Cottesloe Coastal Monitoring Summary Report – Summer 2014/2015

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Prepared for

Town of Cottesloe

Prepared by

BMT Oceanica Pty Ltd

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Quality Assurance

BMT Oceanica Pty Ltd has prepared this report in accordance with our Health Safety Environment Quality Management System, certified to AS/NZS ISO 9001: 2008.

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Cover

Main image: Cottesloe Main Beach, November 2014 (BMT Oceanica Pty Ltd)

Minor images: Beach profile survey November 2014, Cottesloe Beach (Town of Cottesloe)
Remote imagery units at Cottesloe Main Beach, November 2014 (BMT Oceanica Pty Ltd)

Disclaimer

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List of terms and acronyms

AHD	Australian Height Datum
Berm	A plateau on the beach face or backshore, formed by the deposition of beach material by wave action
Berm crest	The highest point on the beach berm
Beach face	The sloping section of beach below berm that is exposed to wave swash under ambient conditions
BoM	Bureau of Meteorology
CD	Chart Datum
Chainage	The cross-shore distance between beach profile survey points
Coastal vulnerability	The degree to which a coastal system is susceptible to, or unable to cope with, the adverse effects of climate change
Cross-shore	Perpendicular to the shoreline
CZM	Coastal Zone Management Pty Ltd
Depth of closure	The seaward limit of significant beach profile fluctuations
DPI	Department of Planning and Infrastructure; now Department of Transport
DoD	Department of Defence
DoT	Department of Transport
Geomorphology	The study of the physical features of the land surface and their relation to its geological structures
LLB	Landward limit of beach
Longshore	Parallel to the shoreline
Morphology	The form and structure of a physical entity
MSLP	Mean sea level pressure
RTK GPS	Real Time Kinematic Global Positioning Systems
Sand bar	A long narrow bank of sand oriented parallel to the shoreline, formed by crosshore sand transport under the influence of breaking waves
Sediment cells	Sections of the coast within which sediment transport processes are strongly related
Scarping	The formation of near-vertical slopes in rock or sediment
SLSC	Surf life saving club
Sub-aerial beach	That part of the beach exposed to the air and not covered by the ocean at mean sea level
Swell	Long-period waves generated by distant weather systems
WAPC	Western Australian Planning Commission

Executive Summary

Cottesloe is a coastal suburb ~12 km west of Perth city centre in Western Australia, known for its iconic beach and terraced lawns overlooking the Indian Ocean. The Town of Cottesloe (ToC) is the local government authority and its jurisdiction extends across ~4 km of coastline. The coastline is highly developed, with key public and private infrastructure situated close to the beach. The beaches at Cottesloe experience seasonal storm erosion on an annual basis, with evidence of ongoing erosion and a potential future increase in erosion due to the effects of climate change (CZM & Damara 2008). There are a number of negative effects associated with such erosion, including loss of beach area, reduction of coastal access, recreational opportunities and aesthetic values, and damage to coastal infrastructure.

The ToC are implementing an ongoing coastal monitoring project to inform future decision making regarding the management of the Cottesloe coastline and to facilitate improved planning for future coastal protection and adaptation. The ToC commissioned BMT Oceanica to assist with implementing the first year of the coastal monitoring project, which involves hourly remote imagery capture and biannual beach profile surveys. This report presents the results of the first 5 months of monitoring from November 2014 to April 2015 (i.e. summer 2014/2015).

Hourly remote imagery was captured at Cottesloe Main Beach and North Cottesloe Beach every day during daylight hours from 19 November to 13 April 2015. Beach profiles were surveyed at 39 cross-shore transects on two occasions: 17–19 November 2014 and 1–7 April 2015. Each profile was spaced ~100 m apart alongshore and extended cross-shore from the kerb of Marine Parade to a location offshore with ~1 m water depth.

The results of the remote imagery and beach profile monitoring showed that the general pattern of beach morphology change along the Cottesloe coastline during summer 2014/2015 was erosion of the beaches north of Cottesloe Groyne/Mudurup Rocks, and accretion of the beaches south of Cottesloe Groyne/Mudurup Rocks (with the exception of a small area of erosion directly north of Beach Street Groyne). Erosion generally occurred via a reduction in beach width and increase in beach face steepness, with an increase in berm crest height along some profiles. Accretion generally occurred via an increase in beach width and an increase in berm crest height along some profiles. The longshore pattern of erosion and accretion at Cottesloe is likely attributable to the net northward longshore sand transport in summer (driven by predominant south-south-westerly winds) being interrupted by cross-shore features such as groynes and rocky outcrops, causing accumulation of sand updrift (i.e. to the south) and erosion of sand downdrift (i.e. to the north) of these features. Remote imagery indicated that periods of accelerated or slowed erosion at Cottesloe Main Beach and North Cottesloe during summer 2014/2015 may have been be linked to variations in sea breeze activity, storm direction, water levels and long-range swell.

As the general pattern of beach change at Cottesloe over summer 2014/2015 was mainly related to seasonal northward sediment transport direction, it is likely that a sediment transport direction reversal during winter will result in some accretion in previously eroded areas. However episodic beach erosion may also occur in these areas during winter due to offshore sediment transport during more frequent and/or intense winter storms. A full year of monitoring is required to fully assess the cyclic nature of beach morphology changes over the seasons and to determine potential areas of concern from a coastal management perspective.

Based solely on the erosion observed during summer 2014/2015, areas that may require further attention in the event of more severe erosion in future include:

- Cottesloe Main Beach, particularly in front of the Indiana Restaurant building
- in front of the North Cottesloe SLSC
- directly north of Beach Street Groyne.

Based on the results of the summer 2014/2015 coastal monitoring, it is recommended that the monitoring programme be continued beyond the first year of monitoring (ending in November 2015), to build understanding of both seasonal and inter-annual changes in beach morphology at Cottesloe. The ToC may also wish to consider the following specific recommendations for future monitoring:

- deploy additional remote imagery units to allow real-time monitoring of other potentially vulnerable areas such as around Beach Street Groyne and North Street
- implement post-storm beach profile monitoring, to help build understanding of how Cottesloe beaches respond to certain extreme conditions
- limit the landward extent of beach profile surveys to the LLB until any major changes to the backshore occur (i.e. construction of new coastal infrastructure) to save time and cost. Costs saved here could be used to fund other improvements to the monitoring (e.g. deployment of extra cameras or post-storm monitoring)
- ensure future beach profile surveys follow the transects surveyed during the April 2015 survey, as all of these profiles have the correct shore-normal orientation
- ensure future beach profile surveys capture elevation measurements within ~1 m either side (alongshore) of the April 2015 transects, to optimise the comparability of profiles between surveys
- ensure during future beach profile surveys that the minimum horizontal distance between survey points is ~5 m and the minimum vertical elevation change between survey points is ~0.5 m, to guarantee the full shape of the profile is captured.
- extend beach profile measurements to the depth of closure using boat-based survey equipment to allow assessment of sediment exchanges across the full width of the active profile and a more comprehensive understanding of seasonal beach profile fluctuations
- analyse beach volume changes using beach profile and geotechnical data, to allow quantification of sediment transport rates which may assist any further assessments of coastal vulnerability.

1. Introduction

1.1 Project background

Cottesloe is a coastal suburb ~12 km west of Perth city centre in Western Australia (Figure 1.1), known for its iconic beach and terraced lawns overlooking the Indian Ocean. The Town of Cottesloe (ToC) is the local government authority and its jurisdiction extends across ~4 km of coastline. The coastline is highly developed, with key public and private infrastructure situated within ~150 m from the shoreline, including:

- scenic parks, walk/cycle-ways and beach access paths
- highly priced residential properties
- Marine Parade, a key coastal access road
- Indiana Restaurant, an iconic Western Australian landmark
- Cottesloe Beach Hotel and the Ocean Beach Hotel, historic establishments dating back to the early 1900s
- several other bars, shops and restaurants.

The beaches along the Cottesloe coastline have undergone both long and short-term erosion over the past few decades with some 'hotspots' suffering significant erosion during storms (ToC 2014, CZM & Damara 2008). Various coastal management actions have mitigated and/or masked this erosion, such as the construction of a ~130 m long curved rock groyne on Mudurup Rocks in 1960 (Figure 1.1), a smaller ~70 m long rock groyne at Beach Street (Figure 1.1), and sand nourishment campaigns since the 1980s. However, the coastline still experiences short-term storm erosion on an annual basis, with evidence of net long-term erosion and a potential future increase in erosion due to the effects of climate change (CZM & Damara 2008). The negative effects of such erosion may include loss of beach area, reduction of coastal access, recreational opportunities and aesthetic values, and damage to coastal infrastructure.

The ToC wish to formulate a better understanding of coastal hazards over an extended timeframe to inform future coastal management decisions and facilitate improved planning for future coastal protection and adaptation work. To achieve this objective, the ToC are implementing an ongoing coastal monitoring project and have commissioned BMT Oceanica to assist with data collection and analysis during the first year of the project from November 2014–November 2015.

Figure 1.1 The Town of Cottesloe coastline

1.2 Project aims and scope

The aim of this project was to implement the first year of a long-term coastal monitoring programme at Cottesloe, to help improve understanding of seasonal fluctuations and eventually long-term trends in coastal erosion, accretion and sediment dynamics. This first year of monitoring will act as a baseline against which future datasets can be compared. The ToC commissioned BMT Oceanica to undertake the following scope of work to assist with the first year of the ToC's coastal monitoring programme:

1. Review relevant literature and data
2. Review and advise on the ToC's initial monitoring plans
3. Coordinate remote imagery monitoring
4. Analyse beach profile data (collected by the ToC) together with remote imagery
5. Prepare a summary report (this report) presenting the results of the first 5 months of monitoring (November 2014 to April 2015, i.e. summer 2014/2015).

2. Literature and Data Review

A number of relevant studies and reports were reviewed to provide context to the monitoring of coastal change at Cottesloe. Key information extracted from this review is presented in the following sections:

- Environmental conditions at Cottesloe—this information may assist in determining the physical causes and mechanisms of any coastal change observed during the monitoring.
- Coastal vulnerability along the Cottesloe coastline—this information may assist in explaining any spatial variability in coastal change observed during the monitoring and may support the understanding of impacts of the changes.
- Knowledge gaps—this information may assist in determining what other studies or data are required to monitor and explain coastal change.

These are further discussed below.

2.1 Environmental conditions

2.1.1 Climate

Climate and weather conditions play a key role in coastal change through their influence on the rain, wind, waves and water levels that shape the coastline.

Perth experiences a Mediterranean climate, with hot, dry summers and mild, wet winters. An eastward moving subtropical high pressure belt causes predominant south-westerly winds in the summer and easterly winds in the winter (Gentilli 1972). During winter, the high pressure belt is disrupted by mid-latitude depressions that generate high energy storms, with the strongest winds usually from the north-west. During summer, strong south-westerly sea breezes occur in the afternoons, with velocities frequently exceeding 15 m/s (Pattiaratchi et al. 1997). Tropical cyclones track down from the north-west coast infrequently during late summer and can have significant impact on the coastline (Eliot & Clarke 1986, Lemm 1996).

2.1.2 Geology and geomorphology

The geology and geomorphology of a coastline considerably affects its response to natural drivers of coastal change such as varying climatic and hydrodynamic conditions.

Cottesloe lies on the western part of the Swan Coastal Plain, which extends from the north of Perth to Dunsborough in the south, and from the Darling Scarp in the east to the Indian Ocean in the west (WAPC 1999). The local geology consists mainly of Holocene sands overlying Pleistocene Tamala Limestone, which rests on older sandstone, siltstone, claystone and shales. The Tamala Limestone is calcarenite and forms small rocky headlands and nearshore reef platforms (Searle & Semeniuk 1985; Sanderson & Eliot 1999).

The beaches comprise a limestone bedrock shelf overlain in most areas by unconsolidated beach sediments. The results of a geotechnical survey undertaken along shore-parallel transects in 2010 between Curtin Avenue and North Street (GPG Maps 2010) indicated that that the depth of the limestone bedrock varies alongshore from 5 m to >10 m below the ground surface. Between south of Curtin Avenue and Gibney Street, the bedrock elevation was mainly above or near mean sea level. The bedrock elevation in other areas was below present mean sea level, in some places >2 m below present mean sea level. The survey also indicated variability in sand compaction with depth below the ground surface and distance alongshore, with poor sand compaction most common in the top 5 m (GPG Maps 2010).

The results of a second geotechnical survey undertaken along shore-perpendicular transects in 2011 between Curtin Avenue and North Street (GPG Maps 2011) indicated that there is a high level of cross-shore variability in the depth of the limestone bedrock, ranging from ~2 m to >10 m below the ground surface. Localised high and low points in the limestone bedrock were observed and may relate to karstic features such as pinnacles and depressions (GPG Maps 2011). Section 2.2 provides further discussion on how this geotechnical information may affect coastal vulnerability.

Cottesloe has been classified as a reef-protected, reflective sandy beach with strong currents, and North Cottesloe has been classified as a reflective (steep) beach (Velardo 1998, in Stul 2005). The beaches are backed by calcarenite dunes in most areas, except along a stretch of beach between Warnham Road and the Cottesloe Surf Lifesaving Club that is backed by concrete seawalls, paved pathways and terraced lawns.

2.1.3 Hydrodynamics

Hydrodynamics such as waves, water levels and currents in the coastal zone are key drivers of coastal change. The regional wave climate in Perth is comprised of short-period, locally generated wind waves, and long-period swell waves. The sea breeze during summer generates southerly to south-westerly wind waves, and storms during winter generate north-westerly to south-westerly wind waves (Lemm et al. 1999). Swell waves come from the south to south-west in summer with a greater westerly component in winter (Lemm et al. 1999). Offshore reefs, islands and sloping bathymetry attenuate wave energy reaching Cottesloe, and consequently inshore wave heights at the Cottesloe wave buoy (in 17 m water depth) are 40–50% less than the offshore wave heights at the Rottnest wave buoy (in 48 m water depth; Sanderson et al. 2000; Masselink & Pattiaratchi 2001). The smallest wave heights are usually experienced directly north of the rock groyne at Cottesloe due to the groyne providing sheltering from south-westerly waves (BeachSafe 2015). The mean significant wave height measured by the wave buoy at Cottesloe is 1.1 m in winter, 0.75 m in summer and 0.8 m annually (DPI 2004).

Perth is located in a microtidal environment, and experiences mixed, mainly diurnal tides with a range of ~0.7 m during spring tides and ~0.3 m during neap tides (DoD 2005). Elevated nearshore water levels can be generated by sea breezes during summer, and low atmospheric pressure systems and high wave energy during winter (Hegge 1994). Analysis of historical mean sea levels at Fremantle (~8 km south of Cottesloe) showed that mean sea level rose by 1.46 mm/year on average between 1897 and 2008, which was slightly lower than the global average of 1.7 mm/yr for the 20th century (Haigh et al. 2011). However the rate of sea level rise at Fremantle has been greater in more recent years, rising at an average of 5.66 mm/year between 1992–2008 (Haigh et al. 2011).

Currents in the Perth coastal waters are predominantly wind-driven, characterised by a net northward flow of water in summer and southward in winter, with longshore current speeds ranging 0.04–0.2 m/s (Searle & Semeniuk 1985, Pattiaratchi et al. 1997). Topographic forcing and longshore variation in wave energy can also create circulating current cells and high-velocity rip currents (Bowyer 1987). Strong rip currents are common around the nearshore rock reefs at Cottesloe, increasing in frequency during winter and high wave conditions (Olsson 2004).

2.1.4 Sediment dynamics

Variations in longshore and cross-shore sediment movements act to change the distribution of coastal sediments and shape the morphology of beaches.

Beach sediments at Cottesloe, as with most beaches along the Perth Metropolitan Coast, are comprised mainly of quartz sands of both marine and terrestrial origin, and calcareous material of biogenic origin (Stul 2005). The calcareous sand is a mixture of fresh skeletal material derived from offshore seagrass banks and reefs, and reworked shell fragments derived from erosion of the Tamala Limestone at the coastline and nearshore area (Sanderson & Eliot 1999).

The definition of 'sediment cells' (sections of the coast within which sediment transport processes are strongly related) along the Western Australian coast by Stul et al (2012) provides a framework for coastal management and supports the understanding of historical, contemporary and future coastal change. The Cottesloe coastline lies within one primary sediment cell (cell F: 'South Mole Fremantle to Pinaroo Point') and straddles two secondary/tertiary sediment cells (cells 25b 'Leighton salient to Mudurup Rocks' and 26a 'Mudurup Rocks to north Swanbourne pipe').

The longshore sediment transport at Cottesloe has been observed to be predominantly northward for ~8 months of the year (September to April) and predominantly southward for ~2 months (June and July), with an annual net sand movement northwards (Kempin 1952). The reef and the rock groyne at Mudurup Rocks act as a barrier to longshore sediment transport, largely blocking southward sediment transport in the winter and northward sediment transport in the summer. This reportedly causes accretion at Cottesloe beach north of Mudurup Rocks in winter and erosion in summer (Kempin 1952; cited in CZM& Damara 2008). The shoreline south of Mudurup Rocks has very little sand cover, which may be due to the combined effect of southwards sand transport into the 'shadow area' behind Fremantle North Mole and scouring of the beach by northerly currents (Kempin 1952). Low-lying offshore reefs present along some parts of the Cottesloe coastline can dissipate a large proportion of incident wave energy, but they do not tend to block longshore sediment transport, and can instead accelerate it because of the wider surf zone they generate (Silvester 1961).

The seasonal pattern of cross-shore sand movement at Cottesloe is characterised by the movement of sediment shorewards by summer swell to construct a steep beach profile (Silvester 1961). The first winter storms then erode the steeply-sloped beach to form an offshore sand bar. Erosion then tends to slow or cease when this sand bar is sufficiently high to cause breaking of incident waves (Silvester 1961).

2.2 Coastal vulnerability

Coastal vulnerability is the degree to which a coastal system is susceptible to, or unable to cope with, the adverse effects of climate change (WAPC 2013). It is a function of (WAPC 2013):

- the character, magnitude, and rate of climate change
- the degree to which the coastal system is exposed to the effects of climate change
- the coastal system's sensitivity and adaptive capacity.

The vulnerability of the Cottesloe coastline to climate change was assessed by CZM and Damara and sections of coastline were assigned different 'risk priority levels' (CZM & Damara 2008). However, limited data on the location of subsurface rock at Cottesloe was available at the time of study, and it was recommended that the ToC gather geotechnical information for the length of the Cottesloe foreshore to enable a more accurate appreciation of the impacts of climate change (CZM & Damara 2008).

Two geotechnical surveys were undertaken along the Cottesloe coastline between Curtin Avenue and North Street in 2010 and 2011 (GPG Maps 2010 & 2011; see Section 2.1 for a general summary of their results). The surveys identified a number of areas along the Cottesloe coastline that were classified as having 'moderate to high' risk of erosion during destructive events based on the depth of the bedrock below current mean sea level, the thickness and density of the overlying sand, and the extent of the weathered limestone.

A review of the coincidence of areas identified as at 'high' or 'extreme' risk under the 2070 'Almost Certain' climate change scenario (CZM & Damara 2008) with areas identified as 'moderate to high' risk based on geotechnical information (GBGMaps 2010) suggests that the following areas of the Cottesloe coastline may be the most at risk of erosion due to future climate change:

- between North Street and Grant Street
- south of Grant Street opposite Grant Marine Park
- between Eric Street and Eileen Street
- between Napier Street and Warnham Road
- between Beach Street and Gibney Street.

2.3 Knowledge gaps

The assessment of the available information relating to physical coastal processes and dynamics at Cottesloe has identified that quantitative data is not presently available on the following:

- beach sediment particle size
- nearshore current speed and direction
- coastal sediment transport rates.

These may be important factors in explaining the magnitude and variation of changes along the Cottesloe coastline and it may be necessary to collect this data in future to enable a comprehensive understanding of long-term coastal change.

3. Methods

This summary report presents the results of the first 5 months of the coastal monitoring programme at Cottesloe, between November 2014 and April 2015 (i.e. summer 2014/2015). Two types of coastal monitoring data were collected at Cottesloe during this period:

- hourly remote imagery capture (coordinated by BMT Oceanica)
- two beach profile surveys in November 2014 and April 2015 (coordinated by the ToC).

Daily weather observations sourced from the Bureau of Meteorology (BoM) were also reviewed in conjunction with the above datasets to give context to the results of the monitoring.

3.1 Remote imagery monitoring

3.1.1 Remote imagery unit installation and maintenance

Remote imagery units were installed at two locations along the Cottesloe coastline on 19 November 2014 to monitor Cottesloe Main Beach and North Cottesloe Beach (Figure 1.1):

1. On the most northerly light pole in the Cottesloe Main Beach car park, opposite Overton Gardens (Figure 3.1).
2. On a light pole on the roof of North Cottesloe Surf Life Saving Club (SLSC; Figure 3.2).

Two units were installed overlooking the Cottesloe Main Beach; the second providing backup in the event of a technical fault with the main unit; Figure 3.1. One unit was installed on the light pole on the North Cottesloe SLSC roof (Figure 3.2). No backup unit was installed at this site due to limited space on the light pole between the roof and light.

