fremantle Harbour entrance and other restrictions at the Narrows and Canning Bridge. Riverine flood flows from the upper Swan are dampened by the Perth Water basin. Storm surge events provide a significant mechanism for increased water levels within the lower estuary. Other oceanographic processes, such as the strength of the Leeuwin Current also affect water levels within the estuary.

Wave conditions within the lower Swan Canning system are developed through a combination of wind waves and vessel wakes. Wind waves generated within the lower Swan Canning System are dependent upon the direction, strength and persistence of winds blowing over the water surface. The distance that winds blow over the water surface (fetch) and the water depth can also affect the generated wave height. In general, wind waves dominant the larger basins and reaches, where longer fetch lengths and deeper waters can generate larger waves, whereas vessel wakes have an increased impact in the narrower upper reaches of the river.

Winds for the Perth metropolitan region are generally strongest from a westerly direction, with frequent winds from the east. Winds in the region are dominated by the passage of high pressure systems with periodic cold fronts and local sea and land breezes.

Cold fronts move west to east and pass the coast approximately every 3 – 10 days. Wind patterns with the passage of cold fronts are generally from the North West, rotating through West to South West. South Westerly winds may persist after the passage of the front for two or three days. Tropical cyclones track down from the North West infrequently during late summer and can have a significant impact on the local weather patterns.

Local sea breezes in the coastal region dominate the summer winds. Easterly land breezes dominate the morning and strong onshore (Westerly through to South Westerly) sea breezes commence around noon. Sea breezes can be quite strong, with winds regularly reaching of the order of 15 m/s (30 Knots).

The larger basin of Melville Water provides the longest fetches within the lower Swan Canning system. In combination with the strong winds experienced in the area, the KFF is one of the more energetic areas of the lower Swan Canning system. The region from the Groynes south to the Sea Scouts is the most exposed wave area of the region, with the central area of Como Beach being the most energetic. Some slight deviations in this can occur with changes in wind direction, with the Groynes area being more affected by waves from the South West and the Sea Scouts area being more affected by waves form the North East.

3.2.3 Wave Heights

Wave heights in the area have been estimated over several studies. The discrepancies are due to variations in the wind strength and water depths used in the calculations.

The wave climate at the KFF during these significant events can be seen to be reasonably large for a low energy environment. It is important to note that wave heights are still of the order of 1 m within a 10 year ARI event. In addition to severe events, regular sea breeze events of the order of 20 to 30 knots blow

regularly from the West to South West over Melville Waters generating waves that impact the study area (Table 6).

Table 6: Wave heights at Kwinana Freeway Foreshore

Study	Location	10 Yr ARI	50 Yr ARI	100 Yr ARI
MRWA (2004)	Como		1.1	1.1
Eliot (2003)	Cale St	1.28		1.46
	Eric St	1.72		1.92
	Milyu	1.09		1.26
URS (2013)	Cale St			0.9
	Judd St			1.2

3.2.4 Water Levels

Sea levels are a function of a number of processes occurring over a multitude of timescales. Given the nature of the lower Swan Estuary, there is a direct link between oceanographic levels off Fremantle and those along the KFF. In addition to the water levels off Fremantle, there is some internal basin dynamics (such as wind set up) which also affect the water levels off the study area. Some of the more dominant processes affecting water levels include:

- Astronomical Tides.
- Storm Surge and Atmospheric Processes.
- Oceanographic Processes.
- Wind Set up.
- Wave Set up.
- Wave Run up.
- Riverine Flow.

Some of the major processes affecting sea levels are of a short time scale, such as atmospheric affects, however others are of longer time scales of the order of years. The ranges of these various processes vary from year to year. Typical ranges for the processes are shown in Table 7 (Pattiaratchi & Eliot 2005).

The Leeuwin Current affects water levels on a yearly basis, with generally higher water levels over the winter months off Fremantle (May to July) and a decreased water level over the summer months.

Table 7: Times Scales of Sea Level Processes South West Australia

Time Scale	Process	Range
12 – 24 hours	Astronomical Tide	0.8 m
1-10 days	Storm Surge & Atmospheric Effects	-0.3 m to + 0.8 m
Seasonal	Leeuwin Current	0.3
Inter – annual (typically 4 – 7 years)	El Nino – Southern Oscillation	0.3

There are tide gauges at Fremantle and Barrack Street. Fremantle has one of the longest water level records in Australia. Barrack Street tidal gauge has been operated by the WA Department of Transport for approximately the last 20 years.

Due to restrictions in flow through Blackwall Reach, some of the shorter period storm surge events are attenuated between Fremantle and Barrack Street. However, longer water level signals have a direct impact on water level signals within the Swan Canning system. This means that a rise in mean sea levels off

Fremantle will result in a directly proportional rise in mean water levels within the Swan Canning Estuary. The Department of Water and URS (DoW and URS 2013) found that some attenuation of the tidal range would occur between Perth Waters and Melville Waters due to the constriction at the Narrows.

3.2.5 Tidal Planes

Tidal levels for Barrack Street and Fremantle are provided in Table 8 (in relation to Australian Height Datum).

Table 8: Tidal Planes for Barrack Street and Fremantle

Location	HAT	MHHW	MSL	MLLW	LAT
Barrack Street	0.55	0.19	-0.03	-0.22	-0.42
Fremantle	0.58	0.20	-0.01	-0.23	-0.56

The tidal planes indicate that there is a slight attenuation between Fremantle and Barrack Street, however given that Barrack Street is upstream of the Narrows and the Narrows is a major flow restriction point, it is expected that during the majority of marine surge scenarios that the KFF would largely experience water levels similar to that of Fremantle.

3.2.6 Storm Surge

The KFF is affected most during a combination of high water levels and strong winds. The reclaimed beach profile of the area has a shallow terrace, with a steeper sloped upper bank section. This beach profile is vulnerable to higher water level storm events, when the active zone moves onto the higher, steeper sloped upper bank. These beaches are characterised by episodic event based erosion, in which the higher water levels and wave action generated by the storm surges and strong winds significantly erode the upper bank.

Some accretion occurs during lower energy periods, however this is primarily limited to the lower terrace as the water levels and active zone are not high enough to replenish the upper bank. Accretion of the upper bank is limited. Material deposited onto the terrace is subject to alongshore and cross shore current processes which mobilise the sediment and shift it along the foreshore. Structures along the KFF have aimed to capture and slow some of these alongshore sediment processes in order to maintain these beaches.

The highest water level recorded at Barrack Street occurred during a storm in May 2003. This storm recorded a water level at the Barrack Street tide gauge of +1.16 m AHD and Fremantle of +1.22 m AHD.

Given that there is some attenuation of water flow through the Narrows, in addition to wave and wind set up on the wide and shallow KFF, it is likely that the water level offshore from the study area was slightly higher than that at Barack Street.

3.2.7 Extreme Water Levels

A summary of expected marine surge ARI water levels for both Fremantle and Barrack Street is provided in Department of Water (DoW and URS 2013). The tidal record at Fremantle is approximately 100 years long, with reliable measurements available since 1950. The tidal record at Barrack Street is based off approximately 20 years of water level measurements. It is generally accepted that the ability to predict ARI events is limited to approximately twice the duration of the record analysed. Assuming 20 years of measurements were analysed for the derivation of the extreme value water levels at Barrack Street, care should be taken when using ARI values above approximately 50 years (Table 9).

Table 9: Estimated marine ARI Events

Annual Return Interval (Years)	Fremantle (m AHD)	Barrack Street (m AHD)
1	0.87	0.84
2	0.94	0.92
5	1.03	1.01
10	1.10	1.08
20	1.16	1.15
50	1.24	1.23
100	1.30	1.29
200	1.36	1.35
500	1.43	1.43

3.2.8 Flood Levels

DoW and URS (2013) undertook a comparison of the impacts on water levels of riverine floods and marine surge events on the lower Swan Canning Estuary.

Present day simulations by DoW and URS (2013) indicate that the 100 year riverine flood would still slightly exceed the 100 year storm surge event on the lower Swan and Canning Catchment with a level of approximately +1.36 m AHD along the KFF. This exceeds the previous 1982 Swan River Flood Study which estimated the level as +1.15 m AHD along the majority of the KFF and +1.17 m AHD near Mt Henry Spit.

Present day 100 year ARI marine surge events were estimated as +1.29 m AHD along the KFF (Table 10).

Including wind set up, Table 11 outlines the total water levels that would be expected along the foreshore. In addition to these levels, there may be some degree of wave set up and wave run up. No specific details of wave set up or run up levels are provided within the DoW and URS (2013) report.

This study has a medium term focus of the next 20 to 30 years. As outlined in the Climate Change Section of this plan (Section 3.2.9), an appropriate allowance for mean sea level increases for the next 30 years to 2040 is 0.15 m. Estimated 100 year ARI water levels at present day, 30 years and 100 years with climate change mean sea level adjustments made are detailed in Table 12.

Climate change is also expected to affect weather and rainfall patterns. Changes to weather and rainfall patterns may affect extreme flood levels for the region. These are not analysed as part of DoW and URS's study.

Table 10: Estimated 100 Year ARI Event water Level (Maximum Marine Surge or River Flood plus Wind Set Up)

Location	Present Day 100 Yr Annual Return Interval Water Level
Narrows	1.51
Como	1.47
Canning Bridge	1.46
Mt Henry Spit	1.44

3.2.9 Climate Change

Sea level rise within the coastal waters of WA and its application to coastal planning is addressed within the document prepared by the Department of Transport (DoT 2010). Information within this document was largely derived from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, released in 2007 and the Commonwealth Science and Industrial Research Organisation (CSIRO) technical report "*Climate Change in Australia"*. CSIRO provided a regional assessment of observed climate change around Australia, the likely causes and projections of future changes to Australia's climate.

DoT summarised these broader studies in context of Western Australia and the implications for coastal planning. As a result, the following graph was provided in order to provide appropriate allowances for sea level rise to 2110 (Figure 5).

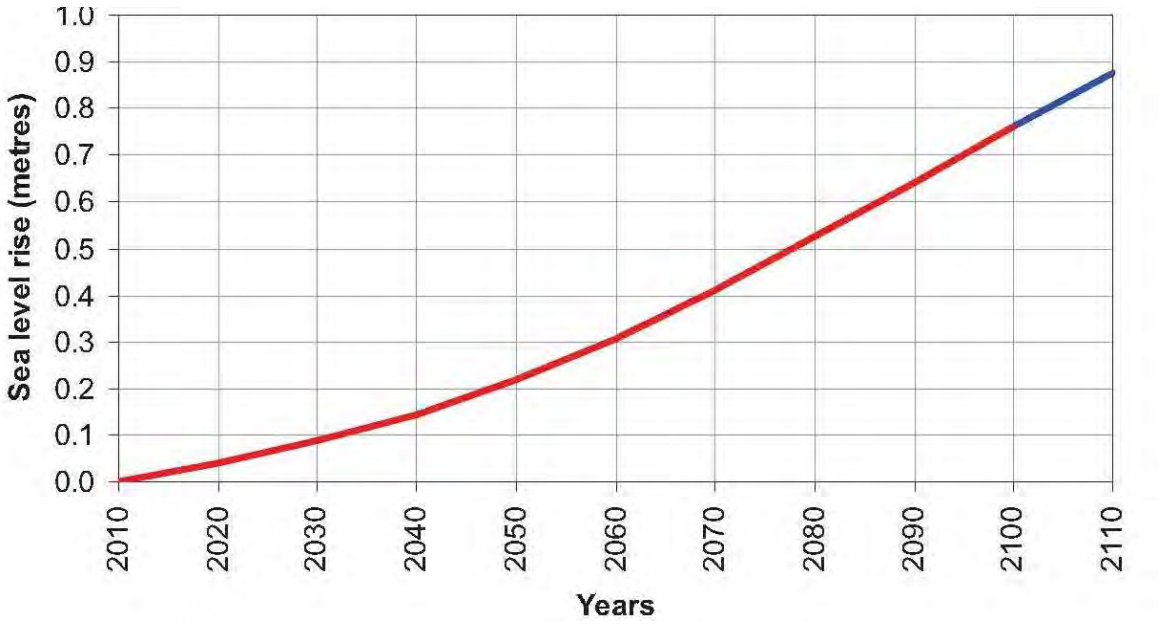

Figure 5: Recommended allowance for sea level rise in coastal planning in WA (red line SRE scenario A1FI 95th percentile after Hunter (2009), normalised to 2010, blue line continuation of scenario to 2110)

This shows that a sea level rise of approximately 0.4 m is expected by 2070 and a 0.9 m rise would occur by approximately 2110. DoW and URS 2013 modelled a number of climate change scenarios. Present day, + 0.4 m,+ 0.9 m +1.2 m. This foreshore management plan has a medium term focus of the next 20 to 30 years. Therefore, during this time, it would be expected that sea levels would rise approximately +0.15 m by approximately 2040.

The recent Fifth Assessment Report released by the IPCC (IPCC 2014) indicate that they have increased their confidence in projections of mean sea level rise because of improved physical understanding of the components of sea level, the improved agreement of process based models with observations and the inclusion of ice sheet dynamical changes. Over the range of different emissions scenarios modelled, the estimate of global mean sea level rise to 2100 will be in the range of +0.26 to +0.98 m relative to 2005. The likely range (95th percentile) of the highest emissions scenario RCP 8.5 is +0.45 to +0.82 m with a mean of 0.63m. Sea level rise is not predicted to be linear, and the likely range of sea level rise for this RCP 8.5 scenario by 2065 is 0.22 to 0.38 with a mean of 0.30 m.

The policy for the allowance of sea level change in coastal planning adopted by WAPC is still consistent with these latest reviews on mean sea level increases.

Global sea level rise will not be uniform. IPCC (2014) suggest that it is expected 70% of the world's coastline will have a value within 20% of the global mean sea level. Climate change may also affect weather patterns and storminess, which may further alter extreme water levels for the region. These are not analysed as part of DoT's study.

Table 11: Future Estimated 100 Year ARI Event Total Water Level (Maximum Marine Surge or River Flood Plus Wind Set up) (DoW 2013)

Zone	Present Day 100 Year Annual Return Interval Water Level (m AHD)	2040 100 Year Annual Return Interval Water Level (plus +0.15 m) (m AHD)	2110 100 Year Annual Return Interval Water Level (m AHD)
Narrows	1.51	1.66	2.29
Como	1.47	1.62	2.26
Canning Bridge	1.46	1.61	2.25
Mt Henry Spit	1.44	1.59	2.23

Increasing mean sea level by +0.15 m would see the 20 year ARI marine surge event at Barrack Street increase in frequency to the 5 year ARI. Correspondingly, the 100 year ARI marine surge event would increase in frequency to the 20 year ARI event. For context, this is the equivalent of the 20 year ARI May 2003 marine surge event within the Swan River occurring on a 5 year basis rather than a 20 year basis.

This May 2003 event is the highest recorded total water level at the Barrack Street Tidal gauge. The event caused widespread flooding of Riverside Drive and disruption to the northbound lanes of the Kwinana Freeway. There was significant damage along the Como Beach Foreshore and erosion of the Western Foreshore. The storm also caused significant coastal erosion along the metropolitan Perth and regional south west coastlines. It is noted that many of the items of infrastructure were damaged as a result of poor maintenance, structures at the end of their service life or not designed to withstand the exposed conditions and wave loads. Photos taken after the peak of the storm from Thelma Street footbridge can be seen in Plate 1. Damage at Como Beach as a result of the storm can be seen in Plate 2.

Plate 1: Photos After the Peak of the May 2003 Storm. Thelma Street Footbridge looking South and North.

Plate 2: Damage at Como Beach after May 2003 storm.

Climate change is also expected to affect weather patterns. Changes to weather patterns and storminess may affect extreme water levels for the region. These are not analysed as part of DoT's study. Within IPCC (2014) they note that while changes to tropical cyclone occurrence and that of other severe storms are potentially important, regional changes to these phenomena cannot be predicted with medium confidence as yet. It is generally accepted that for the southwest of Australia, rainfall events are expected to become fewer due to a reduction in the total volume of winter precipitation due to a reduction in the number of winter cold fronts crossing the coast. This may suggest that the actual number of winter storms that affect the Swan River may be reduced. Dominant weather patterns that would cause large scale erosion along the KFF may shift to high water levels and strong winds associated with decaying tropical cyclones or severe summer thunderstorm events rather than winter cold fronts. Perth's climate may shift to being more similar to that of the mid west.

3.2.10 Geomorphology and Soils

Geomorphology

Perth is situated on the Swan Coastal Plain, part of which comprises of three dune systems of Aeolian dunes. South Perth lies on the junction of the older two of these, the Spearwood and Bassendean dune systems. The Swan and Canning Rivers occupy the interdunal depressions and over thousands of years as the rivers have meandered, alluvial sediments have accumulated along these courses to depths of hundreds of feet. Alluvial soils are normally exposed along river banks, however along the KFF most of the natural alluvial soils were buried under estuarine dredge spoil placed as reclamation for the Kwinana Freeway. The Cloisters zone is one of the only areas within the study area where alluvial soils are present.

The majority of the land in the study area is reclaimed from dredging which occurred in the adjacent near shore regions. Rectified aerial images overlaid on each other are useful for comparing the 1953 pre KFF with aerial images from 2008 (Figure 6). This shows that foreshore between the Narrows and Canning Bridge is all reclaimed dredge fill. Milyu Nature Reserve as it stands today did not originally exist. The shoreline has been heavily modified through reclamation and structures.

Figure 6: 2008 Aerial image with 1953 aerial image inset

As part of the initial reclamation works for the Kwinana Freeway and the construction of the groynes, this foreshore area was supposed to be renourished on a regular basis, however this did not occur except for a large exercise in the 1970's (Damara 2014).

Since this initial renourishment, the shoreline has been effectively eroding, with varied rates of erosion. Structural intervention has occurred along the majority of the northern portion of the KFF and the shoreline has responded to these structural elements. Due to the continued erosion and movement of material, a large number of these structural solutions are also experiencing more energetic conditions, increasing maintenance requirements of the structure or in some cases causing failure of the structures.

Renourishment of the KFF has been explored in the recent report published for the Trust titled "*Feasibility Study of Options for Beach Renourishment Swan and Canning Rivers*" (Damara 2014). This report explores possible options for renourishment, including trucking or dredging and estimates possible costs. This report does not explore additional benefits of renourishment, including reducing requirements for maintenance on the existing structures and reduce requirements for additional crown walls (Damara 2014).

Soils

The entire study area is part do the Spearwood land system (Department of Agriculture and Food Western Australia 2006). It is further divided into 2 subsystems:

- S14: Sand – pale grey to white, medium-grained sub-angular, quartz and feldspar, well sorted, abundant whole and broken bivalves and gastropod shells, of alluvial origin
- S7: Sand, pale and olive-yellow, medium to coarse-grained, sub-angular to sub-rounded quartz, trace of feldspar, moderately sorted, or residual origin

Almost the entire site is S14 and rated Moderate to Low Risk Acid Sulphate Soils (ASS).

A section of south of the Manning Road and north of Aquinas Collage is S7 and rated as having no known risk ASS.

The geomorphology of the study area is presented in Map 1 in Appendix Two.

3.2.11 Hydrology

Hydrodynamics

The hydrodynamics and hydrology of the Swan Canning System was changed from a generally freshwater system to a saline estuarine system with the initial removal of the limestone bar and sand shoals at the river mouth for the creation of Fremantle Harbour in 1892.

The Swan Canning River System is a low energy environment, with hydrodynamics of certain locations varying according to location within the estuarine system. As is typical with an estuarine watery body, the general dominant processes change from runoff dominated behaviour in the upper reaches (Swan/Avon River System & Canning River), to wind and wind wave driven behaviour in the larger basins and tidal exchange through the entrance channel.

Due to the microtidal environment, tidal flows are strong in the entrance channel only (downstream from Point Walter Spit/ Blackwall Reach). Tidal currents at the restriction at Fremantle traffic bridge have been recorded at up to 0.9 m/s (~1.7 knots). Flows within Melville Water and Perth Water are much slower than this, although there are some higher velocities at the restrictions at the Narrows and Canning Bridge.

The Swan Canning System is saline from Fremantle up the Swan River beyond Belmont and up the Canning River to Kent Street Weir.

Hydrology

The hydrological conditions of Perth's metropolitan waters change seasonally, depending on the volume of freshwater river flow. The system is primarily estuarine, with saline pushing in through the ocean entrance. The salt wedge pushes upstream beyond Belmont, significantly upstream from the study area. Salinity within the Swan Canning system increases over the summer months due to a lack of rainfall and high rates of evaporation.

The Cloverdale ground water mound lies east of the South Perth foreshore between the Swan and Canning Rivers. The groundwater mound drains both westward and eastward towards both rivers. On the KFF, the groundwater level is close to the surface. It is likely that a salt wedge would exist beneath the near shore groundwater table.

At low tidal periods, groundwater drainage through the foreshore area is clearly evident.

Basic groundwater balance calculations within the City's WSUD guidelines (Aurecon 2012) suggest that the annual extraction rates exceed the recharge rates of the aquifers underneath the City. In addition to the extraction rates exceeding the recharge rates there will be increases in the total impervious areas as the City develops, This suggests that long term depletion of the aquifers underneath the City is occurring.

3.2.12 Water Quality

The City has developed two important plans in order to manage and improve water quality within the catchment boundaries of the City and to improve final water quality entering the Swan and Canning River systems. These management plans are:

- JDA and Ecoscape (2004) *City of South Perth Integrated Catchment Management Plan*
- Aurecon (2012) *Water Sensitive Urban Design Guidelines and Plans for the City of South Perth*.

Integrated Catchment Management Plan

This Integrated Catchment Management Plan (ICMP) considers ways in which water quality can be managed utilising best management practice and innovative approaches in flood mitigation, infrastructure management, land rationalisation and ecological management.

Water Sensitive Urban Design

The City has developed Water Sensitive Urban Design (WSUD) Guidelines in order to manage and improve water quality and runoff from all new developments. WSUD Guidelines for the City (December 2011). Over time, this will lead to a general improvement of the water quality within the City. The objectives of the guidelines are to:

- Assist in the protection and/or enhancement of the environmental values of the Swan and Canning Rivers and other watercourses, consistent with the requirements of the Swan and Canning Rivers Management Act 2006.
- Ensure Water Sensitive Urban Design best management practices are implemented for all new development proposals and City operations to minimise the export of nutrient, sediment and other pollutants to the Swan and Canning Rivers and watercourses.
- Ensure WSUD best management practices are implemented for all new development proposals and City operations to maximise the use of captured lot (roof) rainfall and grey water to reduce the reliance on external resources.
- Protect and where possible, restore and enhance the environmental, economic and social (i.e. recreation and scenic) values of the City's waterways and protected wetlands.
- Retain and or enhance open drains by converting them to living streams in multiple use corridors that provide habitat for wildlife and passive recreation opportunities wherever possible.

- Ensure stormwater within the urban environment is retained and treated as close to source as possible.
- Reduce nuisance flooding and adverse drainage impacts.

In addition to the surface and groundwater improvements being aimed for by the City, the Trust has a Swan Canning Water Quality Improvement Plan and undertakes weekly monitoring at approximately 30 sites within the lower Swan Canning system as a part of their Estuary Water Quality monitoring and reporting. Two of these locations are within Melville Water, with another at Canning Bridge and another at Salter Point, slightly upstream of Mt Henry Bridge.

The Trust monitors the following as a part of their Estuary monitoring program:

- Phosphorus (total, soluble reactive).
- Nitrogen (total, oxidised and dissolved organic).
- Dissolved organic carbon.
- Silicon dioxide.
- Chlorophyll-a.
- Total suspended solids.
- Dissolved oxygen.
- Salinity.
- Water temperature.
- pH.
- Electrical conductivity.
- Algal abundance and community composition.

The Department of Water also monitors a number of groundwater wells within the South Perth catchment, major tributaries to the Swan and Canning Rivers and a number of other surface water sites within the City.

The City also allocates funding to its own water quality program that is undertaken in partnership with SERCUL (testing water quality of the major City's water bodies and drainage inlets and outlets). The City engages local schools in water quality testing and monitoring via Schools Nature Nurturing program that is facilitated in partnership with Millennium Kids (a non for profit organisation).

3.2.13 Bathymetry

Recent surveys undertaken by the Department of Transport and the Trust in 2010 surveyed large areas of the lower Swan Canning system in high detail. This provides an accurate map of the river bathymetry. From this survey, historical clues to the rivers previous characteristics are visible. It appears that a deeper channel exists through Melville Water, with depths of the order of -10 m AHD or greater. The wide shallows of the KFF appear to be a previous floodplain of this central river through Melville waters.

The bathymetry immediately offshore of the KFF has been heavily modified by the dredging of Melville Water. A history of dredging on the river is provided in Riggert (1978) and is additionally summarised in Damara 2014. This suggests that some 3.2 million cubic meters of material have been dredged out of the Swan River for various requirements. Aerial photos from 1953 and 1965 clearly show the dredge pockets along the KFF (Figure 7 and Figure 8).

Some of the dredge material and shell grit recovered from the riverbed was used for road making in South Perth. In the late 1950's in order to construct the Kwinana Freeway, significant dredging occurred along the KFF. Some of the dredge pockets are still easily seen in aerial images of the study area.

In general, the shallows in front of the study area range from 0 m AHD to -1 m AHD. The wide shallow terrace of Milyu extends from approximately Judd Street to the Sea Scouts at Cale Street. The northern

area from Judd Street to the Narrows is generally deeper, being of the order of -2.5 to - 4 m AHD. The Canning River is generally of the order of -2 m AHD deep, with a shallow section in the vicinity of Mt Henry Spit.

Figure 7: 1953 aerial image showing locations of initial freeway dredging

Figure 8: 1965 aerial image showing locations of secondary freeway dredging

3.2.14 Landscape

Construction of the Kwinana Freeway and PSP has limited access to the river foreshore for South Perth residents, reduced the width of the foreshore and destroyed the original fringing vegetation. The shoreline between the Narrows and Canning Bridge is predominantly reclaimed and along the majority of its length is protected by some form of structural element to protect the adjacent infrastructure.

The City has undertaken extensive revegetation works along the KFF in order to enhance the area and return some of the original values of the area to the now reduced foreshore. Two areas of remnant vegetation still exist at Cloisters and Mt Henry. The City is managing these areas in order to preserve these original remnant vegetation areas. Milyu Nature Reserve has also been the focus of revegetation programs over the years. Further information of the management of these areas is detailed in:

- Ecoscape (2002) *Mt Henry Peninsula Foreshore Management Plan*
- Natural Areas Consulting (2013) *Milyu Rehabilitation Plan*
- Syrinx Environmental (2013) *Mt Henry Spit Restoration Plan.*

Given that the current foreshore between the Narrows and Canning Bridge is reclaimed from its original position approximately 80 m eastward, the foreshore is generally experiencing erosion along its whole length. The City, DPaW and MRWA have undertaken significant vegetation works to try and enhance the study area and provide an increased resistance to foreshore erosion.

The shoreline south of Gentilli Way Boat ramp is generally a relatively natural shoreline edge down to Mt Henry Spit. There has been some soft stabilisation works undertaken between Edgewater Street and the northern end of the Spit management zone in order to reduce effects of boat wash on the shoreline edge.

3.3 BIOLOGICAL ENVIRONMENT

3.3.1 Vegetation

Vegetation Condition

Very little actual natural vegetation remains in the study area. Over a third (38.6%) of the study area has been cleared and landscaped. Most of this is landscaping is lawn and recreational facilities, however plantings of local and exotic trees and shrubs have also been carried out.

Some pockets of remnant vegetation communities still occur in the southern half of the study area where the land becomes wider than 50 m. A third of the remnant vegetation was Degraded to Completely Degraded 33.9%), however about a quarter (27.6%) were Good to Very Good (Table 12). The main cause for the degradation is the edge effects, mostly from storms, tides and rising water salinity. Other causes include weeds, clearing and trampling. Revegetation efforts have been carried out to help improve the vegetation in some sections.

Table 12: Keighery (1994) vegetation condition of Kwinana Freeway Foreshore

Vegetation Condition	Ha	%
Excellent	0	0
Very Good	3.6	14.8
Good	3.1	12.8
Degraded	8.0	33.1
Completely Degraded	0.2	0.8
Landscaped	9.3	38.6

The locations of remnant native and their vegetation condition are illustrated in Map 2 in Appendix Two.

Vegetation Complexes

The most northern tip of the study area is Vasse Complex (Heddle *et al*. 1980). The section directly south, approximately between the ski ramp and Preston St Como, is Karrakatta – Central and South. The vegetation south of Preston St is Bassendean – Central and South. The descriptions of the communities are summarised in Table 13 and their distributions illustrated in Map 3 in Appendix Two.

Table 13: Vegetation Complexes in Kwinana Freeway Foreshore (Heddle 1980)

Name	Description
Vasse	Vegetation ranges from woodland of *Eucalyptus marginata - Allocasuarina fraseriana - Banksia* species to low woodland of *Melaleuca* species and sedgelands on the moister sites. This area includes the transition of *Eucalyptus marginata* to *Eucalyptus todtiana* in the vicinity of Perth.
Karrakatta – Central and North	Predominantly low open forest of *Eucalyptus gomphocephala - Eucalyptus marginata - Corymbia calophylla* and woodland of *Eucalyptus marginata - Banksia* species
Bassendean – Central and South	Vegetation ranges from a low open forest and low woodland of Banksia species - *Eucalyptus todtiana* to low woodland of *Melaleuca* species, and sedgelands which occupy the moister sites

Significant Vegetation

The foreshore area south of the Gentilli Way horseshoe bridge is a Bush Forever Site (Mount Henry Bushland, Salter Point, No. 227). The 11.9 ha bushland is an important bushland canopy linkage to the east and is part of a regionally significant contiguous bushland/ wetland linkage. The reserve is considered to be within an area of considerable conservation and landscape, as it is one of the few bushland areas in the Canning Estuary (Government of Western Australia 2000).

The Implementation Recommendation for this reserve is provided below:

> *"Site with Some Existing Protection The existing control and management intent of the reserve is endorsed. The purpose of the reserve should be amended to include conservation and appropriate mechanisms applied in consultation with the management body*."

3.3.2 Flora

Conservation Significant Flora

A DPaW Nature Map search listed the following four significant flora were recorded in or near the study area (Table 14). All four species are priority flora. No state of Commonwealth listed significant flora is known to occur in the study area.

Table 14: Conservation significant flora recorded in or near Kwinana Freeway Foreshore

Scientific Name	Common Name	EPBC	DPaW
Acacia horridula		-	P3
Dodonaea hackettiana	Hackett's Hopbush	-	P4
Dillwynia dillwynioides		-	P3
Thelymitra variegata	Queen of Sheba	-	P3

Weeds

Weed inventories were collated from previous reports and the field assessment. A total of 96 weed species were recorded. However, it must be noted that this list is not exhaustive and additional weed species may be present at different times of the year. An additional nine weed species have been included in the inventory as they may occur in the study area, increasing the total to 105 species.

Priority Weed Species Method

The priority ratings of each weed species were determined after examining:

- The ratings under the:
  - Swan Natural Resource Management (2008b) *DEC Swan Region – Environmental Weed List*: *Environmental Weed Census and Prioritisation* (EWCP).
  - Department of Conservation and Land Management (CALM 1999a) *Environmental Weed* Strategy *of Western Australia* (EWSWA).
  - Dixon and Keighery (Dixon & Keighery 1995) *Recommended methods to control specific weed species.*
- Whether it was listed as a:
  - Declared plant under the Department of Agriculture and Food (2013) *Biosecurity and Agriculture Management Act (BAM).*
  - Weed of National Significance (WONS) (Weeds Australia 2012).
- Its local significance to the natural areas.

The full methodology for determining the priority of each weed species, and associated calculations for each reserve, is presented in Appendix Three.

A total of 34 species were determined to be High Priority to control (Table 15).

Table 15: High Priority weed species at Kwinana Freeway Foreshore

Common Name	Scientific Name
African Love Grass	*Eragrostis curvula*
Arum Lily	*Zantedeschia aethiopica*
Black Flag	*Ferraria crispa*
Blue Lupin	*Lupinus cosentinii*
Bridal Creeper#	*Asparagus asparagoides*
Buffalo Grass	*Stenotaphrum secundatum*
Couch	*Cynodon dactylon*
Doublegee	*Emex australis*
Fingerleaf Oxalis	*Oxalis glabra*
Freesia	*Freesia alba x leichtlinii*
Geraldton Carnation Weed	*Euphorbia terracina*
Great Brome	*Bromus diandrus*
Guildford Grass	*Romulea rosea*
Hare's Tail Grass	*Lagurus ovatus*
Japanese Pepper Tree	*Schinus terebinthifolius*
Kikuyu	*Cenchrus clandestinus*
Lantana	*Lantana camara*
Olive	*Olea europaea*
One-leaf Cape Tulip	*Moraea flaccida*
Pampas Grass#	*Cortaderia selloana*
Perennial Veldt Grass	*Ehrharta calycina*
Petty Spurge#	*Euphorbia peplus*
Pigface	*Carpobrotus edulis*
Rose Pelargonium	*Pelargonium capitatum*
Salt Water Couch	*Paspalum vaginatum*
Sea Barley	*Hordeum marinum*
Sea Spinach	*Tetragonia decumbens*
Soursob	*Oxalis pes-caprae*
Three-cornered Garlic	*Allium triquetrum*
Victorian Tea Tree	*Leptospermum laevigatum*
Watsonia	*Watsonia meriana* var. *bulbillifera*
Wavy Gladiolus	*Gladiolus undulatus*
Wild Gladiolus	*Gladiolus caryophyllaceus*
Wild Oat	*Avena barbata/ fatua*

Weed species may be present in study area, but has not been recorded (Syrinx 2013)

Plant Disease Threats

There are no known plant diseases recorded in the study area. However, the study area has not been formally assessed as no symptoms of diseases have been observed to warrant such an assessment.

There are three main diseases that may threaten the Kwinana freeway foreshore, which are outlined below.

Dieback (Phytophthora cinnamomi)

There are 15 Phytophthora species in Western Australia. These are soil-borne water moulds that kill a wide selection of plant species of the south west of Western Australia. As Phytophthora is a parasite, it requires a living host on which to feed and extracts its food by a mass of thread-like mycelium, which forms the body of the organism. Phytophthora is a water mould that kills its host by girdling the base of the stem, destroying the roots and depriving the plant access to nutrients and water. The most significant Phytophthora species is *Phytophthora cinnamomi*. The life cycle of this Phytophthora requires moist, non-alkaline conditions that favour survival, sporulation and dispersal (Murray 1997).

Honey Fungus (Armillaria luteobubalbina)

Armillaria luteobubalbina (Honey Fungus), is a toadstool-producing parasitic fungus that lives off both live and dead hosts and is native to Western Australia. It commonly occurs in the south-west of the state and unlike *Phytophthora cinnamomi* is not restricted by soil or landform types. It occurs in woodlands, forests, scrublands and parks on a wide variety of eucalypts and other plants such as *Acacia*, *Agonis*, *Banksia*, *Bossiaea*, *Grevillea*, *Hakea*, *Trymalium* and *Xanthorrhoea*. In some circumstances it can act as a virulent parasite that kills hosts including tuarts (Bougher & Syme 1998), jarrah, marri, wandoo and many understorey species. Deaths may occur as either single plants or as multiple deaths (Bailey 1995). The infection is caused by the aerial dispersion of spores, or through mycelium in root systems. Infection entry points for the spores may be provided by wounds caused by fire, broken limbs and insect damage.

Aerial Canker

Aerial Cankers are diseases caused by a group of largely air-dispersed fungi (including *Cryptodiaporthe melanocraespid*a and *Zythiostroma* and *Diplodena* species) that affect the State's flora in the south-west. Occurrence of the disease is dependent on a combination of a susceptible host, infective pathogen, infection site (e.g. pre-existing wounds) and favourable environmental conditions. Under suitable conditions the disease can cause the death of plants within 2 years (Murray 1997). Aerial canker kills twigs in the lower crown and causes lesions called cankers in the bark of the main stem and roots. Severe cankers can cause death in parts of the plants above the canker. The fungus usually enters the plant through an existing wound (insect attack or wind damage). Healthy trees not subject to stress are unlikely to be severely affected (Bailey 1995).

3.3.3 Fauna

Significant Fauna

Database searches of Department of Parks and Wildlife (DPaW 2013) *Nature Map* and Department of Environment (DoE 2013) *Protected Matters Search Tool* indicated the following conservation significant fauna may be present in or near the study area (Table 16). Wetland birds and ocean reptiles from the Protected Matters Search have been removed from removed as they are highly unlikely to occur in the study area. A total of eight birds species are protected under International Agreement as they are Trans equatorial migratory species. These species have been highlighted grey in the table.

Table 16: Conservation significant fauna recorded in or near Kwinana Freeway Foreshore

Scientific name	Common Name	EPBC	DPaW
Bird			
Actitis hypoleucos	Common Sandpiper	Migratory	International Agreement
Apus pacificus	Fork-tailed Swift	Migratory	
Ardea modesta	Eastern Great Egret	Migratory	International Agreement
Calidris acuminata	Sharp-tailed Sandpiper	Migratory	International Agreement
Calidris ruficollis	Red-necked Stint	Migratory	International Agreement
Calidris tenuirostris	Great Knot	Migratory	Threatened
Calyptorhynchus banksii subsp. *naso*	Forest Red-tailed Black-Cockatoo	Vulnerable	Threatened
Calyptorhynchus baudinii	Baudin's Black-Cockatoo	Vulnerable	
Calyptorhynchus latirostris	Carnaby's Black-Cockatoo	Endangered	
Falco peregrinus	Peregrine Falcon	Migratory	Schedule 4
Haliaeetus leucogaster	White-bellied Sea-Eagle	Migratory	
Ixobrychus minutus subsp. Dubius	Australian Little Bittern	-	Priority 4
Limosa lapponica	Bar-tailed Godwit	Migratory	International Agreement
Macronectes giganteus	Southern Giant Petrel	Endangered, Migratory	Priority 4
Macronectes halli	Northern Giant Petrel	Vulnerable, Marine, Migratory	
Merops ornatus	Rainbow Bee-eater	Migratory	International Agreement
Numenius madagascariensis	Eastern Curlew	Migratory	Threatened
Pluvialis squatarola	Grey Plover	Migratory	International Agreement
Puffinus carneipes	Fleshy-footed Shearwater	Migratory	International Agreement
Sternula nereis nereis	Australian Fairy tern	Vulnerable	
Tringa nebularia	Common Greenshank	Migratory	International Agreement
Mammal			
Hydromys chrysogaster	Water-rat	Migratory	Priority 4

Significant Habitats

The Milyu Nature Reserve and Marine Park consists of approximately 100 ha on the western side of the study area, extending out into the river in a triangular shape between Judd Street and South Terrace.

The area is used by a large number of the waders, many of which are Trans equatorial migratory species protected by agreements Australia has with Japan and China. The Park provides an important waterbird resting areas. The foreshore faces into the sea breeze, making flight take off easier and are particularly important during the day when tides are too high to permit feeding and resting at nearby Point Waylen and Alfred Cove (Department of Conservation and Land Management 1999b). The tidal flats support a rich invertebrate fauna, which provide significant feeding areas for bottom feeding fish. The shallower areas contain seagrass meadows which are important fish nurseries and feeding areas.

Feral and Overabundant Fauna

Database searches of DPaW Nature Map and DoE Protected Matters Search Tool indicated the following feral and invasive fauna may be present in or near the study area (Table 17).

Table 17: Feral and overabundant fauna in Kwinana Freeway Foreshore

Scientific Name	Common Name
Birds	
Anas platyrhynchos	Mallard
Columbia livia	Rock Pigeon
Passer montanus	Eurasian Tree Sparrow
Streptopelia chinensis	Spotted Turtle-dove
Streptopelia senegalensis	Laughing Turtle-dove
Mammal	
Canis lupus familiaris	Domestic Dog
Felis catus	Domestic Cat
Funambulus pennantii	Northern Palm Squirrel
Mus musculus	House Mouse
Oryctolagus cuniculus	European Rabbit
Rattus norvegicus	Brown Rat
Rattus rattus	Black Rat
Vulpes vulpes	Red Fox

3.4 SOCIAL ENVIRONMENT

3.4.1 Existing Infrastructure and Assets

The KFF and its adjacent infrastructure provide a vital north to south link for the movement of the population around Perth. It is the main north to south link across the Swan River, with six lanes of freeway, a major pedestrian and cyclist commuter route (Principal Shared Path) and a train line.

In addition, the entire stormwater network associated with the Kwinana Freeway and adjacent suburbs drain westwards towards the Swan or Canning Rivers. This results in a number of drainage pipes passing underneath the Kwinana Freeway in order to drain the adjacent suburbs to the Swan River. In large sections of the KFF, the freeway is slightly elevated compared to the natural surface level, which in a significant rainfall event would lead to some flooding along Melville Parade on the eastern side of the Kwinana Freeway. The study area has approximately 49 drainage elements in the form of pits and drains.

Access to the KFF has been somewhat limited by the development of these major transport assets, however the City still maintains the foreshore along the majority of the length of the study area and provides recreational assets in several locations. The current main recreational areas are the Mill Point Road Jet Ski ramp and PWC freestyle area, Como Beach and Como Jetty, Sea Scouts, and Gentilli Way Boat Ramp. Access to the KFF is predominantly limited to pedestrian or cyclist traffic and is via the Narrows Bridge, Mill Point Road, Canning Bridge, Mt Henry Bridge and six other footbridges; five of which are between the Narrows and Canning Highway. Gates regulate public access to Mount Henry Spit. Gates and bollards have been installed at car parks to prevent the public from driving cars along the PSP and the foreshore.

Existing infrastructure along the KFF is a mix of City and MRWA assets. In 2012, a Memorandum of Understanding (MOU) for the maintenance of all of these infrastructure items along the foreshore was documented between the City and MRWA. This MOU identifies the ownership and maintenance responsibilities in the study area for all infrastructure assets, including drainage, river walls, sections of foreshore and any other items which may require replacement or maintenance.

The responsibilities were determined by whose asset each item of infrastructure was, or what was being protected by the item of infrastructure. For example, in the case where river walls were protecting a MRWA footbridge, the ownership and maintenance responsibility of that section of river wall is with MRWA.

In the case that a section of river wall that was providing protection to a section of the City's foreshore, then the ownership for that wall is with the City. Some sections of the foreshore are shared sections where both parties have an equal interest in the section of foreshore.

Drainage elements sometimes drain City roads only, MRWA roads only or a combination of both. The MOU documents, where known, nominate the ownership of each of the drainage elements along the foreshore. There are a small number of pipes for which the ownership is unknown. It is unclear whether these outlets have become redundant.

Recent erosion of the reclaimed KFF has highlighted the sand buffer which previously existed in front of the majority of river walls was important in reducing effects of significant weather events on the adjacent items of infrastructure. While a number of the assets are reaching the end of their service life and requiring increased maintenance, it appears that the loss of the foreshore sand buffer has increased the degradation of a number of the wall and drainage groyne assets.

The City is also currently updating its capabilities and developing a City wide Asset Management database. All items of infrastructure around the City are being incorporated into this database.

Some of the drains along the KFF have a grated structure at the outfall location which looks similar to a military “Pillbox”. This structure is important in clearing siltation at the end of the outfall pipe. The “Pillbox” allows for a build-up of water head and also allows overflow when the drainage pipes underneath are blocked by sediment. The build-up of water head increases the water pressure to assist the washout of sediment and allow the pipe to self-clean itself in heavy flow events.

Without these “Pillbox” structures stormwater would be backed up on the eastern side of the freeway across Melville Parade.

3.4.2 Current Social Environment

Reserves

The majority of the study area is comprised of four reserves:

- Reserve 21288 – Class A, without a management order, which the City is responsible for under Section 3.53 of the Local Government Act 1995, located between Gentilli Way and Roebuck Drive.
- Reserve 33803 (Milyu) – Class A, vested under DPaW for the purpose of conservation of flora and fauna, located between Lyall St and South Terrace.
- Reserve 33804 - vested in the City, located in two sections:
  - between the Narrows bridge and Lyall Street; and
  - between South Terrace and Gentilli Way.
- Reserve 45066 - vested in the City, located between Roebuck Drive and the Mt Henry Bridge.

Minor reserves include:

- 26085 and 26086, located between Cale St and Henley St.

Recreation and Facilities

The study area accommodates wide variety of on and off-shore recreational activities for the local community and commuters. The main activity is cycling along the PSP. Cyclist activity is high along the PSP with commuters travelling between Perth and southern suburbs surrounding the Kwinana Freeway. Usage can be up to 300 cyclists per hour during peak times (Department of Transport 2013).

In addition to the primary activity, the following activities have also been observed:

- Recreational cycling.
- Walking and jogging.
- Dog walking.
- Nature observation.
- Fishing.
- Jet skiing access.
- Boating access.
- Rowing.
- Skiing.
- Crabbing/ prawning.
- Picnicking.
- Canoeing.
- Nature based play.

The above activities are supported by a variety of facilities and amenities in various states of condition. The foreshore currently has the following facilities and amenities:

- Dual use path.
- Informal tracks.

- Boat ramps.
- Como jetty.
- Shade shelter.
- Barbeque and picnicking amenities.
- Bench seating.
- Grassed areas.
- Signage.
- Toilet bock and exoloo (Narrows toilet block – only open for major events due to antisocial behaviour).
- Toilet block (Como Beach).
- Fencing.

Public Access

Access to the study area is generally restricted for vehicles, especially larger vehicles and trucks. This restricted access adds significantly to the cost of doing any works along this portion of the foreshore. Traffic management costs of projects are significant, especially if closure of a lane of the freeway is required. Deliveries are generally limited to off peak times only.

Access by bicycle appears to be sufficient. Outside of the area from Thelma Street footbridge to Comer Street footbridge, pedestrian access is generally limited. Anecdotally this discourages the number of walkers north of Comer Street and south of Thelma Street. Furthermore, noise levels generated from heavy traffic discourages visitors to the study area due to the proximity of the Kwinana Freeway.

Walking along the Canning River foreshore is popular from Mt Henry Bridge to Canning Bridge. The area is generally shaded.

Dog walking is popular along the KFF, although two of the main areas have recently been lost due to the erosion of the foreshore. The two areas that now have a reduced opportunity for dog walkers are the Palms and Skinny.

The following points have been identified for the various types of access:

Public Vehicle Access

- Mill Point Road
- Gentilli Way.

Maintenance Access

Maintenance access points for use of approved personnel are as follows:

- Mill Point Road.
- MRWA Gates;
  - N1 - Judd Street On Ramp (limited height access);
  - N8 - South Terrace Gate;
  - N2 - Como Foreshore Gate;
  - N3 - Sea Scouts Gate;
  - N4 - North Canning Gate; and
  - N6 – North Mt Henry Gate
- Gentilli Way.

Footbridge Access

- Mt Henry Bridge;
- Edgewater Road;
- Gentilli Way;
- Canning Bridge;
- Cale Street;
- Thelma Street;
- Preston Street;
- Comer Street;
- Hardy Street;
- Mill Point Road;
- Narrows Bridge;
- Water's Edge Access;
- Narrows (Jet Ski Beach);
- Groynes;
- Milyu;
- Como;
- Scout;
- South Canning;
- Cloisters (limited);
- Infill (limited); and
- Mt Henry.

Commercial Operations

The foreshore is generally void of commercial operations. A transportable café used to operate within the Narrows zone, however this has not operated for several years. Opposite Cale Street, the site contains the Como Sea Scouts buildings and amenities. Access to this site is restricted by the Kwinana Freeway. Increases in the usage of the PSP also increases the risks of non experienced public members driving along the PSP to access the Scouts building. The building itself is also at a relatively low elevation and would be subject to inundation in a 100 year ARI event.

There is huge potential to cater for and connect to local commercial developments. Key local commercial developments which could have operations from the foreshore or provide alternate uses for proposed and existing structures include:

- Perth Zoo.
- Canning Precinct Development.
- South Perth train and bus station.

The following existing community and recreational based sites surrounding the foreshore could provide opportunities to assist in facilitating commercial development within the foreshore:

- Mends Street Jetty.
- Windsor Park.
- Richardson Park.
- Comer Street/ Eric Street cricket and Lawn Bowls Park.
- Melville Parade Parkland.
- Gentilli Way Overpass Park.
- Olives Reserve
- School sites including Aquinas College and Manning Primary School.

3.4.3 Indigenous Heritage

The Department of Aboriginal Affairs (formerly Department of Indigenous Affairs) (DIA 2013) *Aboriginal Heritage Inquiry System* (AHIS) online database indicated the following five heritage sites were located in the study area (Table 18). None of the registered heritage sites have restricted access.

Table 18: Indigenous Search results for Kwinana Freeway Foreshore

No.	ID	Name	Location	Type	Access	Gender Restriction
S00053	4406	Como	Off foreshore between Mill Pt Rd and South St and	Fish Trap	Open	None
S02205	3705	Foreshore Camping Ground	Entire foreshore	Camping ground	Open	None
S02548	3536	Swan River	River	Mythological site	Open	None
S20550	3538	Canning River	River	Mythological Site	Open	None
S02966	119	Winjan	Foreshore south of Canning Hwy	Historical	Open	None

3.4.4 European Heritage

The following text was adapted from Crowley (1962).

Melville Water was named in 1827 after Viscount Melville, one time First Lord of the Admiralty by Captain Stirling and other officers from the HMS Success. South Perth was settled many years after Perth, as it was difficult to access and did not have favourable farming soil. The name Como was first used for the foreshore late in the nineteenth century. The name is believed to have been taken from Lake Como, in Italy. It may also be corruption of Comer, who was an early landowner in South Perth.

Como Beach was declared a public beach in 1911. The South Perth Road Board (the forerunner of the City) providing facilities, including a light plank jetty south of Thelma Street and bathing machines at Como Reserve. Mixed bathing was not accepted until the 1920s and men were not permitted to roll their bathers down to the waist at Como, because it was a family beach. The beach continued to be a popular destination into the 1960s, with up to 40 swimming classes held a day. The beach also attracted holiday campers from the Goldfields and Wheatbelt regions.

Early transport between Fremantle and Perth was originally by river barge, sailing ship or rowing boat, and later replaced by steamboats in the nineteenth century. Ferries connected Perth, Point Belches, Mount Eliza, Como. A horse powered ferry connected Canning Bridge and Applecross. A tram service to Perth Zoo was opened in 1922. The tram was later replaced by a bus service.

The first wooden toll bridge across the Canning River was built in 1849. Convicts built a new bridge in 1892, but in time it became unsafe so another bridge was built, finishing in 1938. The Narrows Bridge and riverside drive was envisioned to connect Perth with South Perth. Result in the eventual construction of the Kwinana Freeway and Narrows Bridge which was opened in 1959.

The Old Mill at Mills Point has a long history. The original mill was constructed at Point Belches, 150 metres south of the present Old Mill, with the natural lagoon, Millers' Pool, on its west side. The Mill became disused, before becoming a hotel in 1870, then a residence in 1890, and then wine saloon and poultry farm. In 1992 it was vested in the National Trust. Floods silted up the lagoon, which was eventually filled up in 1938 to improve the scenery as part of a foreshore reclamation scheme, which altered the shape of Mill Point.

The South Perth Yacht Club was original located at Olives Reserve in Como, however the club was relocated to Coffee Point over Melville Water as the result of the construction of the nearby Kwinana Freeway.

3.5 LAND TENURE AND HOLDINGS

The Foreshore contains the following four reserves (Table 19):

Table 19: Reserves within the Kwinana Freeway Foreshore

Location	Reserve No.	Class	Vesting	Purpose	Size (ha)
Narrows	33804	C	City	Recreation	13.9
Milyu Nature Reserve	33803	A	City	Fauna conservation	4.4
South of Como Beach	26086	C	DPaW	Sea Scouts and Pedestrian Access	0.07
Sea Scouts	26085	C	DPaW	Hall leased to Sea Scouts	0.16
Cloisters	21288	A	City	Fauna conservation	2.83
Infill & the Spit	45066		City	Fauna conservation	3.95

The City's existing Department of Aboriginal Affairs Section 18 clearance for the foreshore along the Kwinana Freeway excluded a number of Lots which were held as Unallocated Crown Land. The section of land reserved for Milyu Nature Reserve is also excluded from the Section 18 approval.

The City has now rationalised these parcels of Unallocated Crown Land (nominated within the Section 18 as Lots 14, 16 and 17) into the adjacent Reserve 33804. The City is currently in discussion with DAA regarding the status of these Unallocated Crown Land parcels and how they sit within the current Section 18 approval for foreshore maintenance and rehabilitation works.

It is recommended that the City note as a condition of other Stakeholders undertaking works under the privilege of the City's existing Section 18 approval, the Stakeholders should:

- Make themselves and their Contractors aware of the requirements of the approval and ensure all activities are undertaken in accordance with the approval; and
- Provide a summary report of the activities undertaken and photographic report to the City for its records and reporting purposes.

3.6 MANAGEMENT ZONES

The study area has been separated into 12 Management Zones, according to their site characteristics and end land use. Marked bollards were installed along the PSP by the City to aid ground staff in identifying the boundaries for each Zone. The locations of all Management Zones are presented in Figure 1. The following section discusses the current status of each Zone, in terms of infrastructure, environment and social use.

3.6.1 Narrows

The Narrows Zone occurs at the most northern end of the study area, from the Narrows Bridge to where Mills Point Road terminates into a car park. The Zone is part of Reserve 33804 (vested in the City). The entire foreshore within the Zone is a City foreshore asset.

A boating ramp exists off the car park on a groyne. The foreshore north of the ramp is hard edged, while foreshore to the south is a beach (Plate 3a). The foreshore is approximately 500 m in length. There are two drains with pits along the most northern section of the foreshore. A closed down cafe (Red Box Café) still exists. The Zone primarily serves as a recreational hub; the boat ramp and car park attract jet skiing, boating and parasailing (Figure). There are a number of proposals from additional tourism operators to link tours out of the Perth Zoo (approximately 1.5 km away) to this area and the boat ramp. Sea plane rides and amphibious vehicle tours are some of the tours proposed. The Boat ramp is the main access to the Personal Water Craft (PWC) freestyle area immediately offshore. The Jet Ski West association has paid the City a nominal fee for maintenance of the ramp (Plate 3b).

The Narrows Zone can be divided into two domains (Figure 9):

- Foreshore - Very little native revegetation exists along the Narrows Zone foreshore, mostly weeds.
- Soft Landscape - The bank is simply soft landscaped with couch lawn grasses (**Cynodon dactylon*) and planted Swamp Sheoak (*Casuarina obesa*) trees. Further inland is a mixture of planted exotic trees, including Swamp Sheoak and Rottnest Island (*Melaleuca lanceolata*) trees. Common weed species recorded were Soursob (**Oxalis pes-caprae*), Sea Spinach (**Tetragona decumbens*), Buffalo Grass (**Stenotaphrum secundatum*) and Capeweed (**Arctotheca calendula*).

Plate 3: Narrows Foreshore (a) middle facing north (b) middle facing south

The northern side of the Narrows Zone is heavily affected by vessel traffic given the constriction at the Narrows Bridge. Vessel traffic and significant high water events have led to significant damage of the foreshore protection north from the boat ramp to the Narrows Bridge abutment. The existing structure is a mortared stone revetment in front of an asbestos sheet pile wall with a concrete capping slab.

The river walling around the northern end of the Narrows is currently beyond repair (Plate 4a). Some significant works are required around the northern side of the Narrows Zone. Erosion on the north-western side of the narrows Zone is at risk of undermining the current walk path (Plate 4b). The path will be required to be realigned or the foreshore protection upgraded in the near future.

The southern side of the boat ramp is a sandy beach, with grass embankment on the upper levels and limestone block retaining wall at the southern end of the beach tying into a limestone rock groyne. This beach area is in good condition and the grass protection on the upper slopes provides protection against the erosion of the upper beach face in higher water level events.

The beach section to the south of the boat ramp is held by two control points at either end, the limestone groyne and the boat ramp. This provides controls for this section of beach, and while some rotation and loss of the beach may occur during seasons, transport outside of this cell is expected to be minimal. With the ease of access to this location as well, this beach is therefore a good option for nourishment, and should be identified as a beach node area.

Plate 4: Erosion damage along Narrows foreshore a) to river walling and b) threatening footpath

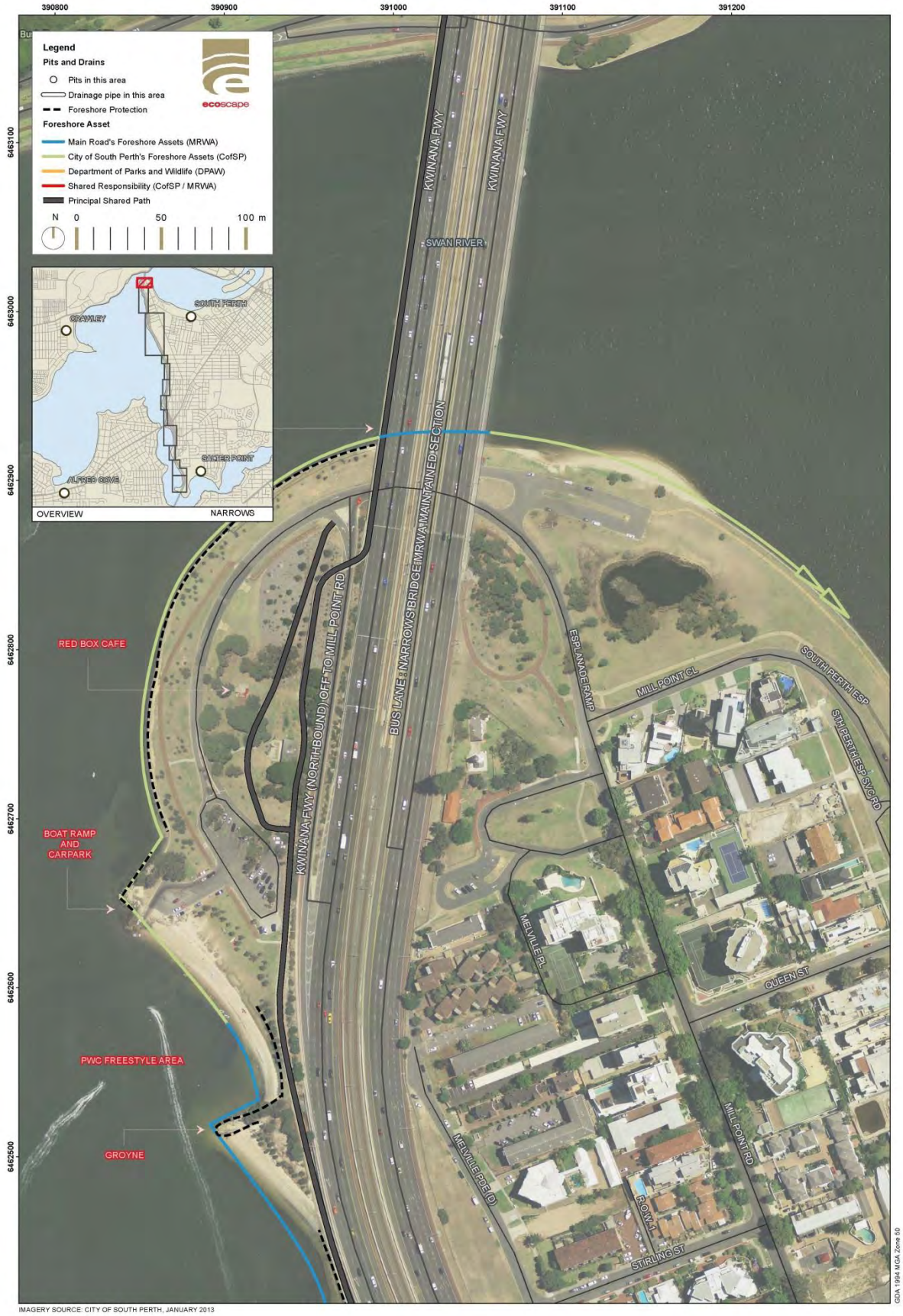

Figure 9: Narrows Zone

3.6.2 Groynes

The Groynes Zone occurs south of the Narrows and north of Lyall Street and the foreshore is approximately 900 m in length. Groynes is part of Reserve 33804 (vested in the City). The entire foreshore within the Zone is a MRWA foreshore asset. The Groynes Zone can be divided into two Domains (Plate 5):

- Foreshore: A total of five rock armoured groynes have been established in this Zone to help reduce soil erosion. Between each groyne are sandy beaches.
- Dryland: The inland is revegetated, consisting of a dense thicket of trees mostly comprising of Swamp Sheoak, Swamp Paperbark (*Melaleuca rhaphiophylla*) and the weed Victorian Tea Tree (**Leptospermum laevigatum*) which plays an important role in screening, stabilising the foreshore and providing wader bird habitat. However almost no native understorey exists, instead herb and grass weeds such as Sea Spinach (**Tetragona decumbens*), Geraldton Carnation Weed (**Euphorbia terracina*) and Hare's Tail Grass (**Lagurus ovatus*).

The Mill Point Road Freeway entrance ramp occurs between the third and fourth groyne. The foreshore adjacent to the entry ramp has a limestone block retaining wall around the base in order to provide room for the PSP and also protect the abutment. There are seven drains along this section, four of which are built with outfalls through the centre of the limestone rubble groynes. Three of the drains are just straight pipes into the river, however it is unclear as to whether these drains are redundant or not (Figure 10). The City is investigating its drainage network to investigate these structures and determine which assets can be rationalised. The rubble mound groynes have some damage to the structure and will likely require some form of repacking within the next 5 to 10 years.

Plate 5: Groyne Foreshore (a) middle facing north (b) middle facing south

Beaches within the Groynes Zone are principal roosting sites for wader birds and studies of the bird's habitats have indicated that they prefer the groynes area to Milyu (Bamford 2002). The birds appear to prefer these beaches as they are well protected from disturbances, PSP and Kwinana Freeway traffic by screening from existing vegetation (Bamford 2002). As the Groynes Zone has been shown to be a principal roosting site for the migratory wader birds it is recommended that this area is maintained as a sandy beach (Bamford 2002). Other recommendations regarding the protection and monitoring of these migratory waders are also detailed in Bamford (2002).

The City or DPaW may monitor the erosion of the beaches with respect to the roosting areas of the migratory birds. If they are concerned that the erosion of the beaches is affecting the migratory bird habitat, then the City shall alert MRWA and will require to liaise with MRWA regarding methods for the minimisation of erosion along this stretch.

The section of foreshore is identified within the MOU as an MRWA asset, however MRWA's main responsibility within the MOU is for the erosion prevention purposes. Works to solely reinstate the foreshore for the purposes of migratory bird habitat are likely to be required to be funded by the City or DPaW. Erosion issues along the Groyne Zone beaches that would affect migratory bird habitat would also be an early indicator for MRWA's assets. It is likely that some funding arrangement between the stakeholders may be required within this area.

In response to rising mean sea levels, some of the groynes may require extension and additional sand nourishment in order to maintain these beaches in the coming 30 plus years.

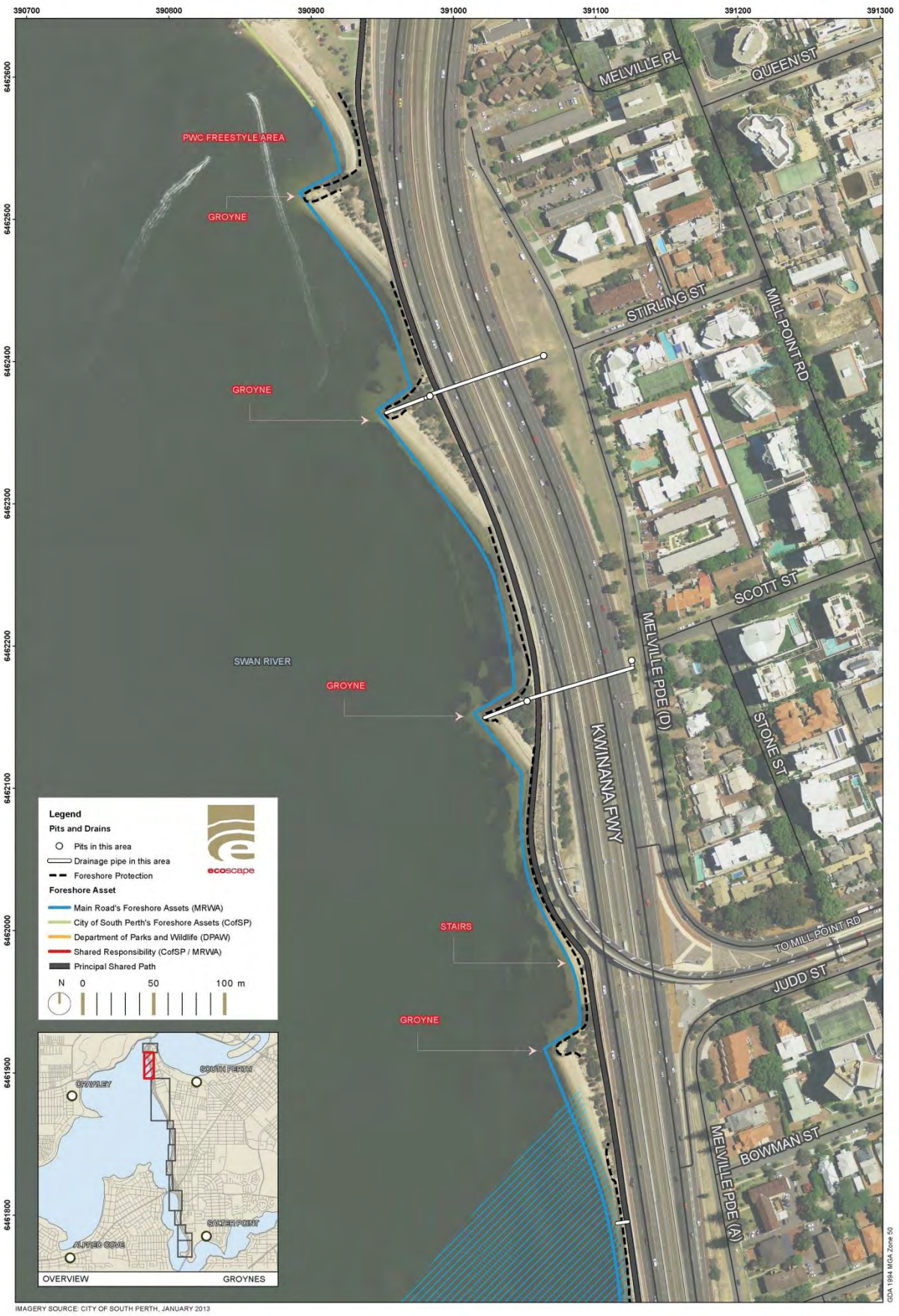

Figure 10: Groyne Zone

3.6.3 Milyu

Milyu occurs between Lyall Street and South Terrace and the foreshore is approximately 1.5 km in length. The Zone is adjacent to Richardson Park and Royal Perth Gold Club. The entire foreshore within the Zone is a DPaW foreshore asset. There are five drains and six pits along the foreshore. The main items of infrastructure through Milyu are the PSP, Kwinana Freeway and drainage elements. Seven drains exist along this section of the foreshore. Ownership of these drains are outlined within the MOU between the City and MRWA (Figure 11).

The entire foreshore of Milyu is a sandy beach (Plate 6). Limestone groynes exist at the northern end of Milyu and act to maintain the beach areas to the south by reducing longshore transport at the site. It is important to note that the whole of the Milyu foreshore has been reclaimed as part of the Kwinana Freeway widening projects in the late 1950's and again in the 1970's. All of the vegetation along this stretch has been planted since the creation of the Freeway in the late 1950's. The site has generally being eroding since.

Plate 6: Milyu Foreshore (a) middle facing north (b) middle facing south

Milyu has four domains:

- Foreshore - sparsely vegetated with samphires and sedges *Cyperus gymnocaulos* and *Juncus kraussii*.
- Transitional - a narrow band that serves as a change in site and vegetation between the foreshore and inland. It is subject to high tides, making it frequently subjected to inundation and water logging. Vegetation is mostly understorey sedges *Juncus kraussii Cyperus gymnocaulos* and *Suaeda australis*.
- Dryland - primarily dominated by water tolerant trees *Casuarina obesa* and *Melaleuca cuticularis*. Some sections more inland contain understorey trees *Acacia saligna*, *Hakea prostrata* and *Jacksonia furcellata*. Common weed species recorded were Black Flag (**Ferraria crispa*), Wild Radish (**Raphanus raphanistrum*) and Pig Face (**Carpobrotus edulis*).\
- Wetland: Stormwater drains form a vital source of freshwater for local wildlife and was identified as one of the main features providing breeding for Black Swans (bringing back the Swans). Some of the drains along Milyu have appeared to form some small wetland type habitats (Plate 7).

The Milyu site has generally appeared to recede, especially the salient offshore from Richardson Park. Milyu itself has seen to lose significant stands of sedges over recent years, resulting in the Zone having a Degraded condition. This has led to a revegetation program being implemented by DPaW and funded by MRWA, to try and increase the foreshores resilience against severe erosion (Natural Area Consulting 2013).

Plate 7: Stormwater drains forming wetland type habitats in Milyu

Milyu Nature Reserve is an A Class Reserve (33803) vested under DPaW, adjacent to the Swan Estuary Marine Park. Both of these areas are an important site to resident and migratory birds. For more on the Marine Park and Reserve, please refer to Section 3.4.2. Although the site is an important foraging site for migratory birds, Bamford (2002) indicated that birds actually prefer the beaches to the north within the Groynes Zone area for foraging and roosting.

DPaW and MRWA in 2012 implemented a coastal monitoring survey program to try and obtain some qualitative information regarding the movements of the shoreline. Milyu is largely fed from sediment from the offshore shallow terrace and from alongshore feeds from the south. Given reduced sediment feeds from the south, it is expected that the erosion threat to Milyu will increase in the coming years.

In some areas of Milyu, there are only small buffers between the PSP and the Kwinana Freeway. Given this potential erosion threat to the PSP and Kwinana Freeway, MRWA and DPaW have developed a management plan for the area which details agreed measures that can be taken in the event of a severe event which causes potential undermining of the any of MRWA's assets (DEC 2012).

Figure 11: Milyu Zone

3.6.4 Palms

The Palms Zone occurs between South Terrace and Comer Street. The sandbagged foreshore within the Zone is a shared responsibility foreshore asset between the City and MRWA, whereas the walled foreshore around the Comer Street footbridge is a MRWA asset. The name of the Zone refers to planted *Washingtonia filifera* palm trees which used to occur here. The Palms were removed as shoreline erosion left them at risk of falling onto the PSP and Kwinana Freeway. The Zone is part of Reserve 33804 (vested in the City).

Palms can be divided into two Domains.

- Foreshore – sandbags and limestone retaining walls.
- Dryland - Almost no native vegetation exists, however some pockets of Sea Rush and other sedges and *Casuarina obesa* trees exist in the upper bank. The remainder of the upper bank is sealed over or simply landscaped with lawn. Common understorey weed species recorded were Black Flag (**Ferraria crispa*), Sea Spinach (**Tetragona decumbens*) and Wild Oat (**Avena fatua*).

The Zone is overall in a Degraded condition.

The shoreline along the Palms section used to be a relatively wide sandy beach. Erosion of the area caused significant recession of the shoreline from 2004 to 2011. This led to the undercutting of the root balls of the four Palms which the area was named after. The City had the Palms assessed by a qualified arborist who determined that they posed a significant risk of falling onto the PSP and Kwinana Freeway. This resulted in the Palms being removed, although their root balls are still evident along the shoreline.

Continued recession of the shoreline saw the erosion to within approximately 5 m of the PSP. MRWA and the City determined that some foreshore protection was required within this area to reduce the risk to the PSP being undermined. Significant access issues along the site due to the presence of a wire rope fence along the Kwinana Freeway led to the decision to install a small geotextile sand bag container wall to prevent further erosion while a longer term strategy regarding the possibility of renourishing this shoreline could be determined.

Most of the entire 400 m foreshore is now reinforced with geotextile sand containers, with the last 50 m being walled to protect the footbridge abutment at Comer Street (Plate 8). There are two stormwater drains along the foreshore, one pill box type outlet and one direct pipe through the footbridge at Comer Street. A footbridge connects the most southern end of the Zone to Comer St and Comer Reserve (Figure 12).

Plate 8: Palms Foreshore (a) middle facing north (b) middle facing south

Figure 12: Palms Zone

3.6.5 Como

The Como Zone occurs approximately between Comer Street and Thelma Street and the foreshore is approximately 530 m in length. The Zone is part of Reserve 33804 (vested in the City) and is adjacent to the Comer Reserve parkland. The entire foreshore within the Zone is a City foreshore asset.

A narrow sandy beach foreshore is reinforced with a wall. There are three overpasses (Comer, Preston and Thelma Street – although Thelma street is actually within the adjacent management zone) that go over the freeway and connect the Zone to the adjacent residential area. There are 12 drains and two pits located along the foreshore. The Zone has been developed for public recreation, including undercover picnic area, a simple playground, toilet facilities and bins, surrounded by formal garden beds and lawn. The Como Jetty extends approximately 210m into the Swan River (Plate 9,Figure 13). While Como Jetty is vested in the Department of Transport, the City has ownership of the lower landing/swimming platform on the northern side of the Jetty. This platform is the remains of the old swimming baths.

Plate 9: Como Foreshore (a) middle facing north (b) middle facing south

Como can be divided into two Domains:

- Foreshore – sandy beach.
- Soft Landscape - The area has been heavily landscaped and has no remnant native vegetation. Coral Trees and the English Poplar trees have been planted. There are some Peppermint Trees (*Agonis flexuosa*), Swamp Sheoak and Rottnest Island Pines trees present, however they have been planted. Most of the soft landscaping consists of locally occurring native flora. Common understorey weed species recorded were Prickly Sow Thistle (**Sonchus asper*), Soursob (**Oxalis pes-caprae*) and Capeweed (**Arctotheca calendula*).

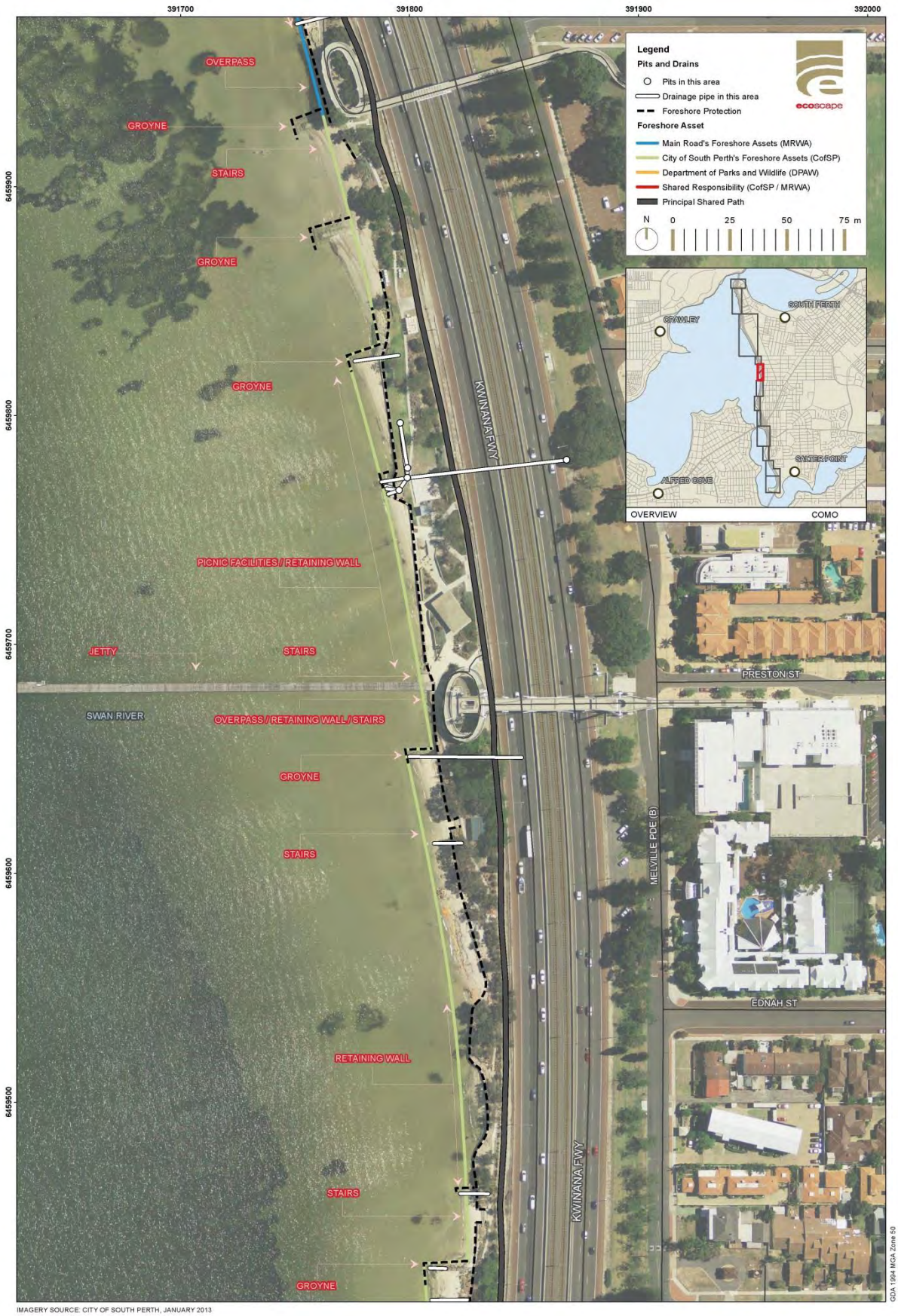

Figure 13: Como Zone

3.6.6 Skinny

The Skinny Zone is a narrow 600 m stretch of the study area between Thelma Street and just south of Saunders Street. The Zone is part of Reserve 33804 (vested in the City). The entire foreshore within the Zone is a MRWA foreshore asset.

Much of the Zone is less than 5 m in width between the water and the pathway and the freeway is immediately adjacent the pathway along this stretch (Plate 10). In severe weather conditions, wind carries wave spray over the freeway, causing some lanes of the freeway to be closed. MRWA added an additional two courses to the river wall to improve the situation and minimise the amount of overtopping water inundating the freeway.

The Skinny Zone can be divided into two Zones:

- Foreshore – a narrow beach of limestone rock.
- Dryland – short and narrow strip at the northern ends of the Zone, with few scattered trees and shrubs and sparse understorey.

The entire foreshore is walled, however a narrow beach section used to exist in front of the walling which was a popular area for dog walkers. The beach area to the south of the limestone retaining wall recently eroded back to the PSP, and MRWA installed a rubble mound headland to provide a pull over area for vehicles along the PSP as well as protect this vulnerable section of the PSP. MRWA have recently repointed the walling along this section and installed toe scour protection to prevent further undermining of the wall.

There are 16 drains and five pits located along the foreshore (Figure 14). Many of the drains used to act as groynes and stabilised the beach along this section, however many of the groynes are completely destroyed and serve little to no coastal stabilisation function. Without significant renourishment of this section it is unlikely that a beach will reform naturally in front of the retaining walls again.

Plate 10: Skinny Foreshore (a) middle facing north (b) middle facing south

Only a few *C. obesa* trees, Harsh Hakea (*Hakea prostrata*) and Coastal Wattle (*Acacia cyclops*) shrubs, grass and herb weeds manage to survive. Common weed species recorded were grasses, Soursob (**Oxalis pes-caprae*) and Sea Spinach (**Tetragona decumbens*).

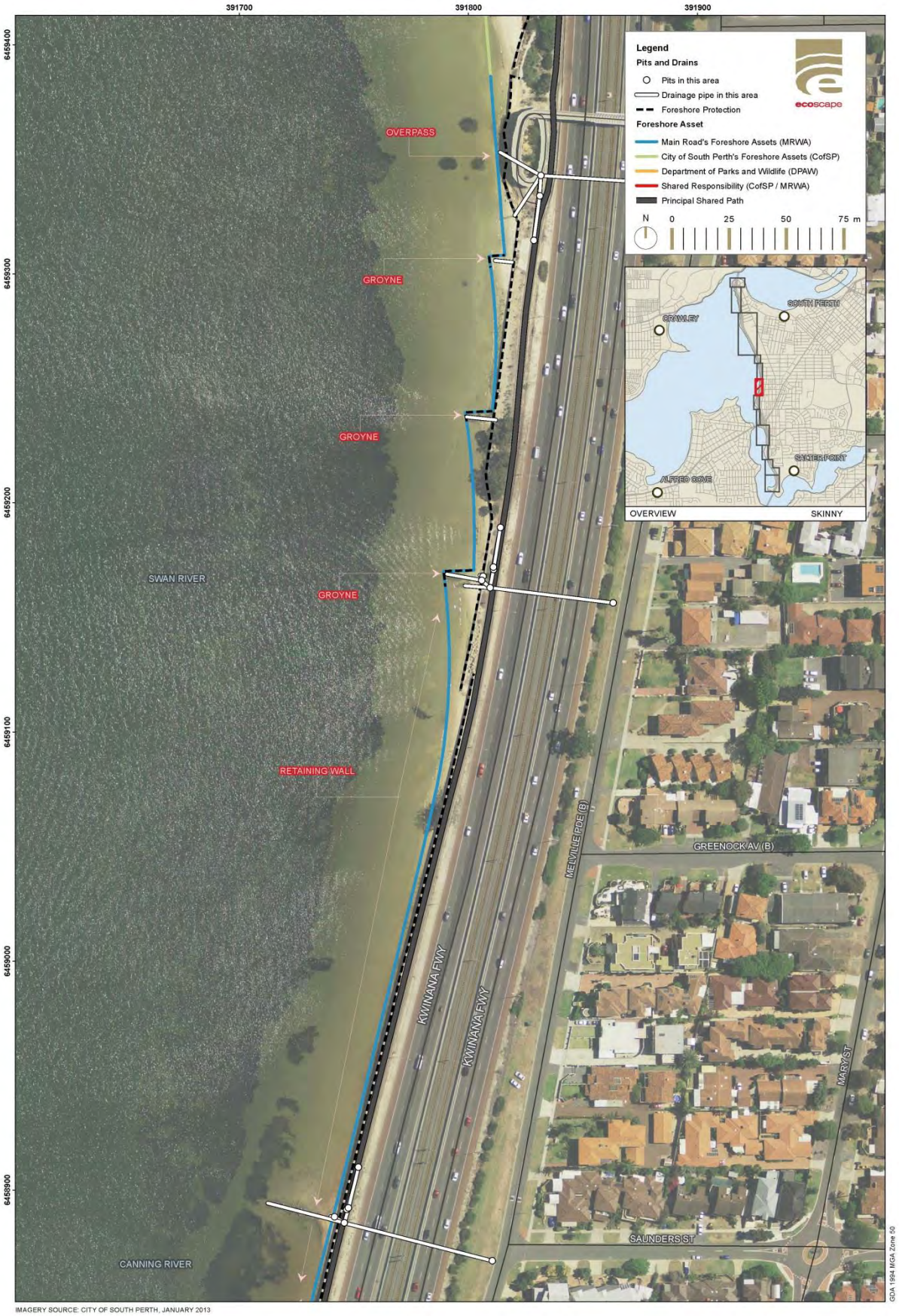

Figure 14: Skinny Zone

3.6.7 Sea Scouts

The Sea Scouts Zone occurs between Saunders Street and Henley Street and the foreshore is approximately 400 m in length. The northern section of the Zone resides is in Reserve 33804 (vested in the City). The southern section contains Reserves 26085 and 26086, which are currently leased to the Sea Scouts Association of WA. The Zone is adjacent to Olives Reserve parkland. The entire foreshore is a City foreshore asset.

As the name suggests, it is the site of the Como Sea Scouts hall, boatshed and jetty. An access gate off the Kwinana Freeway provides relatively good access to this area, and is used by the sea scouts when vehicles or boats are required to be shifted into or out of the sea scouts compound. It is suggested that with increased usage of the PSP and possible removal of the emergency lane on the Kwinana Freeway that access to the Scouts Hall may become increasing difficult and present a conflict of uses.

The jetty is regularly used by fisherman. An overpass connects the Zone to Olives Reserve. The overpass was constructed before the *Disability Discrimination Act (DDA) 1992* was released and is quite narrow and relatively steep. The existing footbridge would not meet any current DDA requirements. There is one drain and two pits located along the foreshore (Figure 15).

Stormwater drainage from the bubble up pits forms a small wetland like area, as the sandy beach has built up to a level where the stormwater does not cut through to the river. Higher stormwater flows would still likely cut through the sandy foreshore given sufficient flow.

Sea Scouts can be divided into four domains (Figure 15):

- Foreshore - sandy beach.
- Transition - edged by sedges and weeds.
- Wetland – small pockets of semi-permanent saline water.
- Dryland - a pocket of native revegetation in Good condition. Common weed species recorded were Perennial Veldt Grass (**Ehrharta calycina*), Geraldton Carnation Weed (**Euphorbia calycina*) and Japanese Pepper (**Schinus terebinthifolius*).

Plate 11: Sea Scouts Foreshore (a) middle facing north (b) middle facing south

The foreshore is vulnerable to erosion from northerly winds and waves. The shoreline appears to be generally accreting and shifting to the south, as is evident by the build up of sediment on the northern side of the jetty. It is likely that a large proportion of the material from the Skinny Zone has been deposited in the Sea Scouts Zone. The natural surface level of the area is quite low. The low level timber jetty is regularly inundated, however this generally suits the usage of the jetty as the vessels used by the Sea Scouts

generally have a low freeboard. The Sea Scouts building would likely experience inundation of the floor in significant high water events. This will become a more frequent issue with sea level rise in the coming 30 plus years. Given the age of the current building, it is likely that it will require replacement within this period and this would provide opportunity to accommodate for sea level rise within the structure.

Consideration should also be given to shifting of the Sea Scouts to another area which may be more easily accessible for members. This could possibly be the Mill Point Road area, or alternatively the Canning Bridge Precinct area if vehicle access to the area is going to be provided.