Each remote imagery unit was installed in a locked box and was equipped with long-life batteries and a polarising filter to reduce sun glare and enhance through-water visibility.

The remote imagery units were serviced on 13 April 2015, approximately 5 months after the initial installation, and all high resolution imagery captured during the monitoring period was retrieved from the units for analysis. The units are currently set to remain in place until November 2015 to complete the first year of monitoring.

Figure 3.1 Remote imagery unit installation on the light pole in the main beach car park, opposite Overton Gardens

Figure 3.2 Remote imagery unit installation on the light pole on the North Cottesloe Surf Life Saving Club roof

3.1.2 Remote image capture

Each remote imagery unit was programmed to capture high resolution (12 megapixels) imagery every hour from 5:00 a.m. and 7:00 p.m. each day. The units were also programmed to transmit one lower resolution (0.5 megapixels) image over the mobile phone network at ~12:00 noon each day. These daily transmitted images were uploaded to a slide-show on a secure web portal, which allowed the project team members to log in and view a timeline of coastal conditions at the monitoring sites.

3.1.3 Remote imagery review and analysis

BMT Oceanica reviewed the lower-resolution daily imagery on the web portal each week to ensure continued function (e.g. sufficient battery life), image quality (e.g. correct orientation, no dirt or obstructions on the lens) and to observe any notable changes in beach morphology. Notable observations were summarised during fortnightly phone calls and monthly email reports to the ToC.

The hourly high resolution imagery retrieved from the remote imagery units on 13 April 2015 was then reviewed in more detail and changes in beach morphology and metocean conditions during the monitoring were qualitatively assessed.

3.2 Beach profile monitoring

3.2.1 Beach profile data collection

The ToC coordinated two beach profile surveys during the monitoring period:

1. a pre-summer survey undertaken by ToC staff over 17–19 November 2014
2. a post-summer survey undertaken by McGregor Surveys Pty Ltd over 1–7 April 2015.

During each survey, the elevation of the ground surface relative to Australian Height Datum (AHD) was measured along 39 cross-shore transects using pole-mounted Real Time Kinematic Global Positioning Systems (RTK GPS). Each profile was spaced ~100 m apart alongshore and extended cross-shore from the kerb of Marine Parade to a location offshore with ~1 m water depth (i.e. the limit of safe wading depth).

Along each transect, the ground surface elevation was measured at every significant change in slope or feature, whilst attempting to ensure that the minimum horizontal distance between survey points ('chainage') was 5 m and the minimum vertical elevation change between survey points was 0.5 m. The horizontal accuracy for both surveys was within ±20 mm, and vertical accuracy was within ±30 mm. The following data were collected at each survey point in addition to ground surface elevation:

- location coordinates (easting and northings)
- date and time of measurement
- horizontal and vertical measurement precision
- survey 'code' which represented the ground surface features (e.g. sediment type, morphological features, vegetation lines, human infrastructure etc.).

During the November 2014 survey, photographs were taken manually at each beach profile facing north, south, east, and west. Photographs were not taken during the April 2015 survey due to time constraints.

3.2.2 Beach profile data analysis

The elevation data were graphed against chainage for each profile from each of the two surveys and the elevation differences between November 2014 and April 2015 were then qualitatively assessed. The data were also plotted in ArcGIS to give a planform view of the beach profile measurement locations.

The landward limit of the beach (LLB) was defined as the vegetation line or the base of the dunes, cliffs or artificial structure at the back of the beach (determined using the survey codes), and the LLB was marked on each profile graph. Only changes in elevation seaward of the LLB were analysed, and all changes landward of LLB were assumed to be a result of profile orientation differences between the surveys. Sub-aerial (dry) beach widths were assessed as the distance between landward limit of the beach, and the point at which the profile met 0 m AHD (i.e. mean sea level). Profiles were classified as stable if they exhibited <5 m change in sub-aerial beach width and/or <0.5 m change in beach elevation. Profiles were classified as eroding or accreting if they exhibited >5 m change in sub-aerial beach width and/or >0.5 m change in beach elevation. Profiles with ≥20 m longshore distance between the November 2014 survey points and the April 2015 survey points were not compared as the large difference in orientation reduced the reliability of beach width comparisons.

3.3 Water level and weather observations

Local water level measurements during the monitoring period were reviewed alongside remote imagery to examine potential links between nearshore hydrodynamics and beach morphology changes. The most relevant water level data available were those measured at Fremantle, ~5 km south of Cottesloe. Only water level data between 1 Januaryand 31 March 2015 were available at the time of analysis (pers. comm., Ms R Lowry, Senior Oceanographic Officer, Department of Transport [DoT], 1 May 2015). For time periods when water level data were not available, mean sea level pressure (MSLP) data were reviewed as a proxy for water levels. MSLP has a direct influence on water levels, with lower MSLP usually generating higher water levels.

It was originally intended that wave data from the DoT's Cottesloe wave buoy also be reviewed to examine potential links between coastal hydrodynamics and beach morphology changes. However, wave data from Cottesloe collected during the monitoring period was not available at the time of analysis (pers. comm., Ms R Lowry, Senior Oceanographic Officer, DoT, 1 May 2015). Instead, wind speed and direction data were reviewed as a proxy for wave data. Wind speed and direction has a direct influence on wave height characteristics, with high-velocity onshore winds generally causing larger, short-period waves. Wind speed and direction data was sourced from the Swanbourne weather station (~4 km north from Cottesloe, and ~1 km from the coast) at 9:00 a.m. and 3:00 p.m. daily (BoM 2015). A key limitation of using only local wind conditions as a proxy for wave data at the study site is that these proxies only indicate locally generated waves and may not provide indication of waves that are generated by weather systems many kilometres away and propagated to the Cottesloe coastline (i.e. swell waves).

4. Results

4.1 Remote imagery

4.1.1 Data quality

Hourly high-resolution imagery was successfully captured between 5:00 a.m. and 7:00 pm every day between the initial installation on 19 November 2014 and the service visit on 13 April 2015, at both monitoring sites. Lower-resolution imagery was successfully transmitted over the mobile phone network on 94% of days between 19 November 2014 and 13 April 2015. Six percent of daily transmissions were skipped, usually due to issues with the Telstra mobile phone network, but this did not affect capture and storage of the hourly remote imagery.

4.1.2 General trends in beach morphology change

The remote imagery captured at Cottesloe Main Beach throughout the summer 2014/2015 monitoring period showed that the general trend of change in beach morphology was a gradual landward recession of the shoreline, resulting in a decrease in beach width (Figure 4.1). The curved section of beach adjacent to the rock groyne generally tended to erode faster than the straighter section immediately to the north, resulting in a gradual increase in beach curvature at the southern end, and gradual rotation of the shoreline in the northern section, from a north-south orientation to a more north-west/south-east orientation.

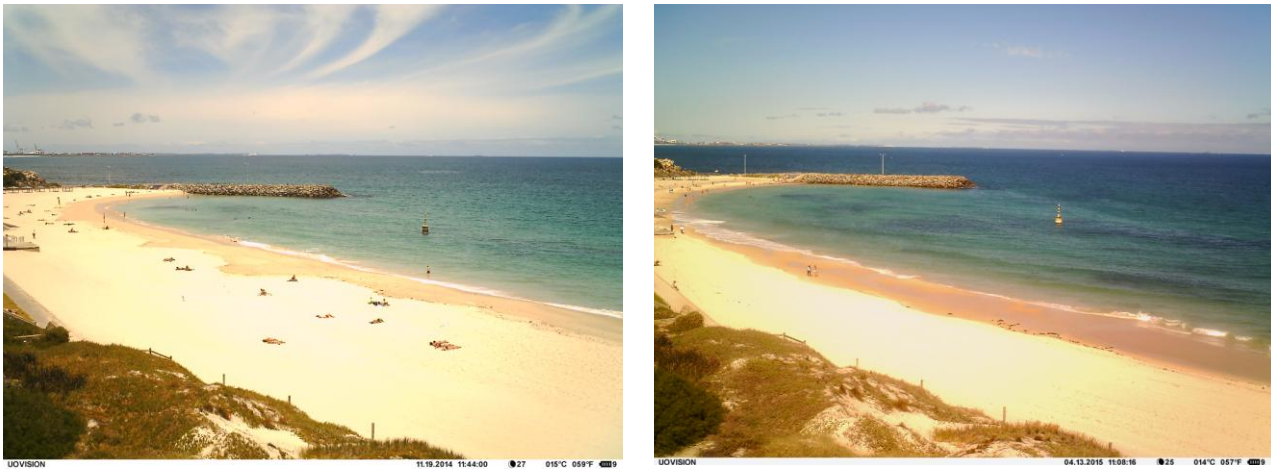

Figure 4.1 Cottesloe Main Beach at 11:08 hrs on 19 November 2014, the day of remote imagery unit installation (left) and at 11:44 hrs on 13 April 2015, the day of the service visit (right)

The remote imagery captured at North Cottesloe Beach throughout the summer 2014/2015 monitoring period showed that the general trend of change in beach morphology was also a gradual landward recession of the shoreline and decrease in beach width (Figure 4.2). The shoreline gradually rotated from a north-south orientation to a more north-west/south-east orientation, and acquired a concave curvature. Shoreline recession at North Cottesloe Beach was generally more gradual than at Cottesloe Main Beach throughout the monitoring period.

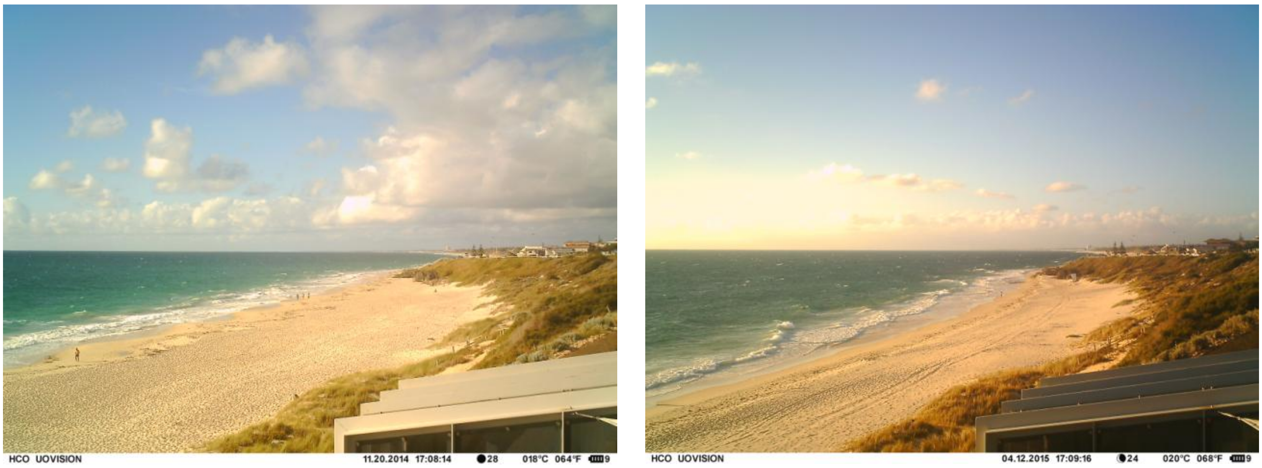

Figure 4.2 North Cottesloe Beach at 17:08 hrs on 20 November 2014, the day after the remote imagery unit installation (left) and at 17:09 hrs on 13 April 2015, the day before the service visit (right)

4.1.3 Notable observations

In addition to the gradual trend of beach morphology change occurring over the monitoring period (Section 4.1.2), there were some notable changes that occurred over shorter timescales.

An unusually high watermark on both beaches was observed in imagery captured on the morning of the 22 November 2014. Localised depressions and mounds had formed on Cottesloe Main Beach seaward of the watermark since the previous day (Figure 4.3). Review of the local weather observations on that day and preceding days found that wind speeds and MSLP around this were fairly average for this time of year (BoM 2015; Appendix A). Swell and water level data may provide additional context to the driving forces behind this morphological change, however none was available for this time period (see Section 3.3). High watermarks were observed on other occasions throughout the monitoring period, but others did not reach as high as 22 November 2014 and were not associated with clearly visible changes in beach morphology.

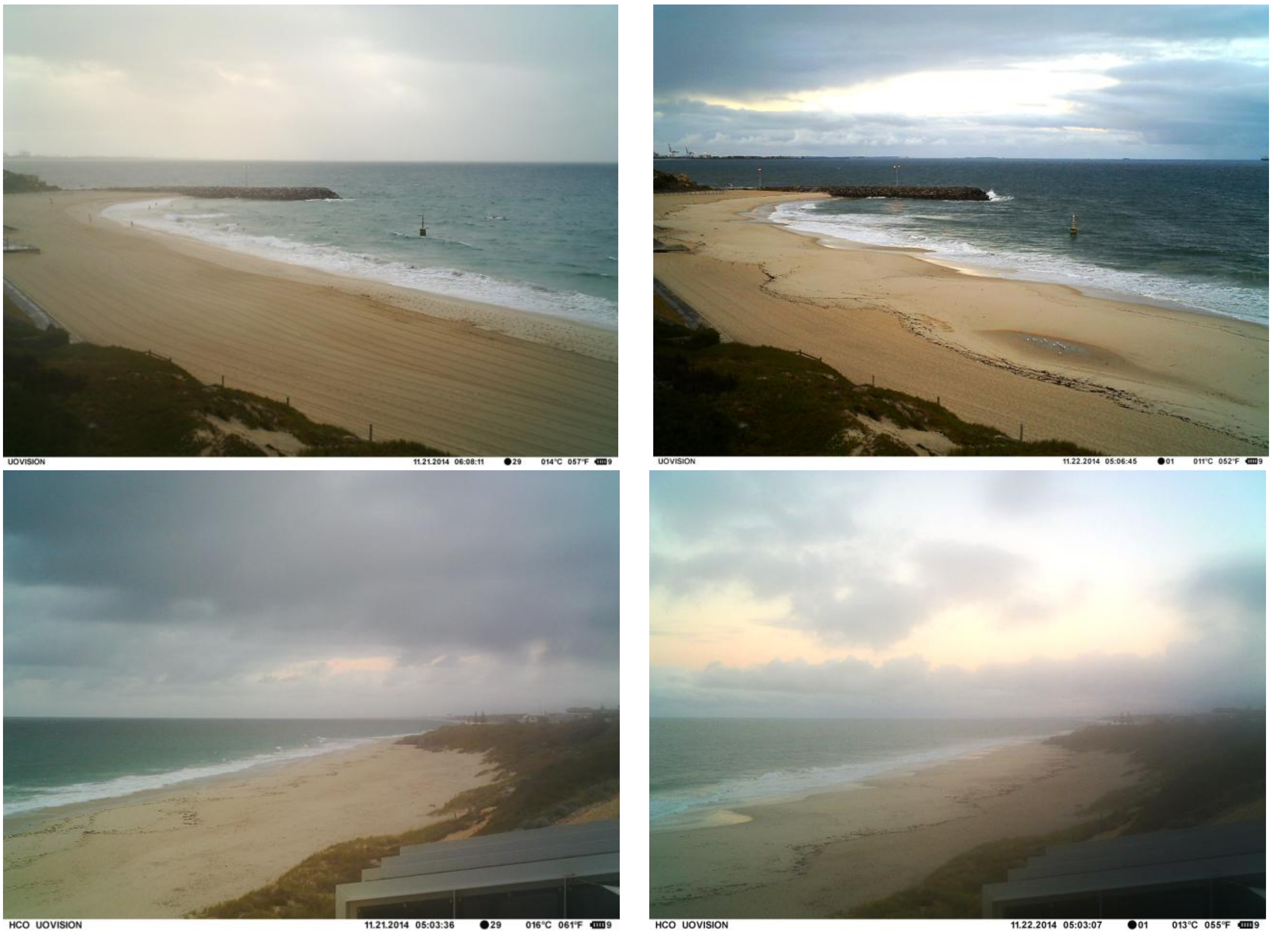

Figure 4.3 Cottesloe Main Beach (top) and North Cottesloe Beach (bottom) ~06:00 hrs on 21 November 2014 (left) and at ~06:00 hrs the following morning on 22 November 2014 (right)

On several occasions throughout the monitoring period, high-resolution imagery of Cottesloe Main Beach indicated the development of 'scarping' in the beach sediment—the formation of low-lying, near-vertical slopes near to the shoreline through accelerated cross-shore erosion during high energy metocean conditions. This was particularly visible in imagery from December (Figure 4.4), and was also evident in a news article photo regarding beach erosion at Cottesloe in mid-March (Appendix B).

Figure 4.4 Close-up of the southern end of Cottesloe Main Beach on 6 December 2014

Weather observations between 26 January and 5 February 2015 indicated a prolonged period of calm weather, with very little evidence of the afternoon sea breeze that typically occurs during summer in Perth (BoM 2015; Appendix A). Water levels during this time period averaged at 0.87 m above Chart Datum (CD) which was slightly higher than the mean sea level of 0.75 m at

Fremantle (Appendix C) but was within one standard deviation from the average water level of 0.79 m between 1 January and 31 March 2015 (Appendix C). This period coincided with a relative slowing of the shoreline recession rate along both Cottesloe Main Beach and North Cottesloe Beach.

Remote imagery captured between 15 and 21 March 2015 indicated a prolonged period of rough sea states and high water levels. The northern part of Cottesloe Main Beach appeared narrower on 18 March 2015, compared to 5 days earlier (Figure 4.5). Review of daily weather observations (BoM 2015; Appendix A) showed that MSLP on 17 and 18 March was lower than average for the month (1008–1009 hPa), and water levels on 16 March were the second highest of the available data, peaking at +1.37 m CD. This peak water level was greater than the highest astronomical tide level at Fremantle (Appendix C) and was greater than three standard deviations above the average water level between 1 January and 31 March 2015 of 0.79 m (Appendix C). The maximum wind gust on the 18 March was the second highest of the month (48 km/h) from a west-north-west direction. Rapid erosion of the beach on the 18 March 2015 led organisers of the 'Sculptures by the Sea' exhibit to move some sculptures further from the shoreline (Appendix B).

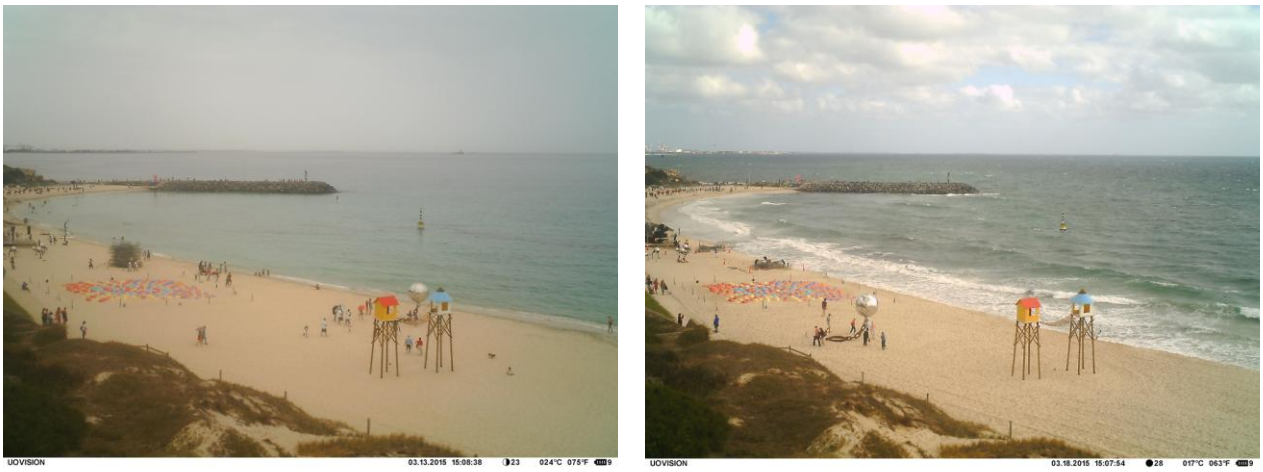

Figure 4.5 Cottesloe Main Beach at 15:08 hrs on 13 March (left) and at 15:07 hrs on 18 March 2015 (right)

Remote imagery captured on the 10 April 2015 indicated stormy conditions with high water levels and a narrow beach compared to the previous day. Dark patches were evident near the shoreline along both Cottesloe Main Beach and North Cottesloe Beach, which may have been wrack or potentially the exposure of underlying rock (Figure 4.6). It was also evident that waves had started to reach the steps at the base of the Indiana Restaurant building. Wave and water level data were were not available for this time period, but review of daily weather observations for 10 April 2015 (BoM 2015; Appendix A) showed that MSLP that day was the lowest of the month (1010.7 hPa) and the maximum wind gust that day was the highest of the month (56 km/h), from a northerly direction.

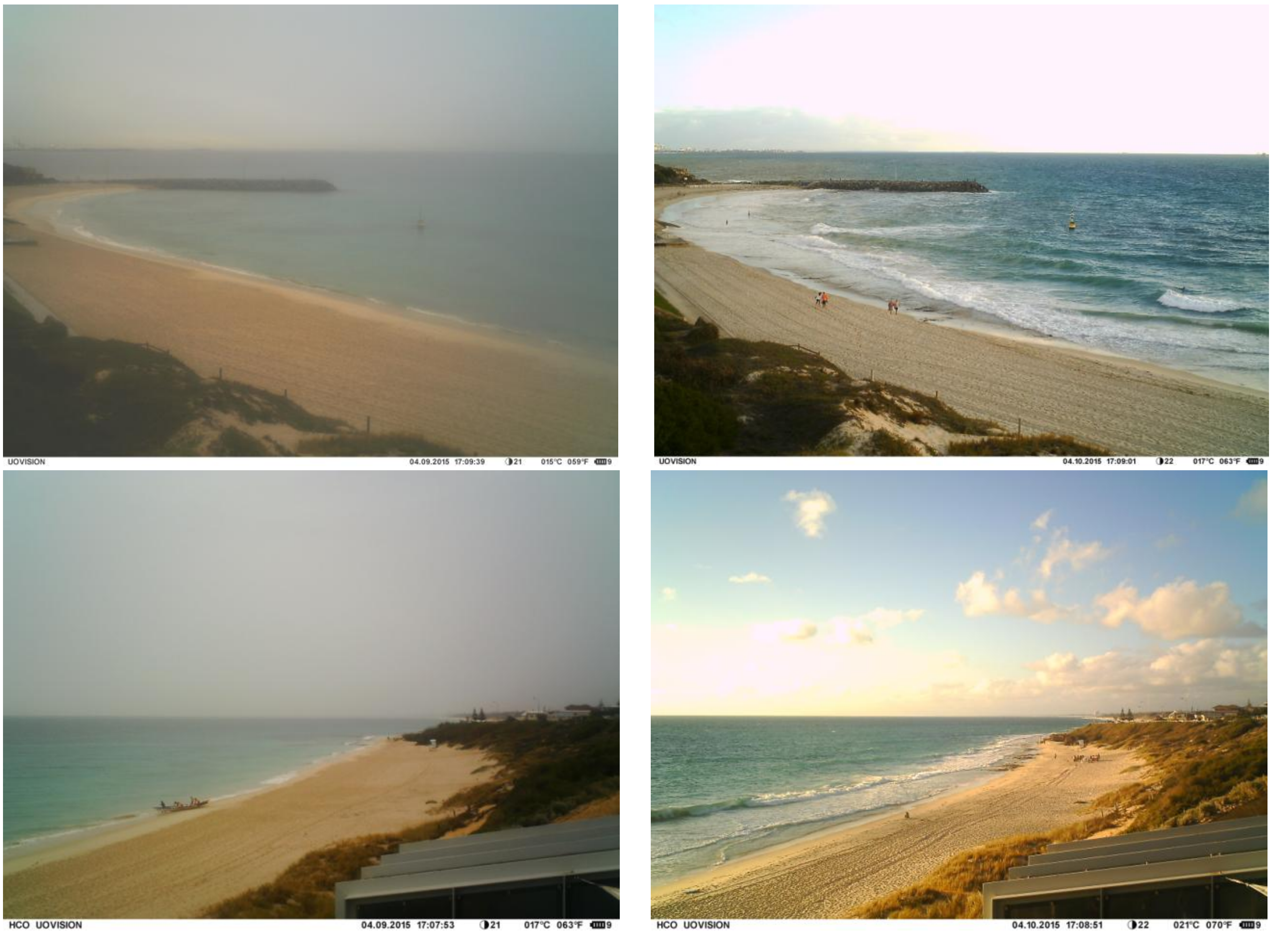

Figure 4.6 Cottesloe Main Beach (top) and North Cottesloe Beach (bottom) at ~17:10 hrs on 9 April (left) and 10 April (right) 2015

4.2 Beach profile data

The beach profile data were graphed to enable visual assessment of beach elevation changes between November 2014 and April 2015 (Appendix D). The quality of the beach profile data and a comparison of beach elevation changes between the two surveys are described in the sections below.

4.2.1 Data quality

The November 2014 beach profile data had high spatial resolution cross-shore, with <5 m horizontal spacing and <0.5 m vertical spacing between survey points. There did not appear to be any outliers or errors in the elevation measurements. Ideally, beach profiles should be straight and orientated shore-normal (i.e. perpendicular to the shoreline) along their entire length; however some November 2014 profiles were not entirely straight along their entire length and some were not shore-normal. The profiles that were not straight and/or shore-normal may not have accurately represented the beach morphology at the time of the survey; for example, profiles that intersect the shoreline diagonally can over-represent the width of the beach.

The April 2015 beach profiles appeared to be straight and shore-normal along most profiles. However, this meant that some April 2015 profiles did not directly overlie the November 2014 profiles, and therefore they were not directly comparable (Table 4.1, Figure 4.7). Profiles 1, 2 7, 18 and 19 were deemed not comparable between the two surveys, and other profiles have been compared despite slight profile offset, which introduces limitations into the analysis. The correction of the profile orientation at this early stage in the long-term monitoring programme was deemed beneficial for comparison of future measurements. The cross-shore resolution of the April 2015 profile measurements was lower than that of the November 2014 survey, with horizontal spacing between survey points often exceeding 5 m and vertical spacing between survey points of up to 13 m. There appeared to be one outlier in the elevation measurements along profile 2, representing a ~4 m dip in elevation at the base of the dune/cliff (Appendix D). This may be a genuine feature of the beach, but this cannot be confirmed as no photographs were captured during the April 2015 survey.

4.2.2 Difference in beach elevation between surveys

The beaches north of Cottesloe Groyne generally exhibited a reduction in beach width (the cross-shore distance between the LLB and where the profile intersected 0 m AHD) and increase in beach face steepness near the shoreline, with a slight increase in berm crest height in some areas (Table 4.1, Figure 4.7, Appendix D). The greatest decreases in beach width (>20 m) were observed at:

- profiles 9 and 10 (north of Eric Street, near the North Cottesloe SLSC)
- profiles 16 and 17 (Cottesloe Main Beach, between Forest Street and Warnham Road).

Most areas that experienced a reduction in beach widths still retained ~20 m of sandy beach width at the time of the April 2015 survey, except at:

- profiles 16 and 17 (Cottesloe Main Beach) where <5 m beach width remained between LLB and 0 m AHD
- profile 29 (directly north of Beach Street Gryone) where ~10 m beach width remained between LLB and 0 m AHD.

The exception to the general pattern of erosion north of Cottesloe Groyne were profiles 5 and 12-14, where the beach morphology remained relatively stable.

The beaches south of Cottesloe Groyne generally exhibited an increase in beach width and beach elevation, apart from the area directly to the north of Beach Street Groyne, where beach width decreased by ~5-10 m and beach elevation decreased by ~0.5–2.0 m (Table 4.1, Figure 4.7, Appendix D). The greatest increases in beach width (>20 m) were observed at:

- profile 30 (directly south of Beach Street Groyne)
- profiles 38 and 39 (at the southern boundary of the ToC).

Table 4.1 Difference in beach elevation at Cottesloe from November 2014 to April 2015

Profile number[1]	Location	Morphology[2]	Differences in beach profiles seaward of the LLB between Nov 2014 and Apr 2015	General pattern of beach change indicated[3]
3–4	North Street to Napier Street	Sandy beach backed by dunes and calcarenite cliff, with some rock outcrops and areas fronted by discontinuous intertidal rock platform. Unconfined to the north.	• ~5–20 m decrease in sub-aerial beach width • increase in beach face steepness	erosion
5			• ~2 m decrease in sub-aerial beach width	stable
6, 8–11			• ~5–20 m decrease in sub-aerial beach width • ~0.2–0.8 m increase in berm crest height on some profiles • increase in beach face steepness	erosion
12–14			• ~0.5 m increase in berm crest height • slight increase in beach face steepness • ~5 m decrease in sub-aerial beach width on profile 14	stable
15–17	Napier Street to Forest Street	Sandy beach backed by concrete seawall and artificial lawned terraces. Confined by Cottesloe Groyne to the south.	• ~5–20 m decrease in sub-aerial beach width • increase in beach face steepness	erosion
20	Mudurup Rocks to Beach Street Groyne	Perched sandy beach backed by dunes and calcarenite cliffs and fronted in places by discontinuous intertidal rock platform. Confined by rocky outcrops and Cottesloe Groyne to the north and Beach Street Groyne to the south.	• ~2 m increase in sub-aerial beach width • ~0.5 m increase in beach face elevation	stable
21–26			• ~0.5–2.5 m increase in beach elevation • increase in berm crest height and width (all profiles except 20)	accretion
27–29			• ~5–10 m decrease in sub-aerial beach width • ~0.5–2.0 m decrease in beach face elevation within • increase in beach face steepness	erosion
30–34	Beach Street Groyne to the southern boundary of the ToC	Sandy beach, confined by Beach Street Groyne to the north and partially confined by rocky outcrops to the south.	• 15–25 m increase in sub-aerial beach width • ~0.2–1 m increase in beach elevation	accretion
35–36			• ~5 m increase in sub-aerial beach width • ~0.2–0.5 m decrease in beach elevation within ~10 m seaward of base of dune/cliff • ~0.5 m increase in beach face elevation	stable
37–39			• ~10–30 m increase in sub-aerial beach width • ~0.5–2 m increase in beach elevation • decrease in beach face steepness	accretion

Notes:

1. Profiles 1, 2, 7, 18 and 19 could not be compared due to the large differences in profile location (>20 m) between the November 2014 and April 2105 surveys, which was necessary to correct the profile orientation (see Section 4.2.1 for more detail).
2. Determined via aerial imagery and site photography
3. Profiles were classified as stable if they exhibited <5 m change in sub-aerial beach width and/or <0.5 m change in beach elevation. Profiles were classified as eroding or accreting if they exhibited >5 m change in sub-aerial beach width and/or >0.5 m change in beach elevation.

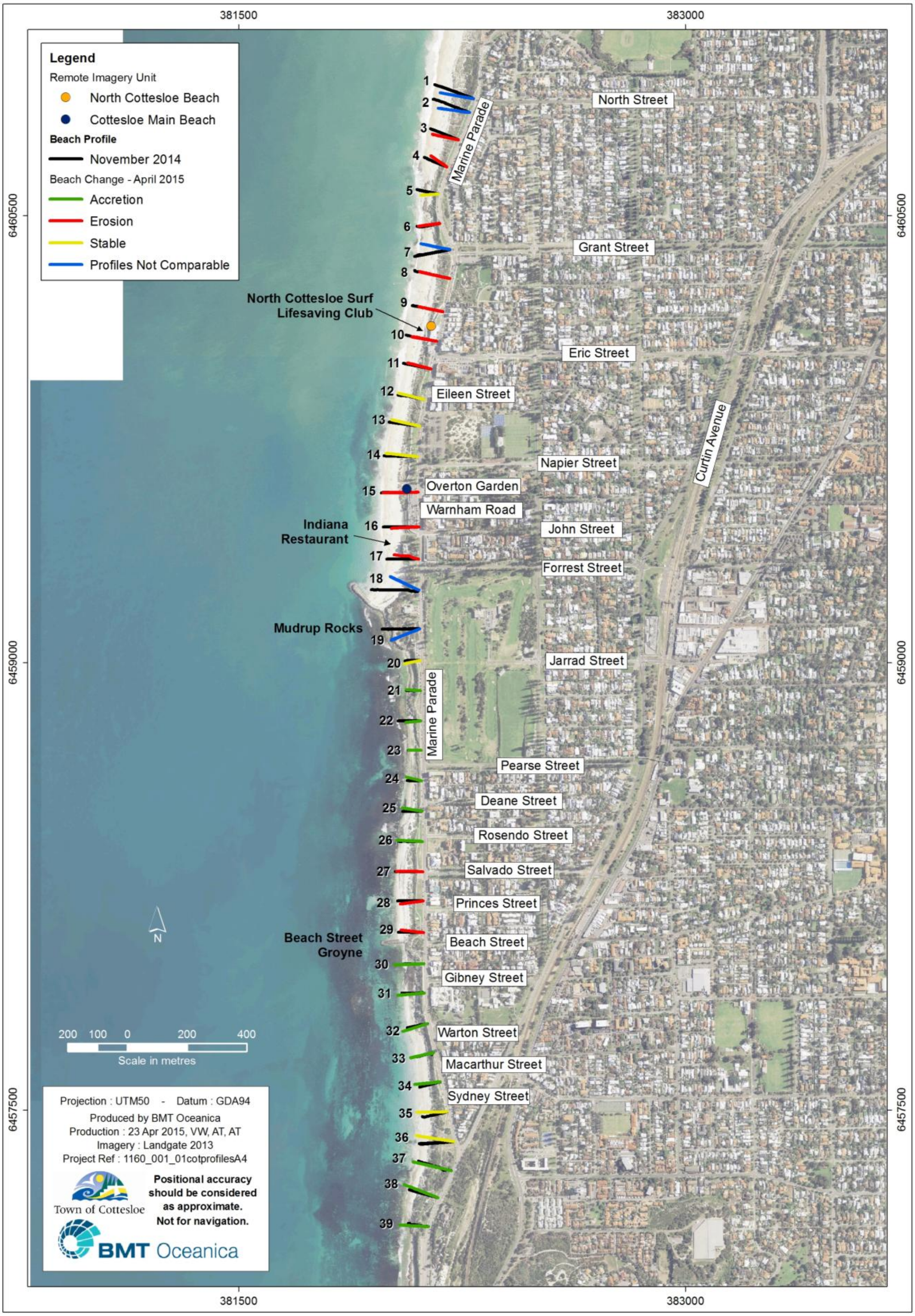

Figure 4.7 Remote imagery monitoring sites and beach profiles measured at Cottesloe during the summer 2014/215 monitoring period

5. Discussion and Recommendations

5.1 Discussion

Change in beach morphology along the Cottesloe coastline from November 2014 to April 2015 appeared to be generally characterised by erosion of the northern beaches and Cottesloe Main Beach, and accretion of the southern beaches (apart from a small area of erosion directly north of Beach Street Groyne). This pattern was likely attributable to net northward longshore sand transport in summer (driven by predominant south-south-westerly winds) being interrupted by cross-shore features such as Beach Street Groyne and Cottesloe Groyne/Mudurup Rocks. This causes accumulation of sand updrift (i.e. to the south) and erosion of sand downdrift (i.e. to the north) of these structures, similar to the observations of Kempin (1952; cited in CZM & Damara 2008; Section 2.1.4). This explanation was supported by the observations that the greatest increase in beach width was observed directly south of the Beach Street Groyne, and the areas experiencing the greatest decrease in beach width were directly north of Beach Street Groyne and Cottesloe Groyne.

Erosion generally occurred via a reduction in beach width and increase in beach face steepness, with an increase in berm crest height along some profiles. Accretion generally occurred via an increase in beach width and an increase in berm crest height along some profiles. Increases in beach face steepness and berm height may have been attributable to the action of summer swell, as suggested by Silvester (1961).

It should be noted that beach profile measurements do not extend offshore to 'the depth of closure' (the seaward limit of significant beach profile fluctuations), which is ideally required to ensure sediment exchanges across the full width of the active zone are accounted for during the analysis. However, this requires boat-based survey equipment which was beyond the scope of this project. Therefore, profile changes seaward of ~1 m water depth at the time of the surveys could not be measured, which limits the assessment of local coastal sediment transport dynamics.

The slowing of the shoreline recession rate at Cottesloe Main Beach and North Cottesloe during a period of relatively little sea breeze activity (as observed during late January/early February 2015; Section 4.1.3), and the acceleration of shoreline recession during storm events from the north (as observed during mid-March 2015 and 10 April; Section 4.1.3), indicated that:

- During ambient summer conditions, predominant south-south-westerly seabreezes resulted in beach erosion to the north of cross-shore structures, due to sediment being transported northward by longshore transport and not being replaced from the south due to blocking of longshore transport by the cross-shore structures.
- During storm conditions, northerly winds resulted in accelerated erosion to the north of cross-shore structures, as these areas were particularly exposed to northerly waves. The northerly storm conditions caused loss of sand from these areas rather than transportation of sand into these areas because offshore sediment transport tends to dominate during storms rather than longshore sediment transport.

This suggests that **calm** northerly conditions occurring during winter may lead to beach accretion at Cottesloe Main Beach and North Cottesloe via trapping of southward longshore sediment transport by the Cottesloe Groyne; but **stormy** northerly conditions during winter may lead to erosion of these exposed areas, via offshore sediment transport.

Accelerated morphological change at Cottesloe Main Beach may have been linked to high water levels associated with storms during summer 2014/2015, particularly during the stormy period in mid-March (Section 4.1.3). However, changes in beach morphology were also observed after high water levels that were not associated with local storm events, for example the high water mark on 22 November 2014 (Section 4.1.3), which instead may have been attributable to large wave runup from long-range swell waves. However, it was not possible to confirm this due to the lack of available wave and water level data during this time period.

As the general pattern of beach change at Cottesloe over summer 2014/2015 was mainly related to seasonal northward sediment transport direction, it is likely that a sediment transport direction reversal during winter (southward, as per Kempin 1952) will result in some accretion in previously eroded areas. However, episodic beach erosion may also occur in these areas during winter due to offshore sediment transport during more frequent and/or intense storms (as observed by Silvester 1961; Section 2.1.4). A full year of monitoring is required to fully assess the cyclic nature of beach morphology changes over the seasons and to determine potential areas of concern from a coastal management perspective.

Based solely on the erosion observed during summer 2014/2015, Cottesloe Main Beach may be an area requiring further attention in future for the following reasons:

- Reduction in beach width reduces beach amenity and restricts the space available for beach-goers at this popular location.
- Scarping of beach sediment and exposure of rock near the shoreline (as observed in remote imagery; Section 4.1.3) may pose a safety hazard to beach-goers and swimmers.
- Periods of accelerated erosion may affect the 'Sculptures by the Sea' exhibit in future summers, as occurred in mid-March 2015 when some sculptures had to be moved further from the shoreline to avoid being damaged due to beach erosion (see news article in Appendix B).
- Loss of the beach fronting the Indiana Restaurant may lead to storm waves breaking onto the building, risking damage to the structure.

The following areas of beach may also require further attention in the event of more severe erosion in future summers, based on the high rates of erosion observed here in summer 2014/2015 and/or relatively small width of beach remaining in April 2015:

- in front of the North Cottesloe SLSC
- directly north of Beach Street Groyne.

The relative coastal vulnerability of each of these areas depends on the characteristics of the backshore. Backshores with high rocky cliffs (e.g. directly north of Beach Street Groyne) may be less vulnerable than areas with lower-lying backshores with infrastructure close to the beach (e.g. Cottesloe Main Beach and in front of North Cottesloe SLSC).

5.2 Recommendations

Based on the results of the summer 2014/2015 coastal monitoring it is recommended that the monitoring programme be continued beyond the first year of monitoring (ending in November 2015), to build understanding of both seasonal and inter-annual changes in beach morphology at Cottesloe. The ToC may also wish to consider the following specific recommendations for future monitoring:

- deploy additional remote imagery units to allow real-time monitoring of other potentially vulnerable areas such as around Beach Street Groyne and North Street
- implement post-storm beach profile monitoring, to help build understanding of how Cottesloe beaches respond to certain extreme conditions
- limit the landward extent of beach profile surveys to ~20 m landward of the LLB, until any major changes to the backshore occur (i.e. construction of new coastal infrastructure) to save time and cost. Costs saved here could be used to fund other improvements to the monitoring (e.g. deployment of extra cameras or post-storm monitoring)
- ensure future beach profiles survey follow the transects surveyed during the April 2015 survey, as all of these profiles have the correct shore-normal orientation
- ensure future beach profile surveys capture elevation measurements within ~1 m either side (alongshore) of the April 2015 transects, to optimise the comparability of profiles between surveys
- ensure during future beach profile surveys that the minimum horizontal distance between survey points is ~5 m and the minimum vertical elevation change between survey points is ~0.5 m, to guarantee the full shape of the profile is captured.
- extend beach profile measurements to the depth of closure using boat-based survey equipment to allow assessment of sediment exchanges across the full width of the active profile and a more comprehensive understanding of seasonal beach profile fluctuations
- analyse beach volume changes using beach profile and geotechnical data, to allow quantification of sediment transport rates which may assist any further assessments of coastal vulnerability.

At some stage, the ToC may also wish to consider monitoring beach sediment particle size, nearshore current speeds/directions, and estimating coastal sediment transport rates, to address the present knowledge gaps identified by the literature review (Section 2.3). However, it is recommended that collection of further data be directly relevant to the objectives of future coastal studies.