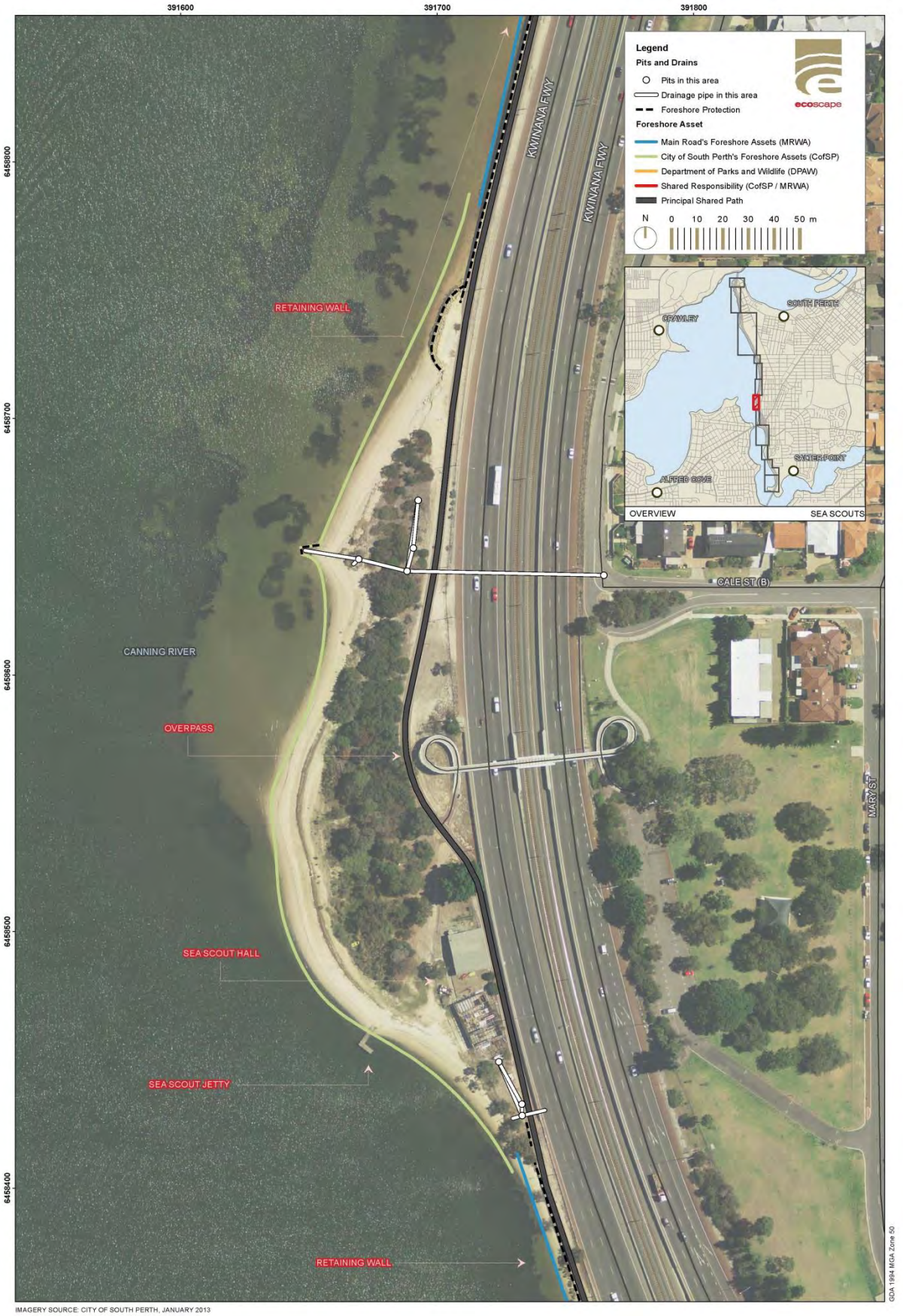

Figure 15: Sea Scouts Zone

3.6.8 North Canning

The North Canning Zone occurs between Henley Street and the Canning Highway and is part of Reserve 33804 (vested in the City). The foreshore is approximately 530 m in length. The narrow, northern half of the Zone's foreshore is a MRWA foreshore asset, whereas the southern portion adjacent to the vegetation is a City foreshore asset. The most northern extreme is narrow, where the water almost meets the path. Most of the foreshore is reinforced with either a wall or rock armouring as the area is vulnerable to wave action from the North (Plate 12). There are two pits but no drains located along the foreshore (Figure 16).

Plate 12: North Canning Foreshore (a) northern end facing south (b) middle facing south

North Canning can be divided into two Domains:

- Soft Landscape – the majority of the Zone lawn with planted trees and shrubs, some native species (Rottnest island Pine, Orange Wattle, Swan Sheoak, Western Sheoak) other exotic (Norfolk Island Pine, Coastal Tea Tree, Geraldton Wax).
- Dryland/ Upper Bank – Some patches of planted native shrubland, particularly *Acacia* and *Melaleuca* species.

The vegetated areas are generally in a Degraded condition, being highly disturbed by clearance and dominated with weeds. Common weed species recorded were grasses, Blue Lupin (**Lupinus cosentinii*) and Geraldton Carnation Weed (**Euphorbia terracina*).

The area was predominantly reclaimed as part of the widening of the Kwinana Freeway to provide an area for the Canning Bridge interchange. MRWA have indicated that there is unlikely to be any widening of Canning Bridge or the addition of any vehicle bridges to this area within the next 30 years. The PSP underpass underneath Canning Bridge on both sides is the lowest point along the foreshore. Increasing mean sea levels are likely to significantly increase the frequency of inundation of this underpass.

The North Canning Zone is part of the Western Australian Planning Commission (WAPC 2001) *Canning Bridge Precinct Vision,* which is to develop the western and eastern foreshore areas around the Canning Bridge to provide better social and transport facilities. The long term vision includes the following features for this Zone:

- Opportunities for cafes, retail and kiosks.
- A possible ferry pavilion and terminal integrated with a bus/ train interchange.
- Short term bus station with a local kiss and ride facility
- Long term bus, pedestrian and cycling routes.
- Pedestrian/ cycling overpass linking to the bus and train stations.

The vision would result in almost the entire site being cleared of vegetation and reshaped.

Figure 16: North Canning Zone

3.6.9 South Canning

The South Canning Zone occurs between Canning Highway and Gentilli Way and part of Reserve 33804 (vested in the City). The foreshore is approximately 820 m in length and is a shared responsibility foreshore asset between the City and MRWA. There are four pits but no drains located along the foreshore (Figure 17).

The South Canning Zone can be divided into two Domains:

- Foreshore - Almost the entire foreshore is walled, however a small sandy beach has been constructed at the northern end for recreational use
- Soft Landscape - The inland is simple landscaping of grass and scattered trees of Peppermint (Agonis flexuosa), Norfolk Island Pine (*Araucaria heterophylla)* and Swamp Sheoak. Common weed species recorded were Subterraneum Clover, (**Trifolium subterraneum*), Wild Gladiolus (**Gladiolus caryophyllaceus*) and Wild Oat (**Avena fatua*).

Plate 13: South Canning Foreshore (a) middle facing north (b) middle facing south

The South Canning Zone is also part of the WAPC (2011) *Canning Precinct Vision*. The vision for this Zone involves the following developments:

- Expanding the foreshore area for increased uses.
- Long term pedestrian and cycling routes.

The City recently undertook in late 2010 repointing of the limestone retaining wall in this Zone as a part of maintenance works to reduce washout from behind the wall and degradation of the structure. Loss of some sediment and recent higher water level events have scoured around the northern end of the walling and eroded the grass edge, forming a scarp. This northern beach was renourished in mid 2011 and the City annually pushes sand backwards from underneath Canning Bridge to this beach area to limit possible erosion of the adjacent path. The northern beach is vulnerable to wind and wave action from the south, and would likely also be affected in high river flow events with increased velocities underneath Canning Bridge. The whole lower Canning estuary waterway is a much lower energy environment than that of the Como Foreshore and Melville Water.

High water level events also cause flooding of the path underneath Canning Bridge. Increased frequency of inundation of the pathways underneath Canning Bridge is likely to occur with future increases in mean sea level. This will cause disruption for commuters travelling along the South Canning Zone.

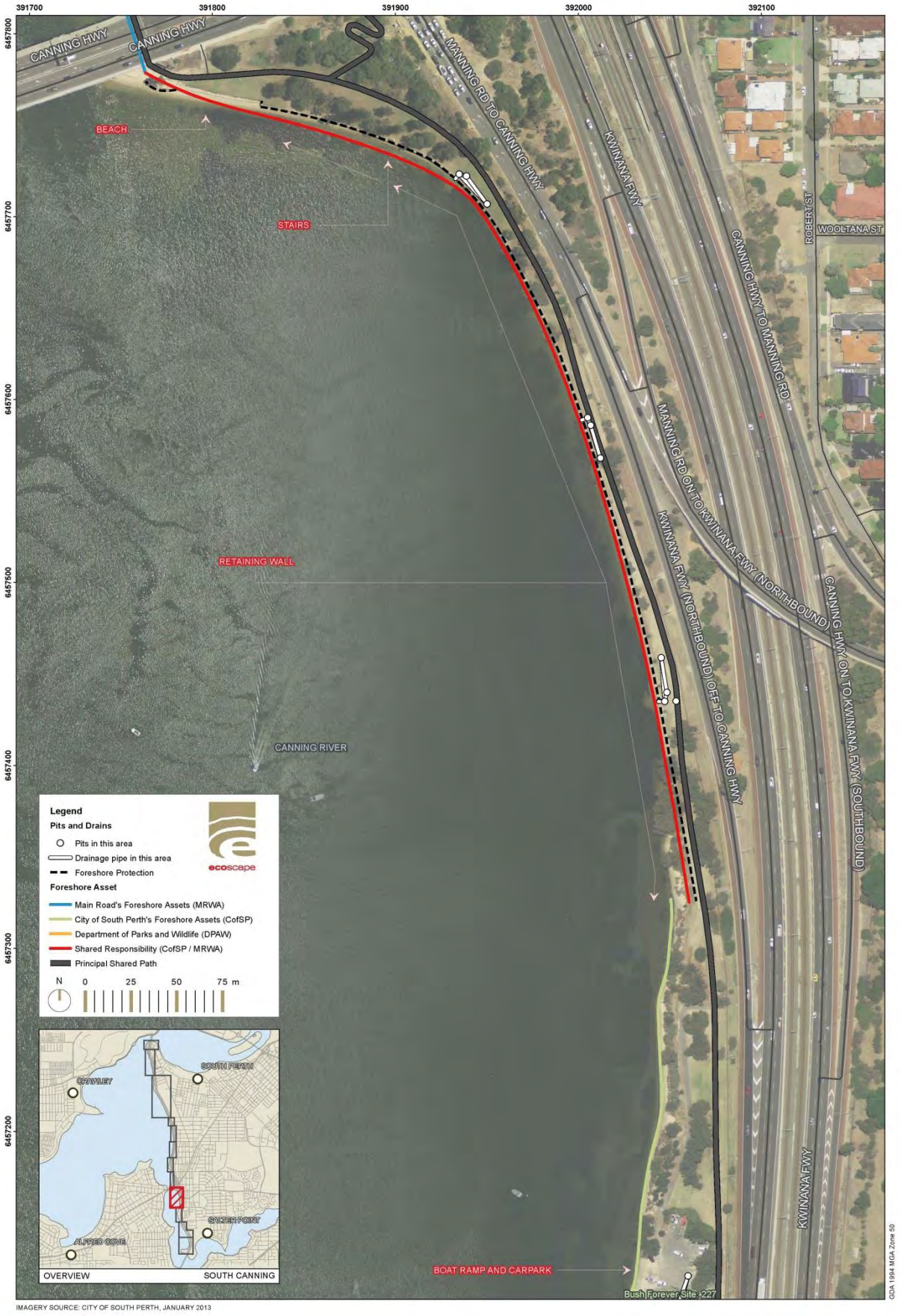

Figure 17: South Canning Zone

3.6.10 Cloisters

The Cloisters Zone occurs between Gentilli Way and Roebuck Drive and the foreshore is 520 m in length. This zone forms part of the Bush Forever Site 227. The entire foreshore is a sandy beach. Gentilli Way crosses over crosses Kwinana Freeway by a single lane bridge and terminates into a car park and boat ramp. There is one drain and two pits located along the foreshore. The entire foreshore within the Zone is the City's foreshore asset (Figure 18).

The PSP splits into two in this section. The majority of the Zone is part of Reserve 21288 (Class A, vested in City), whereas the southern end is a part of Reserve 45066, which is also vested in the City.

The Cloisters Zone can be divided into three Domains:

- Foreshore – sandy beach with occasional sedges.
- Transition - A thicket of Freshwater Paperbark (*M. preissiana*) occurs near the Transition Zone. These plants are declining in heath as the river has become more saline (Plate 14). Other trees include Spearwood (Kunzea glabrescens), Christmas Tree (*Nuytsia floribunda*).
- Dryland – occurring further inland and east of the PSP, the domain consists of woodland containing a verity of overstorey species including Summery Scented Wattle (*Acacia rostellifera),* Peppermint Tree (*Agonis flexuosa*) and Eucalypts.

Cloisters is one of only two areas containing remnant coastal vegetation in the study area. Its condition varies from Degraded to Very Good. Common weed species recorded in the Transition and Dryland/ Upper Bank Zones were Flaxleaf Fleabane (**Conyza bonariensis*), Wild Lettuce (**Lactuca* sp.) and Meliot (**Melilotus indicus*).

Plate 14: Cloisters Foreshore (a)middle facing north (b) northern end facing south

The foreshore in this Zone is a low energy environment. The City has undertaken some soft engineering techniques along the foreshore of Cloisters South towards the Spit Zone. These techniques in this area appear to be reasonably successful given the lower energy environment and the shallow terrace foreshore to break up vessel wake.

Figure 18: Cloisters Zone

3.6.11 Infill

The Infill Zone is between Roebuck Drive and Aquinas Oval and the foreshore is approximately 600 m in length. No drains or pits are present. This zone forms part of the Bush Forever Site 227. The foreshore immediately around the overpass is the MRWA's Foreshore asset, where the remainder of the foreshore is a shared responsibility between the City and MRWA (Figure 19). The Zone is part of Reserve 45066 (vested in City).

The Infill Zone consists of planted riverine vegetation, ranging from Good to Very Good condition. Common weed species recorded were Geraldton Carnation Weed (*Euphorbia calycina), Geraldton Wax (*Chamelaucium uncinatum) and Hare's Tail Grass (*Lagurus *ovatus*).

The Infill Zone can be divided into two Domains:

- Foreshore – sandy beach with little scattered patches of sedges.
- Transition – open woodland of Swamp Sheoak. Some understorey exists, mostly *Scaevola crassifolia, Spyridium globulosum* and sedges

Plate 15: Infill Foreshore (a) northern end facing south (b) middle facing north

Infill was originally a shallow embayment of the Canning River which was reclaimed as part of the works for the Kwinana Freeway. The foreshore was reclaimed using dredge spoil.

The City has undertaken soft engineering along the Infill foreshore. These works appear to be reasonably successful in reducing impacts from the adjacent heavily used water skiing Zone.

The natural surface level of this Infill Zone is reasonably low, and is known to inundate during high water level events. This will increase in frequency with increases in mean sea level.

Figure 19: Infill Zone

3.6.12 Spit

The Spit Zone occurs between Aquinas Oval and Mount Henry Bridge. The foreshore is approximately 900 m in length. The entire foreshore within the Zone is the City's foreshore asset (Figure 20) and forms part of the Bush Forever Site 227. . The Zone is part of Reserve 45066 (vested in City). The entire foreshore is a sandy beach (Plate 16). A limestone path loops throughout the section. No drains or pits are present. The vegetation's condition is widely range from Degraded to Very Good. The Zone is currently used by walkers and occasionally by fishermen.

Plate 16: Spit Foreshore (a) northern end facing south (b) middle facing north-east

The Spit Zone can be broadly divided into three Domains:

- Foreshore – sandy beaches with sedges.
- Transition – Swamp Sheoak.
- Dryland – open woodland of containing a mixture of overstorey species including Christmas Tree, Swamp Sheoak, Banksia species and Jarrah (*Eucalyptus marginata*).

The Spit Zone is the only other area containing remnant vegetation. Its condition varies greatly from Completely Degraded to Very Good. Weeds are prevalent in the degraded sections, especially Perennial Veldt Grass (**Ehrharta calycina*), Kikuyu (**Cenchrus clandestinum*) and Couch (**Cynodon dactylon*) (Syrinx 2013).

Given the dynamic nature of a sand spit structure, this area is expected to respond to slight changes in the predominant wind and wave directions. This area is vulnerable to erosion during high water level events and also vulnerable to wind and wave action from the north. The Zone would also respond to flooding events in the Canning River. Given the popularity of water skiing within the lower Canning River, vessel wakes would have an impact of this section of foreshore during higher water level events.

The Zone has a draft management plan for restoration and management (Syrinx 2013). Restoration works objectives are:

- Mitigating further erosion of foreshore areas.
- Improving condition of dryland vegetation and reducing weed populations.
- Restoring natural vegetation communities through revegetation.
- Managing public access and facilitating more functional recreation use of the area.
- Long term maintenance and monitoring strategy and monitoring.

Figure 20: Spit Zone

4.0 GENERAL MANAGEMENT

4.1 OWNERSHIP AND STAKEHOLDER MANAGEMENT

4.1.1 Vesting and Land Tenure

The spatial extents of the various land holdings and reserves are clearly set out in the MOU document. It can be seen in the mapping of the Reserves that a number of the MRWA assets, particularly the footbridge assets actually sit outside of the allocated reserves. The PSP also sits outside of the road reserve and sits within the Class A nature reserve of Milyu. Currently MRWA undertakes maintenance activities along the PSP within DPaW and the City's Reserves with letters of agreement.

The City currently holds a Department of Aboriginal Affairs Section 18 clearance for the foreshore along the Kwinana Freeway, with the exclusion of a number of Lots which were held as Unallocated Crown Land and the Milyu Nature Reserve.

It is noted that the existing Stakeholders currently utilise the City's Section 18 approval for the KFF to undertake maintenance and capital works along the KFF.

The City has now rationalised these parcels of Unallocated Crown Land (nominated within the Section 18 as Lots 14, 16 and 17) into the adjacent Reserve 33804. Discussions with DAA are currently ongoing as to the status of these parcels of land and the City's existing Section 18 approval.

Other Stakeholders undertaking works under the privilege of the City's existing Section 18 should as a condition of using the approval:

- Make themselves and their Contractors aware of the requirements of the approval and ensure all activities are in accordance with the approval; and
- Provide a summary report of the activities undertaken and photographic report to the City for its records and reporting purposes.

It is noted that no existing Section 18 notice currently covers the Class A Nature Reserve of Milyu.

Table 20: Recommendations for Vesting and Land Tenure at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
1.01	Investigate adjusting the boundaries of Milyu Nature Reserve such that the PSP is not within the Nature Reserve and sits within the Kwinana Freeway Land Tenure	Low	MRWA DPaW
1.02	Investigate adjusting the boundaries of Land Tenures around existing footbridges such that footbridge sits within MRWA Land Tenures.	Low	MRWA
1.03	Follow up on discussions with DAA regarding the rationalisation of Unallocated Crown Land into the adjacent Reserves and the status of the City's Section 18 DAA approval.	High	City
1.04	City to undertake necessary reporting under the requirements of its Section 18 approval.	High	City
1.05	Stakeholders undertaking works under the City's Section 18 should prepare a close out report (including photos of various stages of the works) for the City's records.	High	MRWA Trust
1.06	Investigate the requirements for a Section 18 approval for Milyu.	Low	DPaW MRWA

4.1.2 Stakeholder and Cooperative Management

One of the major outcomes from the 1993 WFMP recently implemented in 2010 was the development of a Kwinana Freeway Foreshore Management Group (KFFMG). This group sees representative members of the stakeholders of the KFF meet monthly. This allows for the programming of works and transfer of knowledge between stakeholders and has been instrumental in the progression of projects and future planning along the foreshore.

Stakeholders invited to the KFFMG meetings include:

- City.
- MRWA.
- Trust.
- DPaW.

In recent years, the KFFMG has undertaken the following successful tasks:

- Asset Management and Annual Condition Inspection of Foreshore Infrastructure Items from the Narrows to Mt Henry Bridge.
- Establishment of the Memorandum of Understanding for the *Maintenance of Principal Shared Paths, Walls and Other Aspects of the Kwinana Freeway Foreshore.*
- Annual Maintenance program to existing infrastructure assets.
- DPaW Five year Revegetation Plan and Implementation Plan for Milyu.
- DPaW *Rehabilitation and Freeway Infrastructure Protection Plan - Milyu Nature Reserve and Swan Estuary Marine Park.*
- Ongoing Coastal Monitoring of the Milyu foreshore.
- Mitigation of Erosion along the Palms Zone through the construction of a GSC revetment
- Investigation of Drainage Elements.
- Installation of a Maintenance Access Gate opposite South Terrace to allow truck access along the Palms and Milyu Sections.
- Installation of Wave Deflector Crown Wall around the Judd Street On Ramp.
- Creation of a sand beach held by two groynes and native revegetation area at Como Beach.
- Updated the KFF Management Plan.

Table 21: Recommendations Stakeholder and Cooperative Management at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
1.07	Continue the Kwinana Freeway Foreshore Management Group monthly meetings.	High	KFFMG
1.08	Continue medium term planning activities for the KFF and cooperate resources and project planning at KFFMG meetings.	High	KFFMG

4.2 CLIMATE CHANGE INUNDATION SCENARIOS

One of the particular concerns for this management plan is future inundation of the Kwinana Freeway. The Kwinana Freeway is a major transport and emergency access route and is the major asset along the shoreline. Inundation mapping of several water level scenarios can be found in Appendix Five.

Currently MRWA drainage design parameters for freeways are:

- 10 year Annual Return Interval Event - Drainage System Capacity (Accepted by the Drainage System in a Controlled Manner).
- 100 year Annual Return Interval Event - Emergency Access. There is an emergency access requirement that one lane must be trafficable (less than 200 mm inundation) in the 100 year Annual Return Interval event.

It is known currently that some particular combinations of wind and waters levels are sufficient to cause minor inundation of the KFF. Water levels at Barrack Street of the order of +1.0m AHD (A 5 year ARI event) begin to cause inundation of the PSP.

What is an acceptable frequency of inundation of the Kwinana Freeway asset will be required to be determined for MRWA going forward. While this is not expected to be a significant issue in the coming 20 years, it will become an important criteria in the determination of future modifications to accommodate climate change to the year 2110.

When strong westerly winds are persistent enough to across Melville Water, they cause what is known as wind “setup”. This occurs when the wind stress is significant enough on the water surface that the whole water level within Melville Water is tilted, such that the water level on the downwind end is higher than that of the upwind end. The end result is that the water level along the KFF is elevated slightly higher than that recorded in the tidal gauge at Barrack Street. In addition, wind generated waves breaking on the foreshore also generate a small amount of setup. Therefore on days with strong westerly winds, the KFF may be inundated even though the recorded water level at Barrack Street suggests that the still water level was below that required to cause inundation.

It is noted that currently the majority of impacts on the Kwinana Freeway are due to overtopping and wave spray in significant storm events rather than actual inundation. Actual inundation of the Kwinana Freeway requires a water level greater than approximately +1.3 m AHD. This would be achieved by a 20 year ARI event plus some wind and wave setup on the foreshore or a more extreme event.

The majority of “inundation” seen along the actual Kwinana Freeway traffic lanes is actually due to stormwater not being able to drain away due to the high marine water levels. This results in backing up through the drainage network in low sections of the roadway rather than direct inundation by marine waters. When high water levels act in conjunction with additional water volume from wave run up, overtopping and spray onto the inner lanes of the freeway the drainage network is overloaded.

This minor flooding in conjunction with impaired vision for drivers from wave spray over the inner lanes of the northbound lanes of the Kwinana Freeway creates disruption to the traffic flow.

Inundation of the PSP is more frequent than inundation of the actual traffic lanes, as the PSP has several sections of the order of +1.0 m AHD. In many cases the PSP sits directly adjacent to the river’s edge, meaning that wave run up and overtopping directly affect the PSP.

Surveys indicate that the majority of the PSP along the KFF is at an elevation of the order of approximately +1.25 m to +1.5 m AHD, however the following sections are at lower elevations and are inundated multiple times per year:

- Canning Bridge Underpass +0.75 m AHD. (This is the lowest section of PSP).
- Edgewater Street and Mt Henry Bridge and is of the order of +1.0 m AHD.
- PSP at Cale to Greenock +1.0 to +1.25 m AHD.
- PSP 150 m Section south of the Sea Scouts +0.75 to +1.0 m AHD.

4.2.1 Inundation Mapping Methodology

Expected inundation from several water level scenarios were mapped based on the latest available topographic survey information from the City and DoW. A digital terrain model (DTM) was established using DoW LiDar information and foreshore survey information provided by the City. The LiDar survey information had a point density of 1 point per square meter and was accurate to ±0.15 m vertically. The foreshore feature survey undertaken by the City was combined with this information to better delineate and represent the foreshore and river wall structures from 0 m AHD to + 0.5 m AHD. The elevations of the DTM were checked against that of the survey of the foreshore to ensure they accurately represented the elevations of the foreshore and associated infrastructure.

Scenario water levels were taken from the latest modelling for the Swan River (DoW 2013) and climate change allowances were taken from those being used for coastal planning in Western Australia published by WAPC and the Department of Transport as detailed in Section 3.2.9 of this report.

These scenarios do not include any flooding from stormwater runoff, therefore it could be considered that in the 100 year ARI and 20 year ARI scenarios significant rainfall on the eastern side of the freeway could add to the inundation shown.

The DoW modelling indicated varying levels of flood levels along the KFF. This was taken into account in all of the DoW scenarios with the still water level varying along the extent of the KFF to match that of the DoW predictions.

Mapping from the scenarios can be found in Appendix Five.

Selection of Scenarios

The following scenarios as detailed in Table 23 have been selected as a guide for various levels of inundation that may be experienced along the KFF. The scenarios have been chosen to provide a wide range of water levels such that the inundation maps are suitable to be representative of a number of different possible events. Reasoning for the selections of the various water levels are detailed in the following Sections.

Table 22: Inundation Mapping Scenarios

Scenario	Event	Water Level (m AHD)	Description
1	Highest Astronomical Tide Plus Climate Change to 2040	0.55 + 0.15 = +0.7 m	Normal Highest Astronomical Tide in year 2040.
2	DoW 100 year ARI Total Water Level (2010)	Range :+1.51 m (Narrows) to +1.44 m (Mt Henry Spit)	Proposed DoW 100 year Flood Planning Level for year 2010 and Normal Highest Astronomical Tide in year 2110.
3	DoW 100 year ARI Total Water Level (2010) Plus Climate Change to 2040	Range :+1.66 m (Narrows) to +1.59 m (Mt Henry Spit)	DoW 100 year Flood Planning Level in year 2040.
4	DoW 20 year ARI Marine Surge Plus Climate Change to 2040	+1.31 m	20 Year ARI storm occurring in year 2040
5	Mean Sea Level (0 m AHD) Plus Climate Change to 2110	+0.9 m	Mean Water Level in 2110 and Moderate storm event occurring in conjunction with HAT in the Year 2040, or a sustained surge of approximately +0.2 m occurring on top of HAT in 2040 due to other oceanic effects, such as effects from the Leeuwin current or El Nino / Southern Oscillation

There are a number of factors which will affect water levels further such as wind and wave setup and wave run up, however they are difficult to quantify without significant further modelling or data collection. These components are also specific to certain directions and foreshore geometries and are therefore very localised.

There is expected to be a degree of tidal attenuation from Fremantle to Barrack Street with higher water levels that may slightly reduce the tidal range at Barrack Street compared to Fremantle, however for the purposes of this management plan, it has been assumed that the full current tidal range at Barrack Street is maintained and climate change is in addition to this current tidal range.

In addition to these still water levels predicted at the tidal gauge, wave and wind setup can cause total water levels at the shoreline to be further elevated. Wind setup modelled in DoW (2013) suggests that along the KFF wind setup may be of the order of 0.16 m for a 100 year ARI wind event and 0.13 m for a 10 year ARI wind event. In addition, there may be additional wave setup along the shallow foreshore. For a 100 year ARI wave event, wave setup was estimated at approximately 0.16 m (MRWA 2004). Therefore the total water level at the KFF shoreline may actually be of the order of 0.3 m above the water level recorded at the Barrack Street tidal gauge. Wave run up onto a foreshore will also increase the total elevation reached by the active wave zone.

Descriptions of the basis of selection of these events are detailed below.

Scenario Descriptions

A number of scenarios have been mapped to provide a range of typical and extreme events. The following frequencies of events are expected within the 20 – 30 year timeframe of this management plan:

- High Frequency – Scenario 1.
- Moderate Frequency – Scenario 5.
- Low Frequency – Scenario 4.
- Rare Extreme Event (to the year 2040) – Scenarios 2 & 3.

Scenario 1

This scenario has been selected to model the predicted inundation level of Highest Astronomical Tide in the year 2040, assuming a mean sea level rise of 0.15 m. Based on water level submergence curves for Barrack Street, this water level is expected to occur approximately 5 % of the time.

This would be representative of the highest expected normal tidal conditions in 2040.

Scenario 2

This represents the latest flood and storm surge modelling by DoW for the Swan and Canning Rivers. Levels from this modelling are proposed to be adopted for future planning decisions along the Swan and Canning Rivers. The water level in this scenario ranges from +1.51 m at the Narrows Bridge to +1.44 m at Mt Henry Spit.

Along the KFF, DoW (2013) shows that the 1 year Marine Surge Event combined with the 100 year Flood event is slightly higher than both the 100 year ARI riverine flood levels and 100 year ARI marine surge level. This 1 Year ARI Marine storm surge combined with the 100 year Flood level is expected to be adopted for planning purposes by DoW along the lower reaches of the Swan Estuary below Maylands to replace the previous 1982 Public Works Department flood modelling.

The water levels within Scenario 2 would also be similar to the inundation that would be expected during a normal highest astronomical tide event in the year 2110, which would have a level of approximately +1.45 m AHD.

This is representative of Scenario 1 with a climate change allowance of approximately 0.9 m to the year 2110 instead of 0.15 m to the year 2040. As noted previously, it is expected there would be some attenuation of the tidal signal at these higher water levels which may reduce the future Highest Astronomical Tide level below that shown. Regardless, this would be generally representative of a normal highest tidal event, with more extreme events to significantly exceed this water level.

Scenario 3

This represents the current DoW 100 year ARI total water level with an additional allowance for climate change to 2040. This is the highest water level scenario modelled for this management plan, and is the most relevant for planning purposes at the end of the management plan timeframe.

Development levels (Minimum Habitable Floor Level) along the Swan – Canning River downstream of the Causeway and Canning Bridge are generally set by being +0.75 m above the Designated 100 Year ARI flood level. Scenario 3 is representative of what this 100 Year ARI flood level would be at the end of the proposed timeframe of this management plan in 2040.

Scenario 4

This scenario is indicative of a 20 year ARI marine surge event and an additional allowance for climate change to 2040. This 20 year event was chosen as it is the equivalent of the May 2003 storm which is currently the highest total water level recorded at the Barrack Street tide gauge.

This scenario shows the possible inundation as a result of the 20 year ARI storm (equivalent to the May 2003 storm) occurring in 2040.

Scenario 5

This scenario demonstrates what the mean sea level would be in 2110 with an increase above 2010 levels of +0.9 m. This would represent the mean water line in 2110, with items below this water line submerged 50% of the time.

This scenario would also be representative of a moderate storm event occurring in conjunction with HAT in the Year 2040, or a sustained surge of approximately +0.2 m occurring on top of HAT in 2040 due to other oceanic effects, such as effects from the Leeuwin current or El Nino / Southern Oscillation.

4.2.2 Inundation Scenarios Results

Scenario 1

This scenario represents Highest Astronomical Tide plus a climate change allowance of 0.15 m for a total still water level of approximately +0.7 m AHD, which is expected to be representative of conditions in 2040.

Analysing the submergence curve for Barrack Street indicates that this water level is currently reached less than 1% of the time. It is expected that a shift in the submergence curve upwards by 0.15 m would have this water level occurring approximately 5% of the time. This water level is currently experienced approximately 5 times per year. This water level would increase in occurrence to approximately 15 times per year by 2040 (Elliot 2012).

No inundation that would affect the Freeway or PSP is expected in these conditions. There would likely be some overtopping onto the PSP at some locations should this water level occur in conjunction with strong westerly winds.

While no severe flooding of infrastructure assets is expected at this water level, it is likely that the increased frequency of inundation of the foreshore areas will cause the loss of some vegetation in Milyu and through Cloisters, Infill and the Spit, particularly for less inundation tolerant species.

Wave height at the foreshore is dependent upon the water depth, therefore increasing the water level allows for slightly larger waves to occur on the foreshore. Some sections of foreshore may benefit from some soft erosion protection measures in order to reduce the potential for erosion at the front edge of the vegetation and provide more durability for the existing vegetation's root structure against increased wave action.

This soft engineering approach has been applied successfully along the stretch of foreshore within the section known as Infill south of Edgewater Street overpass. These techniques are more appropriate in sections such as Infill where the shoreline is a lower energy environment. The foreshore of Milyu is too exposed in severe weather events for soft engineering options at the front edge of the foreshore.

Areas of narrow sandy beach foreshores in front of existing retaining walls will likely also disappear due to the increased wave action and scour against the hard structure.

Given the majority of river walls will be permanently inundated at this level, it is also expected that there will be increased maintenance of these structures, particularly the weathering of the front face of the blocks and mortar.

Many of the existing structures along the KFF have required the installation of toe scour protection over recent years as a maintenance measure due to the loss of the previous sandy shorelines. Additional structures may require toe protection and some existing areas of toe protection may require some maintenance replenishment.

It is likely with higher water levels that there will be increased maintenance of the existing limestone rubble groynes. It would also be possible while undertaking work on these groynes to slightly increase the crest level to reduce damage levels from an increase in overtopping frequency and volumes.

There may also be more wave loading and uplift forces on the City's Jetty assets, such as the swimming platform on the end of Como Jetty and the Sea Scouts Jetty.

Scenario 2

Scenario 2 represents the results of DoW 2013 modelling of the current day 100 year ARI total water level. Scenario 3 detailed in the following section plots this 100 year ARI with an additional allowance of 0.15 m for climate change to 2040. Scenario 2 & 3 have been plotted together to easily identify the wider inundation generated by increases in mean sea level.

Given the low elevation of the KFF, with significant flooding occurring in as little as a 20 year ARI, it is expected that the 100 year water level will cause significant inundation. Overtopping levels along the PSP would be dangerous even for experienced staff along the foreshore and in the inner northbound lanes of the Freeway, would potentially be dangerous for vehicles even travelling at low speeds (DoW 2013).

Inundation of the freeway at Henley Street, Saunders Street and Scott Street are likely to cause a significant traffic hazard for motorists. Overtopping at Judd Street will be reduced by recent works undertaken by MRWA to replace a mortared stone revetment with a rubble mound revetment and a 0.6 m high crown wall. The project has also added a wave deflector bock around the PSP to increase its height approximately +0.6 m.

The inundation at Saunders Street is the largest area of inundation for the Kwinana Freeway northbound lanes. Based on the still water level event alone, this would not block all of the lanes of the Freeway. Should the water level occur with high levels of wave action and additional rainfall volume, the water level may actually extend across all northbound of the freeway, but it is likely to be less than 200 mm of water depth and still be trafficable by emergency vehicles. Therefore the Kwinana Freeway meets MRWA's criteria for a current day 100 Year ARI event.

The water levels within this scenario include wind set up, but do not include wave run up or additional inundation from stormwater effects. Wave run up and wind spray would be expected to increase the areas of flooding on the western side of the freeway, particularly those areas which are affected by the direct inundation.

Areas of the Kwinana Freeway which are close to the actual shoreline would expect to have additional inundation due to wave runup. Areas which may be affected by wave run up would include:

- Along the foreshore of Milyu.
- Hardstand at Como Beach.
- Thelma Street to Saunders Street.
- Gentilli Way.
- Edgewater Drive.

Inundation of the eastern side of the freeway would be predominantly due to backing up through the drainage network. The inundation plots indicate that the 2010 scenario will cause inundation of the Kwinana Freeway in several locations as documented in the Table below, particularly if the storm surge coincides with heavy rainfall.

Table 23: Areas of the Kwinana Freeway expected to be impacted by a 100 Year ARI Event (Maximum Marine Surge or River Flood Plus Wind Set up)

Location	Direction	Cause
Mill Pt Road Offramp	North Bound	Inundation
Stirling Street	South Bound	Drainage
Scott Street	North Bound	Inundation
Judd Street	Both Carriageways	Both
Richardson Park	South Bound	Drainage
Royal Perth Golf Course	Both Carriage Ways	Both
South Terrace	Off Ramp	Drainage
Preston Street	North Bound	Inundation
Thelma Street	North Bound	Inundation
Saunders Street	Both Carriageways	Both
Cale Street	South Bound	Drainage
Edgewater Drive	North Bound	Inundation

There could also be drainage flooding in the southbound lanes of the freeway at Stirling Street, Judd Street, opposite Richardson Park, the South Terrace off ramp and Cale Street.

- Flooding at Judd Street would reach across all of the southbound lanes of traffic.
- Flooding opposite Richardson Park would block the two eastern southbound lanes.
- The South Terrace offramp would be totally blocked.
- Flooding at Cale Street would block the emergency and eastern most lane.

The drainage elements in the above mentioned areas should be preferentially investigated for modification to reduce the effects of marine waters backflowing up the drainage network.

The PSP would be fully inundated in multiple locations, particularly for large extents from Mt Henry Bridge to Manning Road, a large stretch between Henley Street and the Seas Scouts, sections between Cale Street and Thelma Street and a small section near Scott Street. The Canning Bridge underpass would be inundated by approximately 0.7 m of water.

The Mill Point Road carpark under the Narrows would be significantly flooded. It is recommended that any improvements to the riverwall in this area consider lifting the crest of the structure to reduce some of the flooding effects.

The current location of the Sea Scouts building would also be significantly flooded.

It is noted that Scenario 2 would also be representative of Highest Astronomical Tide conditions in 2110 if mean sea levels increase by the full prediction of +0.9 m. This would be representative of conditions experienced under normal tides without any additional storm surge or other processes affecting water levels.

It is therefore evident that significant issues are expected along the KFF in 2110 associated with a 0.9m increase in mean sea levels. Under normal tidal conditions alone, it would be expected that water would breakout across the Freeway in those locations identified above in Table 24. This would present significant and relatively frequent disruption to the Kwinana Freeway.

During moderate storm events in 2110, water levels would regularly add additional 500 mm of water to those shown on the inundation maps. In this case, the Kwinana Freeway northbound lanes would be completely

blocked and not trafficable by emergency vehicles. This would cause significant issues for emergency access along the freeway on a reasonably regular basis.

It is recommended that MRWA's long term planning for the Kwinana Freeway include investigation into suitable options for raising pavement levels at the listed risk locations.

The timeframe for this investigation should be within the next 20 years with the potential for works to be undertaken in 20 – 50 years.

Scenario 3

Scenario 3 represents the 100 year ARI event occurring in 30 years time with an additional mean sea level increase of +0.15 m.

Additional flooding that occurs by including 0.15 m of climate change to 2040 is significant. In addition to the flooding identified in Scenario 2 in Table 24, it is noted that the additional 0.15 m causes significantly greater areas of inundation along the Kwinana Freeway. The wider areas of inundation would be expected to significantly affect traffic, particularly the existing emergency lane and two western northbound lanes. These lanes would largely be inoperable at the locations listed in Table 25.

Table 25: Areas of the Kwinana Freeway expected to be impacted by a 100 Year ARI Event in 2040 (Maximum Marine Surge or River Flood Plus Wind Set up and 0.15 m Climate Change)

Location	Direction	Cause
Mill Pt Road Offramp	North Bound	Inundation
Stirling Street	South Bound	Drainage
Scott Street	North Bound	Inundation
Judd Street	Both Carriageways	Both
Richardson Park	South Bound	Drainage
Royal Perth Golf Course	Both Carriage Ways	Both
South Terrace	Off Ramp	Drainage
Preston Street	North Bound	Inundation
Thelma Street	North Bound	Inundation
Saunders Street	Both Carriage Ways	Both
Cale Street	South Bound	Drainage
Henley Street	North Bound	Inundation
Edgewater Street	North Bound	Inundation

Flooding at Scott Street, Judd Street, Thelma Street and Saunders Streets would break out across all of the north bound lanes of the Freeway. It is likely that the flooding at the following locations would exceed MRWA's 200 mm criteria for emergency vehicle access in the 100 year event

- Scott Street / Mill Point Road northbound On Ramp.
- Judd Street.
- Saunders Street.

Flooding at Henley Street would be significant; however there will likely be clear access for emergency vehicles in the innermost northbound lane.

It is recommended that the following areas are prioritised for the addition of a limestone block retaining wall to the eastern side of the PSP or replacement of the existing steel barrier or wire rope fence with a slipform concrete retaining wall. This would minimise inundation in the next 30 years and maintain emergency access along the freeway:

- Scott Street.
- Judd Street to Hardy Street.
- Saunders Street.
- Henley Street.
- Thelma Street.

Drainage flooding of the eastern southbound lanes are generally in the same locations as identified in Scenario 2. The drainage elements in these areas should be preferentially investigated for modification to reduce the effects of marine waters backflowing up the drainage network.

The KFF is almost entirely inundated in this scenario, particularly the following sections:

- Judd Street through to Comer Street.
- Thelma Street to Canning Highway North Bound On Ramp.
- Manning Road through to the northern end of Mt Henry Spit.

It would be expected that multiple inundations of the KFF at this extent would act to effect vegetation along the KFF, particularly vegetation species planted along the KFF which are not tolerant to inundation.

Access along the PSP would also be expected to be interrupted in multiple locations. Large sections of the PSP would be inundated and be subject to wave runup and overtopping. Underneath Canning Bridge, the PSP would be inundated by approximately 0.76 m of water. If a current was also present, this would add to the danger of the public using this underpass. As a result, it would be recommended that the PSP would require to be closed and diverted. From Mt Henry Bridge, it is though that the PSP would require to be diverted along the western side of the Canning River.

There would be issues crossing the western side of Canning Bridge for path users as well as to access the northbound PSP the western underpass would also be flooded. Pedestrians and cyclists would likely have to cross Canning Highway at the footbridge at Ogilive Road, continue over Canning Bridge and then utilise Melville Parade and Labouchere Road along the eastern side of the Kwinana Freeway and the footpath along the eastern side of the Narrows Bridge. It is expected that the numbers of path users in these conditions would be minimal.

Higher levels of damage would be expected along the KFF during a marine surge event at these extreme water levels than in a pure riverine flood event. This would primarily be due to the erosive effects of the larger wave action on the KFF and flood velocities along the KFF are small except for underneath the Narrows Bridge. If the water level occurs with little wave action, damage along the foreshore would be minor.

Should the extreme water level occur during a period of strong westerly winds and generate significant wave action, it is expected that higher levels of erosion and damage would occur along the KFF. Wave action may cause the erosion of the western side of the PSP as wave rundown scours the front edge of the path. Drainage from wave overtopping, inundation and spray would cause additional scouring of the foreshore in lower elevation areas. Elevated areas of the Kwinana Freeway pavement not protected by a structure may be at risk of undercutting.

Wave spray would also act to disturb the flow of traffic along the Kwinana Freeway. Areas that are not necessarily flooded may experience traffic disruption due to wave spray, particularly the area between Comer Street and South Terrace.

Wave erosion of the foreshore would act to remove sediment from the upper foreshore and deposit it further offshore. This would lead to significant cross shore transport and the erosion of the existing shoreline. This would affect some of the vegetation along the KFF.

Efforts to increase the density of planting within Milyu are being undertaken by DPaW and MRWA in order to increase the durability of the vegetation and shoreline in this area to erosion events. This occurs by having the majority of the soil bound by the roots of the vegetation, making it more difficult to erode than a sandy shoreline. Frequent inundation would begin to affect plants within the area that are not tolerant to prolonged inundation. This will likely lead to loss of some species along the KFF.

The sections of KFF south of Canning Bridge are not expected to be as affected by wave erosion effects due to the limited fetch of the waterway. This makes the foreshore suitable to be protected adequately by softer engineering techniques.

The Canning River Sections are more vulnerable to winds from the North or South blowing along the waterway, which causes erosion on the Spit and Infill areas and also along the shoreline of South Canning. South Canning is reasonably well protected, however the Spit is an important remnant bushland area and intervention along this stretch of area should be minimal to maintain the environmental values of the area.

Scenario 4

A moderate scenario was selected to indicate the levels of inundation during a moderate storm event with climate change at 2040. This scenario maps the 20 year ARI marine surge and includes 0.15 m of climate change to allow for climate change to approximately 2040. This is the equivalent of the May 2003 storm occurring in 2040.