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Appendix A

Daily weather observations November 2015–April 2015

Swanbourne, Western Australia
November 2014 Daily Weather Observations

Most observations from a site just under 1 km from the coast, combined with some from Mount Lawley.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Sa	12.7	29.3	0			E	46	05:46	21.7	38		E	22	1018.2	27.6	28		WSW	17	1013.6
2	Su	14.0	23.9	0			WNW	50	19:37	21.3	74		WNW	7	1012.6	22.0	59		WNW	24	1013.3
3	Mo	15.6	22.5	0.2			SW	41	00:21	19.8	54		SSE	9	1020.8	21.2	43		SSW	26	1021.2
4	Tu	10.9	25.9	0			SSW	41	14:13	21.7	45		ESE	11	1022.9	22.4	59		SSW	24	1019.7
5	We	13.0	24.2	0			SSW	43	16:53	20.3	65		SSW	17	1019.0	21.7	62		SW	24	1014.9
6	Th	13.2	22.6	0			WSW	54	22:27	17.9	67		NW	4	1012.0	20.2	61		NW	22	1008.0
7	Fr	15.5	22.0	2.4			WSW	52	02:16	19.4	52		WSW	26	1013.8	21.0	47		SW	20	1015.9
8	Sa	10.8	25.1	0			SSW	46	17:34	19.9	47		ESE	9	1021.6	21.6	52		SW	28	1019.3
9	Su	13.3	34.6	0			E	35	08:39	24.9	38		ESE	22	1016.4	25.7	60		SW	20	1010.0
10	Mo	17.9	24.2	1.2			NNW	37	03:35	19.6	81		NNE	7	1015.1	22.6	64		WSW	20	1012.8
11	Tu	15.9	24.7	0.2			SSW	43	18:31	21.9	51		WNW	13	1016.7	22.0	63		SW	22	1015.9
12	We	14.3	23.5	0			SSW	48	15:28	19.3	37		SSW	17	1018.4	18.6	56		SSW	31	1016.8
13	Th	10.3	20.6	0			SSW	57	15:19	16.9	40		S	28	1022.9	19.4	43		SSW	37	1021.1
14	Fr	8.0	22.4	0			SW	44	15:49	17.2	41		ESE	13	1026.9	19.3	48		SW	26	1022.6
15	Sa	11.4	24.6	0			SSW	37	15:52	20.4	40		ENE	13	1021.0	23.2	36		SW	20	1015.8
16	Su	12.5	26.3	0			SW	35	15:22	20.4	51		SSW	20	1014.0	24.2	57		SW	19	1010.4
17	Mo	13.4	25.2	0.2			NNW	28	09:59	20.9	66		NNW	17	1012.8	23.5	67		WSW	9	1010.9
18	Tu	16.2	24.5	0			WSW	41	16:38	21.1	74		SW	13	1008.9	21.5	69		W	15	1010.0
19	We	14.7	23.9	0.2			SW	30	15:46	19.8	60		WSW	11	1015.4	22.6	56		SW	17	1015.0
20	Th	13.8	23.5	0			WNW	44	12:02	21.8	61		NW	20	1015.0	23.2	54		WNW	22	1012.8
21	Fr	16.2	23.2	4.8			WSW	41	06:42	18.0	81		WSW	20	1012.7	21.4	53		WSW	20	1012.1
22	Sa	14.8	23.8	0.2			SSW	35	06:46	19.4	62		SW	13	1014.2	21.7	48		WSW	22	1014.0
23	Su	16.6	23.2	0			SW	43	07:23	21.3	49		SW	24	1017.4	21.9	49		SW	24	1016.8
24	Mo	10.9	26.8	0			SSW	44	18:01	19.6	40		ESE	13	1022.1	21.6	52		SSW	30	1018.1
25	Tu	14.8	33.2	0			E	50	23:51	22.7	37		E	28	1018.4	29.1	38		SSW	22	1013.1
26	We	19.8	32.7	0			E	57	00:06	26.1	34		E	24	1012.1	24.6	54		SE	19	1006.8
27	Th	19.1	27.1	9.2			E	41	00:11	24.0	70		SSE	7	1011.3	21.4	88		S	13	1010.2
28	Fr	17.1	24.1	0.8			SW	37	17:22	21.7	76		SW	20	1010.4	22.5	65		WSW	20	1011.0
29	Sa	17.5	24.1	0			SW	39	15:43	21.1	60		SSE	11	1014.9	22.1	59		SW	24	1012.6
30	Su	14.1	24.5	0			SW	37	20:44	22.2	54		W	13	1009.8	22.8	59		SW	20	1007.6
Statistics for November 2014																					
	Mean	14.3	25.2							20.7	54			15	1016.3	22.4	54			21	1014.1
	Lowest	8.0	20.6							16.9	34		NW	4	1008.9	18.6	28		WSW	9	1006.8
	Highest	19.8	34.6	9.2			#	57		26.1	81		#	28	1026.9	29.1	88		SSW	37	1022.6
	Total			19.4																	

Temperature, humidity, wind and rainfall observations are from Swanbourne {station 009215}. Pressure observations are from Perth Metro {station 009225}

IDCJDW6121.201411 Prepared at 13:08 UTC on 5 Apr 2015

Swanbourne, Western Australia
December 2014 Daily Weather Observations

Most observations from a site just under 1 km from the coast, combined with some from Mount Lawley.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Mo	17.4	24.3	0			SSW	41	21:47	20.3	64		SW	20	1008.9	22.2	64		WSW	24	1008.4
2	Tu	13.7	26.3	0			ENE	37	10:55	20.0	46		E	15	1014.8	22.1	47		SW	22	1010.3
3	We	14.1	25.3	0			SSW	44	22:37	23.3	33		NE	7	1010.3	22.9	55		SW	26	1010.3
4	Th	14.2	24.1	0			SW	43	14:01	22.3	44		SSE	15	1017.0	22.8	57		SW	28	1014.8
5	Fr	16.0	26.1	0			S	35	19:16	20.0	59		E	19	1016.6	22.6	58		SSW	15	1014.0
6	Sa	14.8	26.0	0.2			SSW	35	16:44	24.2	48		SSE	6	1014.1	23.3	64		SW	26	1011.5
7	Su	15.5	26.6	0			SSW	35	18:18	25.0	46		ENE	9	1010.6	24.6	60		SW	20	1007.5
8	Mo	18.1	25.1	0			SSW	56	19:27	22.2	61		SSW	30	1010.0	22.7	58		SW	33	1010.0
9	Tu	12.2	22.6	0			SSW	56	16:34	17.8	54		S	15	1017.7	21.8	44		SSW	33	1016.6
10	We	12.0	27.4	0			SW	41	14:56	19.6	38		E	15	1022.0	22.5	49		SW	30	1017.8
11	Th	16.7	32.9	0			E	46	07:56	25.7	39		E	26	1015.8	26.1	56		SSW	24	1010.9
12	Fr	18.9	24.4	0			SW	59	15:29	22.1	65		SSW	31	1013.0	22.3	57		SSW	33	1013.2
13	Sa	12.5	23.3	0			SSW	50	14:51	20.5	45		SSE	11	1019.3	21.9	53		SSW	31	1015.5
14	Su	11.9	23.8	0			SSW	48	15:50	20.8	43		SW	13	1015.4	22.0	52		SW	28	1012.2
15	Mo	14.9	24.4	0			SW	41	15:30	20.6	54		WSW	17	1013.6	23.1	54		SW	26	1012.4
16	Tu	12.1	23.1	0			SSW	35	18:06	20.3	44		E	9	1014.9	21.6	45		SW	22	1011.9
17	We	12.6	23.4	0			SSW	52	18:08	21.4	38		SSE	13	1013.4	21.5	49		SSW	30	1011.8
18	Th	14.4	30.8	0			SSW	41	14:13	22.8	42		E	19	1017.3	23.4	57		SSW	28	1013.8
19	Fr	16.3	38.8	0			SSW	43	18:20	29.6	29		E	22	1012.5	26.6	56		SSW	26	1007.2
20	Sa	20.3	25.8	0			SSW	61	16:15	22.7	70		SW	26	1008.1	24.5	59		SW	30	1008.5
21	Su	15.0	27.5	0			SSW	50	17:38	23.4	44		SE	17	1017.4	24.5	57		SSW	28	1014.4
22	Mo	16.4	27.0	0			SSW	46	16:34	25.1	49		SE	7	1017.2	24.8	55		SSW	30	1014.5
23	Tu	16.1	34.4	0			ESE	50	23:01	23.2	42		ESE	22	1018.3	30.6	39		SW	17	1015.2
24	We	17.0	31.8	0			SSW	46	17:58	24.1	42		ESE	15	1019.0	24.9	55		SSW	33	1015.9
25	Th	15.9	33.3	0			ESE	43	01:20	24.4	26		ESE	19	1021.7	25.5	56		SSW	24	1018.2
26	Fr	14.8	33.4	0			SSW	39	14:55	23.4	37		E	20	1020.8	26.0	44		SSW	28	1015.6
27	Sa	19.0	33.5	0			SSW	39	15:08	29.0	24		NE	17	1016.8	26.8	51		SSW	24	1013.7
28	Su	17.2	28.1	0			SSW	43	16:08	26.7	36		S	11	1016.8	25.7	59		SW	24	1015.1
29	Mo	18.6	34.8	0			SSW	44	13:13	27.6	34		ESE	15	1016.6	26.4	49		SSW	30	1013.1
30	Tu	19.8	37.0	0			NE	44	08:31	34.7	15		NE	22	1009.6	26.9	62		WSW	19	1008.1
31	We	19.5	26.0	0			SW	46	14:02	23.7	63		S	15	1012.4	25.1	56		SSW	28	1010.5
Statistics for December 2014																					
	Mean	15.7	28.1							23.4	44			16	1015.2	24.1	54			26	1012.7
	Lowest	11.9	22.6							17.8	15		SSE	6	1008.1	21.5	39		SSW	15	1007.2
	Highest	20.3	38.8	0.2			SSW	61		34.7	70		SSW	31	1022.0	30.6	64		#	33	1018.2
	Total			0.2																	

Temperature, humidity, wind and rainfall observations are from Swanbourne {station 009215}. Pressure observations are from Perth Metro {station 009225}

IDCJDW6121.201412 Prepared at 13:08 UTC on 4 Apr 2015

Swanbourne, Western Australia
January 2015 Daily Weather Observations

Most observations from a site just under 1 km from the coast, combined with some from Mount Lawley.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Th	16.4	26.6	0			SW	44	14:37	24.7	44		ESE	9	1011.3	23.5	59		SW	26	1008.9
2	Fr	15.5	25.5	0			SW	43	13:00	20.9	58		S	17	1010.9	24.1	61		SW	26	1009.8
3	Sa	14.2	30.2	0			SSW	48	17:42	22.6	40		ESE	11	1015.9	23.6	50		SSW	31	1012.6
4	Su	16.5	34.8	0			SSW	41	17:57	26.4	36		E	15	1013.2	27.2	53		SSW	24	1009.0
5	Mo	22.7	43.2	0			ENE	39	08:46	34.7	27		ENE	15	1008.5	33.6	34		SSW	22	1005.5
6	Tu	20.1	29.6	0			SSW	50	15:57	27.2	64		SE	9	1009.4	25.6	65		SSW	28	1007.2
7	We	18.6	34.6	0			ESE	57	21:44	25.3	47		SE	20	1011.5	26.3	59		SSW	30	1009.3
8	Th	15.7	33.4	0			ESE	50	22:12	21.6	38		ESE	20	1016.2	32.2	16		SE	20	1011.5
9	Fr	14.9	31.1	0			SE	56	02:23	21.0	43		ESE	24	1016.9	30.4	21		SE	24	1012.7
10	Sa	15.9	32.4	0			ESE	57	01:24	21.9	42		E	26	1016.5	30.9	16		ESE	20	1011.9
11	Su	16.9	31.1	0			E	46	06:37	24.1	35		E	20	1011.7	26.8	49		SW	22	1008.1
12	Mo	15.9	34.2	0			SSW	41	16:50	28.8	21		E	15	1008.4	28.1	40		SSW	26	1006.3
13	Tu	18.8	33.0	0			SW	35	14:30	30.6	25		E	13	1008.9	27.6	48		SW	22	1007.4
14	We	18.2	26.9	0			SW	30	16:22	25.8	49		SSW	4	1010.9	24.9	60		WSW	19	1011.3
15	Th	17.6	30.2	0			SSW	52	14:11	24.4	47		SSE	13	1016.5	26.1	51		SW	28	1013.9
16	Fr	17.2	28.2	0			SSW	37	17:05	25.7	40		SE	7	1017.4	25.4	53		SSW	22	1014.1
17	Sa	18.1	38.4	0			E	44	07:10	27.5	35		E	22	1012.2	31.2	42		SSW	19	1007.3
18	Su	20.0	26.8	0			WSW	30	10:52	24.9	72		WSW	7	1008.7	23.6	72		WSW	17	1010.3
19	Mo	18.6	26.4	0			WSW	26	15:32	23.8	57		SSW	9	1012.9	24.9	56		WSW	15	1011.7
20	Tu	16.8	30.8	0			SW	20	13:36	23.7	70		SW	11	1013.7	28.8	56		SW	13	1010.2
21	We	21.0	34.2	0			SSW	48	11:14	30.4	42		SSW	13	1013.0	26.6	65		SW	20	1012.1
22	Th	21.6	27.3	0			SSW	46	15:37	24.4	59		SE	13	1016.8	25.3	55		SSW	26	1015.1
23	Fr	16.3	28.4	0			SW	44	15:53	25.4	42		SE	9	1015.4	25.7	53		SW	28	1013.2
24	Sa	15.1	27.9	0			SSW	48	16:26	22.3	42		SE	13	1016.4	24.3	57		SSW	31	1013.6
25	Su	17.1	32.9	0			SW	41	14:26	23.1	44		ESE	22	1016.5	27.1	50		SSW	26	1012.9
26	Mo	16.6	36.6	0			ESE	46	02:29	25.8	36		ESE	13	1013.2	28.3	52		SSW	22	1008.3
27	Tu	22.2	38.9	0			E	46	08:00	30.5	23		ENE	22	1008.2	32.5	28		SSW	20	1005.2
28	We	25.8	33.9	0			E	31	02:20	31.1	32		NW	9	1008.1	30.5	49		WSW	15	1005.2
29	Th	21.9	29.8	0.6			E	52	04:27	25.5	78		SW	13	1009.4	28.5	62		SSW	20	1007.0
30	Fr	21.6	38.9	0.6			ESE	52	22:50	25.8	37		ESE	4	1011.5	34.8	18		ENE	17	1010.1
31	Sa	20.1	33.1	0			ESE	44	00:10	26.6	42		E	17	1013.9	30.7	21		E	15	1013.1
Statistics for January 2015																					
	Mean	18.3	31.9							25.7	44			14	1012.7	27.7	47			22	1010.2
	Lowest	14.2	25.5							20.9	21		#	4	1008.1	23.5	16		SW	13	1005.2
	Highest	25.8	43.2	0.6			ESE	57		34.7	78		E	26	1017.4	34.8	72		SSW	31	1015.1
	Total			1.2																	

Temperature, humidity, wind and rainfall observations are from Swanbourne {station 009215}. Pressure observations are from Perth Metro {station 009225}

IDCJDW6121.201501 Prepared at 13:09 UTC on 3 Apr 2015

Swanbourne, Western Australia
February 2015 Daily Weather Observations

Most observations from a site just under 1 km from the coast, combined with some from Mount Lawley.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Su	21.2	35.7	0			NW	67	20:12	23.9	44		E	19	1014.3	33.7	24		E	19	1011.6
2	Mo	19.3	34.3	9.4			ESE	65	23:14	25.9	55		E	13	1014.4	22.3	98		ESE	17	1015.1
3	Tu	20.1	37.6	10.2			ENE	50	22:01	23.8	68		E	13	1016.8	31.4	40		SW	11	1011.2
4	We	21.6	30.7	0.4			ENE	31	01:25	28.8	49		NNW	15	1015.0	28.0	66		W	11	1013.8
5	Th	19.3	28.2	0.2			SSW	41	18:11	24.4	76		SW	9	1015.8	26.4	67		WSW	24	1014.8
6	Fr	17.7	28.2	0			SSW	48	15:59	24.0	56		SSE	13	1018.8	25.3	60		SSW	30	1015.9
7	Sa	19.0	32.0	0			SSW	43	14:25	25.0	48		ESE	11	1018.3	27.4	57		SSW	26	1014.5
8	Su	20.0	34.6	0			E	35	00:11	28.3	45		ESE	9	1015.0	30.8	46		SSW	17	1012.7
9	Mo	20.7	28.6	0			SW	31	15:40	25.3	72		SW	13	1018.3	26.8	65		SW	20	1017.3
10	Tu	19.3	31.4	0.2			SW	39	15:15	28.2	53		SSE	9	1019.1	27.9	60		SSW	22	1017.6
11	We	19.8	35.4	0			ESE	43	01:25	26.8	42		ESE	13	1020.0	28.0	59		SSW	22	1015.6
12	Th	20.9	28.9	0			SW	28	15:06	25.9	51		E	9	1015.2	25.3	61		SW	17	1012.6
13	Fr	20.5	27.1	0			SW	33	22:38	23.6	80		NW	9	1010.5	26.2	62		SW	19	1009.9
14	Sa	18.8	25.0	0			SSW	48	06:28	22.4	46		SSW	22	1017.2	23.3	45		SW	28	1016.8
15	Su	13.6	29.5	0			SSW	41	16:47	20.6	40		E	15	1021.0	25.6	48		SW	24	1016.4
16	Mo	17.3	35.7	0			E	44	07:17	23.0	42		E	13	1015.8	27.7	55		SW	17	1012.2
17	Tu	20.5	31.4	0			E	30	08:44	28.6	35		E	13	1012.4	27.4	60		SSW	13	1012.0
18	We	20.8	31.9	0			SSW	31	17:13	25.7	66		ENE	7	1013.2	27.2	67		SW	19	1012.7
19	Th	19.4	28.5	0			SSW	37	17:36	26.8	54		SSE	7	1014.9	26.3	63		SW	24	1013.3
20	Fr	18.0	28.6	0			SSW	46	18:22	25.0	47		SSE	7	1015.2	25.4	60		SW	24	1012.7
21	Sa	16.4	26.7	0			SSW	43	16:54	22.6	54		SE	13	1014.6	24.2	53		SW	26	1011.7
22	Su	17.0	28.9	0			SSW	54	17:01	23.4	59		SSE	15	1014.9	25.6	57		SSW	33	1012.1
23	Mo	15.7	35.0	0			ESE	46	01:21	22.3	40		ESE	19	1016.4	34.0	21		ESE	17	1011.3
24	Tu	21.9	37.3	0			E	41	03:35	31.5	33		ENE	15	1008.4	31.0	48		NW	17	1006.8
25	We	20.6	33.1	0			SW	26	15:35	25.5	79		WSW	11	1008.4	28.0	65		SW	15	1005.9
26	Th	20.8	30.7	0			NW	26	15:20	29.9	56		E	4	1007.0	27.7	66		NW	13	1004.6
27	Fr	20.7	26.3	0			SW	44	13:48	22.5	70		SSW	24	1009.3	24.9	58		SW	26	1009.8
28	Sa	16.7	31.4	0			SSW	44	15:54	23.1	51		SE	17	1016.4	26.0	53		SSW	30	1012.7
Statistics for February 2015																					
	Mean	19.2	31.2							25.2	53			12	1014.9	27.3	56			20	1012.6
	Lowest	13.6	25.0							20.6	33		E	4	1007.0	22.3	21		#	11	1004.6
	Highest	21.9	37.6	10.2			NW	67		31.5	80		SSW	24	1021.0	34.0	98		SSW	33	1017.6
	Total			20.4																	

Temperature, humidity, wind and rainfall observations are from Swanbourne {station 009215}. Pressure observations are from Perth Metro {station 009225}

IDCJDW6121.201502 Prepared at 16:08 UTC on 16 Apr 2015

Swanbourne, Western Australia
March 2015 Daily Weather Observations

Most observations from a site just under 1 km from the coast, combined with some from Mount Lawley.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	Su	17.3	30.1	0			SSW	48	17:22	24.0	48		SE	13	1010.8	27.1	54		SSW	26	1007.3
2	Mo	18.7	30.9	0			ESE	46	23:20	23.9	49		SE	19	1014.6	28.4	35		SE	17	1013.7
3	Tu	16.9	31.6	0			SSW	41	15:45	23.2	54		ESE	17	1020.3	26.0	58		SSW	28	1016.7
4	We	17.5	33.2	0			ESE	41	23:32	23.7	51		ESE	19	1022.2	27.4	58		SSW	20	1018.4
5	Th	17.9	35.3	0			E	39	01:10	23.7	47		E	15	1023.7	33.9	21		ESE	13	1019.1
6	Fr	18.5	33.1	0			SSW	41	17:42	24.9	46		E	15	1020.8	27.1	53		SSW	22	1016.7
7	Sa	16.8	31.7	0			SSW	37	16:37	24.7	45		ESE	13	1018.6	27.3	55		SSW	22	1014.4
8	Su	18.2	28.8	0			SW	43	15:10	25.6	39		ENE	6	1018.2	25.6	60		SW	26	1015.6
9	Mo	18.6	31.4	0			SSW	37	17:11	26.1	49		ESE	6	1017.2	27.5	55		SSW	19	1014.5
10	Tu	16.7	28.2	0			SSW	37	14:40	24.8	50		SE	7	1015.5	25.5	63		SSW	24	1013.3
11	We	18.1	33.5	0			SSW	35	15:44	25.0	51		ESE	11	1016.4	28.4	56		SSW	17	1012.9
12	Th	20.5	37.2	0			E	37	08:04	27.1	38		ENE	20	1013.6	29.6	51		SSW	15	1010.5
13	Fr	21.2	34.8	0			SSE	31	21:48	30.0	26		ENE	11	1010.1	29.1	39		NW	7	1010.2
14	Sa	19.9	32.9	10.0			SW	41	17:06	25.5	66		ESE	11	1005.8	28.4	62		SE	15	1002.2
15	Su	21.3	27.6	0.2			WNW	37	09:20	23.9	82		WNW	20	1010.9	26.7	57		WNW	20	1011.0
16	Mo	19.9	27.6	0.4			WSW	30	14:51	22.9	71		WNW	15	1012.7	26.0	56		WSW	19	1011.7
17	Tu	20.8	27.3	0			NW	35	17:27	24.0	65		NW	22	1010.1	25.3	66		NW	20	1008.0
18	We	18.8	24.2	7.2			WNW	48	05:26	21.8	98		WNW	17	1007.2	23.5	51		SW	24	1009.5
19	Th	17.0	26.3	1.2			SSW	35	17:18	20.7	67		SE	7	1016.8	23.6	56		SW	20	1016.4
20	Fr	15.7	31.3	0			SSW	39	15:27	20.1	52		E	24	1020.4	27.1	51		SW	20	1014.8
21	Sa	17.6	24.6	0			SW	50	15:51	23.2	64		WNW	7	1012.9	23.6	67		SW	28	1015.4
22	Su	14.9	26.4	0			SSE	43	18:59	19.8	54		SSE	20	1025.8	25.6	29		SE	15	1024.3
23	Mo	11.7	26.0	0			ESE	43	00:23	17.7	41		ESE	19	1030.1	25.3	22		SE	15	1023.9
24	Tu	13.2	25.1	0			S	46	18:34	19.2	40		E	20	1023.4	23.5	45		SSW	26	1020.0
25	We	15.2	29.9	0			ESE	44	01:15	20.2	43		E	22	1025.2	29.0	20		SSE	19	1021.6
26	Th	16.0	32.0	0			ENE	48	08:39	21.4	44		ENE	28	1023.7	29.6	24		E	13	1019.0
27	Fr	16.4	26.2	2.4			SSW	35	16:59	21.7	61		ESE	15	1020.4	24.2	59		SW	20	1017.4
28	Sa	14.4	24.9	0			SW	37	15:41	21.2	70		S	13	1021.3	23.2	54		SW	26	1018.5
29	Su	14.5	26.8	0			SSW	30	16:37	22.5	52		E	15	1020.4	25.9	58		SSW	17	1016.5
30	Mo	16.6	24.7	0			SW	30	13:04	24.5	45		NE	2	1016.2	22.5	72		SW	15	1015.3
31	Tu	16.4	25.8	0			SW	35	16:16	21.2	65		SSE	9	1018.0	23.6	61		SW	20	1016.8
Statistics for March 2015																					
	Mean	17.3	29.3							23.2	53			14	1017.5	26.4	50			19	1015.0
	Lowest	11.7	24.2							17.7	26		NE	2	1005.8	22.5	20		NW	7	1002.2
	Highest	21.3	37.2	10.0			SW	50		30.0	98		ENE	28	1030.1	33.9	72		#	28	1024.3
	Total			21.4																	

Temperature, humidity, wind and rainfall observations are from Swanbourne {station 009215}. Pressure observations are from Perth Metro {station 009225}

IDCJDW6121.201503 Prepared at 13:08 UTC on 14 Apr 2015

Swanbourne, Western Australia
April 2015 Daily Weather Observations

Most observations from a site just under 1 km from the coast, combined with some from Mount Lawley.

Australian Government
Bureau of Meteorology

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9am						3pm					
		Min	Max				Dirn	Spd	Time	Temp	RH	Cld	Dirn	Spd	MSLP	Temp	RH	Cld	Dirn	Spd	MSLP
		°C	°C	mm	mm	hours		km/h	local	°C	%	eighths		km/h	hPa	°C	%	eighths		km/h	hPa
1	We	13.6	28.6	0			E	33	17:08	19.1	59		SE	13	1023.8	26.2	37		E	6	1020.1
2	Th	15.1	28.8	0			E	41	04:50	19.3	54		E	24	1021.9	24.5	54		SW	22	1016.9
3	Fr	15.2	28.4	0			SSW	33	17:52	23.0	51		ENE	11	1018.3	25.2	61		SSW	20	1014.9
4	Sa	15.3	26.5	0			SSW	28	15:26	20.1	59		SSE	6	1018.0	25.1	58		SSW	15	1015.7
5	Su	17.3	31.8	0			E	48	23:45	22.0	54		ESE	19	1020.9	30.5	27		ESE	15	1017.8
6	Mo	16.9	25.3	0			E	56	01:10	18.8	59		E	26	1021.3	25.0	39		E	24	1017.3
7	Tu	14.3	20.8	12.6			ENE	46	11:26	16.3	98		E	22	1018.9	20.1	66		NE	24	1016.4
8	We	16.1	24.3	16.6			ENE	33	00:50	18.0	98		ENE	13	1015.2	24.1	80		WNW	13	1013.6
9	Th	18.0	24.8	2.0			NE	41	22:42	19.3	99		E	9	1015.4	21.2	99		NE	9	1012.3
10	Fr	19.1	24.4	14.0			N	56	02:35	21.5	99		WNW	13	1009.4	22.1	78		WSW	17	1010.7
11	Sa	19.3	24.1	0.8			WSW	48	10:44	22.4	65		W	22	1013.8	22.1	67		WSW	26	1012.5
12	Su	16.4	22.7	11.2			SW	46	06:18	17.7	98		SSW	24	1015.4	21.8	64		SW	22	1014.1
13	Mo	14.0	22.9	0.2			SW	30	15:22	18.5	78		SSW	6	1016.6	21.5	63		SW	19	1013.5
14	Tu	15.6	24.3	0			SE	31	19:51	18.1	78		ENE	6	1017.0	21.8	64		SW	15	1015.7
15	We	11.3	23.9	0.4			SW	39	13:37	17.0	58		ESE	17	1026.4	23.1	38		SSE	17	1024.1
16	Th	12.3	24.1	0			E	37	10:00	16.8	55		ENE	17	1031.7	23.6	33		SE	15	1026.9
17	Fr	12.0		0						18.4	50		E	7	1026.1						
Statistics for the first 17 days of April 2015																					
	Mean	15.4	25.4							19.2	71			15	1019.4	23.6	58			17	1016.4
	Lowest	11.3	20.8							16.3	50		#	6	1009.4	20.1	27		E	6	1010.7
	Highest	19.3	31.8	16.6			#	56		23.0	99		E	26	1031.7	30.5	99		WSW	26	1026.9
	Total			57.8																	

Temperature, humidity, wind and rainfall observations are from Swanbourne {station 009215}. Pressure observations are from Perth Metro {station 009225}

IDCJDW6121.201504 Prepared at 02:21 UTC on 17 Apr 2015

Appendix B

News article on beach erosion in March 2015

Shifting sands: Sculpture by the Sea director David Handley on the eroded beach yesterday. Picture: Bill Hatto

It's Sculpture in the Sea

Claire Tyrrell

Organisers of Cottesloe's Sculpture by the Sea worked to save exhibits as the beach eroded yesterday.

Two sculptures were shifted inland and one was dismantled as winds and waves lashed the coast.

Director David Handley said some works were moved at the weekend when the remnants of cyclone Olwyn threatened.

"We always plan for this because we lose a fair bit of sand each year but we have never lost as much as this," he said.

Works were engineered to withstand 75km/h gusts but 100km/h winds were predicted on Saturday.

They did not reach that level but heavy rain and north-westerly winds contributed to the erosion.

Mr Handley said it seemed there had been more rain this year than in the other 10 years combined.

Weather Bureau duty forecaster Michael Symonds said the cold front brought 7mm of rain to Swanbourne and more than 10mm to the area at the weekend.

"The outlook for the next 10 days is looking to be cooler, windier and rainier than it has been," he said.

"It's looking pretty windy for the weekend, with a high ridging along the south coast."

Appendix C

Water Level Data

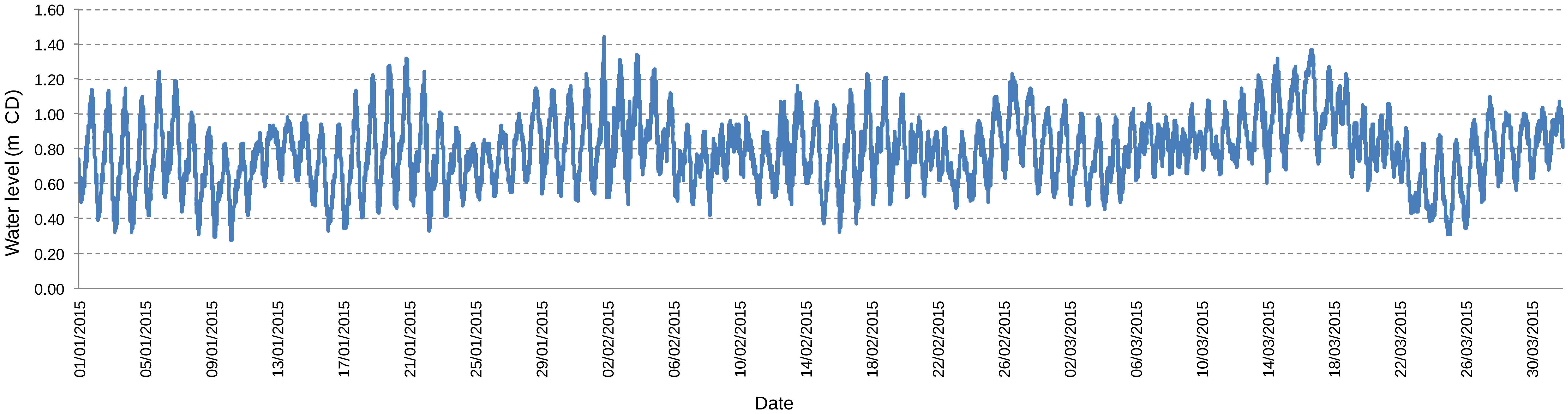


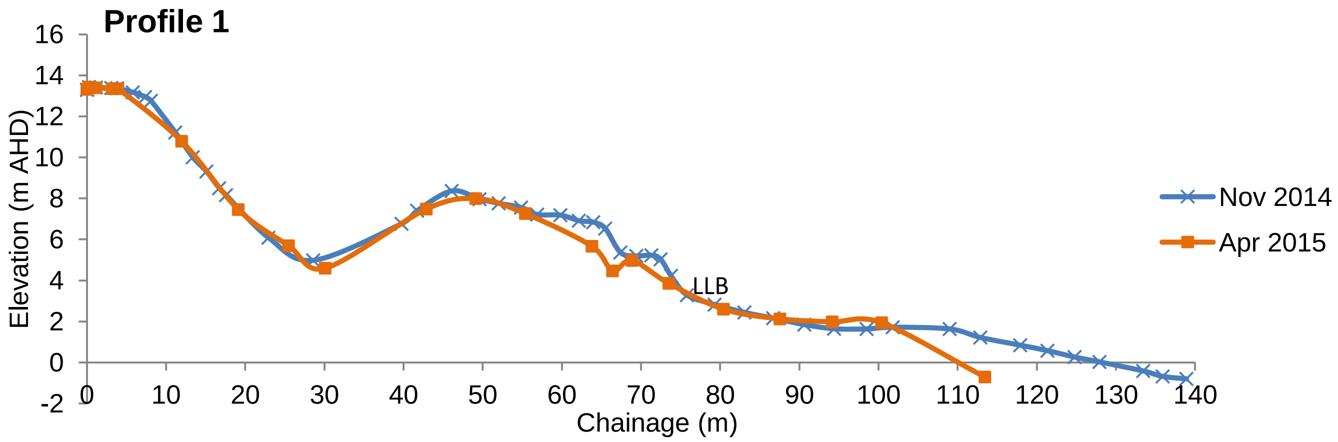
Figure C1 **Water levels measured at Fremantle between 1 January and 31 March 2015**

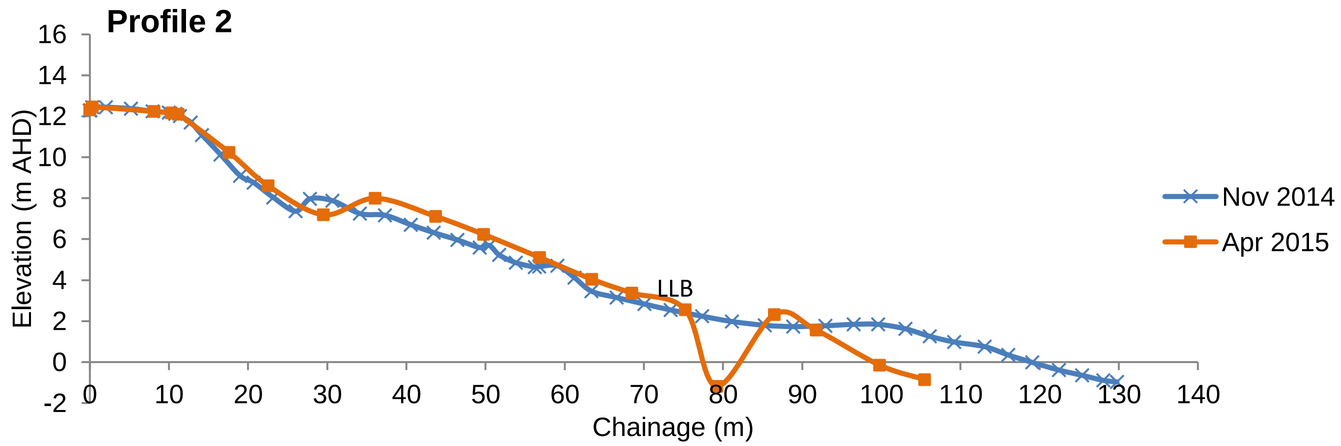
Table C1 **Descriptive statistics for water level data measured at Fremantle**

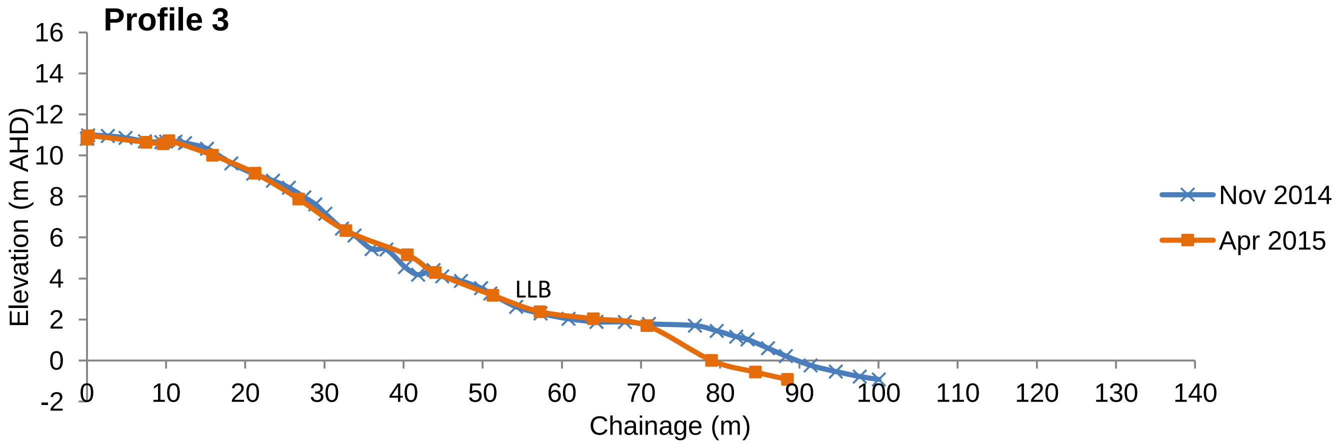
Mean Tidal Heights	**Value (m)**
Highest Astronomical Tide	1.34
Mean Sea Level	0.75
Lowest Astronomical Tide	0.20
Descriptive statistics for 1 January and 31 March 2015	**Value (m)**
Average water level	0.79
Standard deviation	0.19
Average plus 1 x standard deviation	0.98
2 x standard deviations	0.38
Average plus 2 x standard deviation	1.18
3 x standard deviations	0.58
Average plus 3 x standard deviation	1.37