While large sections of foreshore are inundated, no areas are significantly breaking across the lanes of the Kwinana Freeway. Therefore the Kwinana Freeway would be open for emergency vehicle access. Traffic disruption would largely be a result of wave spray and overtopping, which may slow traffic. Any flooding would be a result of water backing up through the drainage network in conjunction with any rainfall.

When considering the effects of wave run up and spray, potential areas of concern are limited to those that currently experience issues during storm events. These locations would be:

- Mill Point Road (inundation of car park entry).
- Stirling Street (wave spray).
- Scott Street (wave spray).
- Judd Street (PSP wave spray).
- Lyall Street (Wave Spray – although should be minimal due to construction of new rock revetment).
- South Terrace to Comer Street (wave spray).
- Thelma Street to Cale Street (wave spray).
- Henley Street (wave spray).

The PSP would be fully inundated for large sections along the Canning River, a section south of the Sea Scouts building opposite Henley Street, sections between Thelma to Cale Streets and would be heavily affected by wave action at South Terrace to Comer Street, Lyall Street, Scott Street and Stirling Street.

Scenario 5

This scenario depicts the mean sea level in 2110. These conditions would be expected to cause significant loss of vegetation through the Groynes, Milyu, Cloisters, Infill and Mt Henry Spit management zones. Assuming that the tidal range is not significantly altered, normal tides would cause significant flooding of the study area and Kwinana Freeway if they are maintained at their current elevations. Highest Astronomical Tide in 2110 would inundate the shoreline in a similar extent to Scenario 2.

The most significant item of note in terms of assets is that the underpass under Canning Bridge would be constantly submerged. A new pedestrian link will be required to link the north and south pathways on the eastern side of Canning Bridge.

The greatest ecological impact would be the continual inundation of the remnant vegetation areas of Cloisters. The Spit area would likely suffer from the loss of fringing vegetation within 10 m of the existing shoreline edge.

Several sections of the foreshore currently have elevations of the order of +1.0 m AHD. These areas would be constantly inundated when taking into account wave action:

- Large sections of the PSP near Edgewater Road and Aquinas College.
- Section of the PSP near Henley Street.
- Sea Scouts Jetty (jetty would be submerged).
- Como Jetty Swimming Platform (platform would be submerged).

Large areas of the lower Swan Canning system would be affected by a mean sea level increase of this magnitude, therefore management actions are likely to be required at a State or Federal government level rather than by the City. Water levels by 2110 are going to require significant modification to the KFF to

maintain what currently exists. While within the period of this management plan effects from mean sea level rise are expected to be minimal, by 2110 there will be significant impacts. Without significant intervention works it would be expected that the majority of foreshore along the Kwinana Freeway will be regularly inundated.

This Scenario would also be representative of a typical winter storm event occurring in conjunction with Highest Astronomical Tide in the Year 2040, or a sustained surge of approximately +0.2 m occurring on top of Highest Astronomical Tide in 2040 due to other oceanic effects, such as effects from the Leeuwin current or El Nino / Southern Oscillation. With significant wave conditions, it is expected that there would be additional inundation due to the effects of wave runup. This water level would also cause erosion of higher levels of the sandy foreshores along Milyu, however no significant inundation occurs that would affect traffic on the Kwinana Freeway. As detailed above, the majority of impacts are restricted to the PSP.

4.2.3 Stormwater Drainage

The City is currently investigating its drainage network. As part of this work, the drainage network should be checked for obstructions and siltation to ensure all items are operating at full capacity. This will assist in improving the water quality being discharged to the Swan and Canning Rivers and limit potential flooding of the Melville Parade area.

Where possible, the City should aim to consolidate the existing drainage where possible and remove redundant outfall pipes from the KFF. Over time, all discharges to the Swan and Canning River System should aim to go through a GPT or similar device prior to discharge.

The City officers report that large amounts of rubbish and syringes appear on the KFF. It is thought that the majority of these items are washed into the river through the stormwater network. The number of direct outlet drains into the river should be reviewed and consolidated over time in conjunction with the adding GPT's to minimise rubbish and dangerous items entering the waterway.

Best practice WSUD guidelines shall be continued to be implemented to minimise surface water flows, nuisance flooding and also enhance the water quality reaching the Swan and Canning Rivers. As part of this, the City should aim to improve construction site practices to reduce amount of siltation within the drainage network.

Typically the land parcel between the Kwinana Freeway and PSP is solely loose sand. During rainfall events, the freeway overflows its drainage and appears to drain across the PSP towards the river. This pulls sediment and debris across the PSP. There is an opportunity to incorporate some sort of biofilter swale drainage along the edge of the freeway. This would assist in improving the water quality of the discharge to the Swan and Canning system

The current 'Pillbox' outfall structures serve a purpose but most are reaching the end of their service life and are significantly degraded. It is recommended that the City and Main Roads investigate replacement of these Pillbox structures with a backflow prevention device, fitted either inline or on the end of the outfall pipe. This would reduce backflow issues up the stormwater network and reduce flooding on Melville Parade.

The design of the backflow device should prevent siltation of the pipes and have a self cleaning function for when flow starts if sedimentation has built up over the device. The installation of these units do cause some head loss, however the structure will likely maintain the pipe in a cleaner state than currently exists, allowing a higher discharge. The upgrading of the outfall structures to include a backflow prevention device could largely offset increases in mean sea level over the next 15 to 30 years.

If sea level rise continues as predicted and in 100 years the mean surface level is approximately +0.9 m higher, there are few opportunities available for the City. Flooding under normal astronomical tidal conditions would be significant, with highest astronomical tide correlating with a current day 100 year ARI event.

It is likely that pumped drainage systems would be required along KFF in combination with some significant infrastructure changes.

4.2.4 Response to Sea Level Rise

Drainage

Given the reclamation for the Kwinana Freeway and the extension of the drainage system from the eastern suburban areas, the hydraulic grade line for stormwater pipes underneath the Kwinana Freeway is expected to be quite flat. This makes drainage across the area difficult. The City should ensure that all drains are actively working and not blocked to ensure 100% capacity of the system in the event of a significant flow event.

Problems with flooding are generally caused when storm surge events coincide with large rainfall events. While sea level rise within the next 30 years is not expected to cause issues during normal tidal events, the increased water levels during storm surge events may cause more frequent issues for the drainage network and flooding of Melville Parade. This inundation may be able to be reduced with the installation of one way backflow prevention devices on the KFF stormwater outlets. One unit that has been installed with success around Australia is a unit called a 'Tideflex' valve. Valves such as these Tideflex valves would potentially restrict backflow up the stormwater network underneath the Kwinana Freeway, providing more capacity on the Melville Parade side of the stormwater network.

Options for increasing the flow capacity of the pipes should also be investigated. Relining pipes with HDPE liners can reduce the head loss coefficient of the pipe network, increasing the capacity of the system even though the backflow devices have been installed onto the end of the pipelines.

The City currently has a number of pumped drainage systems, although these are predominantly on the City's northern foreshore. Long term sea level rise of approximately +0.9 m will cause significant drainage issues along the KFF. It is likely that full sea level rise of +0.9 m will require some sort of pumped drainage network in the study area.

From the inundation mapping the following areas are of significant concern within the coming 30 years as they could potentially block emergency access along the Kwinana Freeway in a current 100 year ARI event. The following areas should be prioritised for drainage system improvements:

- Judd Street Southbound Lanes.
- Flooding opposite Richardson Park blocking southbound lanes.
- The South Terrace south bound offramp.
- Flooding at Cale Street would block the emergency and eastern most lane.

River walls

The majority of the river walls along the foreshore have been built with a climate change allowance built into the design of the structure. This allowance would vary along the KFF as the walls have also been built to generally match the existing natural surface levels of the areas for visual aesthetics and also drainage reasons.

In the case of the majority of these walls, this climate change freeboard will slowly be reduced over the next 30 plus years. During normal tidal conditions over the next 30 years, this is unlikely to cause any significant catastrophic effects to function of the existing retaining walls. The following effects are anticipated:

- Increases in the water level at the base of the walling will generally result in slightly larger waves for similar wind conditions, therefore there may be some increases in the amount of scour at the toe of some the structures. This can be easily accommodated by installing and maintaining toe scour protection at the toe of structures.
- Maintenance timeframes for items such as repointing or refacing blocks may also be reduced.
- Reduced freeboard will likely result in increases in the level of overtopping of these structures.

Perhaps the greatest concern is the effects of increased overtopping. Increased overtopping rates can cause the following issues:

- Increased scouring of the areas behind the walling due to increased overtopping volumes.
- Increased impact on vegetation due to increases in the level of salt spray and inundation.
- Safety concerns for PSP users in some areas.
- Spray inundation onto the Kwinana Freeway.

Storm surge events at the end of the 2110 period are likely to cause significant inundation of the entire foreshore and total water levels of the order of + 2 m AHD could occur under severe storm surges. This would totally block all emergency access along the Kwinana Freeway in moderate storm events. Solutions on a much larger scale are going to be required for this longer term issue of sea level rise as the Kwinana Freeway would be inundated in some areas by of the order of 500 mm of water.

Sea Scouts

While the Sea Scout building should continue to be on dry ground in normal tidal conditions, it may be increasingly inundated during higher storm surge events.

The building is currently leased by the Sea Scouts Association of Australia from the City. Consideration should be given to the relocation of the Sea Scouts Building when the lease is required to be renewed. Should a decision to rebuild in this location be undertaken, then sea level rise shall be accommodated when rebuilding this structure, with thought given to a multiple storey building. The lower level can be a hardstand and equipment stores area so that inundation has minimal effects, particularly if electrical items are high on the wall rather than being at ground level, with the upper storey being hall area and rooms, which is safe from inundation. This approach has been taken with the Ascot Kayak Club built at Garvey Park and many kayaking or rowing clubs in flood prone areas in the eastern States.

Strong consideration should also be given to shifting the Sea Scouts Building, particularly to an area which provides easier vehicle access for the members of the club. A structure as part of the Canning Bridge development or up at the Mill Point Road Jet Ski car park could be suitable alternative locations.

Canning Bridge Underpass

The pathway under Canning Bridge will become inundated on a more regular basis, to the point that by 2110 it would be inundated for more than 50% of the time. This continual inundation is likely to require management by MRWA as the underpass is the lowest section along the KFF and will flood before other

areas of the PSP. MRWA should start investigating possible options for the PSP underpasses at Canning Bridge to provide safe access across Canning Highway for PSP users.

Foreshores

Major erosion of the foreshore will continue to be driven by episodic high water level events. However, they will become more frequent over the timeframe with lower intensity storms.

Due to the nature of the reclaimed foreshore and hard structures along the majority of the foreshore, it is likely that the general erosion trend for the foreshore will continue and be driven by episodic high water level and strong westerly wind events.

Given the number of hard structures along the foreshore and the shape of the foreshore profile, it is unlikely that the shoreline will substantially accrete naturally. In areas where a sandy foreshore is required or preferred, these areas will likely have to be managed with a regular nourishment program.

Areas of natural vegetation, such as Mt Henry Spit, Cloisters and Milyu should continue to be densely vegetated to increase the shorelines durability against inundation and erosion. The front edge of the shoreline should be heavily planted out with sedges to act as a natural wave attenuator.

It may be beneficial to 'strengthen' this front edge with some soft engineering stabilisation work in areas where erosion is of concern, particularly along the lower energy areas of Cloisters, Infill and the Spit. Soft engineering techniques are not expected to be sufficient along the more exposed areas of Milyu and the Palms.

Increasing saline inundation may also affect some of the vegetation, particularly through the Cloisters, Infill and Spit Zones. Some of these remnant areas may require to be irrigated to provide freshwater and establish a freshwater groundwater lens for survival of the vegetation.

Long term impacts of mean sea level increases out to 2110 are expected to be significant on the KFF vegetation. It is expected that the majority of existing foreshore and vegetation between the Narrows and Mt Henry Bridge will be lost due to mean sea level increases of +0.9 m.

Major foreshore modifications would be required in order to maintain vegetated foreshores along the majority of the KFF. This would be primarily through the widening and raising of the natural surface level. Alternatively suitable land parcels should be set aside for the establishment of natural vegetation and fauna to offset the losses of the KFF.

4.2.5 Mitigation Strategies

General strategies for managing the impacts of climate change fall into the following broad actions:

- No Action.
- Retreat.
- Accommodate.
- Mitigate.

No Action Approach

The No Action approach would mean that these increased levels of overtopping and inundation of the Kwinana Freeway are accepted and the infrastructure is maintained in its current state. The MRWA and the public would accept greater levels of disruption to the Freeway and greater levels of inundation in the 100 year ARI event. There is the potential that the Kwinana Freeway could be blocked for emergency vehicle access in the 100 year ARI event in 30 years time. This No Action approach may be applicable along the Kwinana Freeway between Canning Bridge and the Narrows as emergency vehicles would be able to take

alternative routes and with the construction of major emergency response centres (such as the new Fiona Stanley Hospital) access along the Kwinana Freeway between Canning Bridge and the Kwinana Freeway may not necessarily be required.

Retreat Approach

Retreat generally refers to the shifting of the asset away from the risk. This is difficult to undertake with the Kwinana Freeway as it is not able to be shifted easily. Retreat is not likely to be a viable option for the major infrastructure items, however it would be possible to shift recreational items such that they are not as impacted by the effects of climate change. This would be possible by relocating items such as the Sea Scouts Building and recreational assets such as barbecues and playground areas to areas which are not affected by climate change. The Canning Bridge Precinct provides an opportunity to relocate some recreational assets to a higher elevation area.

Retreat could be a possible option for the PSP, particularly through the section from Mt Henry to Canning Bridge. An alternative route option could be formalised for the PSP so that commuters are minimally affected should the PSP be inundated. An alternative route through the section from Canning Bridge to the Narrows could also be provided, utilising Melville Parade and Labouchre Road.

Accommodation Approach

Accommodating climate change generally refers to building structures that are able to withstand increased levels of inundation. In terms of riverwalling, this may be changing rear side of the riverwalls such that they are able to withstand greater frequency of overtopping and inundation with no damage. This has occurred at Como Beach where the riverwall has been modified by removing a garden bed and replacing with a wider concrete path section that is able to accommodate overtopping and inundation with no damage.

Options to accommodate increased mean sea level rises are most appropriate for the PSP. The PSP is going to be increasingly inundated and there is little room for retreat on the section between the Narrows and Canning Bridge. An option to enhance the durability of the PSP and accommodate climate change for the next 20 – 30 years would be to formalise the edge of the PSP with a concrete block or similar to prevent the scouring and undermining of the path.

This would be dug in such that the path can tolerate approximately 0.3 to 0.5m of scour from wave runup and rundown without the path being damaged. This would be a suitable accommodation method for the next 20 – 30 years for the PSP through Milyu, the Palms, Skinny, Cloisters and Infill.

Mitigation Approach

Mitigating the effects of climate change generally refer to structural changes that reduce the effects of climate change. Possible mitigation options include:

- Raising the natural surface level of the foreshore.
- Raising the crest levels of structures by the addition of crown walls or similar.
- Construction of barriers or widening of the foreshore to reduce the effects of increasing mean sea levels.

The inundation mapping has shown that the Kwinana Freeway meets the requirements for emergency access in a 20 year ARI event but would not meet the requirements for a 100 year ARI event in 2040.

It is recommended that additional crown walls or retaining walls are built in these areas which flood across the freeway in the 100 year ARI event to reduce the inundation and maintain emergency access along the freeway.

The easiest option for the timeframe of this management plan to provide this protection is likely to be the construction of a concrete slipform barrier along the western edge of the freeway in these areas, or alternatively placing a two block high limestone block wall along the eastern edge of the PSP. This would be sufficient to maintain emergency access along the freeway in a 100 year ARI event.

Increasing the natural surface level of the freeway will likely be required in the coming 100 years in order to mitigate against the effects of increased mean sea levels.

Other factors which impact the PSP and cause disruption to traffic are increased levels of wave spray and overtopping. This slows traffic and adds to the drainage water load but generally is not sufficient to impede emergency access along the freeway. Overtopping studies undertaken in DoW (2013) indicate that overtopping rates along the KFF are high, primarily due to the freeboard of the structures compared to the still water level. This results in overtopping volumes 2 to 3 orders of magnitude greater than what is deemed acceptable for pedestrians on the PSP. Vehicles are able to tolerate larger flows, however in some locations along the KFF, a 1 year ARI water level with 10 year ARI winds will be deemed dangerous for vehicles along the PSP. The following options are available to reduce the effects of wave spray and overtopping:

- Increasing the crest height and modifying structures to increase the surface roughness.
- Shifting the wave breaking further away from the freeway and PSP.

Increasing the crest height of structures provides a greater freeboard to the still water level, which reduces the volume of overtopping. Increasing the roughness of the structure (such as replacing smooth surface structures with rough ones) reduces the extent of wave runup, particularly on sloping structures, and aids in reducing the overtopping volumes.

Where existing structures exist, it would be reasonably straight forward to increase the crest level of these structures, either by the retrofitting of a crown wall to the existing wall or by increasing the crest height when rebuilding the structure at the end of its service life.

Several examples exist of increasing the crest height of the structure by adding additional courses of limestone blocks or the addition of a crown wall to new structures. Some recent examples around the river are including a form of recurve on this top course in order to try and reduce the effect of vertical wave spray. In 2014, MRWA replaced one of the mortared sloping revetments with a rubble mound structure in order to reduce wave run up and spray affecting the PSP and Freeway between Bowman and Lyall Streets.

Retrofitting of additional courses or crown walls to aid in reducing overtopping to existing walls is expected to cost of the order of $1,500 - $2,000/ m. Projects currently being tendered by MRWA would provide a closer estimate of the full project costs. This involves the procurement of the materials and installation to the existing river wall structure. Should the existing river wall not be suited to the addition of the additional courses or crown wall, then the costs may be higher as the wall will require to be reinforced, or rebuilt to handle the additional loads of the higher wall.

In some cases, particularly the existing walls immediately adjacent the PSP are not going to be able to be increased in height enough to be able to reduce spray to safe levels in extreme events.

Other options to reduce wave spray onto the freeway are to cause the waves to break further away from the Freeway, such that any spray generated does not impact the freeway. Overtopping and spray volumes generally decrease by an order of magnitude for every ten metres of additional distance you are away from the structure. This could be achieved by:

- Widening the Existing Beaches.
- Installing offshore breakwaters.

Widening the existing beaches back to what was the previous reclaimed shoreline profile is one option. The feasibility of this has recently been investigated by the Trust (Damara 2014). Widening the beach profile by sand nourishment (either via trucking or dredging) provides a wider beach for waves to dissipate onto and shifts the breaking zone away from the PSP and freeway. In order to maintain the wider beach profile, a number of the existing groynes would have to be rebuilt or the groynes extended to minimise the longshore and cross shore transport of sand.

Undertaking renourishment along the whole KFF utilising dredging as a renourishment source was likely to cost of the order of $17 million dollars over a 20 year timeframe. Using a combination of dredging and hauled sand as a source of renourishment is costed at approximately $22 million. This costing included rebuilding a number of the groynes along the KFF which have been destroyed. Over the approximate 5.5 km of foreshore, this equates to approximately $3,000 to $4,000 per metre over a 20 year timeframe (Damara 2014). Some revegetation works would also be required to minimise windblown sand issues onto the Freeway during the summer months.

Based on recent construction costs of the study area, this price is similar to costs for the construction of a rubble revetment or limestone retaining wall along the KFF, which would have a similar service life before any requirements for maintenance.

Dredging for renourishment has benefits in that there are significantly reduced traffic management costs over direct placement via trucking. An alternative option would be to transport sand from a quarry source by truck to an area where the sand can be stockpiled and can then be pumped along the foreshore. This removes requirements for traffic management along the freeway and also reduces possible damage to existing items of infrastructure, particularly the PSP.

Additional sand nourishment of the KFF may increase the prevalence of siltation of the drainage outfall structures. It is recommended that the drainage outfalls are all upgraded to accommodate siltation prior to the sand nourishment works.

Alternative options to minimise wave spray in these areas is to construct some offshore headlands. These also break up the wave energy and spray further offshore, providing a calm area behind the structure. These are most effective when the crest of the structure is higher than the still water level for the event. Once the still water level exceeds that of the structure's crest height, wave energy is transmitted over the structure, albeit at a reduced level. The negative impact of these structures is to be effective at higher water levels, they are visually prominent at lower water levels.

Offshore headlands can be constructed out of armour rock, geotextile sand containers, or other alternatives such as a floating attenuator.

Concept options of possible foreshore protection measures to reduce wave spray and overtopping onto the freeway are provided in in Appendix Five.

One significant impact of the increase in mean sea level is the increase in the low tide level, which will require a change in methodology and significant increase in costs of riverwall construction and repairs.

Increasing the low tide level will impact the current construction method, in which the footings for the walls are generally placed in the dry during low tidal periods when the foreshore dries out. Not being able to take advantage of the low tidal periods will impact significantly on the construction costs of any masonry structure in the study area as dewatering will be required to be able to place the footings. Alternative construction methods may be required in order to be able to construct the footings.

Climate change effects within the next 20 to 30 years are likely to result in increased inundation of some areas, loss of some beaches (if nourishment does not occur), increased issues with drainage and nuisance flooding and increased levels of maintenance on existing river wall structures.

4.2.6 Long Term 100 year Mean Sea Levels

Long term climate change is a significant issue for the KFF as shown in the inundation mapping for Scenario 2 which also depicts the extent of inundation in a normal high tide event in 2110. While beyond the scope of the timelines for this management plan, this scenario illustrates that future climate change of +0.9 m would require significant infrastructure changes along the whole lower Swan Canning System, not just the study area. Without significant works, it is expected that the majority of existing foreshore and vegetation between the Narrows and Mt Henry Bridge will be lost and significant flooding of the Kwinana Freeway would occur on a regular basis. Emergency access routes along the Kwinana Freeway would potentially be blocked on frequent occasions.

Long term options to deal with this climate change could take many forms or be a combination of a number of items, in general they could be:

- Accepting loss or reduced foreshores in some areas.
- Set aside or rejuvenate existing areas that would be suitable natural vegetation or recreation areas to offset the losses of the current areas.
- Progressively raising existing items of infrastructure and the natural surface level behind them once they reach the end of their service life.
- Protecting foreshore infrastructure with protective walls or dykes.
- Create a tunnel over the existing Kwinana Freeway and Train Line, turning the land above into parkland foreshore and a combination of residential and commercial spaces.
- Relocate, provide alternatives or abandon threatened sections of the PSP or existing items of recreational infrastructure or recreational nodes.
- Increasing setback distances from the river by way of widening and increasing the height of the existing shoreline
- Prevent the increased water level from occurring at the entrance of the Swan River, such as by the installation of a ship lock or storm surge barrier.

Raising the natural surface level is also an option to mitigate this +0.9 m increase in mean sea levels. This would require lifting of the freeway pavement level. Drainage systems would require to be modified such that the train line does not become the low point of the freeway.

Barriers could be provided to isolate the freeway from the effects of flooding. Taking this option further, the freeway and train line could be enclosed to form a tunnel like structure and the land created above the freeway could be turned into parkland and residential or commercial offices.

Decisions regarding the foreshore would be required; whether to try and maintain the current foreshore, or solely lift the freeway and provide an alternative PSP route. Raising the foreshore level will require significant upgrades to the drainage systems on the eastern side of the Kwinana Freeway in order to cope with the additional stormwater drainage volumes. This is likely to require the installation of a number of pumped drainage systems.

Alternatives to raising the current natural surface levels, or the addition of barriers to the freeway would be to limit the effects of higher water levels at the entrance of the Swan River.

There are numerous storm surge barriers installed around the world which undertake a similar coastal protection function. On a large scale, such as the storm surge barriers on the River Thames in the UK and

Maeslantkering in the Netherlands the barriers are in effect large gates that close off the waterway entrance to the ocean. Alternative options are inflatable barriers (inflatable dams) that can be inflated along a shoreline to protect it from higher water levels and wave events. Any of these alternative options would have to be investigated in specific detail to determine the actual costs of implementing such an option.

This long term option would require a multitude of environmental factors would require to be assessed, including options to maintain the water quality upstream of any structure. A lock or storm surge barrier would have to be upstream of the Fremantle Port to avoid impacting commercial traffic. The narrow stretch of waters between Fremantle Traffic Bridge and Blackwall Reach would be possible locations.

Table 24: Recommendations for managing sea level rise and inundation at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
2.01	Investigate options to install retaining walls along following sections to maintain emergency access in a 100 year ARI event: Scott Street/Mill Point Road On Ramp Judd Street to Hardy Street Saunders Street Thelma Street Henley Street	Moderate	MRWA
2.02	Investigate drainage system in the following areas for the prioritisation of the installation of backflow devices: Judd Street Richardson Park South Terrace Off Ramp Cale Street	Moderate	City MRWA
2.03	Investigate condition of existing pipe networks. Where required, clean existing stormwater pipe network to maintain and maximise existing capacity. Clean existing drains to minimise the flushing of large volumes of sediment in large flow events to the river and also maintain drainage network capacity, reducing nuisance flooding. Investigate options for relining of the stormwater pipes if pipes in poor condition.	High	City MRWA
2.04	Determine long term strategy and required general structural response for KFF. Sand nourish, retrofit crown walls/increase height of replacement structures, offshore headlands or offshore wave barrier. Investigate options for beach nourishment based on Trust Feasibility Options for Beach Nourishment Swan and Canning Rivers Report.	Moderate	City Trust DPaW MRWA
2.05	Commence any required approvals once higher level concept confirmed.	Low	City MRWA
2.06	Consider inundation issues when the Sea Scout building is replaced. Consider relocation of Sea Scout building and jetty.	Low	City
2.07	Investigate options for managing inundation issues with the Canning Bridge PSP underpass.	Moderate	MRWA
2.08	Manage existing beach areas with a nourishment program. Recommend nourishment in main recreational and environmental areas of Groynes, Milyu, Como and Sea Scouts. Hard structures will be required in alternative areas given the limited opportunity for retreat.	Moderate	City MRWA
2.09	Revegetate important vegetation areas to increase durability against erosion. Some areas may require stabilisation of the front edge by soft engineering approaches to reduce erosion effects. Continue increasing density of vegetation through the shorelines of Milyu, Cloisters, Infill and the Spit. Investigate planting more salt and inundation tolerant species along the foreshore as increased inundation by saline water may affect some of the existing vegetation.	Moderate	City
2.10	Consider alternative construction methodologies with rising water levels and reduce periods of low tide for the installation of foundations.	Low	City MRWA
2.11	Possible nourishment in front of hard structures to reduce weathering of structures, maintenance requirements and spray onto Freeway.	Moderate	City
2.12	Determine suitable “level of service” requirements for the Kwinana Freeway with regards traffic disruption by wave overtopping and inundation.	Moderate	MRWA
2.13	Longer term studies should commence a high level investigation for stormwater drainage requirements with a scenario of an increased mean sea level of +0.9 m.	Low	City MRWA
2.14	Continue MRWA program of Capital Upgrades on Existing Revetments to reduce spray and inundation of PSP and Kwinana Freeway	Moderate	MRWA
2.15	Investigate a longer term option of replacing the wire rope fence with a slipform concrete wall along western side of Kwinana Freeway to reduce inundation in extreme events and as a measure to mitigate rising sea levels.	Low	MRWA
2.16	Investigate alternative route options for the PSP around the Canning Bridge Underpass. Alternative to look at options for raising levels of path in this area.	Low	MRWA

4.3 MANAGEMENT OF PHYSICAL ENVIRONMENT

4.3.1 Erosion Control

Erosion control will predominantly be an issue in areas of vegetation and natural shorelines. Areas of valuable foreshore and significant vegetation can be either protected and managed to reduce the levels of erosion or allowed to naturally recede.

It is likely along the sections of Milyu, Infill and Cloisters some protection is going to be required to prevent possible erosion of the adjacent PSP. It is suggested that this would be in the form of a soft engineering approach or a form of hard engineering, softened by vegetation. Erosion control in Milyu is already being undertaken by increasing the density of vegetation through DPaW's *Milyu Five Year Rehabilitation Plan*.

In sensitive areas such as Milyu, where it is not preferred to have large amounts of machinery trafficking along the shoreline, nourishment of the area could occur by nourishing adjacent up drift areas rather than direct nourishment. Sand would be allowed to naturally move into the area by longshore transport, which would allow some recovery of areas after an erosion event. The disadvantage and risk of not undertaking direct nourishment is the sediment may not end up in the preferred location required if weather patterns are such that the sand transport is in the opposite direction. A planned approach to tackling erosion management within the Milyu area is documented within the DPaW report titled "*Rehabilitation and Freeway Infrastructure Protection Plan – Milyu Nature Reserve and Swan Estuary Marine Park.*" (DPaW 2014)

Areas in which hard structures already exist will need to be monitored for the following erosion effects:

- Undercutting.
- Flanking erosion.

Undercutting can be reduced by the installation of toe scour protection. This is likely to be in the form of rock rip rap, or alternatively geotextile sand containers in areas in which people may access the water in front of the walling. New structures should account for toe scour and be founded at appropriate depths.

Flanking erosion can be reduced by appropriately tying in structures, or by providing flexible protection solutions on the ends of structures. In many cases flanking erosion is difficult to reduce without additional effects further along the general longshore transport direction.

It is recommended that beach nodes should be identified and these areas maintained as sandy beaches, complimentary of what the original shoreline in the study area represented. The Groynes beaches in particular should be maintained as they form an important brooding area for the wader birds.

Canning River should be much less at risk of erosion than the foreshore north of Canning Bridge. It is expected that vegetation of the remnant vegetation areas with some minor soft engineering should be sufficient for the majority of the foreshore. Mt Henry Spit is more vulnerable given the dynamic nature of the sand structure.

The City is addressing Mt Henry Spit with its management plan for the area. Revegetation works are proposed to be concentrated above the 1 m AHD contour initially, with the initial buffer around the outside of the existing spit are of 10m to allow for shoreline movements. Once the central area of the spit is being revegetated successfully, effort can concentrate on the outside of the spit area to stabilise shoreline movements. There will be the undercutting of some of the trees on the boundary of the spit area dependent on shoreline movements. Where possible these trees should be left on the shoreline, even if they require some stabilisation in order to provide habitat for fauna.

Table 25: Recommendations for erosion control along Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
3.01	Continue shoreline monitoring of Milyu Foreshore to quantify shoreline movements.	Moderate	DPaW MRWA
3.02	Confirm overall strategy and visual aesthetics for KFF. Investigate offshore structures to reduce wave energy impacting the KFF.	Moderate	City Trust DPaW MRWA
3.03	Recommend nourishment in main recreational and environmental areas, Groynes, Milyu, Como, and Sea Scouts. Hard structures will be required in alternative areas given the limited opportunity for retreat.	Moderate	City MRWA DPaW
3.04	Continue revegetation of Milyu, Cloisters and Spit to enhance durability against erosion.	Moderate	DPaW City
3.05	Investigate possible sand nourishment of Palms area to reduce impact on GSC wall, erosion of PSP and overtopping onto freeway. Also to provide sediment feed to Milyu	Moderate	City MRWA DPaW

4.3.2 Water Quality Management

The City and MRWA best opportunity for improving and managing water quality is to implement WSUD best practice. The City has already prepared both an Integrated Catchment and WSUD management plan. The continued implementation of these plans will improve water quality over time. This should include improved construction practices (primarily sediment runoff from building sites) within the City to reduce siltation of the drainage network.

There may be opportunity for MRWA to improve some of the drainage along the Kwinana Freeway, to incorporate more drainage swales in the study area. This will remove a lot of the issues with sand washing from the edge of the freeway and over the PSP during rainfall events. It is suspected that this sand is also contributing to the siltation of a number of the drainage outlets along the Freeway. Improving the drainage of the freeway will also reduce small areas of flooding.

Some drainage areas within Milyu Reserve have formed small wetland type areas, which are important to bird life within the area as a source of freshwater.

These should be encouraged and built upon formally to act as a biofilter for drainage discharge into the Swan - Canning estuary where space permits. Using natural biofilters for the drainage discharge would enhance the Milyu, Cloisters and Spit areas and encourage greater numbers of fauna to utilise the areas.

Table 26: Recommendations water quality management at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
3.06	Ensure implementation of City's Water Sensitive Urban Design Guidelines and Integrated Catchment Plan.	Moderate	City
3.07	Clean existing drains to minimise the flushing of large volumes of sediment in large flow events and to maintain drainage network capacity.	High	City MRWA
3.08	Consolidation of drainage network where possible. Move towards the installation of GPT's on all outlets to the Swan or Canning Rivers.	Moderate	City MRWA
3.09	Ensure appropriate maintenance undertaken on existing GPT's.	High	City MRWA
3.10	Review opportunities for WSUD along the Kwinana Freeway.	Low	MRWA
3.11	Investigate options for backflow prevention device on stormwater outlets to prevent backflow up the drainage network.	High	City MRWA
3.12	Continue to monitor Melville Waters for Water Quality. Provide City with feedback of any possible concerns.	Moderate	DPaW
3.13	Monitor groundwater bores within region.	Moderate	DoW City
3.14	Shift to improve siltation management on building and construction sites throughout the City. This reduces the siltation load to the drainage network.	Moderate	City
3.15	Investigate improving the existing wetland areas that have formed around drainage outfalls in Milyu and at Sea Scouts. Encourage these areas as biofilter areas. Investigate the potential for Constructed Wetlands at drainage elements within Milyu.	Low	City MRWA DPaW
3.16	Increase community awareness of water quality issues. Use of low nitrogen fertilisers and actions of washing items down the drains.	Moderate	City

4.4 MANAGEMENT OF BIOLOGICAL ENVIRONMENT

4.4.1 Fauna Management

Migratory Birds

The northern part of Kwinana Freeway Foreshore is an important habitat for migratory birds, in particular the sandy bars and tidal flats. It is important that these birds are not disturbed so they can rest from their travels. While Milyu has been fenced off to the, Groynes is still unfenced and open to the public and dogs and is adjacent to jet ski activity. Some signs exist along the PSP to educate the public of the migratory bird site, however none were observed at Narrows where the jet skis are launched.

The public should be further educated to become aware of the importance of the site to migratory birds and to limit their disturbances, such as signs at Narrows. Bamford (2002) recommended constructing vegetation barriers to separate the land activity from the Groynes tidal flats. Alternative protected roosting sites could also be created along northern area of the foreshore to further encourage the roosting of these bird species.

Native Fauna

The study area is also habitat for local birds, reptiles and invertebrates. Tree hollows, logs, branches, rocks and litter should be retained in the Dryland and Transition domains as they provide refuge for the local native fauna. Trees and shrubs that provide food for birds and invertebrates should also be promoted in revegetation and soft landscape activities.

Domestic Pets

It is acknowledged that domestic pets such as cats and dogs are often important companions to people, however these pets can have quite significant impacts on native fauna.

Dogs, when allowed to run freely, disturb wetland and bushland environments and native fauna habitat. Dogs should remain on a leash throughout all areas of the Kwinana Freeway Foreshore except in designated exercise areas to minimise their impact on:

- Habitat and newly established seedlings
- Soil disturbance which may promote weed invasion
- Native fauna safety, breeding cycles, health, diseases may be passed on to native fauna through excrement
- Native fauna territory, spoiling vegetation may interfere with territorial behaviour of native fauna.

Table 27: Recommendations for managing fauna in Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
4.01	Continue to educate the public about migratory bird sites and how not to disturb the sites.	Low	DPaW City
4.02	Promote and maintain alternative roosting sites for migratory birds.	Moderate	DPaW City
4.03	Retain vegetation and rocks to provide refuge for local native fauna.	Moderate	City
4.04	Promote flora that provide food for local native fauna in revegetation and soft landscaping.	Moderate	City
4.05	Educate dog owners to keep their pets on a leash when visiting the foreshore.	Moderate	City

4.4.2 Revegetation

Approach

Revegetation is simply the act of introducing vegetation to a cleared or disturbed area. The approach most suitable for this act depends on the end land use. The main approaches used in revegetation are outlined below:

- *Restoration* – returning the site to (nearly) the same conditions and characteristics before the disturbance, using the same (or most likely) local plant species.
- *Resemblance* – planting the site to appear similar to its original conditions, using non-local flora that appear similar to local species, either in addition to or in substitute of local species.
- *Replacement* – planting the site with local and/or non-local species to suit a new land use.

The general approach of revegetating the study area is that of *Restoration*. Although the foreshore may have changed in characteristics that may be more hostile to general plant growth (e.g. increased salinity and water levels), there are a suite of flora in the Perth region that may be tolerant of these characteristics.

In some cases, it may appear similar to *Replacement*, as the revegetation species may not have been recorded within the study area but species will still be local to the Perth area. For example, it may be more appropriate to plant Saltwater Paperbark trees (*Melaleuca cuticularis*) where locally recorded Freshwater Paperbark trees (*Melaleuca preissiana*) are not coping because of increased saline water, however Saltwater Paperbarks have been recorded along the Swan River.

Likewise, the landscaped sections of the study area may resemble *Replacement,* as they have a new end land use (e.g. garden beds and parklands). However, there is no need to introduce non-local flora, as there are a suite of local native species that may be used for soft landscaping.

Revegetation Domains

Each Zone should be broadly divided up into Revegetation domains (i.e. management areas) according to their site characteristic (e.g. salt spray, inundation, soil type) and end land use (e.g. stabilisation, wind break, aesthetics). The following four Domains were recommended to be applicable for the study area:

- Transition – a buffer area between the foreshore to inland vegetation. Sandy beach soils, susceptible to inundation, storms, high winds and saline conditions.
- Wetland – inland from the Transition domain, seasonal to permanent pockets of water.
- Dryland – further inland, comprising native vegetation.
- Soft Landscape – further inland formally landscaped for recreation and aesthetics.

Species Selection

Revegetation species can then be chosen that can grow in the site characteristics and are suitable for the end land use. Species to be used in the revegetation process need to be local to the area. They also need to be those matching the vegetation complexes. Provenance is paramount to preserving local genetics of plants. Seeds and tubestock used in revegetating the sites should ideally have been sourced from the local region.

A variety of literature was consulted to select local species that may be appropriate for the study area's various communities:

- Ecologia (2003) *Western Foreshore Management Plan.*
- Natural Area Consulting (2013) *Milyu Nature Reserve Rehabilitation Plan.*
- Ecoscape (2002) *Mt Henry Peninsula Foreshore Management Plan*.
- Department of Parks and Wildlife (2013) *Nature Map* database search.
- Syrinx (2013) *Mount Henry Split Restoration Plan.*

Not all local plants may be included in the revegetation plan. Many species cannot be obtained as seeds or tubestock. Other species are known to be extremely poor in either seed germination or establishment. It is expected that species diversity will be increased overt time from colonisation.

Ideal species to be selected should be those that:

- Demonstrate promise in establishment and survival in disturbed conditions.
- Are observed to grow in habitats that match the soil and drainage conditions of the study area.
- Produce sufficient viable seed to harvest economically.
- Have fauna habitat value.
- Legume species that are good colonisers and will improve soil fertility.

(Minerals Council of Australia 1998).

The final composition of recommended species is listed in Appendix Six, taking into account:

- Species observed in the study area.
- Representative species in the Heddle vegetation complexes.
- Species that are known to occur within the region.
- Which species were ideal for revegetation.

Revegetation Method

Choice of Method

Seeding is typically a highly economical, practical and reliable method of establishing many species in large areas. Further, seeding may result in a random distribution of species, allowing for a more natural appearance to revegetated sites (Minerals Council of Australia 1998). Also, seeding allows for more wind-stable mature plants to establish, as the root systems have not been disturbed (Dalton 1993).

However, seeding may not be effective for certain works:

- The price of a seed mix is highly variable as some species prices may vary from as little as $50/kg to over $7000/kg (Tranen 2007).
- Seeds of species desired for rehabilitation may not be available in suitable quantities.
- Seeds of species required may not be highly viable and able to readily quickly establish on the site.
- Seeds are vulnerable to predation by local fauna such as insects and birds.
- Emerging seedlings may not be able compete with present weeds.
- Some species may not respond well to standard seed treatment (e.g. require a specialised dormancy breaking treatment) (Minerals Council of Australia 1998).
- Success of seed germination and seedling establishment is highly vulnerable to seasonal variations (Dalton 1993)
- Seeds may be blown away in sites with strong winds.

Use of tubestock may overcome any shortcomings in the seeding method. Tubestock:

- Are more beneficial in revegetating areas that are difficult to seed.
- Have the ability to overcome understorey growth.
- Allow for numbers of plants and species, spacing and location of trees to be controlled.
- Have a higher survival rate than direct seeding.
- Allow for using desired rehabilitation species that may not be available as seed (such as *Spinifex* species) (Minerals Council of Australia 1998).
- Offer a 'jump start' in revegetating an area, as seedlings have already germinated and grown for several months (Dalton 1993).
- May establish in sites where seeds cant (e.g. wind).

However, it must be noted that tubestock revegetation has several disadvantages:

- Planting tubestock is usually more expensive than seeding.
- Planting tubestock is only practical on a small scale.
- Seedlings need to be pre-ordered several months ahead prior to anticipated use.
- Planting tubestock takes far longer than broadcasting seeds.
- Planting is restricted to times of rainfall to ensure adequate seedling survival (Dalton 1993; Minerals Council of Australia 1998).

Overall tubestock is considered to be the most appropriate method as the zones are subject to frequent strong winds and seeds may be blown away before they can germinate and establish their roots.

Planting Tubestock

Upland plants should be planted in winter. It is preferable for planting to occur as early after the break of season as practicable, when the soil is thoroughly moist and follow-up rain expected. The longer the plants have to establish an adequate root system in the ground before the first summer the higher the success rate that can be expected. Tubestock planted in areas prone to inundation should be planted in spring as water recedes

Care must be taken to ensure the tubestock is planted properly into the ground, fully covering the roots. To maximise survival rates, the tubestock must be disease-free, sun-hardened, have well-developed roots; not be root bound, and be planted to the correct depth.

Fertiliser tablets and tree guards may be installed for each tubestock planted. The type of fertiliser tablets should be slow releasing and appropriate for native plants. Tree guards should be utilised to deter rabbits from feeding on the seedlings. The tree guards should be then removed at a later date once the tubestock have full established.

KFFMP Species Planting Guide

A Spread Sheet has been provided with the following information for all of the candidate revegetation species for the Kwinana Freeway foreshore:

- Links to Florabase, Florabank and Water Rivers Commission websites.
- Vegetation structure – growth form and height.
- Zones and Domains.
- Soil type.
- Water salinity tolerance.
- Known hardiness to wind, salt spray, drought and direct sunlight.
- Other characteristic – dieback resistance, fire retardant, bird attracting, insect attracting, significant fauna habitat, traditional/ indigenous culture.
- Flowering time and colour.
- Revegetation propagule – cell, tubestock, 130 mm pot.
- General comments.

Table 28: Recommendations for revegetating Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
4.06	Divide each zone into revegetation domains according to their site characteristic and end land use. Use appropriate local native species for each revegetation domain.	High	City
4.07	Plant tubestock in winter after onset of rains. Foreshore edge plantings to be undertaken in late spring and watered to allow for establishment prior to winter storms.	High	City
4.08	Monitor each zone to determine any significant tubestock mortalities and the conduct infill planting if required.	Moderate	City

4.4.3 Weed Control

Priority Species

Resources should focus on controlling the High Priority weeds identified during the weed survey, as these are considered the most invasive and threatening. However, other weed species should not be excluded from control activities if there are enough resources available.

In general:

- High Priority weed species should be targeted first.
- Moderate Priority weed species should be controlled opportunistically if resources allow after targeted control of High Priority Weeds.
- Low Priority weed species should be controlled opportunistically if resources allow after control of Moderate and High Priority Weeds.

It should also be noted that as weed control of priority species progresses, other weed species which previously may not have been rated as high, may become more important. Therefore, it is important to keep weed control programmes flexible and updated according to monitoring data to ensure that as bushland condition changes and weed species dominance changes, the control activities are adjusted accordingly.

Optimal Control Times

The optimal control times for each weed mapped have been provided in the KFFMP Weed Management Spread Sheet. The optimal control times for targeting the known weed species was determined by referring to DEC (2012) *Swan Weed Database*. In general, it is most cost effective to conduct weed control in April and August, as contractors can target a weeds, as these months are most of the species are most vulnerable to herbicides. Additional weed control works are still required.

The months may need to be adjusted to accommodate the change in the inventory that may occur over time to aid in targeting the new weed species and removing weed species that have been determined to no longer occur.

The optimal times to control each weed species is summarised in Appendix Four.

Targeting Weed Growth Forms

Weed species were separated into four growth form groups according to their biology. The growth form groups were then subdivided to group weed species with similar methods of control. The grouping was to aid in understanding what types of weeds were dominating the study area and what main control actions would be needed to reduce their diversity and presence (Figure 21).

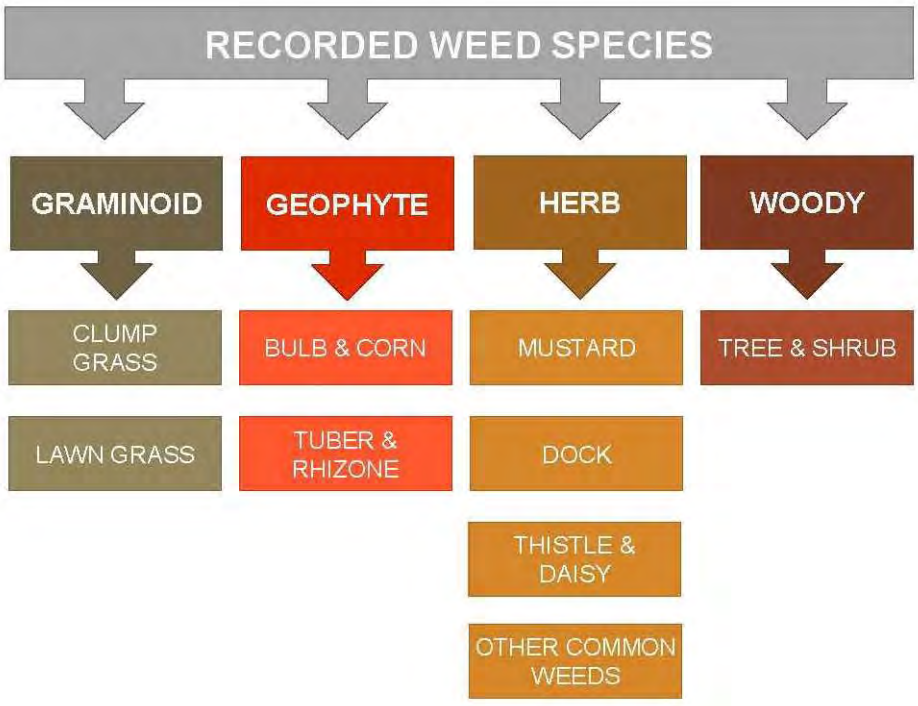

Figure 21: Growth forms of Kwinana Freeway Foreshore weed species

It is important to understand the biology of each identified weed species in order to determine the best way to control them. Knowledge should focus on how the plant grows and propagates in order to both remove the existing plants and to prevent future generations. As such, the identified weed species were separated into four types, according to their biology and the type of control methods.

The following section describes the biology of each of the four weed growth forms and notes which of the below control methods are the most effective to control that type. Table 29 lists which High Priority weed species belonged to that growth form.

Geophytes

Many geophyte weeds are 'garden escapes'; originally planted in people's gardens for aesthetics where seeds have entered adjacent bushland. Most of these species are Irises (family Iridaceae) from the cape region of South Africa. The similar climate and soil types made the Perth metropolitan region and south west highly suitable for these species to proliferate and become major environmental weeds.

Geophyte weeds are plants capable of reproducing though underground propagules such as bulbs, corms and tubers. Normal weed control practices are inefficient, as the parent plant may be killed, but the plants may return from sprouting underground propagules. Weed control therefore requires targeting the propagules as well as the parent plant.

If the populations are small, it may be practical to manually remove the plants. Care must be taken to dig around each plant and ensure that all of the underground propagules are also removed, otherwise new plants will appear in the following year. Caution must also be taken if digging in aboriginal heritage sites, as this method risks damaging burial remains.

Certain herbicides such as chlorsulfuron, metsulfuron and 2, 2 DPA are often used to control geophytes, as they can poison both the parent plant and the underground propagules. Such herbicides are best applied when the plants are flowering to maximise the absorption into the propagules. Application can be carried out by either wicker wiping or spot spraying, depending on the species (e.g. wicker wiping is ineffective on Guildford Grass but is highly effective on Watsonia). Special care must be taken to ensure that adjacent native plants are not exposed to these harmful chemicals. Metsufluron is a common herbicide control treatments that will control most of the recorded geophyte weeds (e.g. Arum Lily, Black Flag, Soursob).

A total of 15 geophyte weed species were recorded or thought to occur in the study area. Of these, 11 are rated High Priority.

Graminoids

Grass, sedge and rush species are all closely related monocots. They have similar physiology which makes them susceptible to certain herbicides that may not be as harmful to broad leaf plants. Using grass selective herbicides such as Fusilade® may assist in controlling monocot weeds while having minimal impact to adjacent broad leaf native plants. Herbicides may be applied through wicker wiping or spot spraying. Many of these species are highly competitive with native plants and can dominate the understorey. Most monocot weeds, particularly annuals, produce high numbers of seeds to ensure seedling recruitment in the following year. It is therefore vital to control infestations before they set seed to prevent further spread of these populations.

Some of these species, in particular lawn grasses, can also spread by rhizomes and stolons. If the grasses cover the ground, effectively forming a lawn, they may in some circumstances be controlled by smothering them in black plastic in summer. If the grasses are invading into bushland areas, they may be controlled by manually gathering the spreading rhizomes/ stolons and removing them off the site.

A total of 19 Graminoid weed species were recorded or thought to occur in the study area. Of those, eight are rated as High Priority.

Herbs

Along with grasses, herbs are usually the most common type of weed species in a bushland. Most species do not invade good condition bushland, rather they are opportunists that enter when a site is disturbed. Broad leaf herbs are generally easier to control than geophytes, as they only spread by seed and do not have underground propagules. Such weeds should therefore be controlled before they can set seed, as this is their only method of reproduction. Herbs can be controlled through most general methods. Small populations should be manually removed before they set seed. Care must be taken to remove the crown and taproot, otherwise plants may resprout.

Most species are susceptible to glyphosate when actively growing, although other herbicides may be required on some glyphosate tolerant species. Herbicide application may be through either wicker wiping or spot spraying, depending on the size and nature of the infestation in each reserve.

Mustard Weeds are members of the Brassicaceae family. Common weed species in this family include Wild Radish (*Rhananus rhaphistrum*), Wild Turnip (*Brassica tournefortii*). Most are susceptible to metsulfuron (e.g. Ally®, Brushoff®), triasulfuron (Logran®) and diflufenican (e.g. Bonanza Elite® and Broadal®) based herbicides.

Dock Weeds are members are all in the genus *Rumex*. They are also prolific seeders and can readily invade bushland. Once mature, they develop deep root stock and can resprout from root fragments, making manual eradication difficult. Most members are susceptible to chlorsulfuron based herbicide (e.g. Glean® and Lusta®).

Thistles and Daisies are all part of the Asteraceae family. Common weed species in this family include Flatweeds (*Hypochaeris*), Sowthistles (*Sonchus*) and Ursinia (*Ursinia anthemoides*). Most of these weeds tend to occur in disturbed and degraded sites and do not frequent good condition vegetation. Glyphosate is usually effective, as well as clopyralid based herbicides such as Archer® and Lontrel®.

Other common herb weed species include Legumes (*Lupinus* sp.), Carnation Weed (*Euphorbia terracina*),. Fumitory (*Fumaria* sp.) and Geranium (*Geranium* and *Pelargonium* sp.). Most of these herb weed species are susceptible to glyphosate, clopyralid and metsulfuron herbicides.

A total of 50 herb weed species were recorded or thought to occur in the study area. Of those, eight species were rated High Priority.

Woody Weeds

Many woody weeds (tree, shrub and climbers) are ‘garden escapes’ which have invaded adjacent bushlands. Other species, such as the Summer Scented Wattle, are local native species which can be aggressive and dominate in disturbed environments. Most species of this type are generally easy to control. Timing should focus on when they are actively growing and before they set seed.

Mature plants of trees, shrubs and perennial climbers may be cut to ground level and the stump treated with straight glyphosate to prevent the roots from resprouting. Trees and shrubs with prominent stumps may be treated with stem injection or basal bark spraying. Seedlings and annual climbers should be eliminated before they can mature. If numbers are small, it is best to manually remove them. If numbers are high, spot spraying would be more practical.

A total of 18 woody weed species were recorded or thought to occur in the study area. Of those, four species were rated High Priority.

Table 29: Growth forms of High Priority weeds species at Kwinana Freeway Foreshore

Growth Form	Group	Species
Geophyte	Bulb and Corm	Black Flag (*Ferraria crispa*) Fingerleaf Oxalis (*Oxalis glabra*) Guildford Grass (*Romulea rosea*) One-leaf Cape Tulip (*Moraea flaccida*) Soursob (*Oxalis pes-caprae*) Three-cornered Garlic (*Allium triquetrum*) Watsonia (*Watsonia meriana* var. *bulbillifera*) Wavy Gladiolus (*Gladiolus undulatus*) Wild Gladiolus (*Gladiolus caryophyllaceus*)
	Tuber and Rhizome	Arum Lily (*Zantedeschia aethiopica*) Bridal Creeper# (*Asparagus asparagoides*)
Graminoid	Clump Grass	African Love Grass (*Eragrostis curvula*) Great Brome (*Bromus diandrus*) Hare's Tail Grass (*Lagurus ovatus*) Pampas Grass# (*Cortaderia selloana*) Perennial Veldt Grass (*Ehrharta calycina*)
	Lawn Grass	Buffalo Grass (*Stenotaphrum secundatum*) Couch (*Cynodon dactylon*) Kikuyu (*Cenchrus clandestinus*)
Herb	Other Common Weeds	Blue Lupin (*Lupinus cosentinii*) Geraldton Carnation Weed (*Euphorbia terracina*) Petty Spurge# (*Euphorbia peplus*) Rose Pelargonium (*Pelargonium capitatum*)
	(no grouping)	Doublegee (*Emex australis*) Freesia (*Freesia alba* x *leichtlinii*) Pigface (*Carpobrotus edulis*) Sea Spinach (*Tetragonia decumbens*)
Woody	Tree and Shrub	Japanese Pepper Tree (*Schinus terebinthifolius*) Lantana (*Lantana camara*) Olive (*Olea europaea*) Victorian Tea Tree (*Leptospermum laevigatum*)

4.4.1 Application of Herbicides

It is necessary that the application of herbicides be in accordance to labelling requirements or the manufacturers Materials Safety Data Sheet (MSDS) and must be undertaken by personnel trained in the use of herbicide chemicals. The application of any herbicide for purposes not specified on the labelling requires an Off-Label Permit from the National Registration Authority in Canberra.

Where possible, a variety of herbicides are recommended for controlling each weed species. It is up to the contractor to decide which herbicide is the most appropriate to use, depending on costs and availability of the herbicides. Specific herbicides (e.g. grass specific herbicides) are preferred over general herbicides (e.g. glyphosate) as they are formulated to kill that weed growth form and have little impact on nearby native plant species. It should be noted that no specific herbicides are harmless to all native plant species, so application of any herbicide should be done with care.

The application of herbicides must also be in accordance with water catchment restrictions. Chemical based weed control strategies, in particular, must recognise potential adverse impacts on water resources such as lakes, wetlands, streams, rivers and dams. Significant control measures must be implemented in Public Drinking Water Sources Areas. The Department of Water's (Department of Water 2000) *Statewide Policy No.2 Pesticides in Public Drinking Water Sources Areas* provides further advice on this matter.

Information relating to the mobility of herbicides in soil, average half life in soil and water, and bioaccumulation can be found within the herbicide's Materials Safety Data Sheet (MSDS). The herbicide's label should also contain a section outlining appropriate measures for the "Protection of Wildlife, Fish, Crustaceans and Environment".

Details of herbicides recommended for controlling weeds in Central Park Mandurah are also provided in the Weed Control Spread Sheet.

Herbicide Techniques

Stem Injection

An easy method to kill large trees and shrubs is to drill a hole into the trunk at a 45 degree angle and to immediately fill the hole with herbicide. The hole must be deep enough to penetrate the sapwood to ensure the herbicide is absorbed and circulated within the plant. If the plant has multiple stems, then all stems will need to be treated (Dixon & Keighery 1995).

Cut Stump

Some species may be controlled by cutting down to ground level and treating the stump with straight herbicide. Typical species suitable for such treatment are trees, shrubs and vines (Dixon & Keighery 1995).

Wicker Wiping

Herbaceous weed species may be treated with herbicide by wicker wiping. This involves sponge or rope soaked in a concentrated herbicide solution which is wiped against the leaves of the plant (Dixon & Keighery 1995). Wiping is often more effective in targeting weed plants and not harming adjacent native plants, however this process may be more labour intensive. Weeds most ideal for this treatment are small populations of small shrubs and broadleaf herbs.

Spot Spraying

Spot spraying involves fine spraying a weak solution of herbicide over the foliage of the weeds. Certain tree species may also be treated by spot spraying the base of the trunks with herbicides diluted in diesel. Care must be taken to avoid spraying adjacent native plants. Use of selective herbicides may reduce impact of herbicides on native flora (Dixon & Keighery 1995).

KFFMP Weed Management Spread Sheet

A Spread Sheet has been provided with the following information for all of the weed species recorded of thought to occur in the Kwinana Freeway foreshore:

- Inventory – full list of weed species and their growth form.
- Priority - state and national ratings and calculated priority rating.
- Control Time - optimal and suboptimal control times.
- Management.
- Identification, including a links to Florabase, Weed Australia, SEWPAC and other information websites.
- Manual and herbicide control methods.
- Extra Information – taxonomy, reproduction method, threat and impact on native vegetation.
- Herbicides – names, active ingredient, schedules and registrations.
- References.

Table 30: Recommendations for weed management at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
4.09	Target High Priority Weed species in the bushland to reduce their presence and threat. Moderate and low weed species may also be targeted if resources allow.	High	City
4.10	Target weed species by using appropriate treatments according to their growth form	High	City
4.11	Ensure that only appropriate herbicides are used and are correctly applied.	High	City
4.12	Direct weed control activities to occur in April and August each year to effectively control most of known high Priority weed species.	High	City

4.4.2 Plant Disease Management

Prevention

Human activity is perhaps the biggest factor contributing to the spread of plant diseases. Infected soil can be moved around the Reserve on vehicles or bikes, footwear, animal movements, road construction and earth moving equipment. It should be noted that the City cannot police against the spread of dieback, but can only provide facilities to minimise the spread.

There are two main types of human activity in the study area:

- Onsite construction and revegetation activities by ground personnel.
- Social activities by the general public.

Ground Personnel

Construction and revegetation contractors should have appropriate equipment to prevent diseases from being introduced into the bushland. Contractors should inspect and clean all footwear, equipment and vehicles before going to the study area. Plant cutting equipment such as secateurs or saws should always be cleaned before being used on a plant. Any contractors who need to access the bushland should also be made aware of the disease risk and what management measures are required to prevent the introduction and spread of dieback.

All incoming materials may potentially contain disease. Therefore the City should ensure that any revegetation materials only come from disease free sources, such as certified nurseries and mulch suppliers.

General Public

The public may unknowingly introduce disease into the bushland. To minimise this risk, the public should be informed through the use of signs of the threat of these diseases and what they may do to assist in reducing the risk.

Suggestions for how they may minimise the risk include:

- Not entering the bushland areas.
- Not allowing pets to enter the bushland areas.
- Not dumping any material that may contain soil into the bushland.
- Not cutting any plants in the bushland.

Management

Dieback

A formal system is required to conduct regular dieback assessments of the study area for signs of any disease infection. The City should engage a certified dieback consultant to conduct the assessments.

If dieback is detected, the boundaries of the infection should be marked. The following management considerations are required to mitigate the further spread of the disease (Dieback Working Group 2000):

- Signage to be placed on all tracks traversing the infested areas at the infested boundary.
- All authorised staff entering the bushland to be made aware of the quarantine boundaries and limit unnecessary use of tracks in moist-soil conditions.
- The infested boundary to be re-assessed annually to determine if it has spread further.
- The City is to be informed of the infection and what actions are being conducted to reduce the risk of it being spread.

Honey Fungus

There is no known cure for honey fungus. None of the fungicides tested by Bailey (1995) were shown to control this fungus in bushland.

Aerial Canker

There is no large scale control method for Aerial Canker but on an individual tree scale control is largely through the removal of infected limbs. They can be controlled using clean secateurs and a benzimidazole fungicide, such as Carbendazin® (Murray 1997).

Table 31: Recommendations for disease management in Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
4.13	Ensure that all contractors have appropriate equipment to prevent diseases from being introduced into the bushland.	High	City
4.14	All contractors are to be made aware of the disease risk and what management measures are required to prevent the introduction and spread of dieback.	High	City
4.15	Ensure that any revegetation materials only come from disease free sources.	High	City
4.16	The local public is to be made aware of dieback and what they may do in reducing the risk of introducing and spreading the disease.	Moderate	City
4.17	The City is to be informed of any detected infection and what actions are being conducted to reduce the risk of it being spread.	High	City
4.18	Any detected small infections of Aerial Canker are only to be removed using removing the infected limbs with clear secateurs and a benzimidazole fungicide.	Moderate	City

4.4.3 Fire Management

The Fire Management Strategy has three core elements as follows:

1. Fire Prevention – minimising the possibility of a fire outbreak.
2. Fire Preparation – preparation in the case of a fire outbreak.
3. Fire Recovery – restoring the damaged parts of the study area after a fire.

Fire Prevention

Prescribed Burning

Prescribed burning is a commonly used practice in the Swan Coastal Plain for reducing fuel loads in vegetated areas. Fuel reduction involves reducing fuel levels to a point where any potential fire can be controlled by fire fighting crews on a normal summer day (Wychery & Robley 1983). Fuel reduction burns are typically carried out in the form of *mosaic burning*, in small sections at a time.

However, prescribed burning should not be conducted in certain circumstances. Mosaic burning is impractical in small stands of vegetation. It may not able to safely control burn offs in areas containing large fuel loads and highly ignitable vegetation. Smoke generated from any prescribed burning may be wind blown into adjacent residential areas. It is also unknown what impact fires will have on the ecology of this study area. Species composition may change, promoting fire adapted species while declining non-fire adapted species. Populations of any significant flora may be impacted or even destroyed.

Prescribed burning is therefore not recommended for the study area.

Fire Restriction

The risk of fire outbreak occurring can be minimised by restricting and forbidding certain activities and reducing the presence of potential hazards. Any activities that may pose as a fire risk needs to be either eliminated by replacing with another activity that is less fire hazardous whenever possible or otherwise minimised by setting a variety of safety controls.

Fire restriction legislation and practices are currently in place to minimise fire outbreaks throughout the City.

Community Involvement

In the context of fire management, it is considered important that local residents and cyclists are kept informed of:

- The ecological and social value of the study area.
- The risk of fire to the study area.
- The need, due to proximity of the built environment to the bushland, to be fire aware and prepared.
- The City's plans and activities in relation to protecting the study area.
- The community's role in reducing the fire threat and risk to the built environment and to the study area.

Within the framework of a communication/engagement programme, adjoining residents could be provided readily available information, including pamphlets provided by DFES, to assist them in their own fire preparedness. Relevant pamphlets are available from DFES's Community Development Unit's Resource Officer.

The City should continue to educate the local residents about the ecological and social importance and fire risk of the study area so they may become interested in the care and management of the study area. Information and action plans may be provided in the form of public meetings, leaflets and fridge magnets. The residents can play a role in fire prevention and preparation by:

- Talking to their children.
- Surveillance of the study area and reporting any:
  - suspicious behaviour to the City
  - reporting any smoke or lit fires by ringing 000.

Fire Preparation

It must be noted the fire risk hazards and vegetation communities are expected to change across the study area over time as weed control measures should decrease fire ignition risk and revegetation strategies may increase fuel loads. Annual or biennial site assessments may be required to update the fire risk component of the Fire Strategy.

Weed Management

As discussed in Section 3.4.1, the management of a number of weed species is critical in managing the fire hazard risk of the site. The bushland's grassy weeds and other fire ignition risk weed species are of highest priority to control. Woody weed species should be eliminated at the seedling stage before they can mature, contribute to the fuel load and/or the soil seed bank.

Natural vegetation abutting paths are vulnerable to weed infestation as a result of edge effect disturbance and the introduction of weed seeds by pedestrian traffic. All access paths throughout the study site should be routinely inspected and controlled for all weeds.

Community Involvement

In addition to their role in the prevention of fire, the residential community within and adjacent to the study area, should be provided information regarding the reduction of fire risk to their properties. The City currently informs residents through letters and news releases how to prepare for fire, including removal of accumulated flammable material, slashing long grass and maintaining fire breaks. Rangers inspect properties to ensure they are complying with the City's fire notices.

The City should consider distributing to adjoining residents information on fire prevention currently available from DFES. Such information will help residents prepare for any fire outbreak and minimise the risk of loss of life and or property.

Fire Recovery

Investigating Cause of Fire

Investigation of the cause of any fires should be undertaken, in order to assist in apprehension of the offenders if arson is the cause, and to prevent future fires. Activation of the Fire Investigation Team is the responsibility of the DFES Incident Controller. When arson is suspected, the Incident Controller should initiate an immediate investigation (FESA 2004).

The first attending fire brigade completes a *Fire Incidence Report Form* which is then entered into the FIRS database (Fire Incident Reporting System), which is used to assist in community safety initiatives and for resource/ response needs. The form should be submitted to DFES, who will combine the information with that supplied by the responding suppression unit into their database. The form collates various data including:

- An estimate of area damaged.
- What property and infrastructure were damaged.
- Problems encountered when combating the fire.
- Other agencies involved.
- The fire danger index and weather conditions on the day.
- Success of preparedness initiatives.
- Fire response activity undertaken.

The information will assist any insurance claims by residents whose property is damaged by fire and also to assist DFES assess their response strategies.

Access and Safety to Public

Any damaged fencing should be replaced or repaired as soon as possible following fire. If substantial areas have been burnt, prominent signage should be erected to explain the damage caused by fire, and the risks associated with trespassing in the burnt areas of the study site.

Fauna

Following a serious fire and clearance for entry by the local fire brigade, the site should be immediately searched and any injured fauna rescued and treated by qualified carers that are approved by the DPaW. Animals may be released back into the study site once the bushland is deemed to have enough suitable habitat and refuge.

Post-Fire Monitoring and Maintenance

Monitoring

It should be remembered that although the fire risk hazard of an area is initially negligible after a fire, this status can quickly increase over the following years as fuel load and ignitable plant materials return. Future monitoring should continue to assess the fire risk hazard of burnt areas and adjust the management actions as appropriate.

Weeds and native vegetation regrowth throughout the burnt areas should be monitored. Monitoring should include the establishment of fixed random quadrats in each burnt vegetation community. Each quadrat should be GPS recorded. Photos should be taken of each quadrat at the time of monitoring to establish a visual record. Records of native and weed species, their numbers and health and any general observations should also be recorded.

Weed Control

Prevention of weed invasion is the most urgent requirement following fire within the bushland. Increased nutrients and light together with decreased competition from native vegetation will support enhanced weed growth and spread. Any increase in the presence of weeds will degrade the condition of the bushland and also increase fire ignition risk. The post-fire situation provides an ideal opportunity, with improved weed management access and enhanced weed germination, to significantly impact the weed population of the study site.

Weeds should be targeted during regeneration following fire, with options such as spraying or hand weeding to be considered, as appropriate. Any weed control should follow the strategy described in the recommendations in **Section 3.4.1**. Weed control should target the source of the returning weeds – germinating seeds, resprouting plants or both.

Revegetation

Natural regeneration should be monitored post-fire. Depending on the intensity and/or frequency of fire, or other factors, natural regeneration may be inhibited. An intense fire may sterilise areas through the death of existing vegetation and destruction of the seed bank. In such a case, direct seeding or revegetation with local provenance tubestock should be considered.

Fire History

Fire history has a major role to play in the determination of fuel condition and quantity. The recording of accurate fire histories is an essential component of fire management planning. This involves the recording, preferably using Geographical Information Systems (GIS), of the following factors:

- Location of ignition.
- Cause of ignition, if known (e.g. arson).
- Date of ignition.
- Fire damage distribution (scars).

Fire histories built up in this way will provide a firm basis for identifying areas at high risk because of frequent burning. Identification of the time since the last burn will allow more accurate mapping of fuel loads in bushland areas of good condition. Time since last burn is less important in areas where grassy understorey is present as this returns to pre-fire fuel loads rapidly. Mapping of fire histories will also allow identification of areas that have not been burnt for many years, as these are also an important conservation value.

Table 32: Recommendations for fire management in Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
4.19	Ensure that prescribed burning is not conducted in the study area as part of a fire prevention strategy	High	City
4.20	Raise awareness of the community's role in protecting the local bushland and their own properties.	High	City
4.21	Ensure all paths and tracks in and around the study area are routinely inspected for weed presence and controlled.	High	City
4.22	Provide information to residents within or adjacent to the study area on their role in preparing for risk of fire outbreak.	Low	City
4.23	After a fire, promptly complete and submit a Fire Incidence Report Form to DFES.	Moderate	City
4.24	Reduce public access to fire-damaged areas of the study area through provision of signage and fence repair.	High	City
4.25	Following a fire, arrange for the immediate rescue of any injured fauna.	High	City
4.26	Following a fire, monitor the natural revegetation of the bushland and conduct weed control and revegetation maintenance if required.	Moderate	City
4.27	Maintain a record of the study site's fire history	Low	City

4.5 MANAGEMENT OF SOCIAL ENVIRONMENT

4.5.1 Heritage

Indigenous Heritage

The Swan River has significance to the Nyungar people. In particular, the base of Mt Eliza is the sacred home of the mythological Waakal (Rainbow Serpent). The entire foreshore is registered as a camping ground heritage site. The City should obtain Section 18 approvals from the Minister for Aboriginal Affairs before undertaking any site works to ensure no damage or alteration occurs to an Aboriginal site. Annual summary reports of ongoing works should also be provided to the DIA to ensure ongoing works do not impact on Aboriginal sites.

There is much opportunity in promoting local Aboriginal culture and heritage along the foreshore. The City should work with local Aboriginal groups and elders to develop ways to promote heritage, including interpretive signage, artworks, and nature based play areas. Several plant species with aboriginal significance (e.g. food, materials) have been identified and listed in the revegetation species list (Appendix Six). Such species should be promoted in the planting design and integrated with interpretive signage. A Wayfinding and Interpretation Plan should be developed to strategically facilitate coordination for this work along the entire foreshore.

Table 33: Recommendations for Indigenous heritage at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.01	Incorporation of interpretive items and artworks as per the outcome of the Section 18 approval.	High	City
5.02	Yearly summary report of works undertaken provided to DAA.	High	City
5.03	Work collaboratively with local Aboriginal Groups and elders in the development of interpretative elements including signage, artworks and nature based play elements.	Moderate	City
5.04	Promote local native flora that have Aboriginal culture significance	Moderate	City
5.05	Develop and implement a Wayfinding and Interpretation Plan for the foreshore to facilitate a co-ordinated plan for interpretation and education.	High	City

European Heritage

The river and foreshore of the study area has been part of Perth's European history. More research should be undertaken with local community groups and historians to discover more of the local history. From this knowledge, interpretive themes and elements may be developed and included in the proposed Wayfinding and Interpretation Plan to strategically promote the study areas' history to the public.

Table 34: Recommendations for European heritage at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.06	Review and liaise with local community groups and historians to develop interpretative themes and elements including signage, artworks and nature based play elements.	High	City

4.5.2 Recreation

Amenities

Previous reports and anecdotal evidence identify a number of recreational activities occur within and around the site. These include:

- Walking, cycling, dog walking, jogging, rollerblading/ scooting.
- Boat launching, canoeing, skiing, jet skiing.
- Fishing, picnicking, swimming.
- Nature based play.

Recreational support infrastructure is mainly located at the Como overpass node which includes picnic tables, a toilet facility, a swing and some bench seating. Other infrastructure within the foreshore is limited but includes:

- Irregularly spaced rubbish bins.
- Jetties.
- Boat ramps.
- Bench seating.
- Shade structures.
- Signage.

These facilities and amenities are in various states of condition and style, and are subject to vandalism depending on their location.

The increasingly hotter climate in Perth necessitates the provision for regular drinking fountains and shaded rest spots along the PSP. Additional amenities which should to be considered include bike racks, fitness equipment, drink fountains, bench seating for contemplation, nature based play equipment, fish cleaning stations and toilet facilities.

All new amenities should be consistent in design and colour and complement other amenities and the surrounding natural areas. They should also be co-located to cater for a variety of recreational activities.

Table 35: Recommendations for amenities at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.07	Conduct an audit of existing facilities and amenities assessing safety compliance, condition and accessibility.	Moderate	City
5.08	Prepare a detailed Foreshore Landscape Master Plan and costing to guide the upgrade of the foreshore's facilities and amenities on a stage by stage basis.	High	City
5.09	Ensure all amenities are complementary in colour and style and blend in with the natural environment.	Moderate	City

Visual Amenity

The study area generally can be classified as having a high visual amenity due to the presence of native vegetation, the natural amenity and visual access across the Canning River and Swan River. Natural amenity values can be improved over time with the ongoing beach nourishment, weed control and revegetation of the existing vegetation types located along the foreshore.

Maintaining visual access to the west and providing locations to appreciate the riverine visual amenity can be achieved through specifically located rest locations with framed view sheds for users of the foreshore. The use of screening vegetation between the freeway and the PSP should be considered to reduce the visual and noise impacts associated with the Kwinana Freeway. There are limitations on the extent of screening vegetation opportunities based on the structure of the site in some locations along the foreshore. Main Roads WA' guidelines require a setback of 9 m to the nearest plant with a stem/trunk diameter of 100 mm if there is no protective guardrail. Protective guardrails would need to be installed if additional screening shrubs and trees are to be planted closer to the freeway. An additional factor to be considered for screening vegetation is it will detract from the visual amenity to freeway users. This is important given the large number of people that use the freeway would benefit from views to the river and foreshore while travelling.

Table 36: Recommendations for visual amenity at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.10	Prepare a detailed Foreshore Landscape Master Plan and costing to guide the installation of screening vegetation to key areas of activity and where it does not pose a hazard or detract from the visual quality to freeway users.	Low	City

Access

Pedestrian Access

Pedestrian and cycle access can be achieved from various points along the foreshore, they include:

- Mt Henry Bridge.
- Edgewater Road.
- Gentilli Way.
- Canning Bridge.
- Cale Street.
- Thelma Street.
- Preston Street.
- Comer Street.
- Hardy Street.
- Mill Point Road.
- Narrows Bridge.

These points provide access for pedestrians, bicyclists and wheelchairs. However the ramps to Edgewater Street, Hardy Street and Cale Street are too steep to be managed by a wheelchair without assistance. Disabled access is a high priority for this area as there are several nursing homes and aged residents in the area, so any future constructions must facilitate equal access.

Public awareness of access points along the foreshore is limited and should be signed and connected to surrounding cycle, pedestrian, bus and train networks to create a better connectivity of the foreshore and surrounds.

Vehicular Access

Vehicular access is limited for public vehicles especially larger vehicles and trucks, however regular maintenance utilities can access the PSP to conduct inspections and minor works via removable bollards and locked gates at key locations.

The following locations can be accessed by the public:

- Mill Point Road.
- Gentilli Way.

The following locations can be accessed by approved personnel from the City, Trust and MRWA:

- MRWA Gates;
    - N1 - Judd Street On Ramp (limited height access);
    - N8 - South Terrace Gate;
    - N2 - Como Foreshore Gate;
    - N3 - Sea Scouts Gate;
    - N4 - North Canning Gate; and
    - N6 – North Mt Henry Gate

Restricted access for large trucks adds significantly to the cost of doing any major works along the foreshore. Traffic management costs of projects are significant, especially if closure of a lane of the freeway is required and construction material deliveries are generally limited to off peak times only.

Water's Edge Access

The foreshore has a number of access points to cater for the various water based activities which occur at along the foreshore. These points include:

- Narrows (Jet Ski Beach).
- Groynes.
- Milyu.
- Como.
- Como Sea Scouts.
- South Canning.
- Cloisters (limited).
- Infill (limited).
- Mt Henry.

Public awareness of water's edge access points along the foreshore should be signed at key locations and identified on the City website.

Table 37: Recommendations for access at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.11	Assess access points for equal access and ensure adequate access is achieved at regular locations by all users.	Moderate	City MRWA
5.12	Investigate and assess feasibility of access opportunities at key locations to cater for large maintenance/ works trucks.	Moderate	City
5.13	Provide detailed information regarding public access to the foreshore on the City website including pedestrian, cycle, equal access, vehicle and water based activities.	Moderate	City
5.14	Replace footbridges which do not meet requirements for disable access. Hardy Street, Cale Street and Edgewater Street footbridges.	Moderate	City MRWA
5.15	Replacement for Hardy Street footbridge should be shifted to link across to the proposed South Perth Train Station and Richardson Reserve	Low	City MRWA

Paths and Walkways

The foreshore paths and walkways cater to a wide variety of recreational and commuter users. The primary path is the PSP which provides the spine to the foreshore. This path is connected to the local residential path network on the eastern side of the Kwinana Freeway via overpasses and car parks. Secondary tracks also support the PSP providing an intimate experience for recreational users and connection to key activity places along the river foreshore.

As with most complex user groups there are conflicts between the various types. The primary conflict is the actual and potential conflicts on the PSP between cyclists and walkers, particularly walkers with unrestrained dogs and commuter cyclists riding in groups.

Dog walking is a popular recreational activity and was occurring in numerous zones however there are a number of conflicting user groups which have led to certain zones being banned from having dog walking. The long term management and protection of local flora and fauna should provide guidance in locating appropriate dog exercise and dog on leash activity areas.

Conflict between path users and maintenance vehicles is also another issue which requires management. Currently vehicles when accessing certain sections of the foreshore on the PSP, have limited points to pull off the path and avoid conflict. This is of particular concern when a large group of cyclists are using the path.

Table 38: Recommendations for path and walkways at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.16	Prepare a detailed Foreshore Landscape Master Plan and costing to assist in planning for dog off leash areas and sign posting of dog on leash conditions	Low	City
5.17	Include Water Points on the Walk Path along the Canning River between Mt Henry and Canning Bridges	Moderate	City
5.18	Separation of cyclists and walkers where possible	Moderate	MRWA

Car Parks

The foreshore has two public car parks catering for boat and jet ski launching. Access to these car parks is variable, based on the time of day and day of the week. Peak use of both of the car parks is normally on the weekends:

- Mill Point Road.
- Gentilli Way.

The Mill Point Road car park is well defined and provides a variety of parking options. A boat ramp is located on the south western side of the car park with a turning area for cars to clear the area once launching their boat/ jet ski. The car park has limited shade and amenities surrounding it.

The Gentilli Way car park is poorly defined and consists of a large bituminised space with a wide beach access. The car park has good shade around the edges from well-established trees. Pedestrian access across the car park is not clear and may pose safety concerns. Access on and off the over pass is poorly defined with conflicting pedestrian paths converging on the access point. Flood lighting is located on either side of the car park, with limited other facilities available to recreational users.

Table 39: Recommendations for car parks at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.19	Prepare a detailed Foreshore Landscape Master Plan and costing to guide the upgrade of the foreshore's facilities and amenities on a stage by stage basis.	Moderate	City
5.20	Prepare a review of the car parks to ensure they meet standards and safety requirements.	Low	City MRWA

Water Based Recreation

The Narrows is a popular picnicking area where various water activities take place. However there are minimal shelter and barbecuing facilities to support these activities, with lack of shade in summer being a major issue. Gentilli Way boat ramp recreational area also has a picnic area similar to the Narrows, which has inadequate shade and barbecuing facilities. Como Beach is another popular recreational node, which requires regular maintenance to prevent possible beach erosion caused by the high number of visitors.

The Sea Scouts area and Olive Reserve have poor pedestrian connection. This can be improved with a footbridge at Cale Street to encourage more visitors.

There is also an opportunity to replace the old Sea Scouts building with a multi-purpose function centre and Scout facility, providing views over the Swan River from the second storey. The Sea Scouts building would

likely experience inundation of the floor in significant high water events in its current location. This will become a more frequent issue with sea level rise in the coming 30 plus years. Given the age of the current building, it is likely that it will require replacement within this period and this would provide opportunity to accommodate for sea level rise within the structure.

Consideration should also be given to shifting of the Sea Scouts to another area which may be more easily accessible for members. This could possibly be the Mill Point Road area, or alternatively the Canning Bridge Precinct area if vehicle access to the area is going to be provided

Table 40: Recommendations for water based recreation at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.21	Improve shade facilities and possibly picnic and barbeque facilities at the Narrows. Consideration of personal water craft usage of the area.	Moderate	City
5.22	Continue to maintain beach areas at Como Beach and encourage this area as a recreational node for water interaction.	Moderate	City
5.23	Improve the recreation area at Gentilli Way boat ramp with the provision of shade and picnic facilities on the adjacent grassed areas.	Low	City
5.24	Increase the activation between the Scouts area and Olive Reserve. A better footbridge at Cale Street would encourage improved access to this area.	Low	City
5.25	Investigate the potential for the relocation of the Sea Scouts and Jetty. Investigate the potential for the incorporation of a function centre.	Low	City
5.26	Given loss of dog walking areas at Skinny and Palms, alternative dog walking areas shall be identified. It is suggested that Scouts and North Canning zones would provide opportunities for dog walking.	Low	City

4.5.3 Public Awareness, Education and Training

Signage

Signage is a critical component in the short and long term management of public open space for communicating risks, regulations and points of interest. The key is providing a balance of information and the number of signs; as too much signage can detract from the visual amenity of a place and can lessen the impact of the content of the information.

The foreshore currently has a variety of signage types which have been installed in an ad hoc manner. Prior to installing additional signage an audit should be conducted to assess the style, format, location, safety compliance and condition of the existing directional, informative and interpretive signage. This will provide an overview of the current situation and highlight any gaps in signage requirements.

Due to the contextual location of the foreshore and the limited points of access across the freeway, it is difficult to determine the spatial location of each access point and what activities are available within a short distances. Commuter cyclists access the PSP from various locations around southern Perth and are more likely to move through the space rather than stop to appreciate the natural environment or recreation. However recreational users are often deterred due to the limited direct access to the key nodes along the site. Providing strong connections to the local residential community and open space network to the east of the Kwinana Freeway will assist in strengthening recreational user activity within the foreshore area.

Establishing these connections through the implementation of a Wayfinding and Interpretation Strategy will capitalise on the local landscape character, recreational assets and provide physical and visual references for the local community and visitors to the foreshore. Ultimately a Wayfinding and Interpretation Strategy will

utilise existing public meeting places and highlight the destinations within walking distance, thus promoting a healthy and vibrant community environment.

Primary wayfinding signage should be located at each point of entry to the foreshore, so that all users can orient themselves; this would include all overpass and car park locations. It may also be beneficial to have secondary wayfinding signage on the eastern side of the Freeway in reserves and car parks which connect to the foreshore.

Interpretation media is critical in communicating the complex environmental and cultural complexities of the foreshore. This may take various forms in addition to traditional signage to communicate season based knowledge (e.g. art works, pod casts, geocaching or ephemeral interpretation).

Interpretation of the site's histories will be a key component to establishing a strong connection between the user and the site and ensuring the community value. The Swan River has a strong Aboriginal history with many stories that can be expressed via multiple forms of media or play elements. In addition to the Aboriginal culture, the site is exposed to complex environmental processes and a rich European history. Creating a balance and sense of journey along the foreshore will be key to the implementation of a successful Interpretation Strategy.

Risk and legislative signage is critical to ensuring users of the reserve are aware of the issues associated with accessing the site. Specific risks should be communicated at the location where the risk is located, and should be incorporated into the overall signage strategy.

Table 41: Recommendations for signage at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.27	Conduct an audit of existing directional, informative and interpretive signage assessing style, format, location, safety compliance and condition.	Low	City
5.28	Research and develop strong themes for interpretation based on the complex social, cultural and environmental complexities of the site.	High	City
5.29	Develop and implement a Wayfinding and Interpretation Plan for the foreshore to facilitate a co-ordinated plan for interpretation and education. This plan should also address digital methods of communication as well as physical signage.	High	City

Education and Training

Community Education

Community education and involvement is critical for the long-term conservation of the site's environmental and cultural values. Raising awareness can be achieved by a number of ways including local newspaper articles, signage, guided walks and tours and visits to local schools. These should always be positive and community orientated rather than as rules and regulations. Developing a sense of ownership within the community will empower people and encourage them to devote their own resources to appropriate care and management. The local community and school groups could also be involved in activities around the area such as bird watching, weeding, tree planting, plant identification, creating herbariums and assisting in the preparation of signage.

Recommendations for community involvement include:

- Information leaflets or links on the City website on topics such as pesticide/fertiliser use, recycling of green waste and other plants and garden plants that may escape into natural areas

- Continue and extend the local school program “School’s Nature Nurturing Program” and Millennium Kids
- Continue to support the local South Perth Environmental Group
- Educational walks and regular seminars to benefit the local and wider community
- Litter campaigns to reduce litter and participation in annual ‘clean up Australia’ days.

Dedicated community “Friends of” groups are another way in which the community can become involved in the care of their natural areas. This is particularly beneficial when volunteers belong to a friend’s group involved with a specific area. The Mt Henry Peninsula Conservation Group has been successful in rehabilitation, weed control and erosion control on Mt Henry Peninsula and have contributed greatly to enhancing the natural environment. A similar group involved with the KFF area would be of benefit.

School and Youth Groups

Schools are a beneficial way of developing environmental stewardship in the younger members of the community. School groups can assist in programs for the improvement of natural and cultural areas. Students of Aquinas College have actively been involved in rehabilitation of the Mt Henry Peninsula under the direction of the Mt Henry Peninsula Conservation Group. Activities have involved collecting, smoke treating and storing seed, weed removal and tree planting. These activities could also be extended to the study area and involve other nearby schools. (Mt Henry Peninsula Foreshore Management Plan, 2002)

Bushland rehabilitation and an understanding of environment is increasingly becoming an important part of school curricula at all levels. Liaison between the City’s Environmental Officer and local schools will help facilitate conservation programs. Local Scout groups (Beeloo district), South Perth Primary School and Millennium Kids as well as other local sporting clubs could also contribute to the management of the area. In approaching these groups it is important to always stress the community’s ownership of the resource, as this will encourage people to better look after it than if it is regarded as common property. (Ecoscape 2002). Involving the South Perth Youth Group may be another opportunity to garner support.