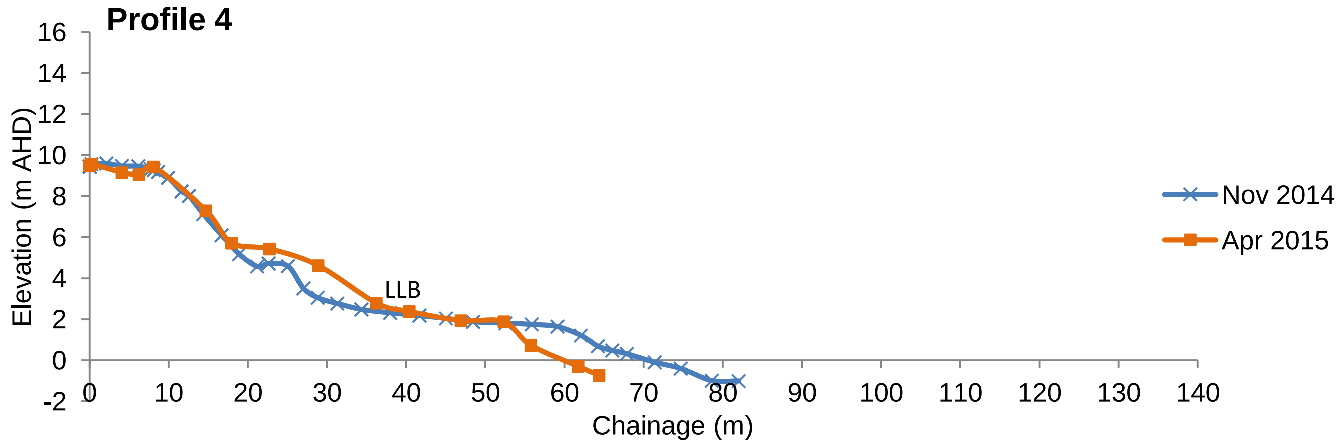
Appendix D

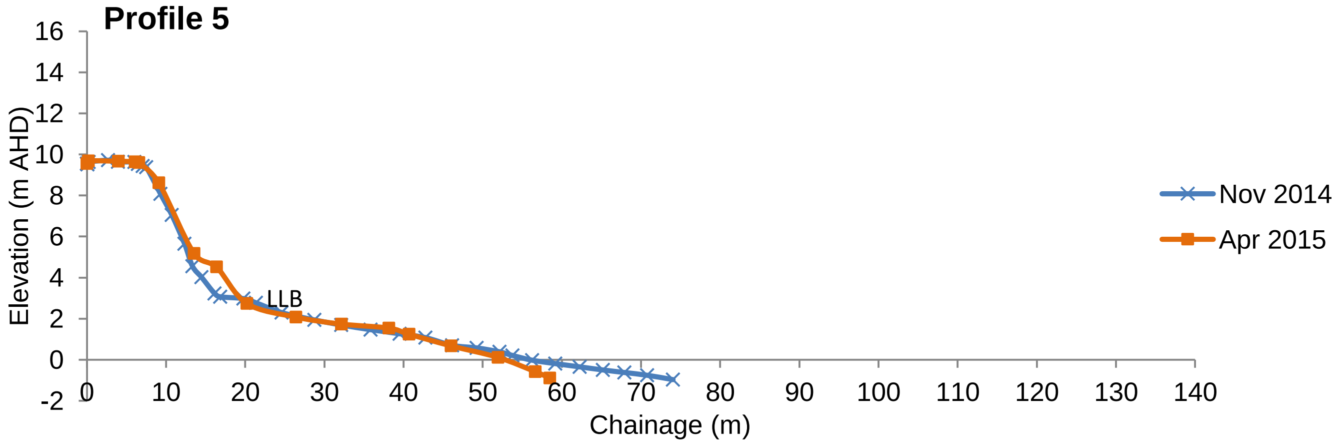
Beach profile data

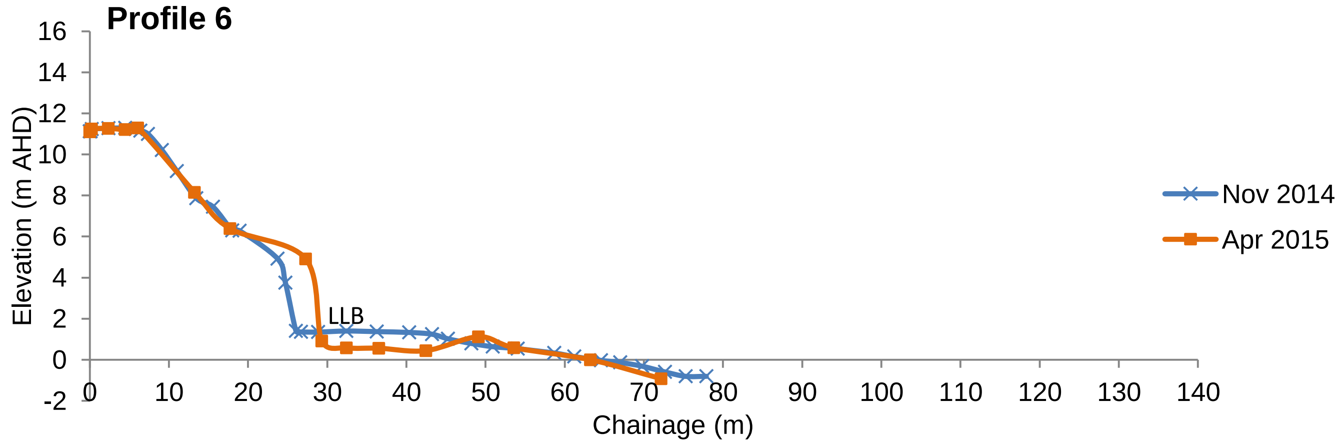

Profile 1
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

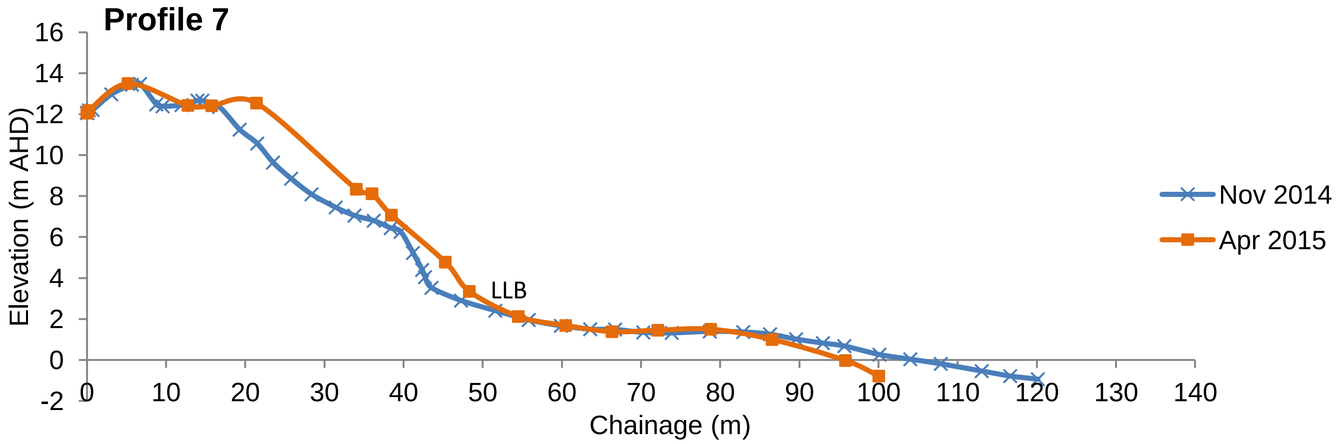

Profile 2
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

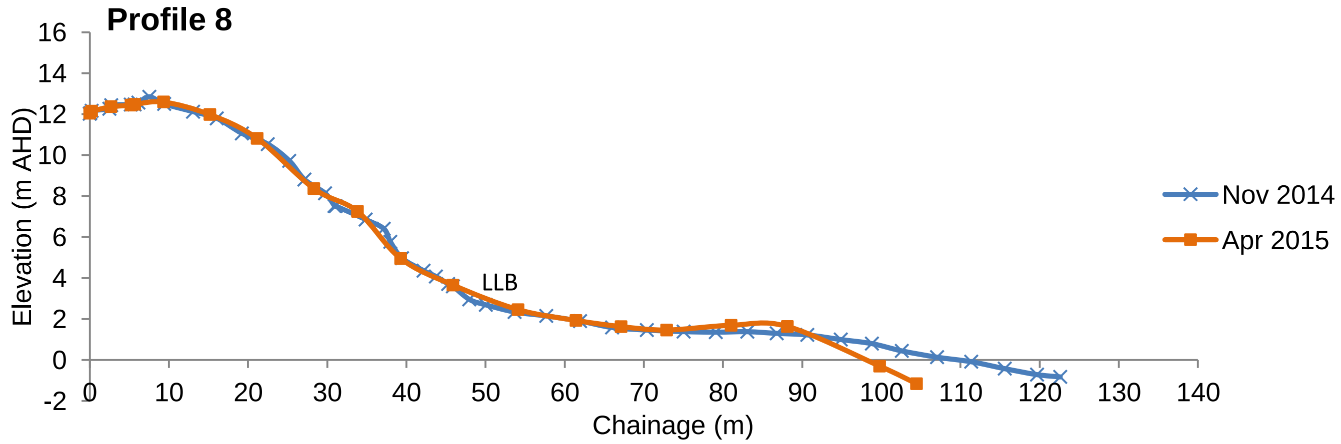

Profile 3
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

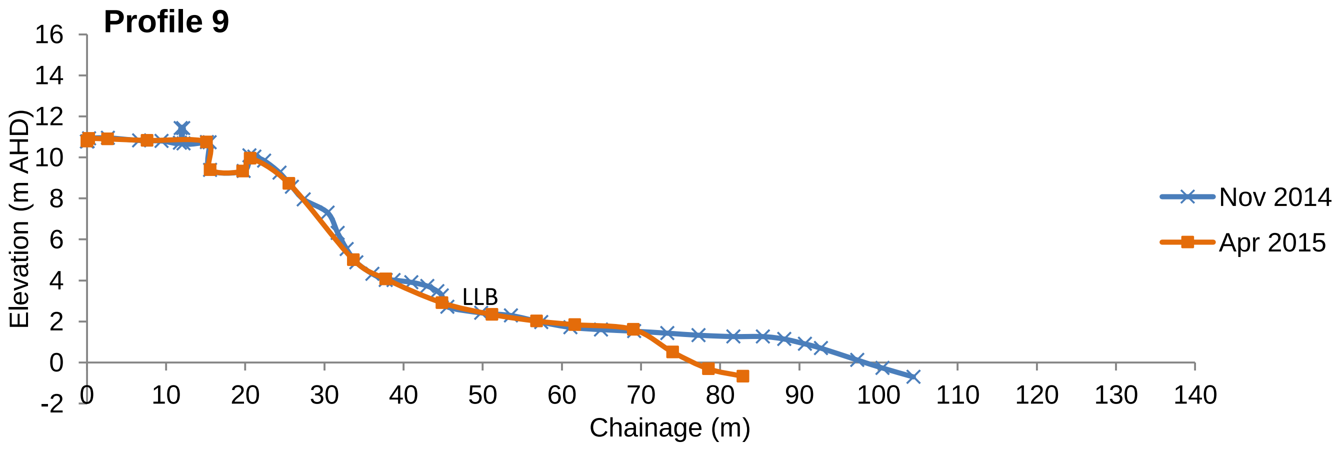

Profile 4
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

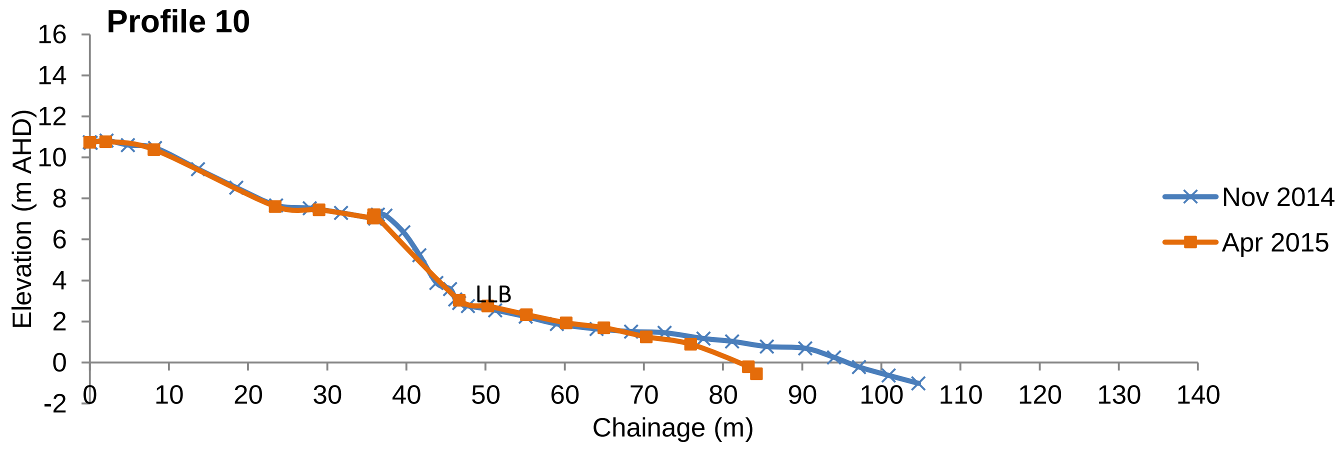

Profile 5
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

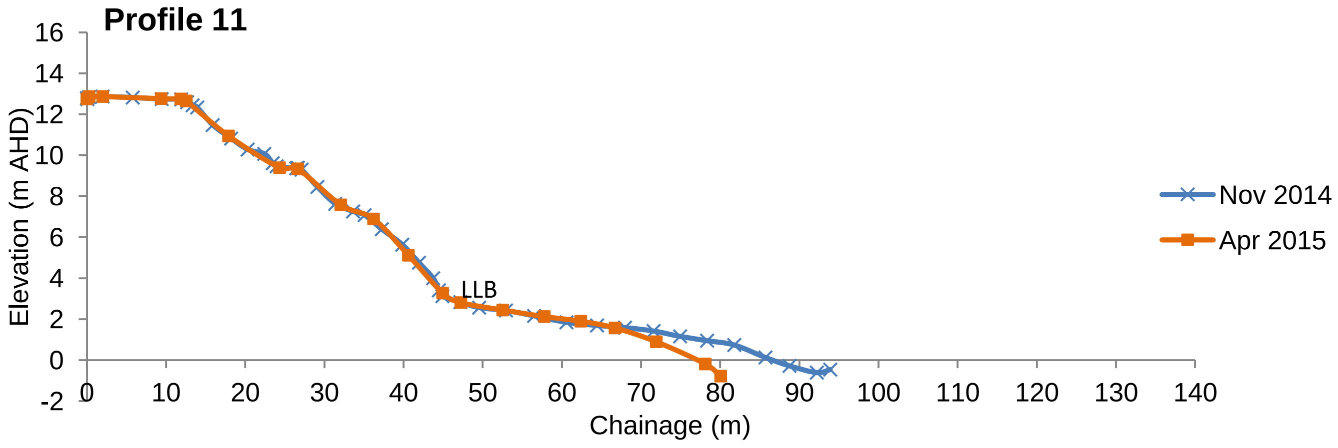

Profile 6
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

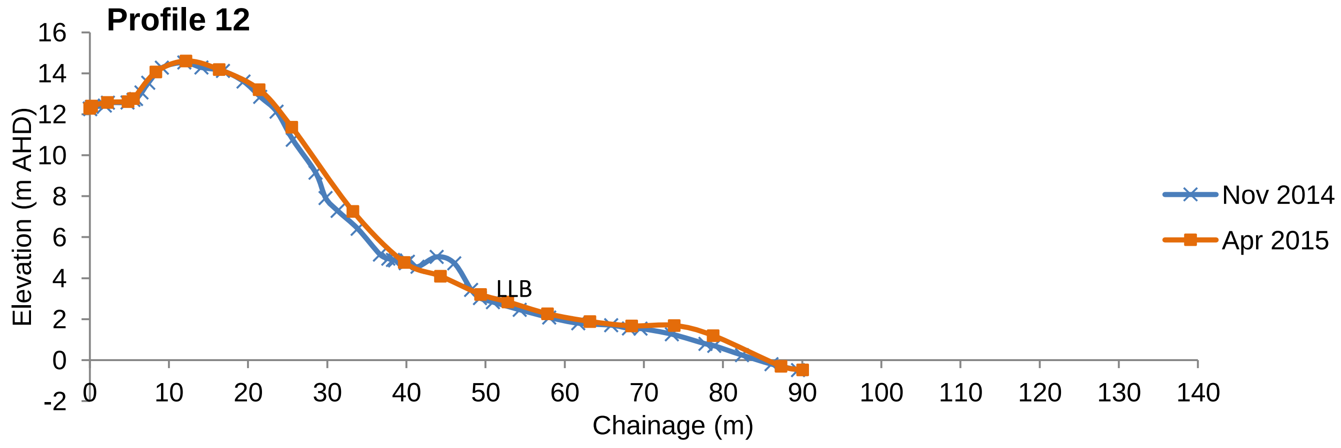

Profile 7
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

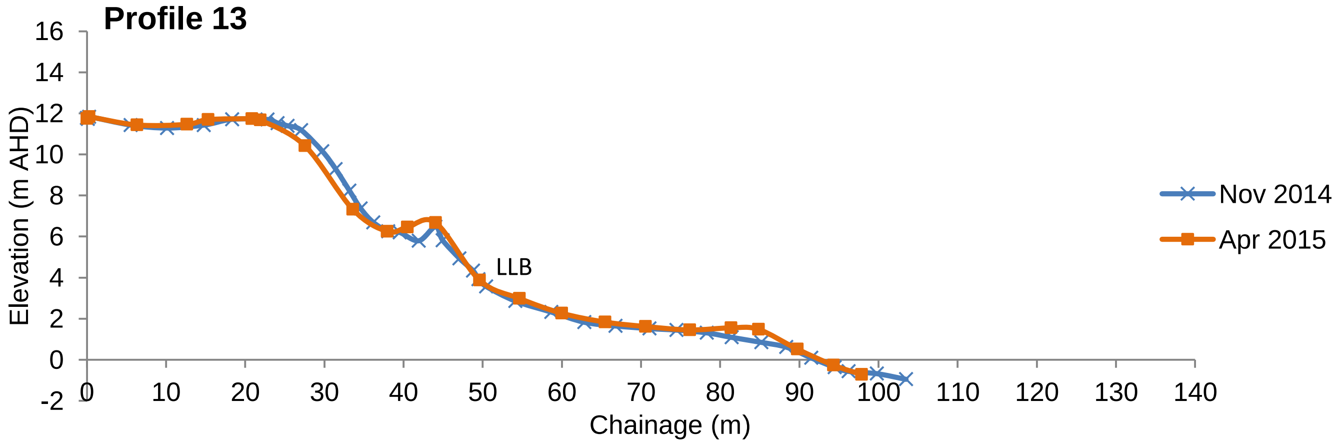

Profile 8
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

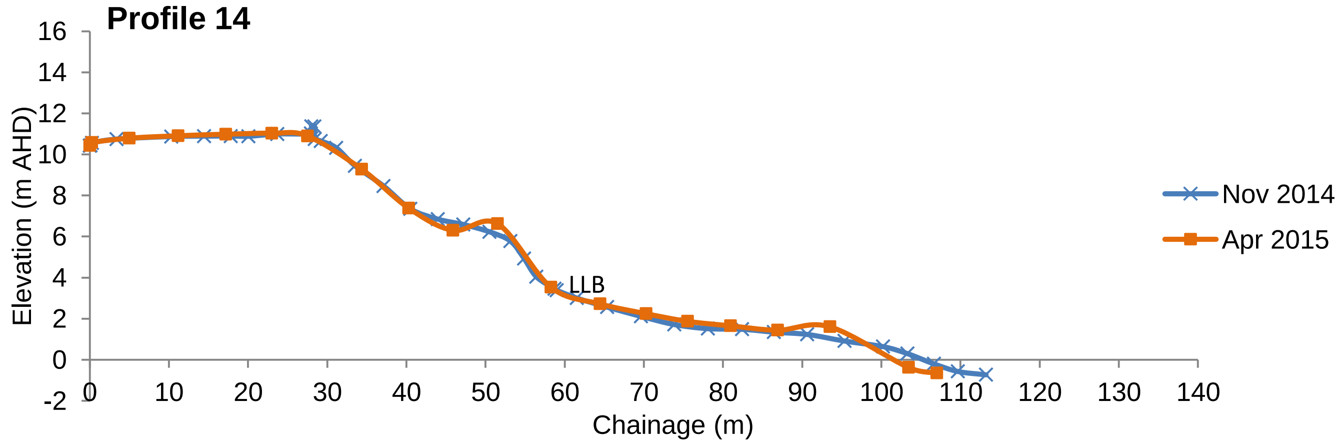

Profile 9
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

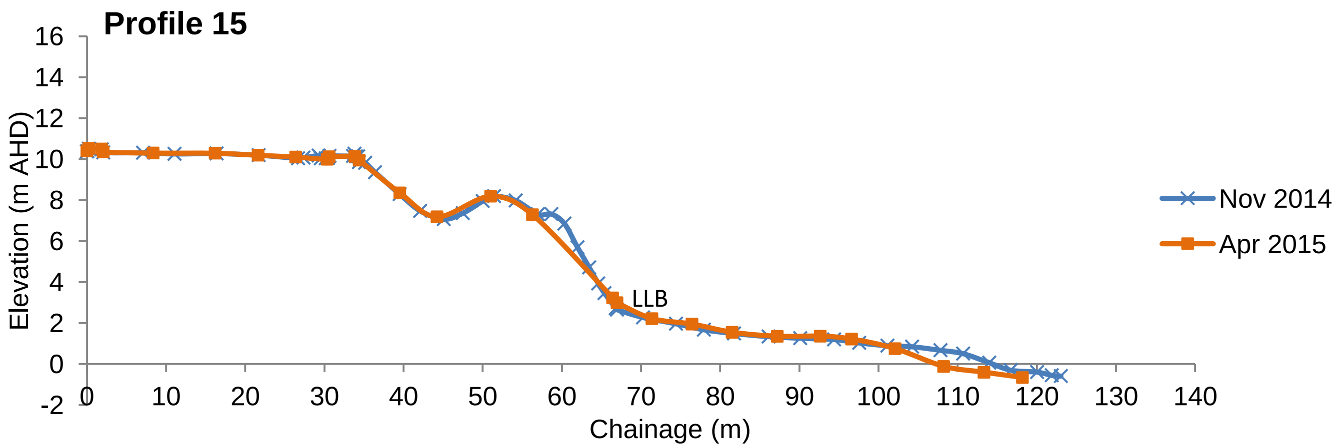

Profile 10
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

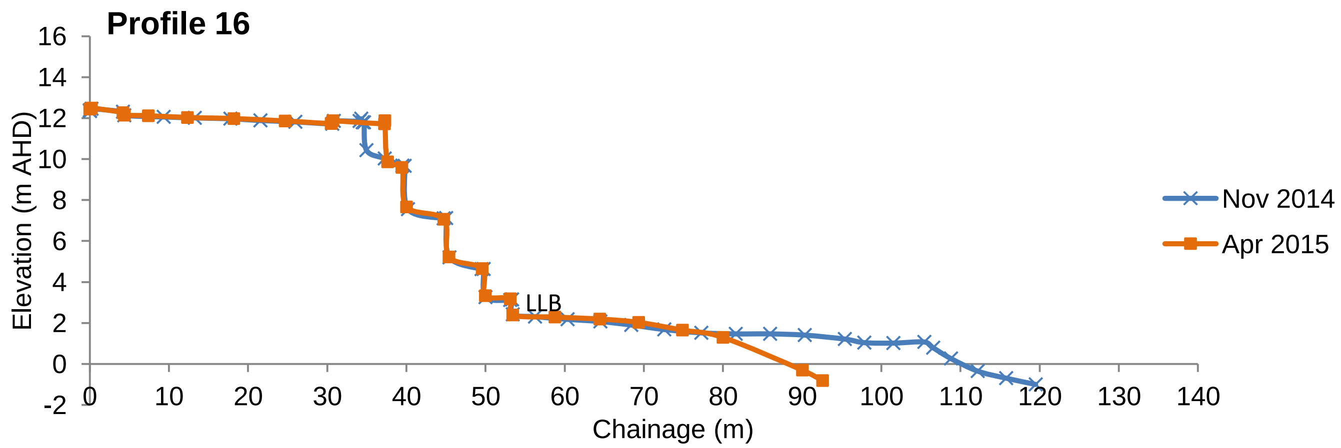

Profile 11
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

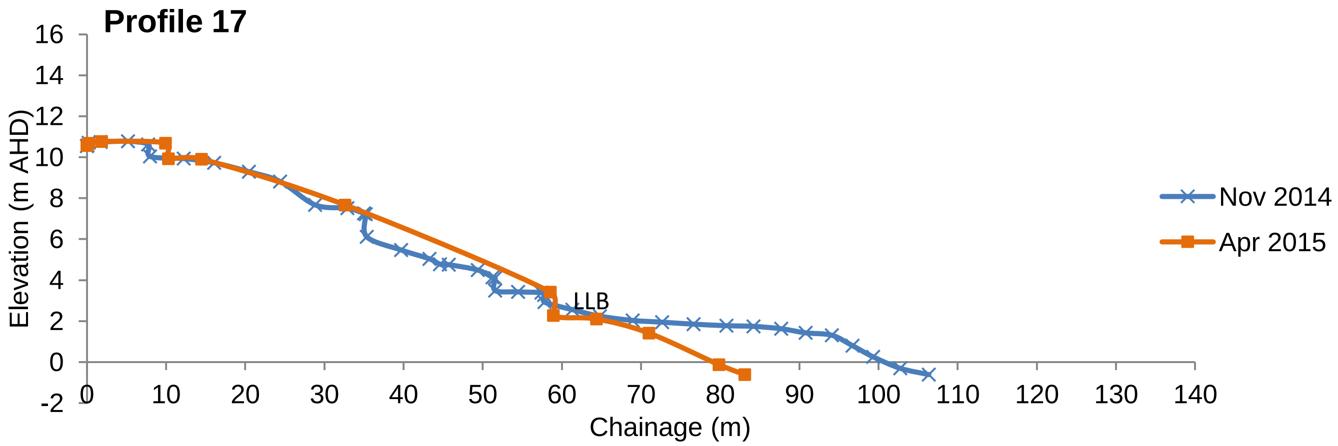

Profile 12
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