Table 42: Recommendations for education and training at Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
5.30	Where possible involve the community in management of the foreshore. Always reinforce community ‘ownership’ in this respect.	Moderate	City
5.31	Involve school groups and the local community in educational activities in the natural areas of the site including stencilling projects, signs, geocaching, media and holiday recreation programs.	Moderate	City
5.32	Seek involvement from the South Perth Youth Network and provide supervision and support via the Environmental Officer and Infrastructure Services. Support should include the provision of equipment and guidance.	Moderate	City
5.33	Continue support for the formation and ongoing involvement of local friends groups and provide supervision and support via the Environmental Officer and Infrastructure Services. Support should include the provision of equipment and guidance.	Moderate	City
5.34	Continue to provide bushland regeneration courses to interested members of the public who actively commit more than 40 hours per annum to bushland and wetland maintenance.	Low	City
5.35	Establish an Eco-news column in the local paper to raise awareness about the environment	Low	City

4.6 MAINTENANCE

4.6.1 Recreational Infrastructure Maintenance

Existing infrastructure including the PSP, signage, fences, tracks and existing and future infrastructure such as toilet and water facilities, picnic facilities, play equipment and barbecues should be constantly assessed, maintained and when necessary upgraded so that they may continue to:

- Function in good working order.
- Have a good appearance with uniform style.
- Do not pose a health or safety hazard.
- Continue to function as they were designed.

Wear and tear over time, vandalism and changing user requirements mean that regular assessment of infrastructure needs to take place depending on the circumstances and type of infrastructure. The following table depicts suggested maintenance schedules for the existing infrastructure. Incorporating new infrastructure will require the maintenance schedules to be updated.

4.6.2 Primary Infrastructure Maintenance

The City and MRWA had a condition inspection and five year plan for rehabilitation and maintenance prepared in 2010 for the KFF. This provides a rough guideline for maintenance and major rehabilitation works in the study area. The five year plan is flexible in that items that have deteriorated quicker or have been damaged in storm may become a priority. A revised condition inspection is scheduled to be undertaken in 2014.

The City is currently developing an asset management database to manage items of infrastructure under its ownership. It is recommended that this database be updated with condition information for all of the river foreshore protection assets in conjunction with other recreational assets so that they are included in general inspections and these assets are also allocated sufficient funding for repairs.

MRWA undertake weekly inspections along the PSP for damage and areas requiring maintenance. MRWA operations staff also regularly clean the path of debris, trim overhanging branches and identify any items requiring repair. City and MRWA operations staff should continue to maintain visual inspections while undertaking other works in the study area and identify any issues.

After severe events it is suggested that the KFF assets are inspected for any failures or maintenance as a result of the conditions. These events could occur anytime throughout the year. An annual inspection at the end of the winter months is suggested in case that no significant event occurs.

Conditions which cause damage in the study area are a combined wind and high water level event. Suggested criteria for a significant event where the foreshore should be inspected should be:

- Water levels above approximately +0.5m AHD (+1.26 m Chart Datum at Barrack Street storm surge gauge).
- Sustained wind from the SW through to NW directions of over 30 knots sustained for a period of greater than 1 hour.

It is recommended that the KFF is walked from the north to the south in order to undertake a detailed assessment of the area. The following items should be identified:

- Major failures of structures.
- Voids formed behind retaining walls.
- Undercutting of structures.
- Major damage to rubble groynes.

- Damage to wall pointing.
- Weathering of blocks or pointing.
- Erosion of the backside of any structures due to overtopping or stormwater runoff.
- Undercutting or erosion of PSP or any other items of infrastructure.
- Damage to drainage outfalls.
- Undercutting of any vegetation.

The City and MRWA have a set of generic repairs methodologies for maintenance repairs to items of infrastructure along the KFF:

- MRA 2010. *City of South Perth – Generic Specification for Repairs to Western Foreshore Walls*
- MRA 2011. *MRWA - Generic Specification for River wall Repairs*

Repair details specified within these specifications include but are not limited to:

- Repairs to limestone block retaining walls, including repointing and replacement of damaged blocks.
- Backfilling of voids created behind the back of the walls.
- Maintenance of limestone block walls (replacement of blocks, repairs to sunken blocks).
- Toe scour protection to retaining walls.
- Filling and installation of geotextile sand containers.

Operations staff should consult these technical specifications prior to undertaking repairs to items of infrastructure in the study area.

Table 43: Recommendations for Infrastructure Maintenance along Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
6.01	Undertake regular inspections of infrastructure and repair or replace where necessary.	High	MRWA City DPaW
6.02	Update Condition Inspection and Five year Rehabilitation and Repair Maintenance Plan	High	MRWA City
6.03	Incorporate asset condition information into City Asset Management Database	High	City
6.04	Have Operations staff identify any issues during routine works	High	City
6.05	Undertake walk throughs of KFF after a significant storm event	Moderate	City
6.06	Undertake walk through of KFF annually after winter to identify any items requiring maintenance	Moderate	City
6.07	Undertake routine maintenance to GPT structures and drainage outfalls to ensure pipes are clean and not blocked.	High	City MRWA

Table 44: Typical Maintenance Schedule for Kwinana Freeway Foreshore

Item	Maintenance Issue	Inspection Frequency
Principal Shared Pathway	Dips, hollows and irregularities Surface Degradation Vandalism Public Risk	Quarterly
Walking tracks	Erosion Surface Degradation Public Risk	Bi-annually
Fencing	Breaks Appearance Public Risk Vandalism	Quarterly
Bollards	Appearance Public Risk Vandalism Structural integrity	Quarterly
Signage	Visibility Appearance Public Risk Vandalism	Monthly
Seats, benches and tables	Wear and Tear Public Risk Vandalism	Monthly
Rubbish bins	Vandalism Rubbish removal	Monthly/ fortnightly (rubbish removal)
Walls and edging	Appearance Public Risk Vandalism Structural integrity	Quarterly
BARBEQUE	Wear and Tear Public Risk Vandalism Structural integrity	Monthly
Play Equipment	Wear and tear Appearance Public Risk Vandalism Structural integrity	Annually
Irrigation	Broken pipes and fixtures Public Risk Vandalism Efficiency	Monthly
Jetties	Appearance Public Risk Vandalism Structural integrity	Monthly
Toilets	Appearance Public Risk Vandalism Structural integrity	Weekly

4.6.3 Litter Collection

Litter is an identified problem in the study area. The City has installed twenty four 240 L bins between the Narrows and Mount Henry Bridge and they are emptied weekly. Based on anecdotal evidence, litter was considered to be a significant detriment to community enjoyment of the foreshore area.

Access to collect the rubbish is limited to three points along the foreshore and is usually undertaken mid-week between 11:30am and 1:30pm when the PSP traffic is at a minimum and travel speeds are limited to 8 to 10km. The biggest issue is the limited pull over locations along the PSP for the rubbish truck to get off the PSP for cyclists or pedestrians.

It may be possible to involve the community in the management of litter through the involvement of friends groups and participation in national clean up days such as 'Clean-up Australia Day'. In addition local schools and scout groups may also like to participate in the removal of accumulated rubbish. Any insurance and public liability issues must be resolved before involving the public in these activities.

Discarded syringes continue to be a problem in many parks in Perth. If reports of discarded needles increase, needle-bins should be provided at selected locations, such as within the toilet facilities. The toilets should also be locked at night to further deter antisocial behaviour.

Table 45: Recommendations for litter collection along Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
6.08	Prepare a detailed Foreshore Landscape Master Plan and costing to locate additional pull over locations for maintenance and rubbish trucks along the PSP.	Moderate	City
6.09	Involve the community in litter collection through the Clean-Up Australia Day.	Low	City
6.10	Investigate the feasibility of providing syringe disposal at key locations if the incidence of carelessly discarded needles is high.	Low	City
6.11	Investigate the feasibility of providing syringe disposal and condom dispenser in all toilet facilities.	Low	City

4.6.4 Irrigation

To address the DoW allocation reductions scheduled over the next couple of years, the City should consider implementing hydro zoning and eco zoning strategies to proposed landscape designs and retrofitting existing reserves.

Hydrozoning is a landscape practice that groups plants with similar water requirements together in an effort to conserve water. This practice seeks to take advantage of microclimates. Plants that tolerate more heat and wind might be planted near the street, while more sensitive plants might be planted in shade, under roof overhangs, or in fenced areas.

Ecozoning is the division of a park or reserve into zones of turf and natural areas to promote biodiversity and conserve water, while keeping the area's amenity and function. Ecozones are the park areas featuring mulched areas planted with native and 'water wise' vegetation. Typically these areas are not irrigated and the plants get their water from rain events.

Table 46: Recommendations for irrigating Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
6.12	Review and consolidate turf areas to active recreation areas only.	Low	City
6.13	Prepare and implement a Water Conservation Plan for the foreshore, detailing hydro zoning and eco zoning strategies to assess and monitor the watering requirements for the foreshore.	High	City

4.6.5 Graffiti and Wilful Damage

Graffiti and wilful damage has been highlighted by the City and by local residents as being a significant problem in the foreshore area. This problem is particularly apparent at Como Beach, Cloisters Car Park and the Sea Scouts. The following occurs at key locations on a regular basis within the foreshore area:

- Burning and destruction of rubbish bins.
- Wheelies or 'burnouts' in car parks.
- Removing bark and limbs from trees.
- Lighting fires.
- Removing and destroying signs.
- Graffiti on the overpass and on existing signs.
- Destroying fences and bollards.
- Driving cars and motorbikes along the PSP.

The constant vandal activity within the foreshore area is a significant problem and is a major impediment to installing new amenities and infrastructure.

Graffiti and wilful damage tends to primarily occur at main access points with resulting damage to fences and signs by trespassers. Moving infrastructure away from access points may reduce the frequency of vandalism. Making the susceptible areas less attractive for vandals can also alleviate the problem to some extent.

Lighting is likely to be the most effective way of reducing the incidence of undesirable behaviour. Power and water is available at Cloisters car park, Sea Scouts, Como Beach and the Narrows. The Canning Bridge Interchange only has power. Providing lockable vehicle barriers to the overpasses is also an option however this has the following drawbacks:

- It requires someone to close and lock the gate every night and reopen it in the morning.
- People using the boat ramp and returning late at night may be locked in.
- It imposes restrictions on legitimate recreational users who may want to use the area at night, (e.g. fishermen).

Options to alleviate some of these drawbacks exist and include time-delay locks with one-way gates, however these pose an additional cost and steps must be also taken to ensure that they are not vandalised. Despite the potential drawbacks of the above options, both should be evaluated before infrastructure and amenities such as picnic tables and benches, bins, barbecues or play equipment are installed.

Graffiti and other vandalism should be repaired as soon as possible after its occurrence, as its continued presence tends to invite further acts of vandalism. Graffiti resistant compounds should also be applied to any property that is targeted constantly. The community should also be encouraged to report any acts of vandalism or antisocial behaviour to the police and Council. Successful arrests should then be followed up with a note of thanks to the person who reported.

Table 47: Recommendations for managing graffiti and wilful damage along Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
6.14	Repair all damaged facilities immediately after any act of vandalism to discourage vandals.	Moderate	City
6.15	Investigate the feasibility of providing locked gates at the entrance to key overpasses.	Low	City MRWA
6.16	Remove graffiti and repair damage to infrastructure as soon as possible after it occurs to discourage graffitists.	Low	City
6.17	Encourage the community to report anti-social and destructive behaviour to the police and council authorities.	Low	City

5.0 ZONE SPECIFIC MANAGEMENT

5.1 FORESHORE PROTECTION ASSETS

5.1.1 City's Asset Management Database

Foreshore protection infrastructure items requiring maintenance between the Narrows and Mt Henry Bridge are identified in an annual condition inspection of the area undertaken for the City and MRWA. Estimates on service life, maintenance budgeting and capital requirements are also provided in the City's asset management database.

5.1.2 Foreshore Protection

Currently the KFF has issues with extreme water level events without even taking into account climate change impacts of rising mean sea levels. The largest extreme water level event recently recorded achieved a level of +1.16 m AHD at Barrack Street. This event currently only has an annual return interval of approximately 1 in 20 years (DoW 2013). Should a more extreme event occur, significant flooding and disruption would occur as is illustrated in the flood mapping for the 100 year annual return interval event.

Increasing mean sea levels over the 30 year period of this plan are likely to not significantly impact existing structures more than currently occurs, although the frequency of inundation is likely to increase. Should the status quo asset management of the previous 20 years occur, it is expected that the following will occur:

- There will be increased maintenance requirements of the existing structures due to increased frequency and greater magnitude of inundation. This has been seen along infrastructure items along the entire KFF.
- Existing structures may subsequently have a shorter service life, due to increased exposure.
- There will be episodic catastrophic failure of structures. This has occurred at walls in the Como, Skinny and Groynes zones.
- There will be continued erosion of existing sandy shorelines as has occurred in the Palms, Como, Skinny and Spit zones.
- Existing structures will be replaced with more durable structures and include crown walls or crest height increases in order to minimise overtopping effects onto the adjacent shorelines.

Up until recently, this foreshore management was purely reactive to critical failures. Since the significant May 2003 storm, the City in particular has been actively repairing and replacing riverwall structures along the South Canning, North Canning, Skinny, Como and Palms zones. Several sections of sandy foreshore now replaced by retaining walls in order to limit damage occurring due to foreshore erosion. Soft engineering approaches have also been adopted within the Infill zone in order to provide durability to the shoreline, however due to the exposure of the northern half of the KFF, these soft engineering techniques are generally limited to the Canning River sections.

MRWA are also already undertaking a program of increasing crest heights of structures in vulnerable areas, particularly those which cause disruption to traffic through wave spray. They have also recently completed the addition of a limestone block wall along stretches of the Kwinana Freeway. This will further reduce inundation impacts onto the Kwinana Freeway itself, but not the PSP. Crown walls have been added a section of PSP around Judd Street in order to limit wave overtopping onto the PSP.

An agreed methodology for emergency foreshore protection works has been developed between DPaW and MRWA. This document is titled "*Rehabilitation and Freeway Infrastructure Protection Plan - Milyu Nature*

Reserve and Swan Estuary Marine Park". This shall be consulted in the case of significant erosion or threats to the PSP within Milyu.

DPaW are also increasing the density of vegetation within Milyu in order to improve the durability of the foreshore to extreme water level events and inundation to avoid the requirement for emergency foreshore works. The rehabilitation of this area is documented in the report "*Milyu Nature Reserve Rehabilitation Plan*" (NAC 2013).

DPaW are also undertaking a program of coastal monitoring in order to quantify some of the shoreline recession seen along the KFF. Analysis of aerial photography has been undertaken in MRA (2009) however the shoreline of the estuarine system moves on much smaller scales than open ocean beaches where the aerial photography is of most use. This profile monitoring of Milyu is recommended to continue to build up a historical dataset to better understand shoreline movements in the area and for a data set for possible future beach nourishment.

The Trust has also undertaken a study titled "*Feasibility Study of Options for Beach Renourishment Swan and Canning Rivers*" to determine the feasibility of renourishing sandy shorelines around the river that were previously created by historical dredging.

As this study by the Trust indicates, there are opportunities for the stakeholders to adopt alternative methods of foreshore protection, which would act to preserve some of the existing foreshore amenity and ecological values. Particularly areas of remnant vegetation at Cloisters and Spit and the conservation area of Milyu could greatly benefit from beach nourishment and reduce the current erosive trends and pressures on the foreshore vegetation.

Infrastructure more at risk within the coming 30 years is the PSP rather than the actual Kwinana Freeway itself. The PSP and connecting pathways currently have issues due to erosion, inundation or overtopping at the following zones:

- Narrows – Erosion around Mill Point Road Link.
- Groynes – Wave run up and overtopping at Stirling & Scott Streets.
- Milyu – Inundation in 100 year ARI event.
- Palms – Erosion pressure and Inundation in 100 year ARI event.
- Skinny – Overtopping and Spray between Thelma and Cale Streets and Inundation in 100 year ARI event.
- Sea Scouts - Overtopping and Spray opposite Henley Streets and Inundation in 20 year ARI event.
- North and South Canning – Inundation of the Underpass under Canning Bridge above +0.7 m AHD.
- Cloisters – Inundation in 100 year ARI event.
- Infill - Inundation in 100 year ARI event.

Major capital works are required on the revetment along the northern side of the Narrows as the existing wall has collapsed and the area is currently bunded off. When replacing this structure, the crest height should be increased to prevent the existing undermining of the footpath and significant inundation shown in the 20 and 100 year ARI inundation mapping.

The current structure at the Narrows is believed to be an asbestos sheet pile wall, therefore it is preferred to build over the structure rather than disturb and remove the structure. It is likely that the footpath around this area will also require being replaced as part of this works.

The Palms area is one of the highest energetic areas of the KFF. Due to recent recession of the area, a geotextile sand container seawall was constructed to limit further erosion and undercutting of the PSP. This

area is going to be subject to continual erosion and inundation during major events. A long term plan for the area requires to be confirmed so the City and MRWA can either progress with beach nourishment options or alternatively commence planning for further hard edged protection along this section. Concept options for the structure along this stretch of the Palms should be investigated, taking into consideration the overtopping volumes onto the PSP and adjacent freeway lanes.

Walls within this Como zone have largely been replaced or repointed over the last five to 10 years. Regular inspections and maintenance works, such as repointing, shall continue to be undertaken on a regular basis to gain the longest service life out of these structures.

Due to the close proximity of this section to the Kwinana Freeway and the PSP, the Skinny Zone shall continue to be inspected annually for any signs of damage. Preventative maintenance shall be carried out as required on the walling to prevent major failures or disruptions to the PSP. These items are identified in the annual condition inspection undertaken for MRWA. Part of this maintenance will be the replenishment of toe scour rip rap at the toe of the structure. Loss of significant amounts of sand in front of this walling has increased the exposure of the river walls along this section. Weathering of the block surfaces shall also be monitored annually.

The Skinny section is prone to overtopping and spray onto the freeway. Increasing mean sea levels over the next 20 to 30 years may increase the frequency of these occurrences. It is suggested that the number of overtopping incidents that cause lane closures or issues with the Kwinana freeway commence being recorded by MRWA. Additional treatments through the Skinny Section may be required in front of the existing wall to try and absorb some of the wave energy.

North of the existing raised limestone block wall along Skinny, a slipform concrete barrier along the western side of the Kwinana Freeway may be appropriate

Future replacement of the Sea Scouts building may look at utilising a two storey structure to reduce the risk and effects of inundation of the lower level within the next 20 to 30 years. Investigations into the possible relocation of the Sea Scouts to either the proposed Canning Bridge development or the Mill Point Road Jet Ski carpark should also occur.

The South Canning Zone is largely protected by a large section of walling which had significant maintenance works conducted in 2011. The wall shall continue to be monitored and any items of maintenance conducted.

The pathway underneath Canning Bridge is likely to be inundated at an increased frequency over the coming 30 years. It is recommended that the inundation of this pathway is considered in any improvements to the area undertaken as part of the Canning Bridge Precinct Plan as this underpass on both sides of the Bridge will become a significant disruption to the PSP. Investigations should look at alternative routes and infrastructure for the PSP in extreme water level events.

Foreshore protection through the Infill Zone has predominantly been undertaken through revegetation, brushwork and the installation of some small limestone rip rap. This treatment is appropriate in this section due to the low energy environment. Increased frequency of inundation of this area will require to be managed in the next 20 to 30 years.

5.1.3 Drainage

The drainage network along the KFF is a mix of assets owned by the City and MRWA. Except for some upgrades undertaken by MRWA with the expansion of the Kwinana Freeway for the Busway Project, the drainage elements appear to be from the original construction of the Kwinana Freeway. Comments provided below are appropriate to all of the zones of the KFF.

The initial effects of climate change are thought to be initially experienced through the backing up of stormwater drains when high water levels and high rainfall events occur jointly. This is going to lead to increased nuisance flooding along the KFF, particularly the eastern side of the freeway and Melville Parade.

These increased water levels may lead to the collapse of pipework in poor condition. This would cause a significant issue for the Kwinana Freeway. Undertaking a condition inspection of the current drainage system is currently of a higher priority than reviewing the existing foreshore assets.

The majority of the drainage outfalls along the Palms, Como and Skinny Zones are significantly degraded and require replacement. It is worth noting that these same drainage elements were noted in the 1993 Western Foreshore Management Plan as also requiring immediate replacement.

It is expected that the majority of the drains along the entire KFF are heavily silted. Some of this siltation occurs through wave action and high storm surge levels pushing sediment backwards up the pipeline. The installation of backflow prevention devices on the pipe outlets would act to reduce the amount of siltation of the pipes and also aim to prevent nuisance flooding from storm surge up the pipe network.

A number of the drainage elements within Milyu are well protected by vegetation, therefore the condition of the concrete units is better than outlets in more exposed locations. The drains appear to be acting as an important freshwater source for the local birdlife. There is the opportunity to create small wetland areas around these drains

MRWA are currently undertaking an initial pilot program to investigate the condition of the stormwater network underneath the Kwinana Freeway. The outcomes of this study are required to further provide direction, however the recommended outcome is for the drainage elements to meet the following criteria:

- Be fully functional and have capacity to cope with the design rainfall event; and
- For all outfalls to meet current WSUD best practice guidelines and provide a filtering capacity for rubbish and particulates to prevent them entering the waterway.

As part of the Busway project, MRWA recently upgraded a number of drainage outfalls to include GPT's . The City has a number of outlets along the entire KFF, the majority of which do not have GPT's.

It is recommended that the City investigate consolidating its drainage network and install GPT's on all of its drainage items to improve the water quality entering the waterway.

5.1.4 Sand Renourishment

The City has committed to maintaining the beaches within Groynes Zone as the migratory birds prefer to roost within this area than at Milyu (Bamford 2002). It is however noted that under the MOU, the responsibility for this section is now with MRWA. As such, MRWA should be made aware of the significance of the Groynes Zone to the wader birds. Some renourishment and extensions of the groynes may be required within the future in order to maintain these sections.

Being a primary recreation node, the City should aim to maintain a sandy foreshore along the Como Zone to enable interaction between the foreshore and the water. This will require regular nourishment and the extension of some of the existing drainage outlet groynes which are significantly damaged.

The northern side of the shoreline in the Sea Scouts Zone shall continue to be monitored for erosion. It is suggested that a rock revetment be built along this section and then the shoreline renourished in front of the revetment. This may also require some rehabilitation works to the existing drainage outlet and groyne structure.

There is an area of sandy shoreline in South Canning, between Canning Bridge and the end of the existing river wall, which should be monitored. Currently sand is back passed from underneath Canning Bridge to this section of shoreline annually to maintain it. If the erosion trend of this area is significant over the coming years, the wall may have to be extended.

Table 48: Specific Foreshore Asset Protection Recommendations for Kwinana Freeway Foreshore Management Zones

No.	Recommendation	Priority	Responsible Party
7.01	Confirm condition of current drainage network	High	City MRWA
7.02	Rationalise drainage between the City and MRWA to minimise number of outlets along foreshore	High	City MRWA
7.03	Upgrade rationalised drainage outlets along the KFF. Investigate use of backflow prevention to minimise storm surge up network and include GPT or necessary structures to improve water quality	High	City MRWA
7.04	Investigate options for beach nourishment based on Trust *Feasibility Options for Beach Nourishment Swan and Canning Rivers* Report.	High	Trust
7.05	Continue Annual Maintenance Inspections and Maintenance Works along the KFF	High	City MRWA
7.06	Progress Options for Palms Foreshore	Moderate	City MRWA
7.07	Continue MRWA program of Capital Upgrades on Existing Revetments to reduce spray and inundation of PSP and Kwinana Freeway	High	MRWA
7.08	Replace and lift crest height of revetment around Narrows	High	City
7.09	Investigate additional retaining walls along western side of Kwinana Freeway to reduce inundation in extreme events and as a measure to mitigate rising sea levels.	High	MRWA
7.10	Investigate alternative route options for the PSP around the Canning Bridge Underpass. Alternative to look at options for raising levels of path in this area.	Moderate	MRWA
7.11	Undertake nourishment of Como Beach and Groynes as required to maintain sandy shorelines.	High	City MRWA
7.12	Investigate potential for Constructed Wetlands at Drainage Elements within Milyu	Moderate	DPaW Trust
7.13	Continue Milyu Monitoring for coastal erosion to establish a dataset that quantifies shoreline movements.	High	DPaW
7.14	Continue increasing density of vegetation through the shorelines of Milyu, Cloisters, Infill and the Spit	Moderate	DPaW City
7.15	Monitor shoreline of South Canning Section	Moderate	City MRWA
7.16	Ensure MRWA and DPaW procedures reference *Rehabilitation and Freeway Infrastructure Protection Plan – Milyu Nature Reserve and Swan Estuary Marine Park* for procedures should emergency erosion protection be required along Milyu.	High	DPaW MRWA

5.2 ENVIRONMENTAL VALUES

5.2.1 Current Foreshore Management Plans

Revegetation works should ensure that they are aligned with the following works and plans within nominated zones:

- Milyu Zone – NAC (2013) *Milyu Nature Reserve Rehabilitation Plan (Final)*
- North Canning and South Canning Zones – *WAPC (2001) Canning Bridge Precinct Vision*
- Spit Zone – Syrinx (2013) *Mount Henry Spit Restoration Plan.*

5.2.2 Revegetation and Soft Landscape Domains

Each zone has been broadly divided into at least one of the four domain types described in Section 3.4.2, according to their site characteristic and end land use. The domains and focus of revegetation works are summarised in Table 49. Candidate local native species for revegetation and soft landscaping in the each domain are listed in Appendix Six and in the KFFMP Species Planting Guide Spread Sheet.

Table 49: Revegetation and Soft Landscape Domains of Kwinana Freeway Foreshore Zones

ZONE	DOMAIN				
	Wetland	Transition	Dryland	Soft Landscape	TOTAL
Narrows				*	1
Groynes			*		1
Milyu	*	*	*		3
Palms			*		1
Como			*		1
Skinny			*		1
Sea Scouts	*	*	*	*	4
North Canning			*	*	2
South Canning				*	1
Cloisters		*	*	*	3
Infill			*		1
Spit		*	*		2

Revegetation works in the Wetland, Transition and Dryland Domains should focus on:

- restoring the inland vegetation to nearly the original conditions and characteristics
- promoting local native species with fauna habitat value, in particular migratory birds in Milyu and Groynes Zones.

Revegetation works in the Soft Landscape Domains should be focused on:

- promoting local native flora in a visually aesthetic manner
- integrating local and appropriate exotic flora with social and recreational use of Zone.

5.2.3 Weed Control

Weed species identified in each zone and their growth form are summarised in Table 50. All weed species should be targeted using the methods recommended in Section 3.4.1 and the KFFMP Weed Management Spread Sheet.

Table 50: High Priority Weed species in Kwinana Freeway Foreshore Zones

GROWTH FORM		WEED SPECIES		DOMAIN											
General	Group	Common Name	Scientific Name	Narrows	Groynes	Milyu	Palms	Como	Skinny	Sea Scouts	North Canning	South Canning	Cloisters	Infill	Spit
Geophyte	Bulb and Corm	Black Flag	*Ferraria crispa*		*	*	*				*				
		Fingerleaf Oxalis	*Oxalis glabra*												
		Freesia	*Freesia alba x leichtlinii*			*									
		Guildford Grass	*Romulea rosea*	*	*	*	*			*	*				
		One-leaf Cape Tulip	*Moraea flaccida*			*				*	*		*		
		Soursob	*Oxalis pes-caprae*	*		*	*	*	*	*	*				*
		Three-cornered Garlic	*Allium triquetrum*												
		Watsonia	*Watsonia meriana* var. *bulbillifera*												
		Wavy Gladiolus	*Gladiolus undulatus*			*									*
		Wild Gladiolus	*Gladiolus caryophyllaceus*			*				*	*	*	*		*
	Tuber and Rhizome	Arum Lily	*Zantedeschia aethiopica*												
		Bridal Creeper#	*Asparagus asparagoides*												
Graminoid	Clump Grass	African Love Grass	*Eragrostis curvula*			*									
		Barley Grass	*Hordeum leporinum*												*
		Great Brome	*Bromus diandrus*		*	*						*			*
		Hare's Tail Grass	*Lagurus ovatus*		*	*				*				*	
		Pampas Grass#	*Cortaderia selloana*												
		Perennial Veldt Grass	*Ehrharta calycina*		*	*				*					*
		Salt Water Couch	*Paspalum vaginatum*												
		Sea Barley	*Hordeum marinum*												
		Wild Oat	*Avena barbata/ fatua*		*	*	*			*	*	*			*
	Lawn Grass	Buffalo Grass	*Stenotaphrum secundatum*	*		*									*
		Couch	*Cynodon dactylon*	*		*									*
		Kikuyu	*Cenchrus clandestinus*		*	*						*			*
Herb	Other Common Weeds	Blue Lupin	*Lupinus cosentinii*		*						*				
		Geraldton Carnation Weed	*Euphorbia terracina*		*					*	*			*	*
		Petty Spurge#	*Euphorbia peplus*												
		Rose Pelargonium	*Pelargonium capitatum*		*	*									*
		Doublegee	*Emex australis*												
	Succulent	Pigface	*Carpobrotus edulis*		*	*		*							*
Woody	Tree and Shrub	Japanese Pepper	*Schinus terebinthifolius*							*					
		Lantana	*Lantana camara*												
		Olive	*Olea europaea*												
		Sea Spinach	*Tetragonia decumbens*	*	*	*	*	*	*						
		Victorian Tea Tree	*Leptospermum laevigatum*		*					*					
TOTAL				5	13	18	5	3	2	10	8	4	2	2	13

may be present

Table 51: Specific environmental value recommendations for Kwinana Freeway Foreshore Management Zones

No.	Recommendation	Priority	Responsible Party
7.17	Ensure revegetation works are aligned with the current site plans for Milyu, North Canning, South Canning and Spit Zones	High	City MRWA
7.18	Revegetate each zones according to their domain's site characteristic and end land use: • Wetland (native vegetation and fauna habitat) • Transition (native vegetation and fauna habitat) • Dryland (native vegetation and fauna habitat) • Soft Landscape (aesthetics)	High	City
7.19	Target high priority weed species in each zone using methods recommended in the KFFMP Weed Management Spread Sheet	High	City

5.3 SOCIAL VALUES

5.3.1 Landscape Concept Plan

It is recommended that a Landscape Concept Plan be prepared for the Foreshore to enhance its community values. All Zones are used either passively or actively should include the integration of nodes. These nodes could include seating, drink fountains and rubbish bins, as well as interpretive and wayfinding signage to inform visitors where they are in the context of the foreshore and the natural and cultural aspects of the area. Plantings of suitable native tree species around these nodes will assist in providing shade and shelter to these nodes, further encouraging visitors to use and appreciate the area.

Key design issues to be addressed in the Landscape Concept:

- Revegetate using a soft landscape approach, promoting appropriate local native flora.
- Integrate a mixture of nature play elements and off the shelf play equipment in association with picnic amenities and facilities.
- Reduce the amount of turf to active recreational areas and replace all other areas with native species.
- Introduce additional trees for shade particularly adjacent picnic amenities and car park.
- Create specific beach access nodes.
- Promote local native flora that have fauna habitat value for migratory birds.
- Investigate opportunities to incorporate suitable tree species to be planted at the seating and viewing nodes to provide shade and rest opportunities particularly in zones with limited shade.
- Consider locating a drinking fountain adjacent wayfinding signs and rubbish bins where appropriate.

Narrows

The Narrows is the most physically and visually accessible Zone within the foreshore and forms the primary entry way into the foreshore precinct. It should be managed and designed to cater for more varied user groups. There are a number of potential tourism opportunities, including a seaplane area to cater for recreational joy rides, amphibious vehicles and or parasailing. Creating connections to surrounding recreational and cultural facilities such as the Perth Zoo may provide opportunities to educate users about their local environment and the fauna found within the riverine environment.

Groyne

Revegetate the Zone focusing on restoring it to nearly its original conditions and characteristics using appropriate local native flora. To promote local native flora that provide habitat value for migratory birds.

Milyu

The plan should also include opportunities for interpretive signage/ artworks to inform visitors about the flora and fauna found within the Milyu Zone and the important contribution local community groups have on the management of the foreshore.

Palms

Once climate change infrastructure works are confirmed and implemented, landscaping planning can be undertaken for the zone. Any landscaping plan should maintain access points to the foreshore through this section as it is one of the few areas where the water is accessible by machines. Until this can occur, it is the recommended approach is to grow grasses and groundcovers in the area in order to minimise the erosion caused by wave overtopping and drainage scour.

Como

The Como Zone has been identified as a location for a major recreational node, with the potential to service an increased number of visitors.

Plantings of suitable native tree and plant species around these nodes will assist in providing shade and shelter to these nodes, and also opportunities for interpretation as part of the signage and/or nature play design.

Skinny

The Skinny Zone is a long stretch of PSP with minimal protection from the surrounding climatic, physical and visual intrusions due to the nature of the site. This Zone is not a destination along the foreshore, it is primarily a thoroughfare connecting the Sea Scouts to Como Beach.

The City recently undertook a large revegetation program along this stretch of foreshore, however due to the high exposure and high levels of salt inundation of the site, the majority of the revegetation works has died.

Sea Scouts

The Sea Scouts area has been identified as a location for a major recreational node, with the potential to service an increased number of visitors.

The future planning for this zone will also provide an opportunity to assess the current structures on the site and their potential for upgrade and further use. Further investigations should be undertaken into the use of the existing Sea Scout building as a potential venue for events, and the feasibility of improving the footbridge at Cale Street to comply with DDA requirements.

North Canning

Most of the foreshore is reinforced with either a masonry block wall or limestone rock armouring as the area is vulnerable to wave action. It is recommended that a feasibility study be undertaken into the replacement of the limestone rock armouring with terracing and some artificial beaches as part of the Canning Bridge precinct plan and as a means of creating better pedestrian access to the River to activate the shoreline.

South Canning

As a major point of entry to the foreshore for cyclists and pedestrians, it is recommended that a Landscape Concept Plan be prepared for the South Canning area. This plan would incorporate an exercise trail along the foreshore between the Canning and Mt Henry bridges, including rest stops with supporting facilities.

Reducing the amount of turf in the South Canning Zone and replacing it with appropriate native species will reduce the maintenance and irrigation requirements of the area, and also provide an opportunity to showcase the local vegetation to visitors through interpretive signage.

Infill

The existing footbridge at Edgewater Street does not comply with universal access principles, making it difficult for people with mobility issues to access the foreshore at this point. The development of a Landscape Concept Plan for the Infill Zone will provide an opportunity to assess the feasibility of improving the footbridge to comply with DDA requirements.

Spit

The Mount Henry Spit is a unique site in the Perth metropolitan region due to its close proximity to the centre of the city and the value of its remnant vegetation as part of the Bush Forever Site No. 227. The Spit's relative isolation and distinctive ecological characteristics make it an ideal site for comprehensive restoration efforts. The benefits of restoring this site will ensure its long-term sustainability in the face of adverse effects such as erosion of the Spit's western shore. It is envisaged that the implementation of this Restoration Plan will significantly contribute to the protection and enhancement of the biodiversity and aesthetic values of not only the Spit but the entire Bush Forever Site 227 (Syrinx Environmental 2013).

Additionally, Syrinx Environmental (2013) has prepared a Restoration Plan for the Spit Zone which will guide future development of the area.

5.3.2 Interpretation, Wayfinding and Risk Signage

Appropriate signage is critical across all zones within the foreshore reserve to communicate vital information including interpretive, wayfinding and risks. This is particularly relevant in zones which are considered to be major destinations including:

- Narrows.
- Groynes.
- Como.
- Skinny.
- Sea Scouts.

Rest nodes identified in each of the above zones could incorporate key signage to inform visitors where they are in the context of the foreshore and the natural and cultural aspects and any risks of the Zone.

Regulatory signage should be provided where necessary to alert visitors to important information particularly safety issues associated with the jetty's located along the foreshore.

To ensure the community value the foreshore, the City could use a variety of methods to engender ownership and respect. This can be achieved through involvement, education and interpretation about the complex histories of the site. Vital will be communicating an understanding and respect for the foreshore environment to the various user groups.

Milyu

The Western Australian Planning Commission is investigating potential train station locations, and this included a South Perth station, located in the area between Richardson Street and Bowman Street, South Perth. This has highlighted an opportunity to remove the existing Hardy Street footbridge which does not comply with Disability Discrimination Act and construct a new footbridge connecting the station with the east and west sides of the Kwinana Freeway. This new station will provide an excellent opportunity to make strong connections to the foreshore with the Perth Zoo and South Perth town centre, supported by wayfinding signage at the footbridge itself and along the foreshore.

Local community and school groups have had a long involvement with the management and maintenance of the reserve, particularly in this zone.

Como

Major wayfinding signage should be included at the Comer Street, Preston Street and Thelma Street Footbridges to inform visitors of their location in the context of the foreshore, and the facilities available. Interpretive signage will provide visitors with a greater understanding and respect for the natural and cultural aspects of the area.

Skinny

Major wayfinding signage should be included to provide greater connection between the foreshore and Olives Reserve. Interpretive signage will provide visitors with a greater understanding and respect for the natural and cultural aspects of the area, including the history of the Sea Scouts.

North Canning

Potential locations for the signage include the Canning Bridge Interchange and the western side of Canning Bridge.

South Canning

The plan will also encompass improved wayfinding signage at the Canning Bridge Interchange and the southern side of Canning Bridge where the PSP connects with the Highway.

Infill

These rest nodes could also incorporate interpretive and wayfinding signage to inform visitors where they are in the context of the foreshore and the natural and cultural aspects of the Zone, such as the shanty town that once existed in this area.

5.3.3 Recreational activities and equipment

The foreshore has many passive and active recreational activity opportunities. Most activities are zone specific however there are a few which relate to multiple zones.

Dog walking is a popular activity within the foreshore and used to be popular in the Palms and Skinny Zones. The Skinny Zone is no longer appropriate as the beach no longer exists in front of the wall and the Palms Zone is subject to erosion and proposals to restore this zone to its original conditions and characteristics will mean this activity is no longer appropriate for this area.

Alternative locations for dog walking may include the Sea Scouts and North Canning Zones; this activity would need to be appropriately signposted to prevent clashes between user groups, particularly as the foreshore is very narrow in places throughout the North Canning Zone.

The provision for upgrading and provision for playground facilities in the Sea Scouts and Como Zones will support the activation of these two zones as primary destinations and arrival points in the Foreshore. It is recommended that a mixture of nature play elements and off the shelf play equipment be included as part of the node design to provide a variety of experiences. Interpretation of the cultural and natural aspects of the site could be worked into the design of the play elements. Interpretation of the cultural and natural aspects of the site could be worked into the design of the play elements in each zone.

Narrows

The primary recreational activity is water based as the Zone has a formal boat ramp structure and suitable car parking bays to cater for boat trailer parking. The site is mainly used as a thoroughfare during the week and accessed by recreational boaters, jet ski enthusiasts and fishermen on the weekends.

The café and toilet facilities provide some amenity to the Zone however there are limited other picnic facilities such as picnic tables, play equipment and barbecues. The site is also used seasonally for big events such as Australia Day fireworks.

Cloisters

The boat ramp currently operates as a relatively low use facility. It is expected over time that this will become more popular and some upgrades to the ramp and available street parking on the eastern side of the freeway may need to be more formalised.

The overpass at Edgewater Street may require to be upgraded to meet universal access requirements.

Spit

The Spit Zone is a heavily used recreational asset based on its location and proximity to Aquinas College. Students and local community members mainly access the site for water based recreation activities including skiing, boating and fishing. There are limited facilities and amenities within this Zone.

5.3.4 Maintenance

Future landscape planning should provide for maintenance vehicles access, allowing removal of rubbish and maintenance works to occur without interrupting pedestrian and cyclist routes throughout the foreshore reserve.

Narrows

The jet ski boat ramp requires an annual inspection and maintenance to prevent any small maintenance items causing major failures. The City was supposed to collect a maintenance fee from JetSport West for this works.

Groynes

Currently good grass coverage on the foreshore and foredune is providing decent protection to the retaining wall at the most northern section of the Groynes adjacent to the car park and jet ski ramp. This should be maintained where possible.

Palms

Once major infrastructure works are confirmed and implemented through this section, landscaping planning can be undertaken for the zone. Any landscaping plan should maintain access points to the foreshore through this section as it is one of the few areas where the water is accessible by machines. Until the infrastructure upgrades occur, the recommended approach is to grow grasses and groundcovers in the area in order to minimise the erosion caused by wave overtopping and drainage scour.

Skinny

Due to the nature of this Zone, maintenance and rubbish trucks have difficulty in manoeuvring once on the PSP should pedestrians/ cyclists converge, this should be assessed in the development of the Landscape Concept Plan.

Table 52: Social Values works in Kwinana Freeway Foreshore Zones

ZONE	ITEM			
	Landscape Concept Plan	Interpretation, Wayfinding and Risk Signage	Recreation Activities and Equipment	Maintenance
Narrows	*	*	*	*
Groynes	*	*		*
Milyu	*	*		
Palms	*			*
Como	*	*	*	
Skinny	*	*		*
Sea Scouts	*	*	*	
North Canning	*	*	*	
South Canning	*	*		
Cloisters			*	
Infill	*	*		
Spit			*	

Table 53: Specific social values recommendations for Kwinana Freeway Foreshore Management Zones

No.	Recommendation	Priority	Responsible Party
7.20	Prepare a specific Landscape Concept Plan for the Kwinana Foreshore Reserve including all zones considering relevant restoration plans and future planning within the City of South Perth.	Moderate	City
7.21	Investigate tourism opportunities and connections into the Foreshore Reserve.	Moderate	City
7.22	Design and manufacture wayfinding signage at key entry points to the foreshore.	Moderate	City
7.23	Locate appropriate informative signage about safety and regulations	Low	City
7.24	Investigate opportunities if the Sea Scouts building is relocated to utilise the facility for events.	Low	City

6.0 MONITORING AND IMPLEMENTATION

6.1 MONITORING

6.1.1 Monitoring Climate Change

The impact of climate change on the KFF will predominantly be through increased water levels. Tide gauges are available at Fremantle and Barrack Street and the analysis of these water level records provide the best indication for water level increases over the coming 20 to 30 years.

IPCC will continue to release guidelines on climate change over the coming years. These reports should be continually reviewed to ensure that the climate change allowances along the foreshore are still appropriate. Significant acceleration of the climate change projections beyond that currently predicted will cause significant issues for the KFF.

6.1.2 Monitoring Severe Events

The frequency and magnitude of severe events is an important record. For the study area, water levels at Fremantle and Barrack Street, in conjunction with wind records at Melville Water are important datasets. Time histories of these variables should be obtained after severe events so that the average return interval of the event can be estimated.

It is also recommended that MRWA records the number of days or hours per year that the Kwinana Freeway is affected by weather or storm activity. This record should state whether the impact is due to drainage flooding, wave spray and overtopping or direct inundation.

The shoreline at Milyu should continue to be monitored for shoreline movements on a twice yearly basis (end of Summer and end of Winter).

6.1.3 Monitoring Fauna

Bamford (2002) recommended that migratory wader birds should be continued to be regularly monitored in the northern part of the study area, in particular at Narrows, Groynes and Milyu Zones, as well as nearby Alfred Cove and Pelican Point. Monitoring should be conducted occur approximately ten times a year on the tidal flats at/ near Milyu and occur between April and August, towards mid to late afternoon during periods of low tide when wading bird populations are most likely to be at their highest. Some of these surveys should occur on weekends when water craft are most active, to determine their impact on bird numbers.

The City should engage a qualified and experienced zoologist to conduct the bird surveys and report on any changes in migratory bird numbers or diversity and possible causes.

6.1.4 Monitoring Revegetation

Monitoring is essential to verify the success of the restoration program. Reworking may be necessary in areas where rehabilitation is not performing adequately.

Formal Monitoring

The City should appoint an independent consultant to monitor the restoration progress of each Revegetation Domain and confirm actions have been undertaken in accordance of the Revegetation strategy. At the beginning of each survey, monitoring plots shall be selected randomly across each Domain. Items that shall be assessed include species abundance, diversity, vegetation condition and presence of any plant pathogens and will make any recommendations if required.

Monitoring shall occur on an annual basis after restoration has been completed. Maintenance shall be conducted as deemed necessary by the City to ensure each of the vegetation assemblages will comply with the completion criteria.

Monitoring Criteria

Specific monitoring criteria will need to be developed for each zone to determine where revegetation efforts are progressing towards meeting the end land use or whether further infill planting if is required. The following benchmarks should be measured:

- Species diversity.
- Mortality (number of seedling deaths per unit area).
- Vegetation cover.
- Plant health (e.g. signs of stress).
- Damage (e.g. fire, severe storms, unauthorised access).

Informal Monitoring

Informal monitoring of the entire site should be carried out by the City every six months to verify the success of the revegetation program and to direct maintenance in areas where revegetation is not performing adequately. Items that shall be assessed include species abundance and diversity, and presence of any plant pathogens and make any recommendations if required. Maintenance may be conducted as deemed necessary.

6.1.5 Monitoring Weeds

Frequency of Monitoring

It is recommended that the reserves be monitored every year and updating of records should occur as often as practicable to assess the success of weed control programs.

The yearly monitoring should include:

- An assessment of the success of previous weed control efforts.
- Detection of any changes in the weed species present and their distributions.
- Determination of whether the control times and methods of the weed programmes need to be adjusted.

Monitoring Criteria

When monitoring the reserves, the following strategies should be adopted:

1. Establish monitoring quadrats in areas subject to weed control programs to record the effectiveness of control methods.
2. Monitor any change in distribution of the High Priority species.
3. Monitor for establishment of any new weed species.

This can be achieved through the establishment of quadrats, which are typically a 10m x 10m area. In order to determine if weed control is being effective, the following should be recorded within the quadrat:

- Percentage cover of each plant species present.
- The vegetation structure.
- Average height of each plant species present.
- The health of each plant species (observed as healthy, stressed or dead).

Performance Criteria

In order to determine the effectiveness of any weed control programme, there needs to be a method of determining success and ongoing progress. The following performance criteria could be used or adapted, based on the monitoring data collected:

1. Control/ eradicate at least one third of the High Priority weed species from each of the reserves over the next five years.
2. Reduce the area of all High and Moderate priority weed infestations by 50% over five years.
3. Reduce the total number of weed species in the area by at least 50% over five years.

Although not appropriate as performance criteria, other information can be recorded to assist in an overall view of the effectiveness of weed control activities within the site:

1. The number of new weed species recorded – it is expected that, initially, new weed species may be recorded as these species may not have been identifiable at the time of the field survey. Over time, it is anticipated that the number of new species recorded should plateau, and then the total number of weed species decrease.
2. Any new infestations of High Priority species – this information can be used to determine source areas for new infestations, and, assessed against the number of hours spent on its control, allow an analysis of the success of control of particular species.

Weed Mapping

Weed maps should be updated to reflect changes in presence and distribution of weed populations. This will help direct future weed control operations in the timing and targeting of particular weed species. The frequency of mapping of each weed species should be conducted according to their threat to native vegetation and invasive ability. In general:

- High Priority weed species that have the potential to expand rapidly should be mapped each year.
- High Priority weed species that do not expand as rapidly should be mapped every two years
- Moderate Priority weed species should be mapped as resources allow.
- Low Priority weed species usually do not require to be mapped unless they are considerable sized populations.

Use of Weed Monitoring Data

Monitoring data is useful not only for determining the success of weed control activities, but also for planning weed control activities from year to year. In order for monitoring data to be useful, it needs to be fed back to the managing agencies. That is, any work undertaken in the field, whether it be actual weeding or monitoring of previous weed control sites, should be fed back into a central management system to ensure efforts are being focussed where they are most needed and to ensure the managing agency is aware of all activities.

6.1.6 Monitoring Disease

At present there is no formal system to conduct regular dieback assessments of the study area. The City should engage a certified dieback consultant to conduct the assessments on a regular basis (e.g. every few years). If dieback is detected, the boundaries of the infection should be marked and quarantined to mitigate the further spread of the disease (Dieback Working Group 2000). The dieback consultant should also survey for any signs of honey fungus or aerial canker.

Table 54: Recommendations for monitoring Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
8.01	Monitor mean sea level rises against current predictions.	Low	City
8.02	After a severe event, obtain water level records for Fremantle and Barrack Street and wind records for Melville Water.	Moderate	City
8.03	Engage a qualified zoologist to monitor migratory wader birds on Milyu's tidal flats ten times a year between April and August.	Moderate	City
8.04	Engage a qualified environmental consultant to monitor revegetation efforts (at least once a year formally and very six months informally) and adapt works as necessary.	High	City
8.05	Engage a qualified environmental consultant to monitor weed populations (at least once a year formally and very six months informally) and adapt weed control works as necessary.	High	City
8.06	Regularly engage a qualified dieback expect to assess the bushland and mark the boundaries of any detected infection of dieback or other plant diseases.	High	City
8.07	Continue to monitor the shoreline of Milyu for shoreline movements.	Moderate	DPaW
8.08	Start a record of the number of days or hours per year that the Kwinana Freeway is affected by weather or storm activity. This record should state whether the impact is due to drainage flooding, wave spray and overtopping or direct inundation.	Moderate	DPaW MRWA

6.2 IMPLEMENTATION

6.2.1 Coordination

Implementation will be coordinated and facilitated by the KFFMP and the City. It is envisaged that most, if not all, of the management works will be coordinated by the City, MRWA or DPaW. Where suitable, the City will implement works using internal engineering or environmental resources. Alternative or specialist resources where required will use suitably qualified and experienced contractors approved by the City and/or MRWA.

6.2.2 Resource Sharing

The MRWA and City (2012) *Memorandum of Understanding for the maintenance of Principle Shaded Paths and other Aspects of the Kwinana Freeway Foreshore* outlines roles and responsibilities parties in managing certain foreshore assets in the study area, including:

- Reserves
- principle shared paths
- walls and shorelines
- pits and drains
- regulatory and warnings signs and pavement markings.

Resources are to be coordinated and shared where possible through the monthly KFFMG meetings.

6.2.3 Funding

Due to the value of the freeway assets, MRWA are increasingly contributing additional funding to the area to enable management of the issues. Erosion issues over the last 5 to 10 years have become the dominant funding item for the City, which has caused significant budgetary pressures for the City. Drainage items, foreshore erosion control at Comer Beach and Palms areas, the protection of remnant vegetation in Cloisters

and Spit regions and increasing the aesthetics of recreational areas are expected to become major funding items for the City in the next 10 years.

Table 55: Recommendations for implementing the Kwinana Freeway Foreshore Management Plan

No.	Recommendation	Priority	Responsible Party
9.01	Coordinate and facilitate the KFFMP	High	KFFMG City
9.02	Coordinate and share resources to enact KFFMP	High	KFFMG City
9.03	Fund management works to enable management of issues identified in KFFMP	High	MRWA City Trust DPaW

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APPENDIX ONE: RECOMMENDATIONS

Table 56: Summary of General Recommendations for Managing the Kwinana Freeway Foreshore

No.	Recommendation	Priority	Responsible Party
1	**Ownership and Stakeholder Management**		
1.01	Investigate adjusting the boundaries of Milyu Nature Reserve such that the PSP is not within the Nature Reserve and sits within the Kwinana Freeway Land Tenure	Low	MRWA DPaW
1.02	Investigate adjusting the boundaries of Land Tenures around existing footbridges such that footbridge sits within MRWA Land Tenures.	Low	MRWA
1.03	Follow up on discussions with DAA regarding the rationalisation of Unallocated Crown Land into the adjacent Reserves and the status of the City's Section 18 DAA approval.	High	City
1.04	City to undertake necessary reporting under the requirements of its Section 18 approval.	High	City
1.05	Stakeholders undertaking works under the City's Section 18 should prepare a close out report (including photos of various stages of the works) for the City's records.	High	MRWA Trust
1.06	Investigate the requirements for a Section 18 approval for Milyu.	Low	DPaW MRWA
1.07	Continue the Kwinana Freeway Foreshore Management Group monthly meetings.	High	KFFMG
1.08	Continue medium term planning activities for the KFF and cooperate resources and project planning at KFFMG meetings.	High	KFFMG
2	**Climate Change**		
2.01	Investigate options to install retaining walls along following sections to maintain emergency access in a 100 year ARI event: Scott Street/Mill Point Road On Ramp Judd Street to Hardy Street Saunders Street Thelma Street Henley Street	Moderate	MRWA
2.02	Determine active and disused stormwater pipes. Rationalise drainage between the City and MRWA to minimise number of outlets along foreshore network where possible. Upgrade rationalised drainage outlets along the KFF and investigate use of backflow prevention to minimise storm surge up network and include GPT or necessary structures to improve water quality. Investigate drainage system in the following areas for the prioritisation of the installation of backflow devices: Judd Street Richardson Park South Terrace Off Ramp Cale Street	Moderate	City MRWA
2.03	Investigate condition of existing pipe networks. Where required, clean existing stormwater pipe network to maintain and maximise existing capacity. Clean existing drains to minimise the flushing of large volumes of sediment in large flow events to the river and also maintain drainage network capacity, reducing nuisance flooding. Investigate options for relining of the stormwater pipes if pipes in poor condition.	High	City MRWA
2.04	Determine long term strategy and required general structural response for KFF. Sand nourish, retrofit crown walls/increase height of replacement structures, offshore headlands or offshore wave barrier. Investigate options for beach nourishment based on Trust Feasibility Options for Beach Nourishment Swan and Canning Rivers Report.	Moderate	City Trust DPaW MRWA
2.05	Commence any required approvals once higher level concept confirmed.	Low	City MRWA
2.06	Consider inundation issues when the Sea Scout building is replaced. Consider relocation of Sea Scout building and jetty.	Low	City
2.07	Investigate options for managing inundation issues with the Canning Bridge PSP underpass.	Moderate	MRWA
2.08	Manage existing beach areas with a nourishment program. Recommend nourishment in main recreational and environmental areas of Groynes, Milyu, Como and Sea Scouts. Hard structures will be required in alternative areas given the limited opportunity for retreat.	Moderate	City MRWA
2.09	Revegetate important vegetation areas to increase durability against erosion. Some areas may require stabilisation of the front edge by soft engineering approaches to reduce erosion effects. Continue increasing density of vegetation through the shorelines of Milyu, Cloisters, Infill and the Spit. Investigate planting more salt and inundation tolerant species along the foreshore as increased inundation by saline water may affect some of the existing vegetation.	Moderate	City

2.10	Consider alternative construction methodologies with rising water levels and reduce periods of low tide for the installation of foundations.	Low	City MRWA
2.11	Possible nourishment in front of hard structures to reduce weathering of structures, maintenance requirements and spray onto Freeway.	Moderate	City MRWA
2.12	Determine suitable "level of service" requirements for the Kwinana Freeway with regards traffic disruption by wave overtopping and inundation.	Moderate	MRWA
2.13	Longer term studies should commence a high level investigation for stormwater drainage requirements with a scenario of an increased mean sea level of +0.9 m.	Low	City MRWA
2.14	Continue MRWA program of Capital Upgrades on Existing Revetments to reduce spray and inundation of PSP and Kwinana Freeway	Moderate	MRWA
2.15	Investigate a longer term option of replacing the wire rope fence with a slipform concrete wall along western side of Kwinana Freeway to reduce inundation in extreme events and as a measure to mitigate rising sea levels.	Low	MRWA
2.16	Investigate alternative route options for the PSP around the Canning Bridge Underpass. Alternative to look at options for raising levels of path in this area.	Low	MRWA
3	**Management of Physical Environment**		
3.01	Continue Annual Maintenance Inspections and Maintenance Works along the KFF. Continue to allocate funding for annual maintenance works.	High	City MRWA
3.02	Ensure MRWA and DPaW procedures reference Rehabilitation and Freeway Infrastructure Protection Plan – Milyu Nature Reserve and Swan Estuary Marine Park for procedures should emergency erosion protection be required along Milyu.	Moderate	DPaW MRWA
3.03	Replace and lift crest height of revetment around Narrows	High	City
3.04	Possible nourishment of Palms area to reduce impact on GSC wall, erosion of PSP and overtopping onto freeway. Also to provide sediment feed to Milyu	Moderate	City, MRWA, DPaW
3.05	Ensure implementation of City's Water Sensitive Urban Design Guidelines and Integrated Catchment Plan. Shift to improve siltation management on building and construction sites throughout the City. This reduces the siltation load to the drainage network	Moderate	City
3.06	Ensure appropriate maintenance undertaken on existing GPT's	High	City, MRWA
3.07	Review opportunities for WSUD along the Kwinana Freeway.	Low	MRWA
3.08	Investigate improving or maintaining the existing wetland areas that have formed around drainage outfalls in Milyu and at Sea Scouts. Encourage these areas as biofilter areas. Investigate potential for Constructed Wetlands at Drainage Elements within Milyu	Low	City MRWA DPaW
4	**Management of Biological Environment**		
4.01	Continue to educate the public about migratory bird sites and how not to disturb the sites.	Low	DPaW City
4.02	Promote and maintain alternative roosting sites for migratory birds.	Moderate	DPaW City
4.03	Retain vegetation and rocks to provide refuge for local native fauna.	Moderate	City
4.04	Promote flora that provide food for local native fauna in revegetation and soft landscaping.	Moderate	City
4.05	Educate dog owners to keep their pets on a leash when visiting the foreshore.	Moderate	City
4.06	Divide each zone into revegetation domains according to their site characteristic and end land use. Use appropriate local native species for each revegetation domain.	High	City
4.07	Plant tubestock in winter after onset of rains. Foreshore edge plantings to be undertaken in late spring and watered to allow for establishment prior to winter storms.	High	City
4.08	Target High Priority Weed species in the bushland to reduce their presence and threat. Moderate and low weed species may also be targeted if resources allow. Target high priority weed species in each zone using methods recommended in the KFFMP Weed Management Spread Sheet	High	City
4.09	Target weed species by using appropriate treatments according to their growth form.	High	City
4.10	Ensure that only appropriate herbicides are used and are correctly applied.	High	City
4.11	Direct weed control activities to occur in April and August each year to effectively control most of the known high Priority weed species.	High	City
4.12	Ensure that all contractors have appropriate equipment to prevent diseases from being introduced into the bushland.	High	City
4.13	All contractors are to be made aware of the disease risk and what management measures are required to prevent the introduction and spread of dieback.	High	City
4.14	Ensure that any revegetation materials only come from disease free sources.	High	City
4.15	The local public is to be made aware of dieback and what they may do in reducing the risk of introducing and spreading the disease.	Moderate	City
4.16	The City is to be informed of any detected infection and what actions are being conducted to reduce the risk of it being spread.	High	City

4.17	Any detected small infections of Aerial Canker are only to be removed using removing the infected limbs with clear secateurs and a benzimidazole fungicide.	Moderate	City
4.18	Ensure that prescribed burning is not conducted in the study area as part of a fire prevention strategy.	High	City
4.19	Raise awareness of the community's role in protecting the local bushland and their own properties.	High	City
4.20	Ensure all paths and tracks in and around the study area are routinely inspected for weed presence and controlled.	High	City
4.21	Provide information to residents within or adjacent to the study area on their role in preparing for risk of fire outbreak.	Low	City
4.22	After a fire, promptly complete and submit a Fire Incidence Report Form to DFES.	Moderate	City
4.23	Reduce public access to fire-damaged areas of the study area through provision of signage and fence repair.	High	City
4.24	Following a fire, arrange for the immediate rescue of any injured fauna.	High	City
4.25	Following a fire, monitor the natural revegetation of the bushland and conduct weed control and revegetation maintenance if required.	Moderate	City
4.26	Maintain a record of the study site's fire history.	Low	City
5	**Environmental Values**		
5.01	Ensure revegetation works are aligned with the current site plans for Milyu, North Canning, South Canning and Spit Zones	High	City MRWA
5.02	Revegetate each zones according to their domain's site characteristic and end land use: • Wetland (native vegetation and fauna habitat) • Transition (native vegetation and fauna habitat) • Dryland (native vegetation and fauna habitat) • Soft Landscape (aesthetics)	High	City
6	**Management of Social Environment**		
6.01	Develop and implement a Wayfinding and Interpretation Plan for the foreshore to facilitate a co-ordinated plan for interpretation and education. Review and liaise with local historians, community and Aboriginal groups to develop interpretative themes and elements including signage, artworks and nature based play elements. This plan should also address digital methods of communication as well as physical signage. Research and develop strong themes for interpretation based on the complex social, cultural and environmental complexities of the site.	High	City
6.02	Incorporation of interpretive items and artworks as per the outcome of the Section 18 approval. Work collaboratively with local Aboriginal Groups and elders in the development of interpretative elements including signage, artworks and nature based play elements.	Moderate	City
6.03	Promote local native flora that have Aboriginal culture significance.	Moderate	City
6.04	Conduct an audit of existing facilities and amenities assessing safety compliance, condition and accessibility.	Moderate	City
6.05	Prepare a specific Landscape Concept Plan for the Kwinana Foreshore Reserve including all zones considering relevant restoration plans and future planning within the City of South Perth. Prepare a detailed Foreshore Landscape Master Plan and costing to guide the upgrade of the foreshore's facilities and amenities on a stage by stage basis.	Moderate	City
6.06	Ensure all amenities are complementary in colour and style and blend in with the natural environment.	Moderate	City
6.07	Use the detailed Foreshore Landscape Master Plan and costing to guide the installation of screening vegetation to key areas of activity and where it does not pose a hazard or detract from the visual quality to freeway users.	Low	City
6.08	Assess access points for equal access and ensure adequate access is achieved at regular locations by all users.	High	City
6.09	Provide detailed information regarding public access to the foreshore on the City website including pedestrian, cycle, equal access, vehicle and water based activities.	Moderate	City
6.10	Replace footbridges which do not meet requirements for universal access. Hardy Street, Cale Street and Edgewater Street footbridges. If Hardy Street footbridge is replaced, consideration should be given to shifting the link across to the proposed South Perth Train Station and Richardson Reserve.	Moderate	City MRWA
6.11	Use the detailed Foreshore Landscape Master Plan and costing to assist in planning for dog off leash areas and sign posting of dog on leash conditions. Given loss of dog walking areas at Skinny and Palms, alternative dog walking areas shall be identified. It is suggested that Sea Scouts and North Canning zones would provide opportunities for dog walking.	Low	City
6.12	Include Water Points on the Walk Path along the Canning River between Mt Henry and Canning Bridges.	Moderate	City
6.13	Separation of cyclists and walkers where possible.	Moderate	MRWA
6.14	Prepare a review of the car parks to ensure they meet standards and safety requirements.	Low	City MRWA
6.15	Improve shade facilities and possibly picnic and barbeque facilities at the Narrows.	Low	City

6.16	Continue to maintain beach areas at Como Beach and Jet Ski Carpark and encourage these areas as main recreational nodes for water interaction.	Moderate	City
6.17	Improve the recreation area at Gentilli Way boat ramp with the provision of shade and picnic facilities on the adjacent grassed areas.	Low	City
6.18	Increase the activation between the Scouts area and Olive Reserve. A better footbridge at Cale Street would encourage improved access to this area.	Low	City
6.19	Replace Sea Scouts building with a combined function centre/ Scout facility. Scout hardstand to be ground level. Function Centre Rooms on second storey. Investigate the possibility of shifting the Sea Scouts to the Narrows or into the Canning Bridge Precinct to provide better access.	Low	City
6.20	Conduct an audit of existing directional, informative and interpretive signage assessing style, format, location, safety compliance and condition.	Low	City
6.21	Where possible involve the community in management of the foreshore. Always reinforce community 'ownership' in this respect.	Moderate	City
6.22	Involve school groups and the local community in educational activities in the natural areas of the site including stencilling projects, signs, geocaching, media and holiday recreation programs.	Moderate	City
6.23	Continue support for the formation and ongoing involvement of local friends groups and provide supervision and support via the Environmental Officer and Infrastructure Services. Seek involvement from the South Perth Youth Network. Support should include the provision of equipment and guidance.	Moderate	City
6.24	Continue to provide bushland regeneration courses to interested members of the public who actively commit more than 40 hours per annum to bushland and wetland maintenance.	Low	City
6.25	Establish an Eco-news column in the local paper to raise awareness about the environment.	Low	City
7	**Social Values**		
7.01	Investigate tourism opportunities and connections into the Foreshore Reserve.	Moderate	City
7.02	Investigate opportunities to relocate the Sea Scouts buildings to allow better access. Investigate using the new facility for events/functions.	Low	City
8	**Maintenance**		
8.01	Incorporate asset condition information and maintenance activities into City Asset Management Database.	High	City
8.02	Have Operations staff identify any issues during routine works.	High	City
8.03	Identify within a detailed Foreshore Landscape Master Plan maintenance access locations, pull over locations and hardstands for maintenance along the PSP. Maintain access opportunities at key locations to cater for large maintenance/ works trucks.	Moderate	City
8.04	Involve the community in litter collection through the Clean-Up Australia Day.	Low	City
8.05	Investigate the feasibility of providing syringe disposal and condom dispenser in all toilet facilities.	Low	City
8.06	Review and consolidate turf areas to active recreation areas only.	Low	City
8.07	Prepare and implement a Water Conservation Plan for the foreshore, detailing hydro zoning and eco zoning strategies to assess and monitor the watering requirements for the foreshore.	High	City
8.08	Repair all damaged facilities immediately after any act of vandalism to discourage vandals. Remove graffiti and repair damage to infrastructure as soon as possible after it occurs.	Moderate	City MRWA
8.09	Encourage the community to report anti-social and destructive behaviour to the police and council authorities.	Low	City
9	**Monitoring**		
9.01	Monitor mean sea level rises against current predictions.	Low	City
9.02	Continue Milyu Monitoring for coastal erosion to establish a dataset that quantifies shoreline movements.	Moderate	DPaW MRWA
9.03	Monitor shoreline of South Canning Section	Moderate	City MRWA
9.04	Continue to monitor Melville Waters for Water Quality. Provide City with feedback of any possible concerns.	Moderate	DPaW
9.05	Monitor groundwater bores within region	Moderate	DoW City
9.06	Monitor each landscaping zone to determine any significant tubestock mortalities and the conduct infill planting if required.	Moderate	City
9.07	Undertake walk throughs of KFF after a significant storm event.	Moderate	City
9.08	After a severe event, obtain water level records for Fremantle and Barrack Street and wind records for Melville Water.	Moderate	City
9.09	Engage a qualified zoologist to monitor migratory wader birds on Milyu's tidal flats ten times a year between April and August.	Moderate	City

9.10	Engage a qualified environmental consultant to monitor revegetation efforts (at least once a year formally and very six months informally) and adapt works as necessary.	High	City
9.11	Engage a qualified environmental consultant to monitor weed populations (at least once a year formally and very six months informally) and adapt weed control works as necessary.	High	City
9.12	Regularly engage a qualified dieback expert to assess the bushland and mark the boundaries of any detected infection of dieback or other plant diseases.	High	City
9.13	Start a record of the number of days or hours per year that the Kwinana Freeway is affected by weather or storm activity. This record should state whether the impact is due to drainage flooding, wave spray and overtopping or direct inundation.	Moderate	MRWA
10	**Implementation**		
10.01	Coordinate and facilitate the KFFMP.	High	KFFMG City
10.02	Coordinate and share resources to enact KFFMP.	High	KFFMG City
10.03	Fund management and maintenance works and the KFFMG to enable management of issues identified in KFFMP.	High	MRWA City Trust DPaW

APPENDIX TWO: MAPS

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

AUTHOR: RD CHECKED: MM

DATE: NOV -13 PROJECT NO: 3016-13

ecoscape

9 Stirling Hwy,
North Fremantle WA 6159
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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

DAFWA SOIL SUB SYSTEMS (2012)

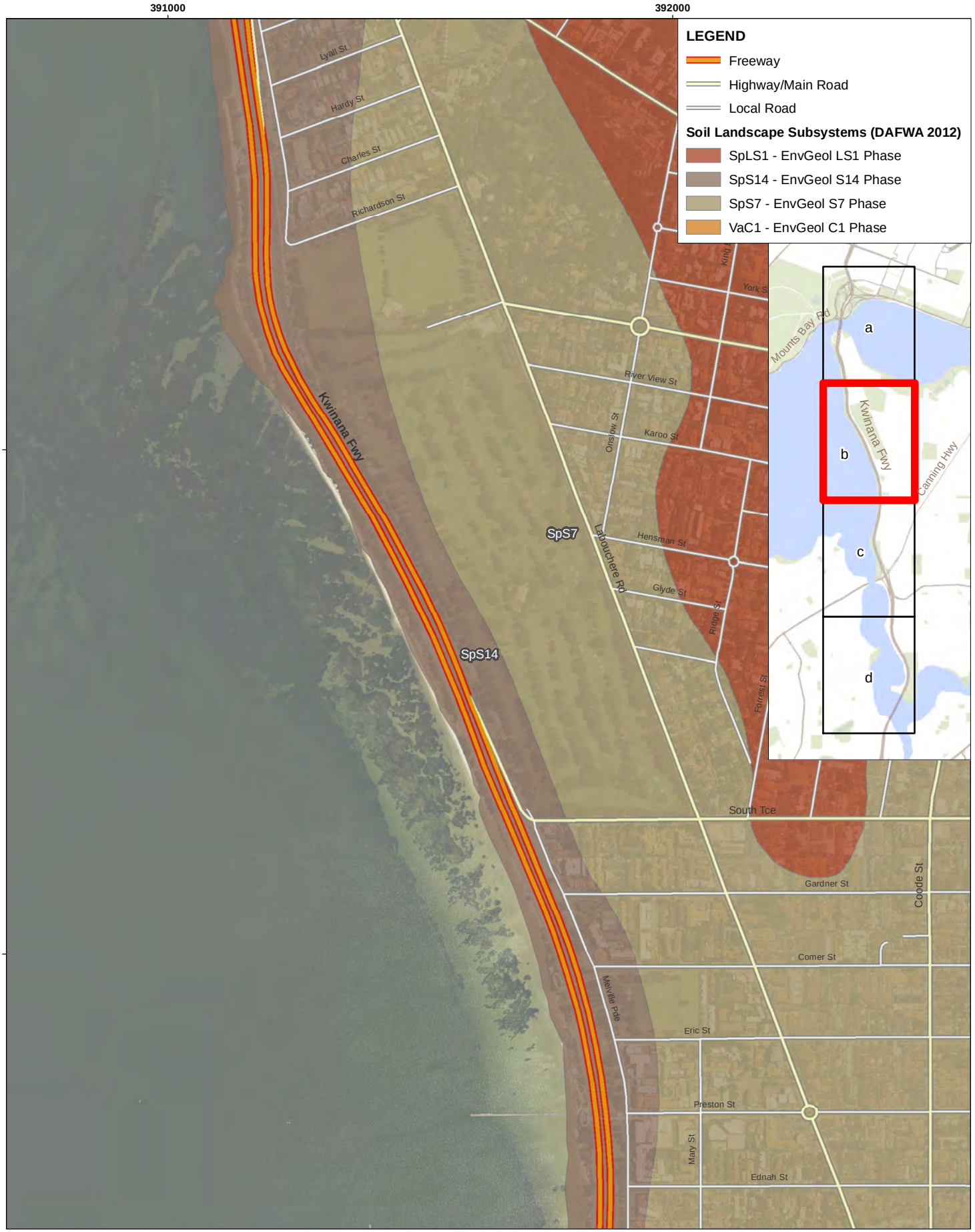
N

Scale 1:10,000 @ A4

0 100 200 300 400 m

GDA 1994 MGA Zone 50

MAP 1a



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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

DAFWA SOIL SUB SYSTEMS (2012)

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 1b

GDA 1994 MGA Zone 50

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

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CLIENT: CITY OF SOUTH PERTH

DAFWA SOIL SUB SYSTEMS (2012)

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 1c

GDA 1994 MGA Zone 50

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

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CLIENT: CITY OF SOUTH PERTH

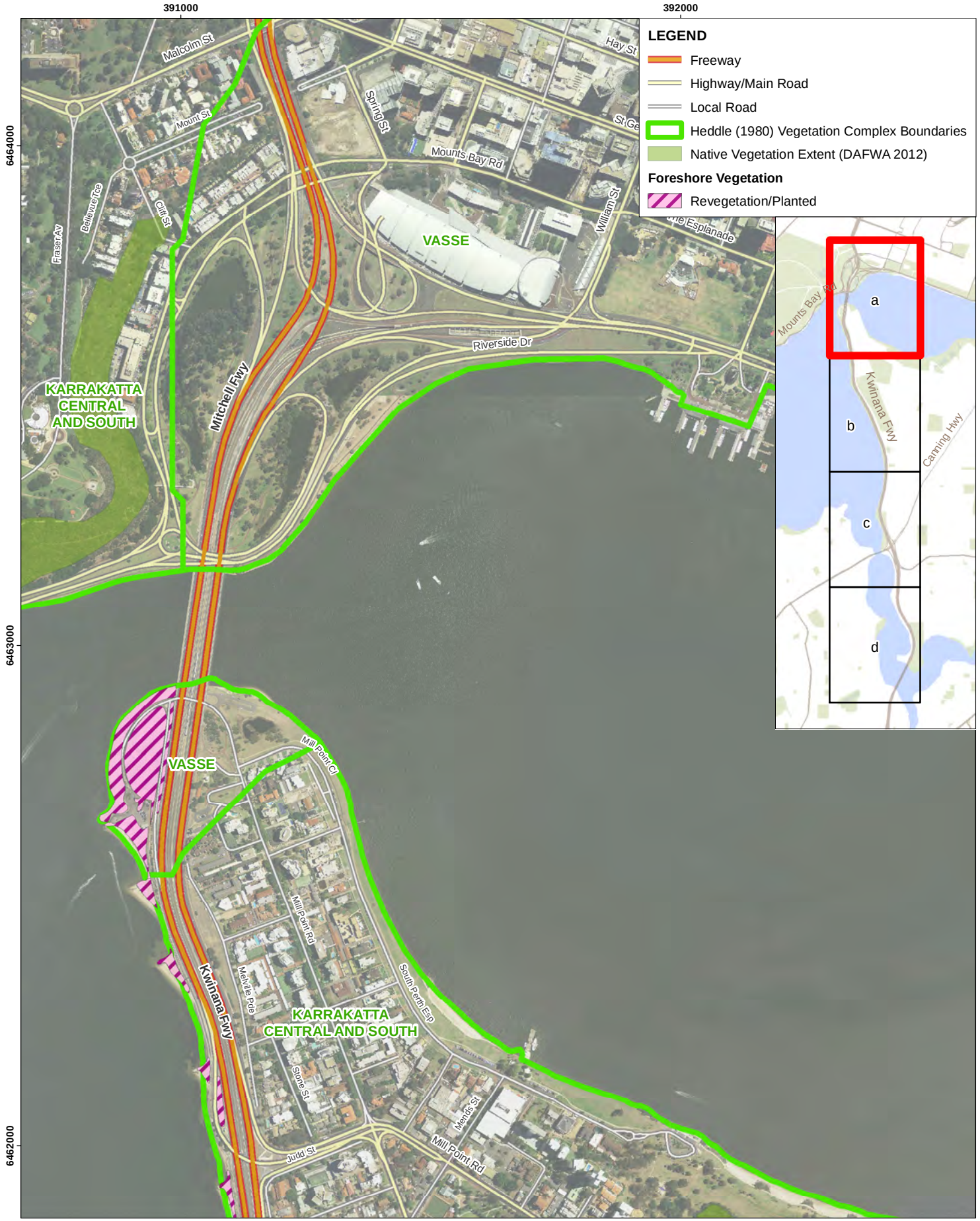
DAFWA SOIL SUB SYSTEMS (2012)

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 1d



IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

HEDDLE VEGETATION (2006)

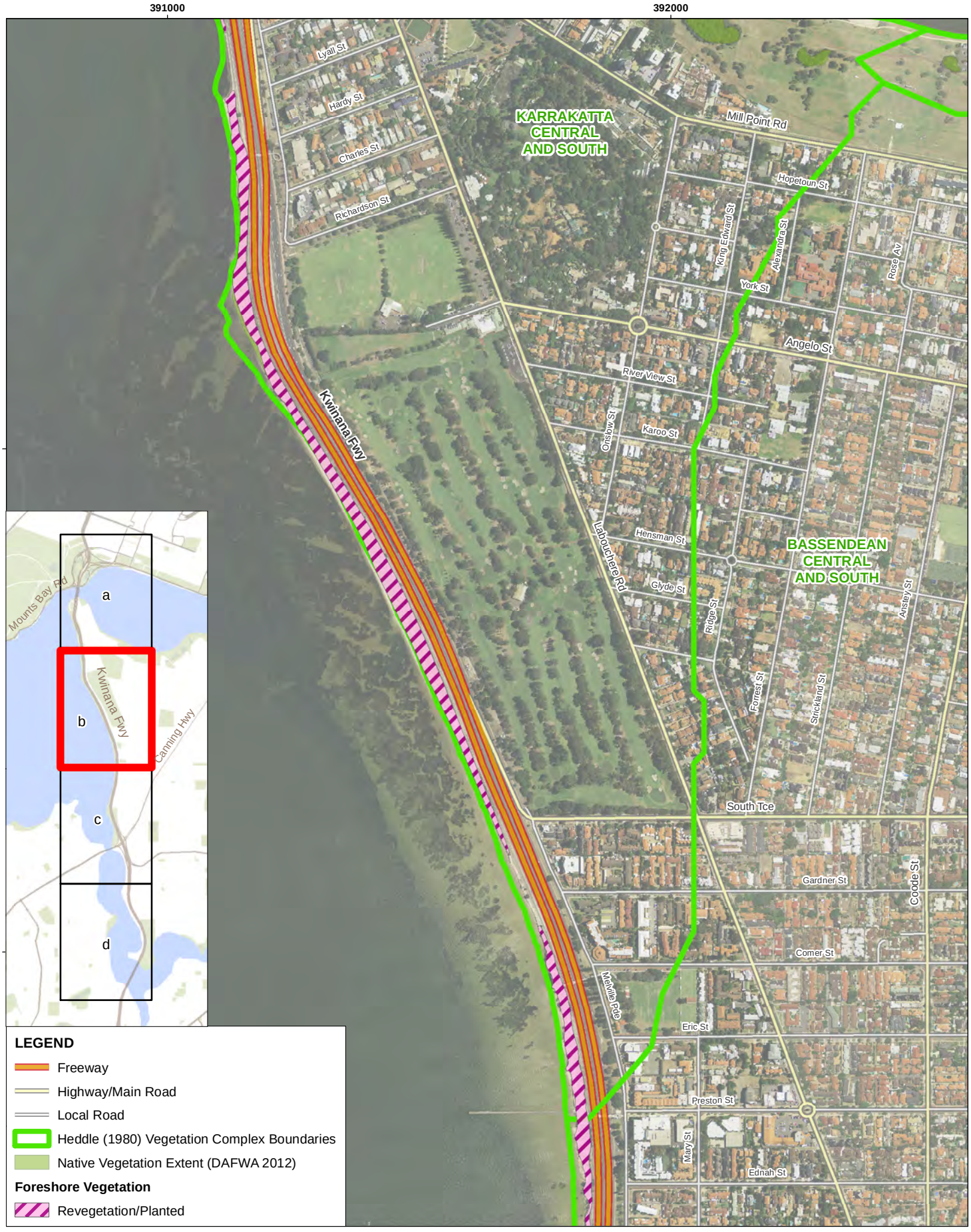
N

Scale 1:10,000 @ A4

0 100 200 300 400 m

GDA 1994 MGA Zone 50

MAP 2a



LEGEND

- Freeway
- Highway/Main Road
- Local Road
- Heddle (1980) Vegetation Complex Boundaries
- Native Vegetation Extent (DAFWA 2012)

Foreshore Vegetation

- Revegetation/Planted

GDA 1994 MGA Zone 50

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

AUTHOR: RD CHECKED: MM

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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

HEDDLE VEGETATION (2006)

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 2b

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

GDA 1994 MGA Zone 50

AUTHOR: RD CHECKED: MM

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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

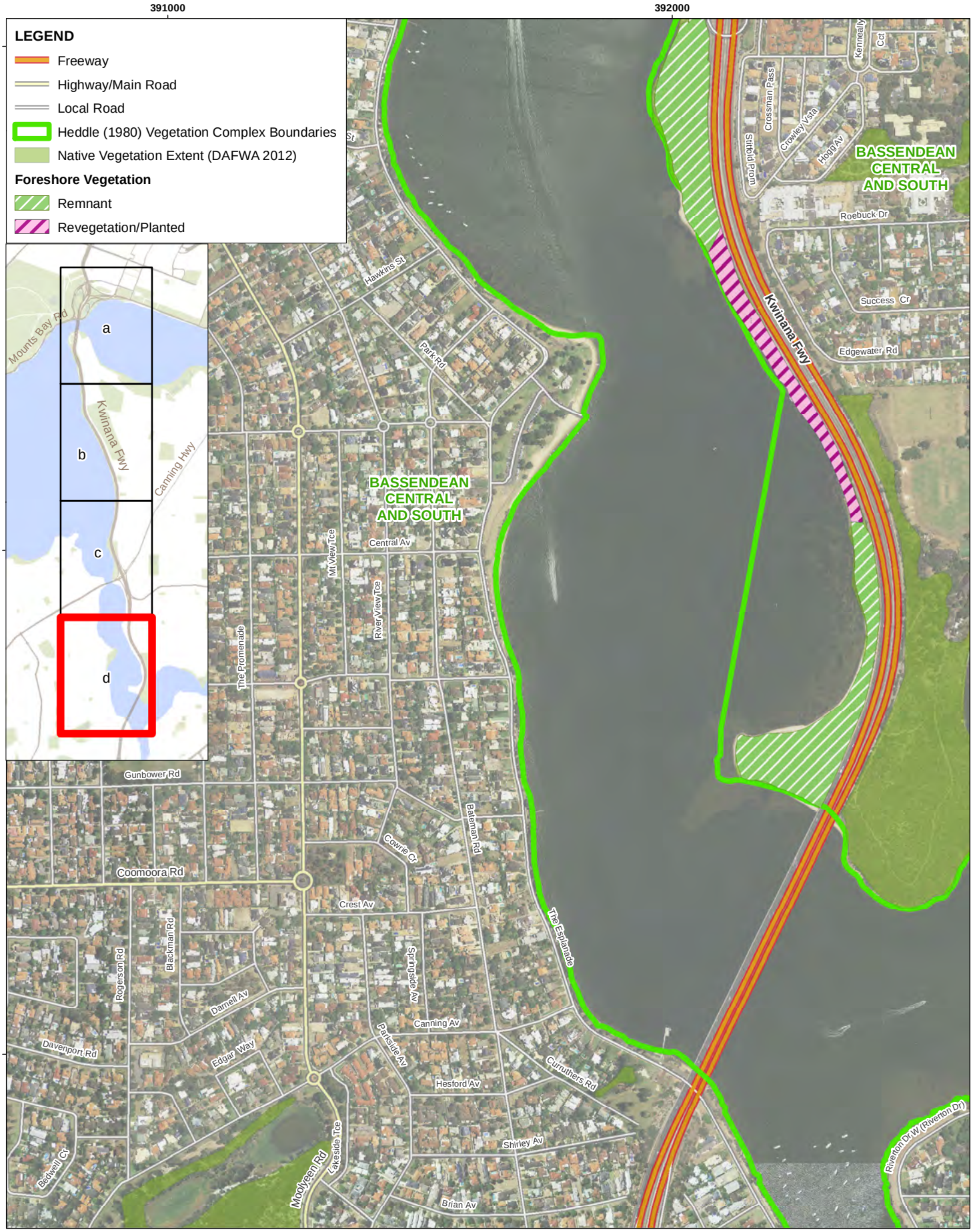
HEDDLE VEGETATION (2006)

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 2c



GDA 1994 MGA Zone 50

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

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DATE: NOV -13 PROJECT NO: 3016-13

KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

HEDDLE VEGETATION (2006)

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 2d

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GDA 1994 MGA Zone 50

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

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DATE: NOV -13 PROJECT NO: 3016-13

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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

BUSHLAND CONDITION

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 3a

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

GDA 1994 MGA Zone 50

AUTHOR: RD CHECKED: MM

DATE: NOV -13 PROJECT NO: 3016-13

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0 100 200 300 400 m

MAP 3b

IMAGERY SOURCE: CITY OF SOUTH PERTH, JANUARY 2013

AUTHOR: RD CHECKED: MM

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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

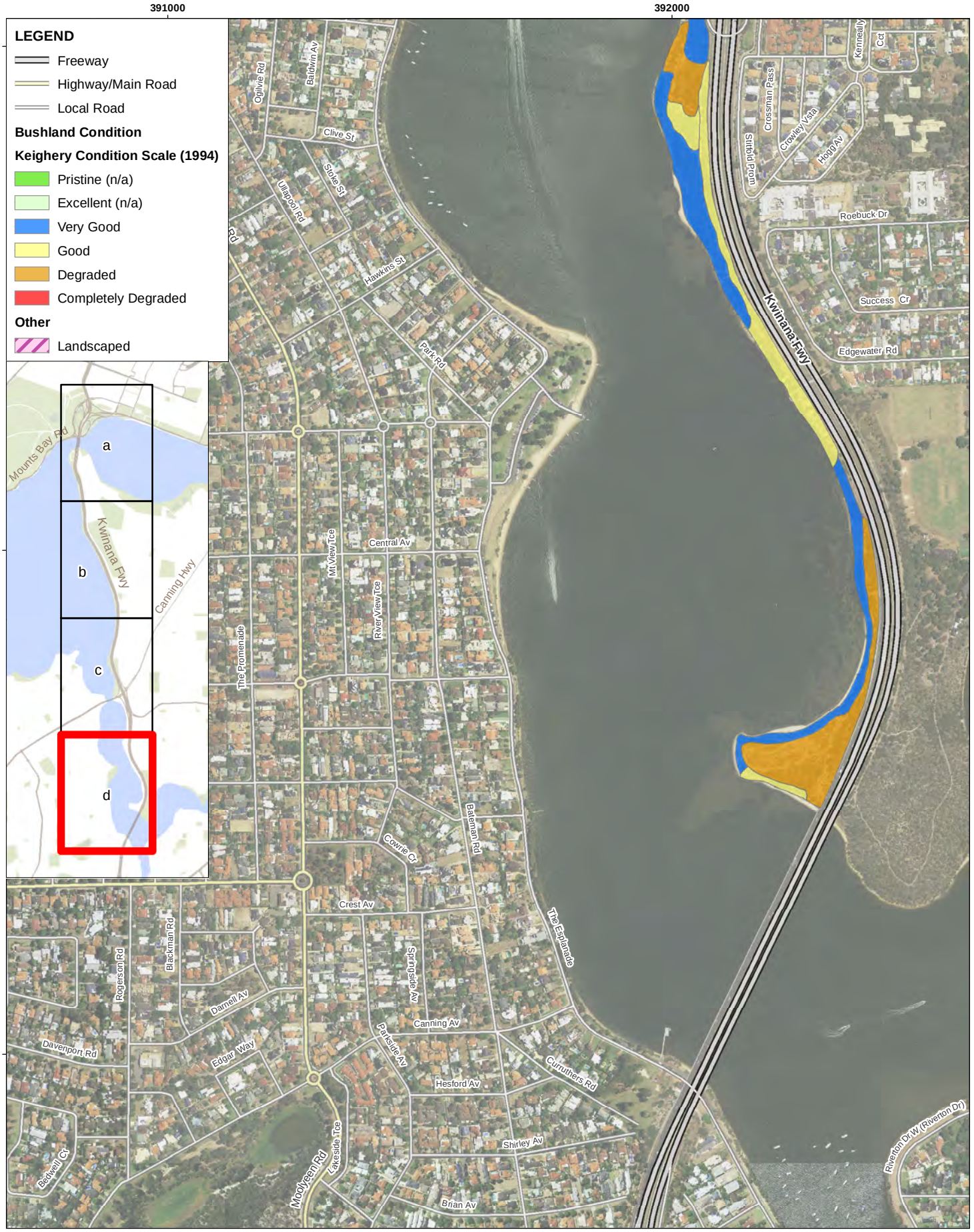
BUSHLAND CONDITION

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 3c



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GDA 1994 MGA Zone 50

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KWINANA FREEWAY FORESHORE MANAGEMENT PLAN

CLIENT: CITY OF SOUTH PERTH

BUSHLAND CONDITION

N

Scale 1:10,000 @ A4

0 100 200 300 400 m

MAP 3d

APPENDIX THREE: WEED SPECIES PRIORITISATION

Methodology of Prioritising Weeds

Rating Systems

The priority ratings of each weed species were determined after examining:

- the ratings under the:
  - Environmental Weed Strategy of Western Australia (EWSWA) by the Department of Conservation and Land Management (Department of Environment and Conservation 2008a)
  - Environmental Weed Census and Prioritisation (EWCP) by the Swan Natural Resource Management (Swan NRM 2008)
  - Dixon and Keighery (Dixon & Keighery 1995) Recommended methods to control specific weed species
- whether it was listed as a:
  - Declared Pest under the Department of Agriculture and Food (DAFWA 2007) Biosecurity and Agriculture Management Act (BAM)
  - Weed of National Significance (WONS) (Weeds Australia 2012)
- its local significance to the natural areas.