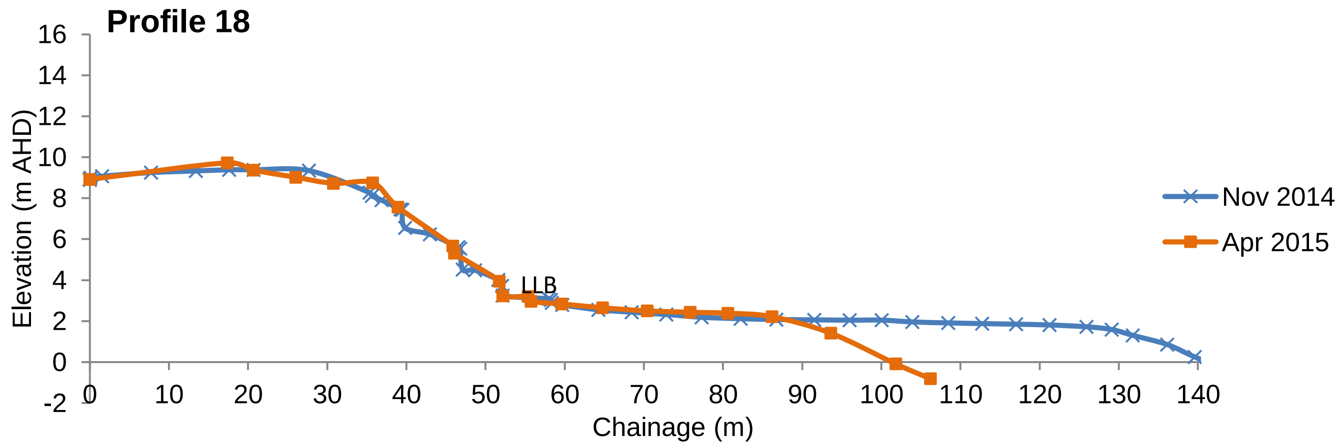

Profile 13
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

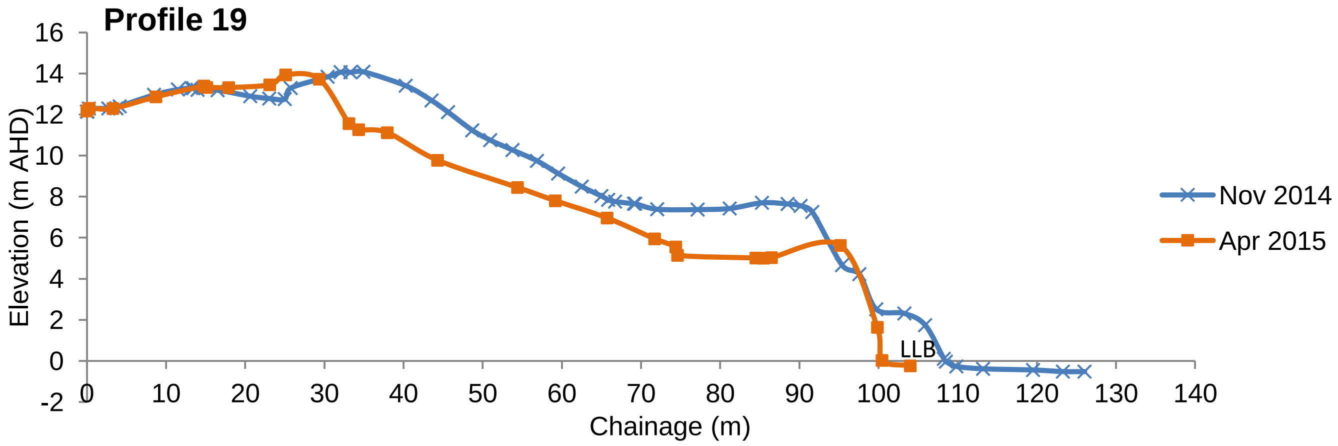

Profile 14
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

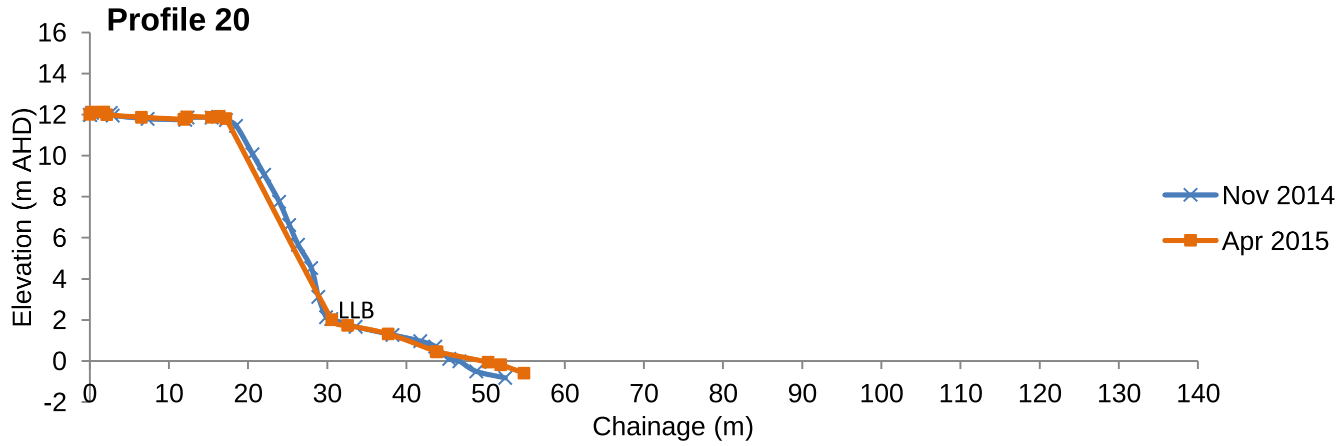

Profile 15
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

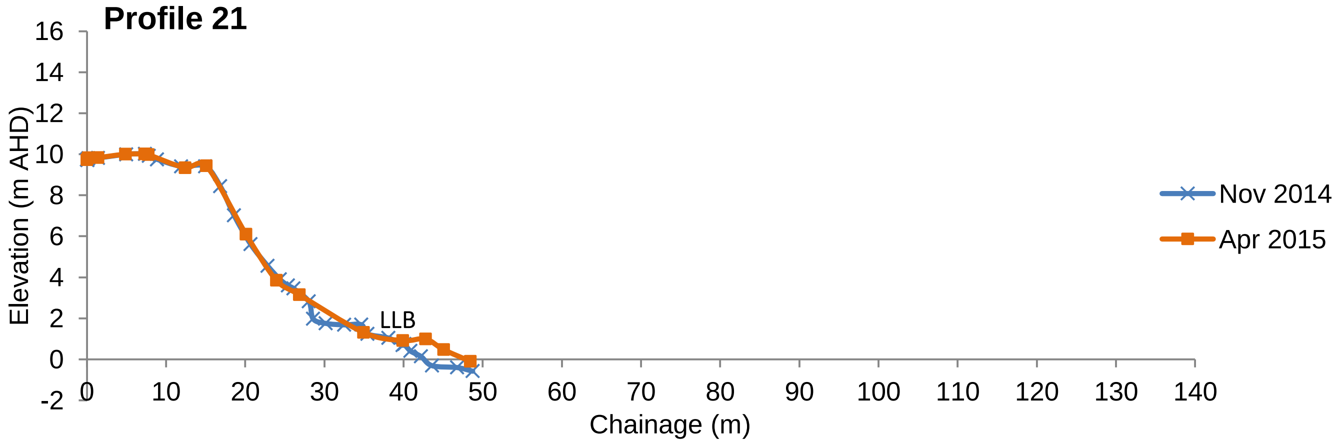

Profile 16
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

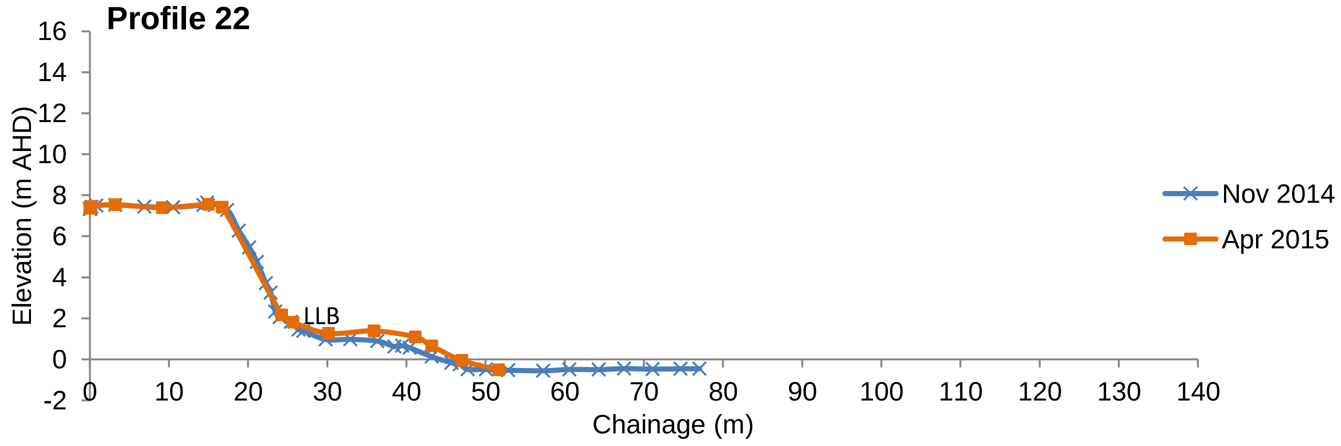

Profile 17
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

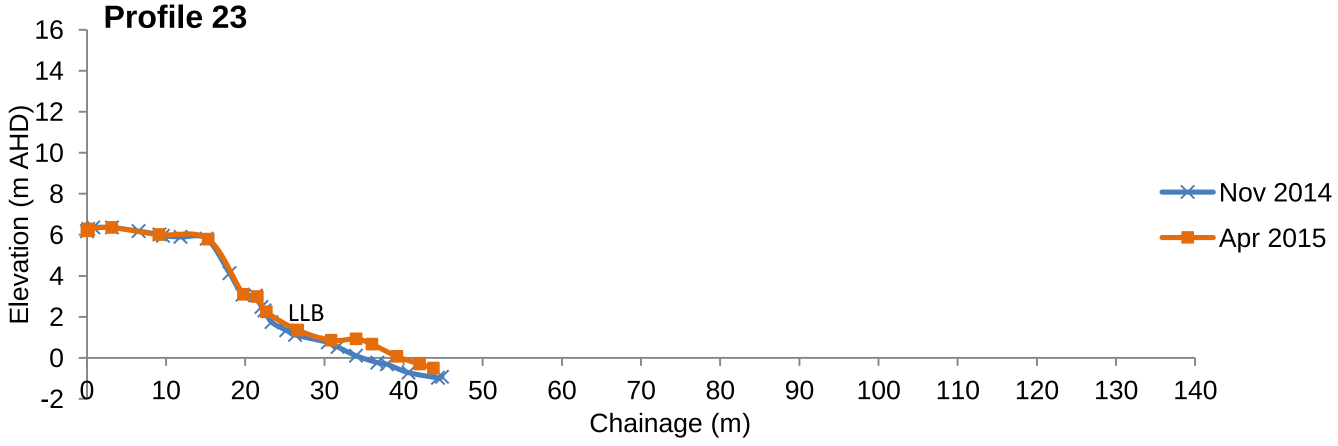

Profile 18
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

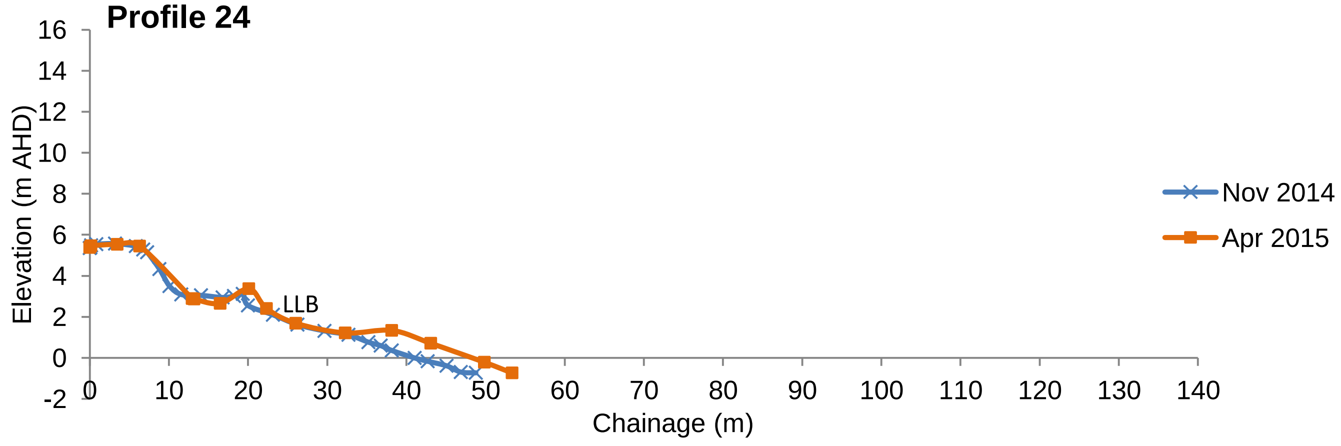

Profile 19
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

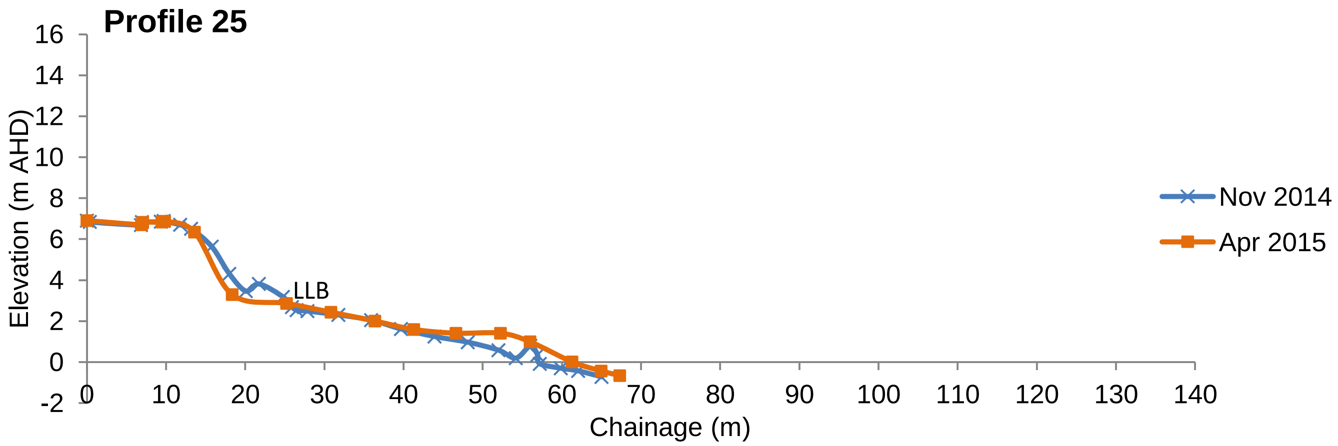

Profile 20
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

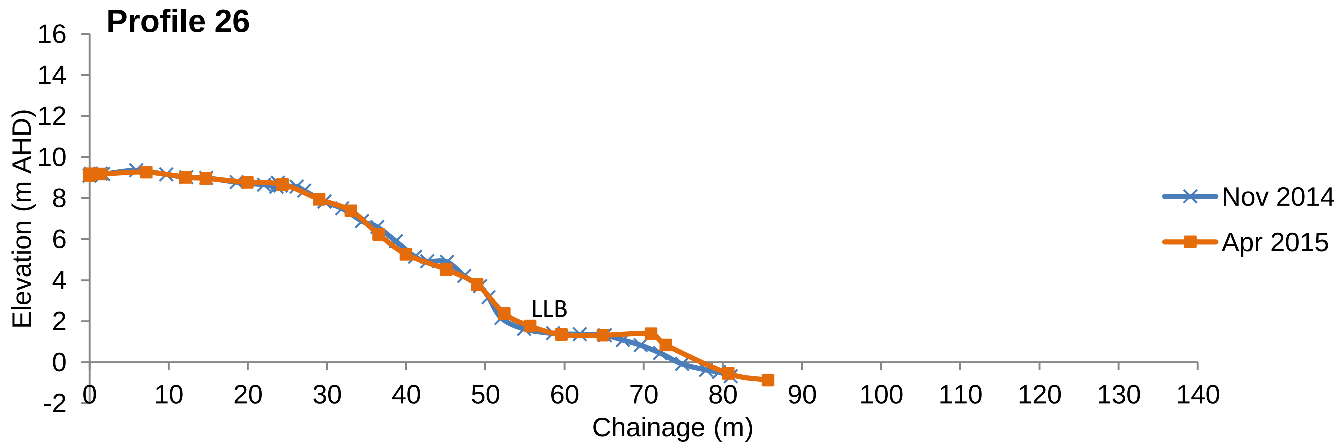

Profile 21
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

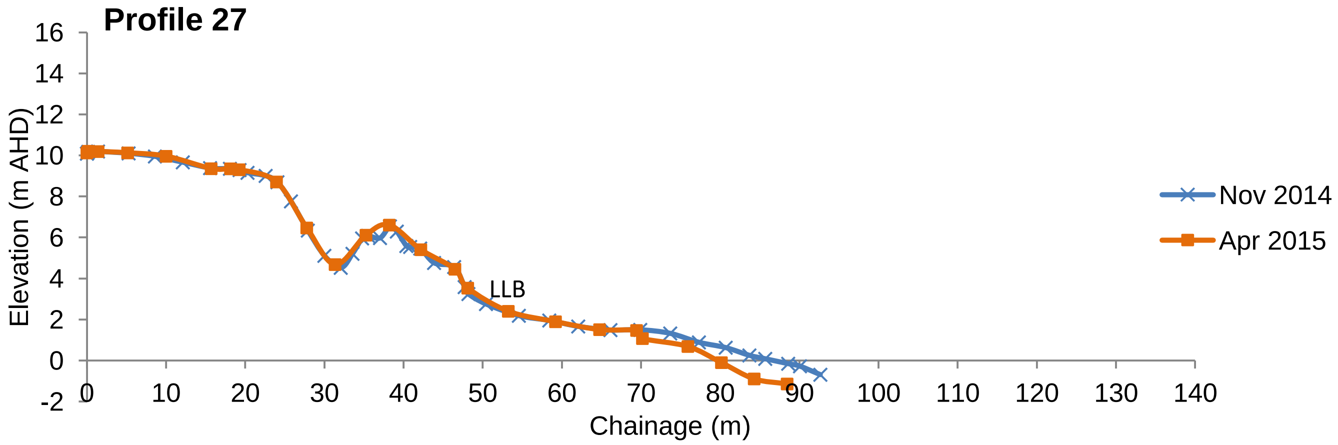

Profile 22
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

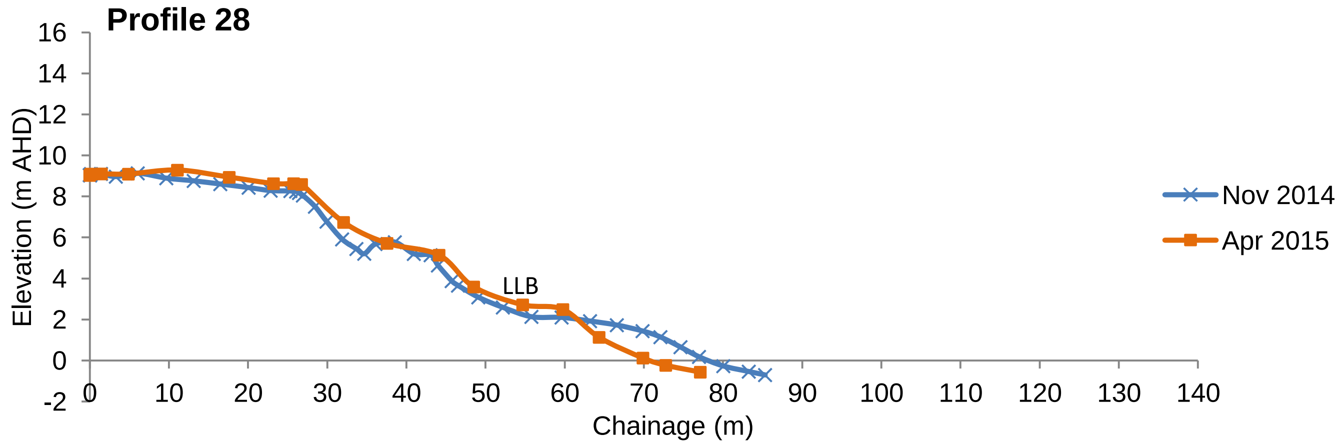

Profile 23
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

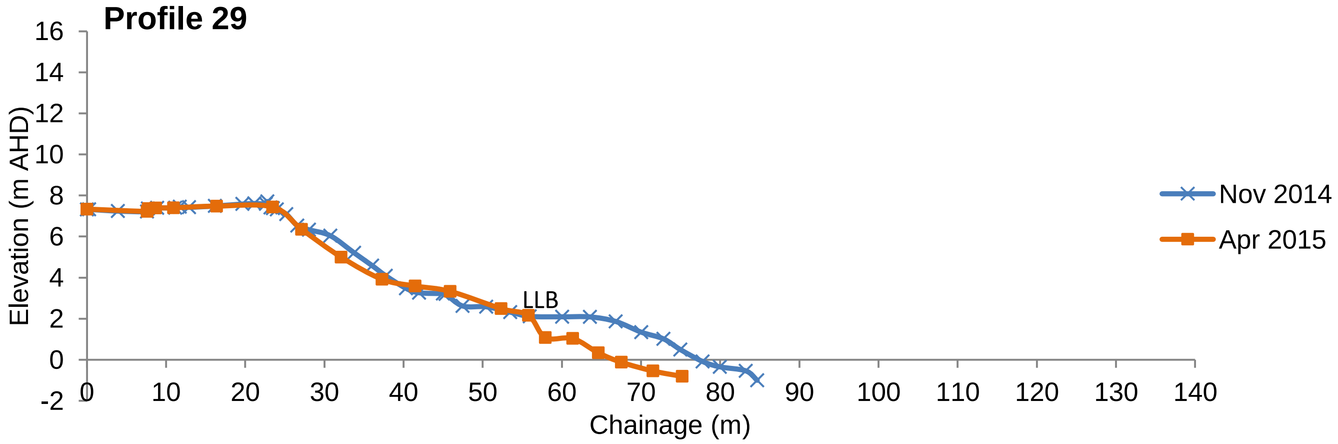

Profile 24
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

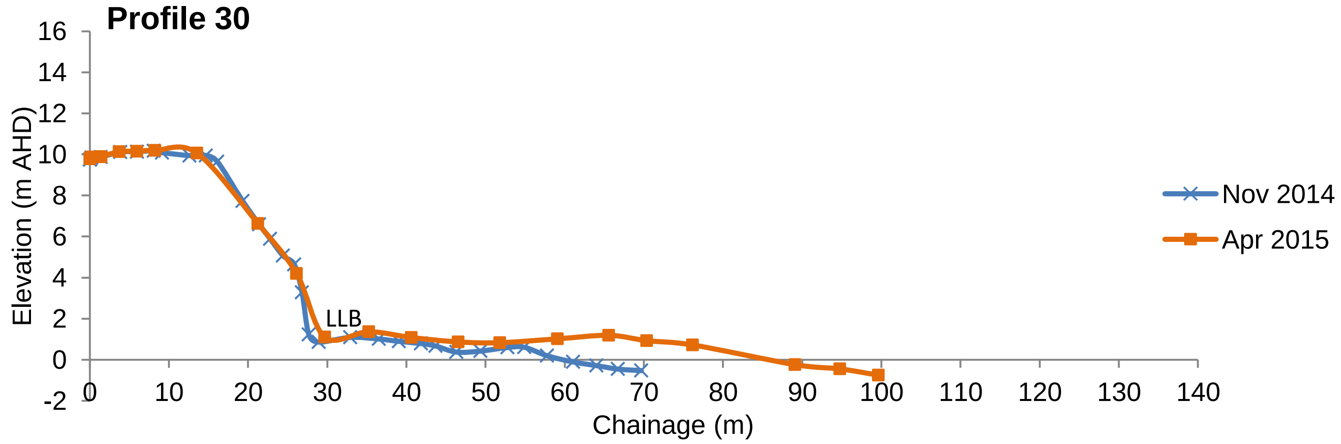

Profile 25
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