The role of EWSWA is to highlight which weed species pose significant environmental risk in Western Australia. The EWSWA rating provides a basis for determining which weeds are most critical to control. The three characteristics used for determining the EWSWA rating are:

- invasiveness – ability to invade bushland in good to excellent condition
- distribution – wide current or potential distribution including consideration of known history of wide distribution elsewhere in the world
- environment impacts – ability to change the structure, composition and function of ecosystems, in particular to form a monoculture in a vegetation community.

EWSWA weed species were rated accordingly:

- High – have all three of the characteristics
- Moderate – have two of the characteristics
- Mild – have one of the characteristics
- Low – not deemed to have any of the characteristics.

However, EWSWA is a general guide for prioritising weeds across the State. The Swan Natural Resource Management (2008) *Environmental Weed Census and Prioritisation* (EWCP) rates weeds species as a threat in Perth bushland conditions. A total of eight ratings are used, according to the risk each species poses to environmental assets in the region, based on invasiveness, ecological impact, current and potential distribution, and thus priority for management. In order of descending, priority, they are:

- Very High
- High
- Further Assessment Required (FAR)/ High
- Moderate/ High
- Moderate
- Low/ Moderate
- Low
- Further Assessment required (FAR).

Dixon and Keighery (Dixon & Keighery 1995) developed a rating system for 145 weed species. The rating system classified each species according to the threat they pose to bushland in the Perth Metropolitan region. The three classifications used were:

- Priority 1 – major weeds, which are the most serious weeds within their ecosystem, often affecting many reserves or habitats in ways likely to permanently degrade them -
- Priority 2 – nuisance weeds, which are generally found only in a few locations or ecosystems, usually in disturbed areas
- Priority 3 – minor weeds, which have little known effect and occur in smaller numbers or are less competitive than Priority 2 weeds.

Under the BAM Act 2007, all declared pests are placed in one of three categories:

- C1 Category (Exclusion) – Pests not established in Western Australia. Control measures are to be taken, including border checks, in order to prevent them entering and establishing in the State.
- C2 Category (Eradication) – Pests present in Western Australia in low enough numbers or sufficiently limited areas that their eradication is still a possibility.
- C3 Category (Management) – Pests established in Western Australia but it is feasible, or desirable, to manage them in order to limit their damage.

WONS was jointly declared by the Minister for Forestry and Conservation, the Minister for Agriculture, Fisheries and Forestry and the Minister for The Environment in 1999 as part of the *National Weeds Strategy*. The four characteristics used for determining where the species was of national significance were:

- invasiveness
- impacts
- potential for spread
- socioeconomic and environmental values.

Ranking Priority Weeds

The above sources were used to rank the recorded weed species in order of priority for control. Both the EWCP (Swan Natural Resource Management 2008) and EWSWA (CALM 1999) ratings were used because it allowed most weeds identified in the study area to be assigned a rating and thereby ranked. If only one source had been used, some of the weed species would have not been assigned a rating score.

The use of two rating systems does result in some conflict when assigning a ranking for a weed species. To overcome this issue, a matrix scoring system was developed to enable the ranking of the weed species. The matrix scoring system is summarised in Table 57**.** For the purposes of this study, the system gave a slight bias to the EWCP system, as this system was more relevant for the study area.

In addition, as weed species listed under either the BAM Act or WONS are required by legislation to be controlled, any of these listed weed species recorded were automatically given a rating of 6.

If any weed species not assigned a rating by these any of the previous sources, the Dixon and Keighery (Dixon & Keighery 1995) rating system would then be used:

- Priority 1 = Rating 6
- Priority 2 = Rating 4
- Priority 3 = Rating 2

If any weed species were not given a rating be any of the previous systems, they would receive a default rating of 1.

Table 57: Matrix scoring system for rating weed priority

RATING SYSTEM		EWSWA				
		Unrated	Low	Mild	Moderate	High
EWCP	Unrated	1	1	3	4	5
	FAR	1	1	3	4	5
	Low	2	2	3	4	5
	L/M	2	3	4	4	5
	M	3	4	4	4	5
	M/H	4	4	4	5	6
	FAR/H	5	5	5	5	6
	H	5	5	5	6	6
	VH	6	6	6	6	6

The calculated ratings were then adjusted according to whether the species were more or less of a threat or dominant in the local native areas. Species with low ratings that were posing a greater threat or were already highly dominant had the rating raised. In contrast, species with high ratings but were not considered to be a local threat had their rating lowered accordingly.

The priority of each weed species was then classified by the final rating:

- Species given a rating of 5 or 6 were High Priority Weeds.
- Species with a final rating of 3 or 4 were Moderate Priority Weeds.
- Species with a rating of 1 or 2 were Low Priority Weeds.

Results

State and National Significance

Bridal Creeper (*Asparagus asparagoides*) and Lantana (*Lantana camara*) are both listed as WONS and declared C3 by BAM. Arum Lily (*Zantedeschia aethiopica*). Doublegee (*Emex australis*) and One-leaf Cape Tulip (*Moraea flaccida*) are declared C3 by BAM. All Five species were given Ratings of 6 (High Priority).

Local Significance

Bulrush (*Typha orientalis*), Capeweed (*Arctotheca calendula*), Edible Fig (*Ficus carica*), Flat Weed (*Hypochaeris glabra/ radicata*), Lemon Scented Gum (*Corymbia citriodora*), Pine (*Pinus* sp.) and Wild Turnip (*Brassica tournefortii*) were all calculated to having ratings of 6 (High Priority). Similarly, Birdsfoot (Lotus angustifolius), Date Palm (*Phoenix dactylifera*) and Wild Lettuce (*Lactuca saligna/ serriola*) were all calculated to having ratings of 5 (High Priority All of these species were downgraded to a rating of 4 (Moderate Priority) as they were considered to be minor threats to the local bushland.

Cape Bluebell (*Wahlenbergia capensis*) was calculated to have a rating of 4 (Moderate Priority) but was downgraded to a rating of 2 (Low Priority) as this species is not considered a problem in the study area.

Table 58: Prioritisation of weed species in Kwinana Freeway Foreshore

WEED SPECIES		PRIORITISATION								
Common Name	**Scientific Name**	**EWCP**	**EWSWA**	**Weeds Australia**	**BAM**	**Dixon & Keighery**	**Calculated Rating**	**Local significance**	**Final Rating**	**PRIORITY**
African Love Grass	*Eragrostis curvula*	High	High			1	6		6	HIGH
Arum Lily	*Zantedeschia aethiopica*	Very High	High		C3	1	6			
Black Flag	*Ferraria crispa*	Very High	Unrated			2	6			
Bridal Creeper#	*Asparagus asparagoides*	Very High	High	WONS	C3	1	6			
Buffalo Grass	*Stenotaphrum secundatum*	Moderate	High			1	6			
Couch	*Cynodon dactylon*	Very High	Moderate			1	6			
Doublegee	*Emex australis*	Unrated	Low		C3	3	6			
Geraldton Carnation Weed	*Euphorbia terracina*	Very High	High			1	6			
Great Brome	*Bromus diandrus*	Very High	High			3	6			
Hare's Tail Grass	*Lagurus ovatus*	High	High			2	6			
Japanese Pepper Tree	*Schinus terebinthifolius*	Very High	Unrated				6			
Kikuyu	*Cenchrus clandestinus*	High	Moderate			1	6			
Lantana	*Lantana camara*	Moderate	Moderate	WONS	C3	3	6			
Olive	*Olea europaea*	Unrated	Low				6			
One-leaf Cape Tulip	*Moraea flaccida*	Very High	High		C3	1	6			
Pampas Grass#	*Cortaderia selloana*	Very High	High			1	6			
Perennial Veldt Grass	*Ehrharta calycina*	Very High	High			1	6			
Petty Spurge#	*Euphorbia peplus*	High	Moderate			3	6			
Salt Water Couch	*Paspalum vaginatum*	High	Moderate				6			
Sea Barley	*Hordeum marinum*	High	Moderate			3	6			
Three-cornered Garlic	*Allium triquetrum*	High	Moderate			3	6			
Victorian Tea Tree	*Leptospermum laevigatum*	Very High	High			1	6			
Watsonia	*Watsonia meriana* var. *bulbillifera*	Very High	High			1	6			
Wavy Gladiolus	*Gladiolus undulatus*	Very High	Moderate			2	6			
Wild Oat	*Avena barbata/ fatua*	Very High	Moderate			1	6			
Blue Lupin	*Lupinus cosentinii*	Unrated	High			1	5		5	
Fingerleaf Oxalis	*Oxalis glabra*	High	Mild			3	5			
Freesia	*Freesia alba x leichtlinii*	Very High	High				6			
Guildford Grass	*Romulea rosea*	FAR	High			1	5			
Pigface	*Carpobrotus edulis*	Moderate/ High	Moderate			2	5			
Rose Pelargonium	*Pelargonium capitatum*	Moderate/ High	High			1	5			
Sea Spinach	*Tetragonia decumbens*	Moderate/ High	Moderate			3	5			
Soursob	*Oxalis pes-caprae*	High	Mild			2	5			
Wild Gladiolus	*Gladiolus caryophyllaceus*	FAR/ High	Moderate			1	5			
Annual Rye Grass	*Lolium rigidum*	Unrated	Moderate			3	4		4	MOD
Annual Veldt Grass	*Ehrharta longiflora*	FAR	Moderate			3	4			
Beach Evening Primose#	*Oenothera drummondii*	Moderate	Unrated			3	4			
Birdsfoot	*Lotus angustissimus*	High	Low			3	5	No		
Black Nightshade	*Solanum nigrum*	Moderate	Moderate			2	4			
Blowfly Grass	*Briza maxima*	FAR	Moderate			2	4			
Bulrush	*Typha orientalis*	Very High	High			1	6	No		
Caltrop	*Tribulus terrestris*	Low	Moderate/ High				4			
Capeweed	*Arctotheca calendula*	Moderate	High			3	6	No		
Century Plant	*Agave americana*	Moderate	Low			3	4			
Common Meliot	*Melilotus indicus*	Moderate	Unrated			3	4			
Date Palm	*Phoenix dactylifera*	Unrated	High				5	No		
Dove's Foot Cranesbill	*Geranium molle*	Moderate	Low			3	4			
Edible Fig#	*Ficus carica*	High	Moderate			1	6	No		
False Hawkbits	*Urospermum picroides*	Moderate	Moderate			3	4			
Flatweed	*Hypochaeris glabra/ radicata*	High	Moderate			3	6	No		
Geraldton Wax	*Chamelaucium uncinatum*	Moderate	Moderate			2	4			
Giant Reed	*Arundo donax*	Unrated	Unrated			2	4			
Larger Wood-sorrel	*Oxalis purpurea*	Moderate	Low			3	4			
Lemon-scented Gum	*Corymbia citriodora*	High	Moderate			3	6	No		

WEED SPECIES		PRIORITISATION								
Common Name	**Scientific Name**	**EWCP**	**EWSWA**	**Weeds Australia**	**BAM**	**Dixon & Keighery**	**Calculated Rating**	**Local significance**	**Final Rating**	**PRIORITY**
Lesser Broomrape	*Orobanche minor*	FAR	Moderate				4			
Mile-a-Minute	*Ipomoea indica*	Moderate/ High	Mild			3	4			
Pine	*Pinus* sp.	Very High	Moderate			3	6	No		
Pretty Betsy	*Centranthus macrosiphon*	Moderate/ High	Low			3	4			
Sea Rocket	*Cakile maritima*	FAR	Moderate			3	4			
Sea Wheat	*Thinopyrum distichum*	FAR	Moderate				4			
Sowthistle	*Sonchus asper/ oleraceus*	Moderate	FAR				4			
Stinkwort	*Dittrichia graveolens*	Moderate	Mild			3	4			
Subterranean Clover	*Trifolium subterraneum*	Moderate	FAR			3	4			
Ursinia	*Ursinia anthemoides*	Moderate	Moderate			3	4			
Vetch	*Vicia sativa*	FAR	Moderate			3	4			
Wall Fumitory	*Fumaria muralis*	Moderate	Mild			2	4			
Watercress	*Rorippa nasturtium-aquaticum*	Unrated	Moderate				4			
Whiteflower Fumitory	*Fumaria capreolata*	Moderate/ High	Mild			2	4			
Wild Lettuce	*Lactuca saligna/ serriola*	High	Low			3	5	No		
Wild Turnip	*Brassica tournefortii*	High	High			3	6	No		
Yellow Wood Sorrell	*Oxalis corniculata*	Moderate	Mild			3	4			
Burr Medic	*Medicago polymorpha*	Mild	FAR			3	3			
Clustered Dock	*Rumex conglomeratus*	FAR	Mild			3	3			
Dock	*Rumex* sp.	Far	Mild			3	3			
Fennel	*Foeniculum vulgare*	Moderate	Unrated			2	3			
Ink Weed	*Phytolacca octandra*	FAR	Mild			3	3			
Monopsis	*Monopsis debilis*	Mild	Unrated			3	3		**3**	
Onion Weed	*Asphodelus fistulosus*	FAR	Mild			1	3			
Strap Lily	*Trachyandra divaricata*	FAR	Mild			3	3			
Tagasaste	*Chamaecytisus palmensis*	Mild	FAR			2	3			
Wild Radish	*Raphanus raphanistrum*	FAR	Mild			3	3			
Winter Grass	*Poa annua*	Low	Mild			3	3			
Canna Lily#	*Canna* sp.	Unrated	Unrated			3	2			
Cape Bluebell	*Wahlenbergia capensis*	Moderate	FAR			3	4	No		
Common Groundsel	*Senecio vulgaris*	Low	Low			3	2			
Coral Tree	*Erythrina* sp.	Low	Low			3	2			
Dandelion	*Taraxacum officinale*	Low	Low				2			
Flaxleaf Fleabane	*Conyza bonariensis*	Low	Low			3	2			
Flinders Range Wattle	*Acacia iteaphylla*	FAR	Low			3	2		**2**	
Garden Orach	*Atriplex hortensis*	Low	Low				2			
Marram Grass#	*Ammophila arenaria*	FAR	Low			3	2			
Nasturtium	*Tropaeolum majus*	Low	Low			3	2			
Oleander	*Nerium oleander*	Low	Unrated				2			
Red Dock	*Rumex bucephalophorus*	Low	Low				2			
Swamp Dock	*Rumex brownii*	Low	Unrated				2			
Bushy Starwort	*Symphyotrichum squamatum*	Unrated	Unrated				1			
Castor Oil Plant#	*Ricinus communis*	Unrated	Low			3	1			
Eau-de-Cologne Mint#	*Mentha x piperita*	Unrated	Low			3	1			
Flax-leaf Alyssum	*Alyssum linifolium*	Unrated	Low				1		**1**	
French Catchfly	*Silene gallica*	Unrated	Low			3	1			
Indian Hedge Mustard	*Sisymbrium orientale*	Unrated	Low				1			
Yellow Lupin	*Lupinus luteus*	Unrated	Low				1			

May be in study area

APPENDIX FOUR: OPTIMAL WEED CONTROL TIMES

Table 59: Optimal control times to target weed species in Kwinana Freeway Foreshore

PRIORITY	COMMON NAME	SCIENTIFIC NAME	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HIGH	African Love Grass	*Eragrostis curvula*												
	Arum Lily	*Zantedeschia aethiopica*												
	Black Flag	*Ferraria crispa*												
	Blue Lupin	*Lupinus cosentinii*												
	Bridal Creeper#	*Asparagus asparagoides*												
	Buffalo Grass	*Stenotaphrum secundatum*												
	Couch	*Cynodon dactylon*												
	Doublegee	*Emex australis*												
	Fingerleaf Oxalis	*Oxalis glabra*												
	Freesia	*Freesia alba x leichtlinii*												
	Geraldton Carnation Weed	*Euphorbia terracina*												
	Great Brome	*Bromus diandrus*												
	Guildford Grass	*Romulea rosea*												
	Hare's Tail Grass	*Lagurus ovatus*												
	Japanese Pepper	*Schinus terebinthifolius*												
	Kikuyu	*Cenchrus clandestinus*												
	Lantana	*Lantana camara*												
	Olive	*Olea europaea*												
	One-leaf Cape Tulip	*Moraea flaccida*												
	Pampas Grass	*Cortaderia selloana*												
	Perennial Veldt Grass	*Ehrharta calycina*												
	Petty Spurge#	*Euphorbia peplus*												
	Pigface	*Carpobrotus edulis*												
	Rose Pelargonium	*Pelargonium capitatum*												
	Salt Water Couch	*Paspalum vaginatum*												
	Sea Barley	*Hordeum marinum*												
	Sea Spinach	*Tetragonia decumbens*												
	Soursob	*Oxalis pes-caprae*												
	Three-cornered Garlic	*Allium triquetrum*												
	Victorian Tea Tree	*Leptospermum laevigatum*												
	Watsonia	*Watsonia meriana* var. *bulbillifera*												
	Wavy Gladiolus	*Gladiolus undulatus*												
	Wild Gladiolus	*Gladiolus caryophyllaceus*												
	Wild Oat	*Avena barbata/ fatua*												
MOD	Annual Rye	*Lolium rigidum*												
	Annual Veldt Grass	*Ehrharta longiflora*												
	Beach Evening Primrose#	*Oenothera drummondii*												
	Birdsfoot	*Lotus angustissimus*												
	Black Nightshade	*Solanum nigrum*												
	Blowfly Grass	*Briza maxima*												
	Bulrush	*Typha orientalis*												
	Burr Medic	*Medicago polymorpha*												
	Caltrop	*Tribulus terrestris*												
	Capeweed	*Arctotheca calendula*												
	Century Plant	*Agave americana*												
	Clustered Dock	*Rumex conglomeratus*												
	Common Meliot	*Melilotus indicus*												
	Date Palm	*Phoenix dactylifera*												
	Dock	*Rumex* sp.												
	Dove's Foot Cranesbill	*Geranium molle*												
	Edible Fig#	*Ficus carica*												
	False Hawkbits	*Urospermum picroides*												
	Fennel	*Foeniculum vulgare*												
	Flatweed	*Hypochaeris glabra/ radiata*												
	Geraldton Wax	*Chamelaucium uncinatum*												
	Giant Reed	*Arundo donax*												
	Inkweed	*Phytolacca octandra*												
	Larger Wood-sorrel	*Oxalis purpurea*												
	Lemon-scented Gum	*Corymbia citriodora*												
	Lesser Broomrape	*Orobanche minor*												
	Mile a Minute	*Ipomoea indica*												
	Monopsis	*Monopsis debilis*												
	Onion Weed	*Asphodelus fistulosus*												
	Pine	*Pinus* sp.												
	Pretty Betsy	*Centranthus macrosiphon*												
	Sea Rocket	*Cakile maritima*												
	Sea Wheat	*Thinopyrum distichum*												
	Sowthistle	*Sonchus asper/ oleraceus*												
	Stinkwort	*Dittrichia graveolens*												
	Strap Lily	*Trachyandra divaricata*												
	Subterraneum Clover	*Trifolium subterraneum*												
	Tagasaste	*Chamaecytisus palmensis*												
	Ursinia	*Ursinia anthemoides*												
	Vetch	*Vicia sativa*												
	Wall Fumitory	*Fumaria muralis*												
	Watercress	*Rorippa nasturtium-aquaticum*												
	Whiteflower Fumitory	*Fumaria capreolata*												
	Wild Lettuce	*Lactuca saligna/ serriola*												
	Wild Radish	*Raphanus raphanistrum*												
	Wild Turnip	*Brassica tournefortii*												
	Winter Grass	*Poa annua*												
	Yellow Wood Sorrell	*Oxalis corniculata*												
LOW	Bushy Starwort	*Symphyotrichum squamatum*												
	Canna Lily#	*Canna* sp.												
	Cape Bluebell	*Wahlenbergia capensis*												
	Castor Oil Plant#	*Ricinus communis*												
	Common Groundsel	*Senecio vulgaris*												
	Coral Tree	*Erythrina* sp.												
	Dandelion	*Taraxacum officinale*												
	Eau-de-Cologne Mint#	*Mentha x piperita*												
	Flax-leaf Alyssum	*Alyssum linifolium*												
	Flaxleaf Fleabane	*Conyza bonariensis*												
	Flinders Range Wattle	*Acacia iteaphylla*												
	French Catchfly	*Silene gallica*												
	Garden Orach	*Atriplex hortensis*												
	Indian Hedge Mustard	*Sisymbrium orientale*												
	Marram Grass#	*Ammophila arenaria*												
	Nasturtium	*Tropaeolum majus*												
	Oleander	*Nerium oleander*												
	Red Dock	*Rumex bucephalophorus*												
	Swamp Dock	*Rumex brownii*												
	Yellow Lupin	*Lupinus luteus*												
OPTIMAL CONTROL TIME TO TARGET PRIORITY WEEDS						X				X				

\# May be in study area

Optimal control time to target specific weed species

Sub-optimal control time to target specific weed species

uncertain, suggested time to target specific weed species

APPENDIX FIVE: CLIMATE CHANGE

APPENDIX SIX: REVEGETATION SPECIES

Table 60: Recommended local native species for revegetating Kwinana Freeway Foreshore

VEGETATION STRUCTURE			SPECIES		SPECIFIC DOMAIN PER ZONE												REVEG DOMAIN				FAUNA			HERITAGE
Growth Form	Height	Height Class	Scientific Name	Common Name	Narrows	Groynes	Milyu	Palms	Como	Skinny	Sea Scouts	North Canning	South Canning	Cloisters	Infill	Spit	Transition	Wetland	Dryland	Soft Landscape	Significant Fauna Value	Bird Attracting	Invertebrate Attracting	Indigenous Culture Value
Tall Tree (> 10 m)	5-15m	> 10 m	*Allocasuarina fraseriana*	Forest Sheoak	X		X	X			X	X	X	X		X			L		Carnaby Cockatoo	*		medicine, wood, seasonal cue
	<40 m	> 10 m	*Corymbia calophylla*	Marri	X						X	X	X	X	X	X			R	R	Carnaby Cockatoo	*	*	
	10 - 40 m	> 10 m	*Eucalyptus gomphocephala*	Tuart												X						*	*	
	5-20m	> 10 m	*Eucalyptus rudis*	Flooded Gum	X		X	X			X	X	X	X	X	X			L	R		*	*	food
Large Shrub / Small Tree (3 – 10 m)	1-6m	3 - 10 m	*Acacia rostellifera*	Summer-scented Wattle								X	X	X		X			R				*	food
	1.5-6m	3 - 10 m	*Acacia saligna*	Orange Wattle		X	X					X	X	X		X			L			*	*	food
	4m	3 - 10 m	*Adenanthos cygnorum*	Common Woolly Bush	X						X	X	X	X		X			R	R		*		
	1-10m	3 - 10 m	*Agonis flexuosa*	Peppermint Tree	X				X		X	X	X	X					R	R	Ring tailed Possum	*		
	0.5-5m	3 - 10 m	*Banksia sessilis*	Parrot Bush		X						X				X			L		Carnaby Cockatoo	*		food
	9m	3 - 10 m	*Callitris preissii*	Rottnest Island Pine				X			X	X	X	X		X			L					
	1.5-10m	3 - 10 m	*Casuarina obesa*	Swamp Sheoak	X	X	X			X	X	X	X	X	X	X			L		Carnaby Cockatoo	*		
	1-7m	3 - 10 m	*Melaleuca cuticularis*	Saltwater Paperbark	X	X	X	X		X	X	X	X	X	X	X	L	L	L			*		bark
	0.5-5m	3 - 10 m	*Melaleuca huegelii*	Chenille Honey-myrtle												X						*		
	1-8m	3 - 10 m	*Melaleuca lanceolata*	Rottnest Teatree	X				X	X	X	X	X	X					L	L		*		
	2-9m	3 - 10 m	*Melaleuca preissiana*	Moonash	X	X	X		X		X	X	X	X					L	R		*		
	0.2-10m	3 - 10 m	*Melaleuca rhaphiophylla*	Swamp Paperbark	X	X	X		X	X	X	X	X	X	X		R	R	R	R		*		bark for roofing or holding food
	10m	3 - 10 m	*Nuytsia floribunda*	Christmas Tree	X	X	X				X	X	X	X		X			L	R				Seasonal cue
	1-7m	3 - 10 m	*Santalum acuminatum*	Quandong	X		X		X		X	X	X	X		X			R	R			*	food
	5m	3 - 10 m	*Xanthorrhoea preissii*	Grass Tree	X	X	X		X		X	X	X	X		X			L	R		*		food, firestick, building material, resin
Medium Shrub (1 – 3 m)	0.5-3m	1 - 3 m	*Acacia cochlearis*	Rigid Wattle								X	X	X		X			L				*	food
	0.8-4m	1 - 3 m	*Acacia cyclops*	Coastal Wattle		X	X	X				X	X			X			L			*	*	food
	0.3-3m	1 - 3 m	*Acacia pulchella*	Prickly Moses	X				X		X	X	X	X		X			L	R		*	*	food
	0.5-2.3m	1 - 3 m	*Acacia truncata*	Cut Leaf Wattle								X							L				*	food
	0.2-2m	1 - 3 m	*Allocasuarina humilis*	Dwarf Sheoak	X		X	X			X		X	X		X			L		Carnaby Cockatoo	*		
	1-3m	1 - 3 m	*Alyxia buxifolia*	Dysentry Bush	X						X	X	X	X					L	R				
	0.6-3m	1 - 3 m	*Anthocercis littorea*	Yellow Tailflower	X		X	X		X	X	X	X	X					L	L				
	2m	1 - 3 m	*Atriplex hypoleuca*	Saltbush	X					X					X				L					
	0.5-2.5m	1 - 3 m	*Atriplex isatidea*	Coast Saltbush	X					X	X	X	X		X				L					
	0.9-2m	1 - 3 m	*Calothamnus quadrifidus*	One-sided Bottlebrush	X				X		X	X	X	X					R	R		*		
	0.3-2m	1 - 3 m	*Conospermum stoechadis*	Common Smokebush	X						X	X	X	X					R	R				
	<4m	1 - 3 m	*Eremaea pauciflora*		X				X		X	X	X	X		X			L	L		*		
	0.1-3m	1 - 3 m	*Eremophila glabra subsp. tomentosa*	Tar Bush	X		X	X	X	X	X	X	X	X					L	L		*		
	0.5-3m	1 - 3 m	*Grevillea vestita*	Grevillea	X			X	X		X	X	X	X					L	R		*		
	1 - 4 m	1 - 3 m	*Hakea varia*	Variable-leaf Hakea		X		X			X	X	X			X			L		Carnaby Cockatoo	*		
	0.4-4m	1 - 3 m	*Jacksonia furcellata*	Grey Stinkwood		X	X	X			X	X	X	X		X			L					
	1.5-5m	1 - 3 m	*Jacksonia sternbergiana*	Stinkwood		X	X	X			X	X	X	X					L				*	
	1.5-4m	1 - 3 m	*Kunzea glabrescens*	Spearwood		X	X				X	X	X	X		X			L			*		spears
	0.3-3m	1 - 3 m	*Leucopogon parviflorus*	Coast Beard-heath	X						X	X	X	X					R	R		*		
	0.5-3m	1 - 3 m	*Macrozamia riedlei*	Zamia Palm												X								food
	0.6-5m	1 - 3 m	*Melaleuca viminea*	Mohan	X		X												L			*		
	0.5-3m	1 - 3 m	*Olearia axillaris*	Coastal Daisybush	X	X		X	X	X	X	X	X	X					L	R				
	0.6-5m	1 - 3 m	*Spyridium globulosum*	Basket Bush		X					X		X	X		X			L					
	0.3-4m	1 - 3 m	*Templetonia retusa*	Cockie's Tongue	X				X		X	X	X	X					R	R		*		
	1-4m	1 - 3 m	*Viminaria juncea*	Swishbush		X	X				X	X	X	X		X			L					
	<1.5m	1 - 3 m	*Xanthorrhoea brunonis*	Grasstree	X				X		X	X	X	X					R	R		*		food
Small Shrub (0.5 – 1 m)	0.15-1.5m	0.5 - 1 m	*Acacia lasiocarpa*	Dune Moses	X			X	X		X	X	X	X		X			L	R			*	food
	0.2-0.7m	0.5 - 1 m	*Acacia stenoptera*	Narrow Winged Wattle	X						X	X	X	X		X			R	R			*	
	0.2-0.8m	0.5 - 1 m	*Astroloma macrocalyx*	Swan Berry												X								

VEGETATION STRUCTURE			SPECIES		SPECIFIC DOMAIN PER ZONE												REVEG DOMAIN				FAUNA			HERITAGE
Growth Form	Height	Height Class	Scientific Name	Common Name	Narrows	Groynes	Milyu	Palms	Como	Skinny	Sea Scouts	North Canning	South Canning	Cloisters	Infill	Spit	Transition	Wetland	Dryland	Soft Landscape	Significant Fauna Value	Bird Attracting	Invertebrate Attracting	Indigenous Culture Value
Small Shrub (0.5 – 1 m) (contd)	0.2-1.5m	0.5 - 1 m	*Atriplex cinerea*	Grey Saltbush	X			X		X	X	X	X	X	X				L	R				
	< 1 m	0.5 - 1 m	*Billardiera heterophylla*	Bluebell						X	X				X	X	R		R			*		food
	0.2-1m	0.5 - 1 m	*Bossiaea eriocarpa*	Common Brown Pea	X		X				X	X	X	X		X			L	R				
	0.3-1.2m	0.5 - 1 m	*Conostephium preissii*													X	R		R					
	0.1-1.3m	0.5 - 1 m	*Corynotheca micrantha*	Sand Lily												X			R					
	1 m	0.5 - 1 m	*Gastrolobium capitatum*													X								
	0.3-1m	0.5 - 1 m	*Gompholobium tomentosum*	Hairy Yellow-Pea	X	X			X		X	X	X	X		X			L	R				
	0.15-1.7m	0.5 - 1 m	*Grevillea preissii*	Spider Net Grevillea	X				X		X	X	X	X					R	R		*		
	0.4-1.5m	0.5 - 1 m	*Guichenotia ledifolia*	Guichenotia	X				X		X	X	X	X					R	R				
	1-3m	1 - 3 m	*Hakea prostrata*	Harsh Hakea		X	X	X				X				X			L		Carnaby Cockatoo	*		
	0.2-1m	0.5 - 1 m	*Hibbertia hypericoides*	Yellow Buttercups	X	X	X		X		X	X	X	X		X			L	R			*	
	<1.5m	0.5 - 1 m	*Hypocalymma angustifolium*	White Myrtle	X	X	X		X		X	X	X	X		X			L	R				
	0.15-1m	0.5 - 1 m	*Lechenaultia floribunda*	Free-flowering Leschenaultia	X	X			X		X	X	X	X		X			L	R				
	0.1-1m	0.5 - 1 m	*Leucopogon conostephioides*													X								
	0.3-2m	0.5 - 1 m	*Leucopogon propinquus*	Beard-heath	X				X		X	X	X	X					R	R				
	0.5-2m	0.5 - 1 m	*Melaleuca systena*	Coastal Honey-myrtle	X				X		X	X	X	X		X			L	R		*	*	
	0.2-1m	0.5 - 1 m	*Petrophile linearis*	Pixie Mops		X	X									X			L					
	0.2-1.2m	0.5 - 1 m	*Phyllanthus calycinus*	False Boronia	X				X		X	X	X	X					R	R				
	0.3-1m	0.5 - 1 m	*Pimelea rosea*	Rose Binjine	X				X		X	X	X	X					R	R				
	0.3-2m	0.5 - 1 m	*Rhagodia baccata*	Berry Saltbush												X			R			*		
	0.1-2m	0.5 - 1 m	*Rhagodia drummondii*	Berry Saltbush							X	X	X				R		L			*		
	0.3-1.5m	0.5 - 1 m	*Scaevola anchusifolia*	Silky Scaevola	X				X		X	X	X	X					R	R			*	
	0.1-1.5m	0.5 - 1 m	*Scaevola crassifolia*	Thick-leaved Fan-flower	X	X	X	X	X	X	X	X	X	X					L	L			*	
	0.05-1m	0.5 - 1 m	*Scaevola repens var repens*													X							*	
	0.2-1.5m	0.5 - 1 m	*Scholtzia involucrata*	Spiked Scholtzia												X								
	0.2-1.2m	0.5 - 1 m	*Synaphea spinulosa*													X								
Dwarf/ Prostrate Shrub (< 0.5 m)	0.3-0.6 m	< 0.5 m	*Acacia willdenowiana*	Grass Wattle		X	X									X			L				*	
	-	-	*Clematis linearifolia*	Old Man's Beard	X				X		X	X	X	X					L	R				
	-	-	*Clematis pubescens*	Common Clematis	X				X		X	X	X	X					R	R				
	0.08-0.5m	< 0.5 m	*Frankenia pauciflora*	Seaheath			X			X	X	X			X	X	R	R	R					
	<0.5m	< 0.5 m	*Hardenbergia comptoniana*	Native Wisteria	X				X		X	X	X	X					L	R			*	
	<0.05-1m	< 0.5 m	*Hemiandra pungens*	Snakebush	X		X		X		X	X	X	X					L	R				
	0.1-0.75m	< 0.5 m	*Hibbertia racemosa*	Stalked Guinea Flower	X				X		X	X	X	X		X				R				
	0.15-1.2m	< 0.5 m	*Hibbertia subvaginata*	Coastal Guinea Flower	X				X		X	X	X	X					R	R				
	0.1-0.6m	< 0.5 m	*Hovea chorizemifolia*	Holly-leaved Hovea	X	X	X		X		X	X	X	X					L	R				
	0.1-0.7m	< 0.5 m	*Hovea trisperma*	Common Hovea	X	X			X		X	X	X	X		X			L	R				
	prostrate	< 0.5 m	*Kennedia prostrata*	Running Postman	X	X	X	X	X		X	X	X	X					L	R		*	*	food
	1m	< 0.5 m	*Leucophyta brownii*	Silver Cotton Bush	X				X	X	X	X	X	X	X				L	R				
	0.1-0.5m	< 0.5 m	*Sarcocornia quinqueflora*	Beaded Samphire			X			X	X				X	X	R	R						
	< 0.5 m	< 0.5 m	*Tecticornia halocnemoides*	Shrubby Samphire			X			X	X				X		R	R	R					

VEGETATION STRUCTURE			SPECIES		SPECIFIC DOMAIN PER ZONE												REVEG DOMAIN				FAUNA			HERITAGE
Growth Form	Height	Height Class	Scientific Name	Common Name	Narrows	Groynes	Milyu	Palms	Como	Skinny	Sea Scouts	North Canning	South Canning	Cloisters	Infill	Spit	Transition	Wetland	Dryland	Soft Landscape	Significant Fauna Value	Bird Attracting	Invertebrate Attracting	Indigenous Culture Value
	0.1-0.5m	< 0.5 m	*Tetragonia implexicoma*	Bower Spinach							X								L					
	0.1-0.4m	< 0.5 m	*Threlkeldia diffusa*	Coast Bonefruit			X	X		X	X		X		X		L	L				*		
Herb	0.2-0.7 m	< 0.5 m	*Acanthocarpus preissii*	Prickle Lily	X				X	X	X	X	X	X		X			L	L			*	
	0.2-1.1m	0.5 - 1 m	*Anigozanthos manglesii*	Mangles Kangaroo Paw	X		X		X		X	X	X	X		X			L	R		*		
	0.1-0.5m	< 0.5 m	*Atriplex semibaccata*	Berry Saltbush						X	X		X		X				L					
	< 0.8 m	0.5 - 1 m	*Burchardia congesta*	Milkmaids												X			R					
	0.05-0.2m	< 0.5 m	*Chamaescilla corymbosa*	Blue Squill	X				X		X	X	X	X					R	R				
	0.05-0.4m	< 0.5 m	*Conostylis candicans*	Grey Cottonhead	X	X	X	X	X	X	X	X	X	X					L	R		*	*	
	0.1-0.4m	< 0.5 m	*Conostylis juncea*	Conostylis												X								
	0.05-0.35m	< 0.5 m	*Conostylis setigera*	Bristly Cottonhead												X								
	0.15-0.6m	< 0.5 m	*Dampiera linearis*	Common Damperia	X	X			X		X	X	X	X		X			L	L		*	*	
	0.3-1m	0.5 - 1 m	*Dasypogon bromeliifolius*	Pineapple Bush	X				X		X	X	X	X		X				L				
	0.3-1m	0.5 - 1 m	*Dasypogon obliquifolius*	Pineapple Bush			X												L					
	0.3-1.5m	0.5 - 1 m	*Dianella revoluta*	Blueberry Lily	X				X		X	X	X	X		X			L	R		*		food
	0.3-2m	0.5 - 1 m	*Haemodorum spicatum*	Mardja												X								food
	0.1-0.6m	< 0.5 m	*Hybanthus calycinus*	Wild Violet	X				X		X	X	X	X		X			R	R				
	0.03-0.1m	< 0.5 m	*Laxmannia squarrosa*													X			R					
	0.2-0.6m	< 0.5 m	*Lomandra preissii*	Mat Rush															R			*		
	0.2-1m	0.5 - 1 m	*Lyginia barbata*													X			L					
	0.1-0.45m	< 0.5 m	*Opercularia vaginata*	Dog Weed															R					
	1.5m	0.5 - 1 m	*Patersonia occidentalis*	Purple Flag	X	X			X		X	X	X	X		X			L	R				
	0.2-0.6m	< 0.5 m	*Phlebocarya ciliata*	Phlebocarya	X											X			L					
	0.5-2m	0.5 - 1 m	*Pteridium esculentum*	Bracken												X								
	0.15-1m	0.5 - 1 m	*Samolus repens*	Creeping Brookweed				X		X					X	X			L					
	0.1-0.5m	< 0.5 m	*Sarcocornia quinqueflora*	Beaded Samphire			X	X			X	X				X	L	L						
	0.15-0.45m	< 0.5 m	*Sowerbaea laxiflora*	Purple Tassles	X				X		X	X	X	X		X			R	R				
	0.1-0.9m	0.5 - 1 m	*Suaeda australis*	Seabite			X			X	X	X			X	X	R	R						
	0.35m	< 0.5 m	*Senecio pinnatifolius*	Coastal Groundsel			X	X	X	X	X		X		X				L					
	0.15-0.5m	< 0.5 m	*Thysanotus patersonii*													X								
	0.1-0.5m	< 0.5 m	*Tricoryne elatior*													X								
Grass	0.3-0.9m	0.5 - 1 m	*Spinifex hirsutus*	Hairy Spinifex	X	X	X	X	X	X	X		X		X		L		L					
	0.1-0.5m	< 0.5 m	*Sporobolus virginicus*	Marine Couch			X			X	X	X			X	X	R	R						
Rush/ Sedge	0.05-0.3m	< 0.5 m	*Alexgeorgea nitens*		X				X		X	X	X	X		X			R	R				
	0.2-03.4m	< 0.5 m	*Baumea acuta*	Pale-Twig-rush			X				X						R	R						
	0.2-1.2m	0.5 - 1 m	*Baumea juncea*	Bare Twig-rush			X	X			X	X					L	L						
	0.3-1.2m	0.5 - 1 m	*Bolboschoenus caldwellii*	Marsh Club-rush			X				X	X						L						
	0.5-2m	1 - 3 m	*Carex appressa*	Tall Sedge			X				X						R	R						
	0.3-0.75m	0.5 - 1 m	*Carex inversa*	Knob Sedge			X			X	X				X		R	R						
	0.35-1m	0.5 - 1 m	*Cyperus gymnocaulos*	Spiny Flat-sedge	X	X	X	X	X	X	X	X	X	X	X		L	R	L					
	0.2-0.3m	< 0.5 m	*Desmocladus fasciculatus*	Rush		X	X												L					
	0.2-1.5m	0.5 - 1 m	*Desmocladus flexuosus*	Tangle Rush		X	X									X			L					
	< 0.7m	< 0.5 m	*Eleocharis acuta*	Common Spikerush			X				X						R	R						
	<1m	0.5 - 1 m	*Ficinia nodosa*	Knotted Club Rush	X	X	X	X	X	X	X	X	X	X	X	X	R	R	L	L				

VEGETATION STRUCTURE			SPECIES		SPECIFIC DOMAIN PER ZONE												REVEG DOMAIN				FAUNA			HERITAGE
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	1.5m	1 - 3 m	*Gahnia trifida*	Coast Saw-Sedge	X					X		X	X		X				L				*	
	0.25-0.75m	1 - 3 m	*Hypolaena exsulca*													X								
	0.3-1m	0.5 - 1 m	*Juncus holoschoenus*	Jointleaf Rush			X				X				X		R	R				*		
	0.3-1.2m	0.5 - 1 m	*Juncus kraussii*	Sea Rush	X	X	X	X	X	X	X	X	X	X	X	X	L	L	L			*		
	0.5m	< 0.5 m	*Lepidosperma angustatum*	Variable Sword-sedge	X				X		X	X	X	X					L	R				
	0.5-1.5m	0.5 - 1 m	*Lepidosperma gladiatum*	Coast Sword-sedge	X		X	X	X		X	X	X	X				L	L	R				food
	0.15-1m	0.5 - 1 m	*Lepidosperma squamatum*																					
	0.3-1.5m	0.5 - 1 m	*Leptocarpus laxus*														R		R					
	0.06-0.2m	< 0.5 m	*Lomandra hermaphrodita*													X								
	0.35-1.2m	0.5 - 1 m	*Meeboldina cana*														R		R					
	0.3-1m	0.5 - 1 m	*Meeboldina coangustata*														R		R					
	0.2-0.75m	< 0.5 m	*Mesomelaena pseudostygia*													X								
	0.1-0.5m	< 0.5 m	*Mesomelaena stygia*			X	X												L					
	0.8-2m	0.5 - 1 m	*Schoenoplectus validus*	Lake Club-rush			X				X	X					R	R						
	0.4m	< 0.5 m	*Schoenus curvifolius*	Bogrush												X			R					
	0.4-1.5m	0.5 - 1 m	*Schoenus grandiflorus*	Large Flowered Bogrush															R					
	0.3-1m	0.5 - 1 m	*Schoenus subfascicularis*													X								
TOTAL				**Total**	**74**	**37**	**56**	**29**	**55**	**30**	**97**	**90**	**86**	**77**	**26**	**82**	**26**	**21**	**113**	**62**				