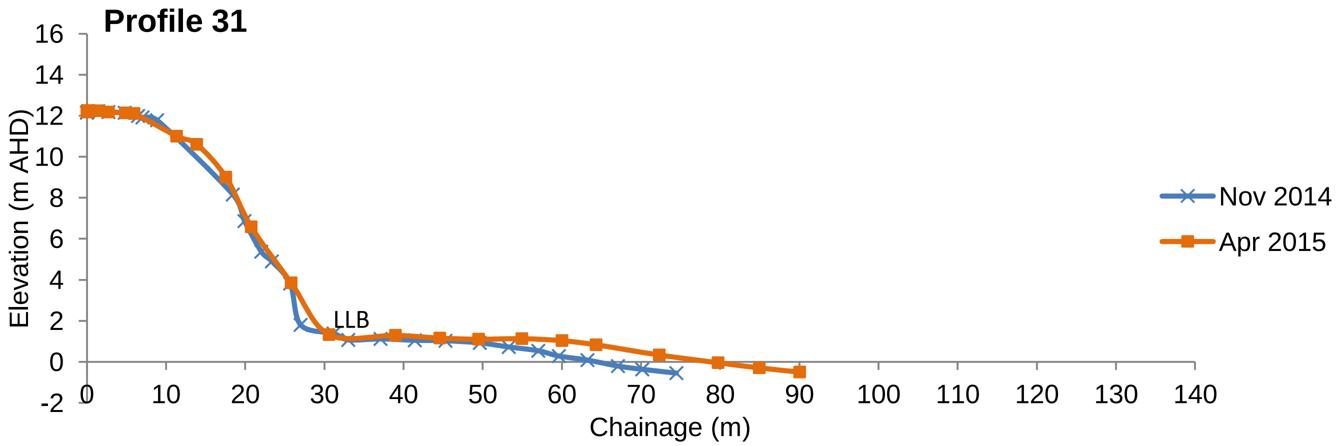

Profile 26
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

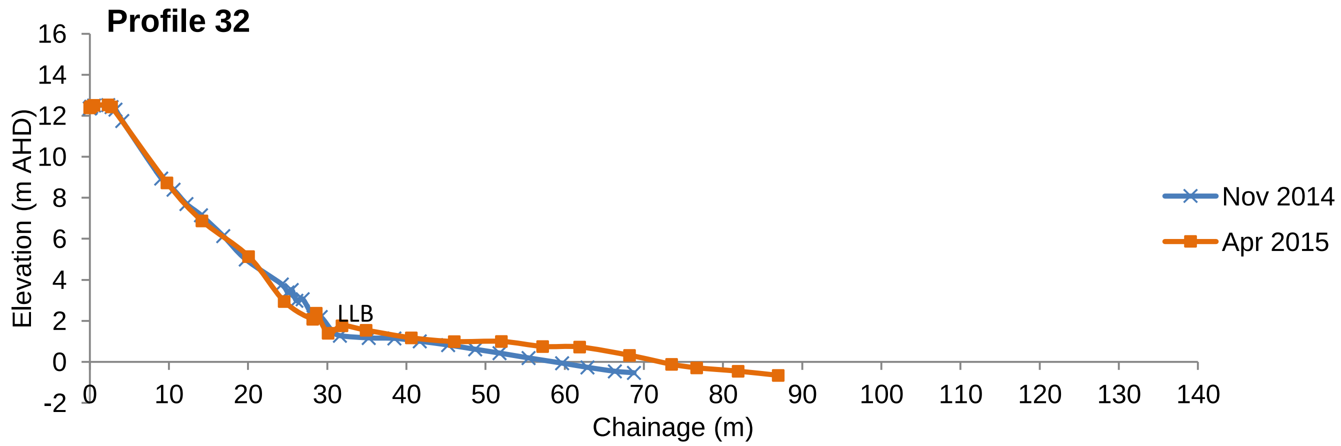

Profile 27
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

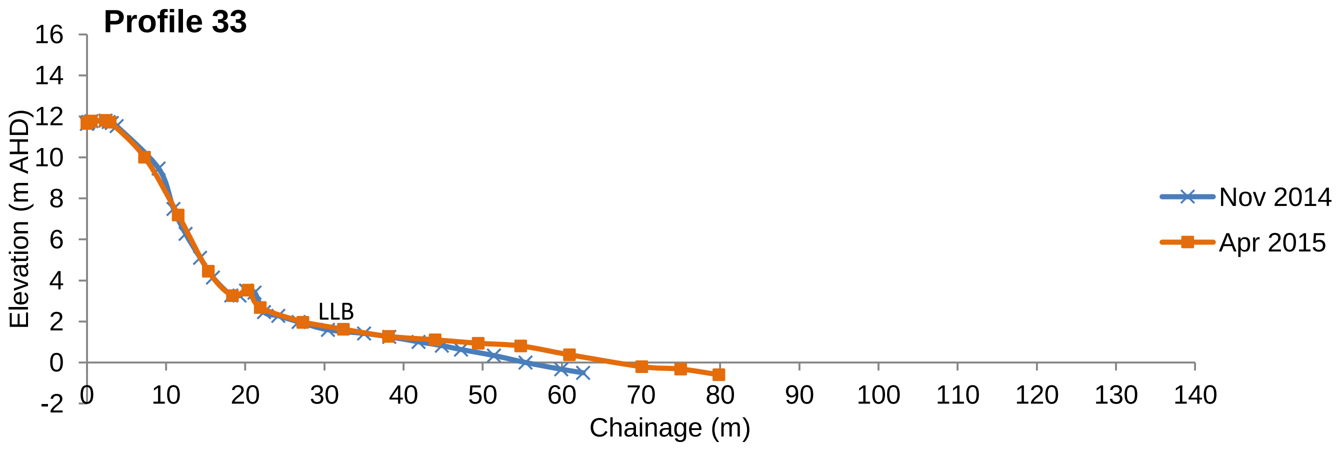

Profile 28
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

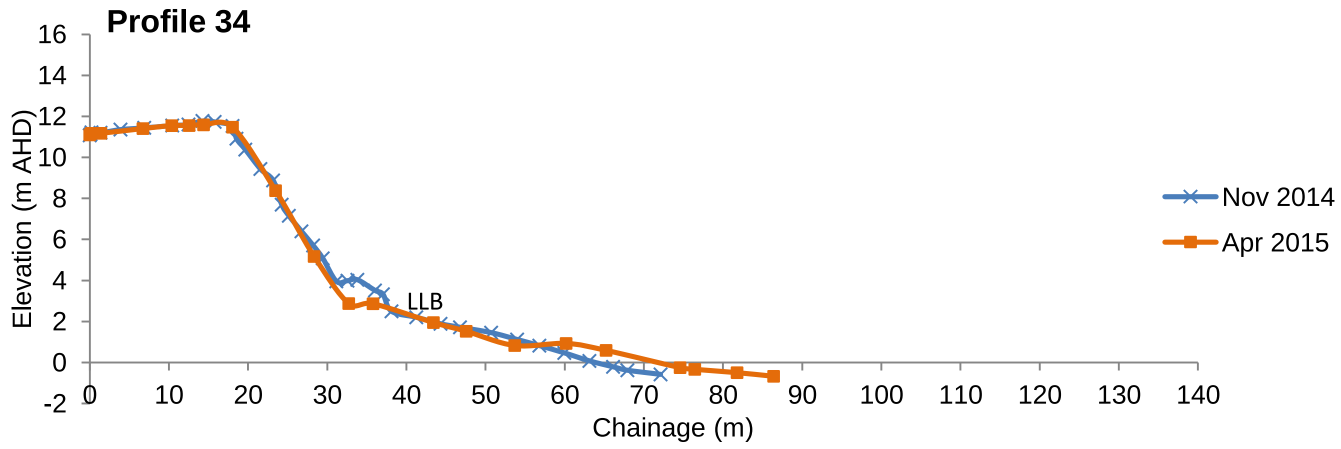

Profile 29
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

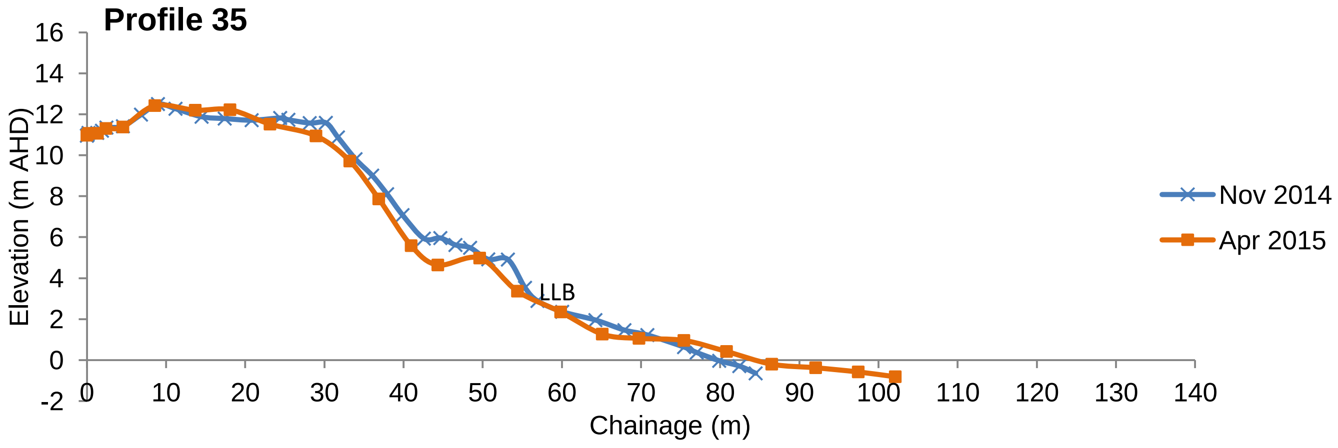

Profile 30
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

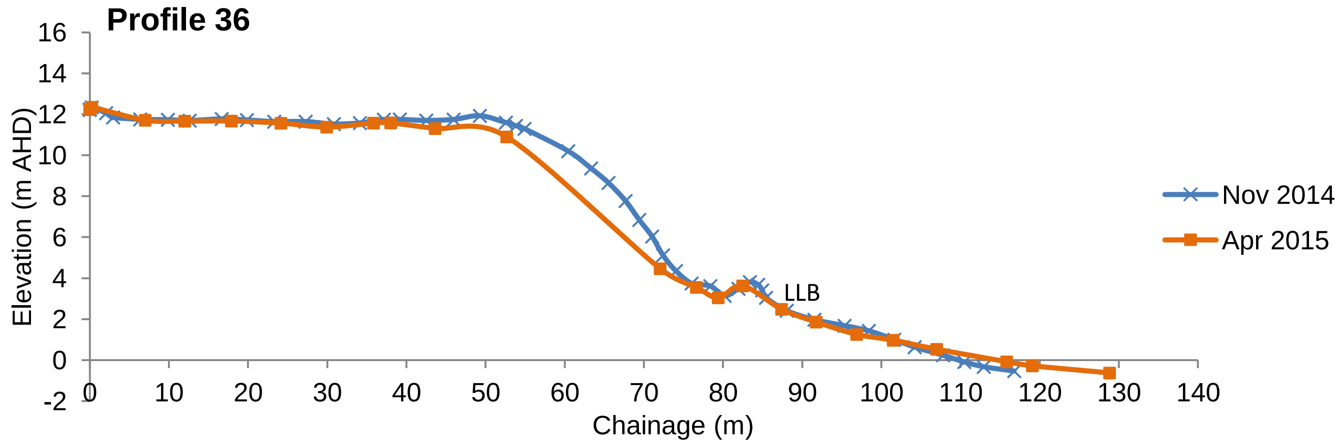

Profile 31
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

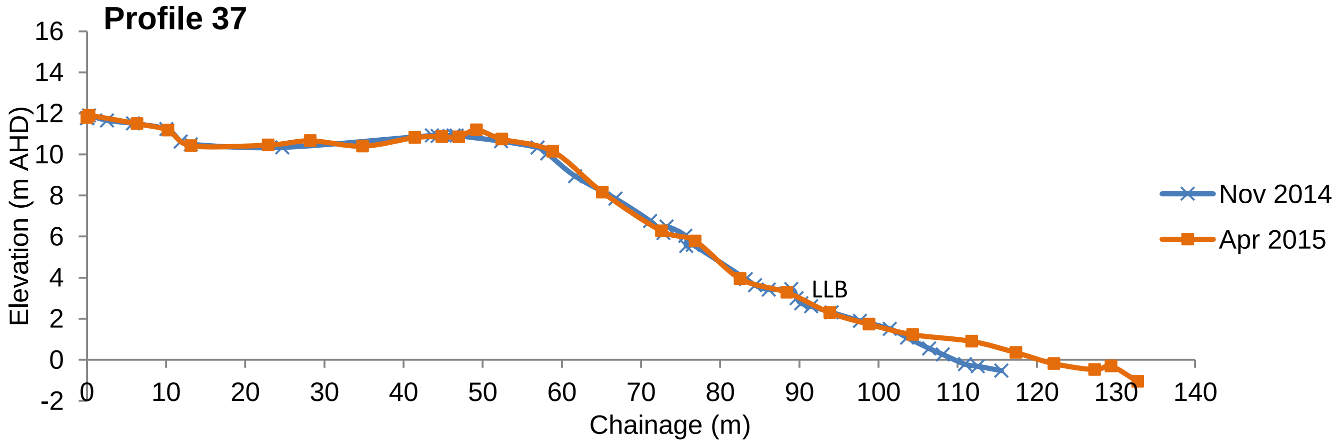

Profile 32
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

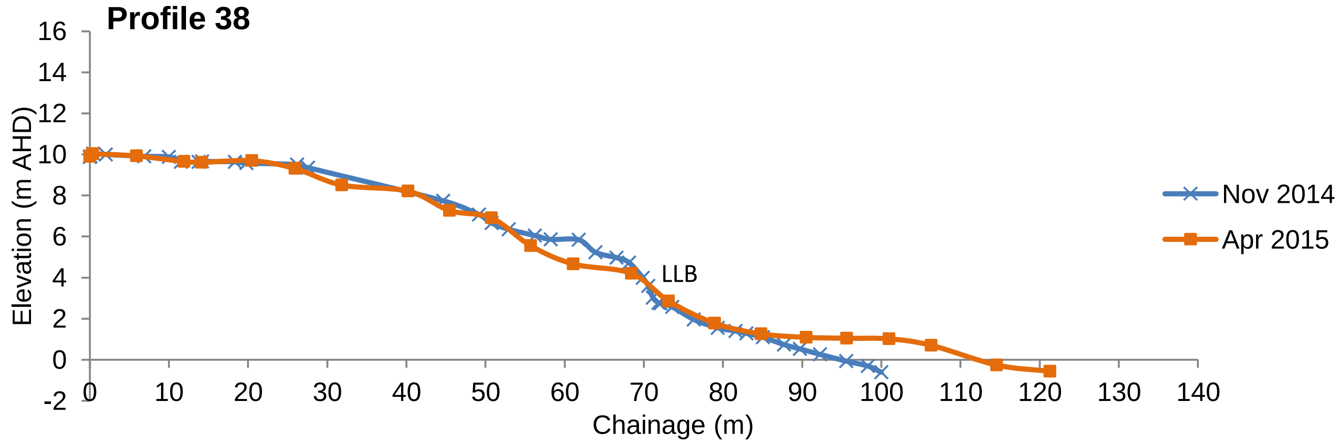

Profile 33
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

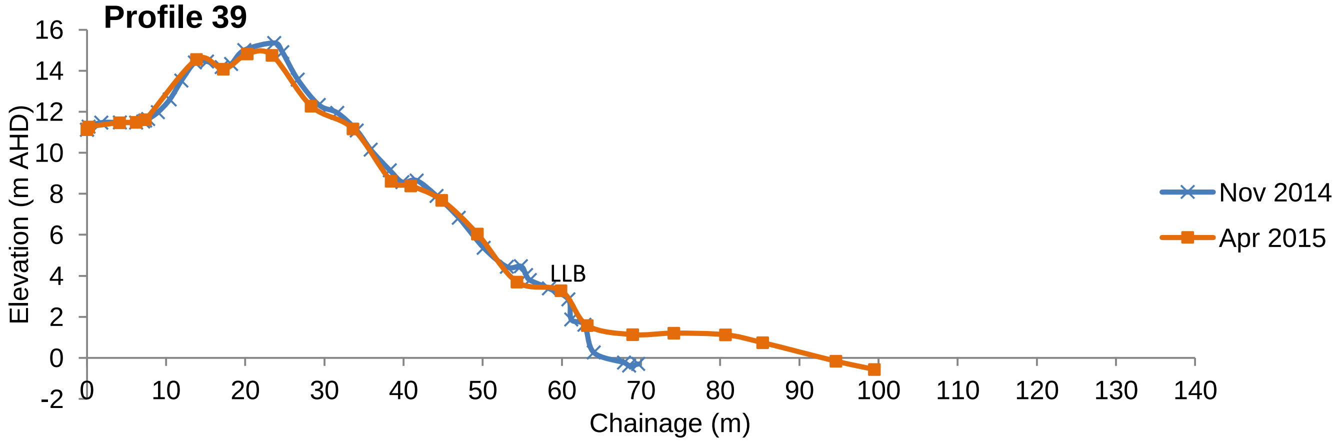

Profile 34
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015


Profile 35
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015


Profile 36
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015


Profile 37
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015


Profile 38
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015


Profile 39
Elevation (m AHD)
Chainage (m)
LLB
Nov 2014
Apr 2015

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