Appendix 18.1

Groundwater-Intertidal Zone Discharge: Conceptual Model

URS

Tidal Lagoon Swansea Bay

Groundwater-Intertidal Zone Discharge: Conceptual Model

November 2013

47065127
Supplement to PEIR / ES Chapter 18

Prepared for:
Tidal Lagoon Swansea Bay Plc

UNITED KINGDOM & IRELAND

Rev	Date	Details	Prepared by	Checked by	Approved by
1	September 2013	Draft	Elaine Gibson Graduate Environmental Scientist	Joanne Foy Associate Sean Needham Principal Hydrogeologist	Richard Knott Associate Director
2	October 2013	Revised Draft	Elaine Gibson Graduate Environmental Scientist	Joanne Foy Associate Sean Needham Principal Hydrogeologist	Richard Knott Associate Director
3	November 2013	Final	Elaine Gibson Graduate Environmental Scientist	Joanne Foy Associate Sean Needham Principal Hydrogeologist	Richard Knott Associate Director

URS Infrastructure & Environment UK Ltd
1 Drake Walk
Brigantine Place
Cardiff
CF10 4AN

Telephone: +44(0)2920 465 960
Fax: +44(0)2920 465 961

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 General Introduction

1.1.0.1 URS Infrastructure & Environment UK Limited (URS) has previously prepared a Land Quality and Hydrogeology chapter for the Preliminary Environmental Information Report (PEIR), submitted by Tidal Lagoon Swansea Bay Plc (TLSB) in support of their proposed tidal-powered electricity generation scheme.

1.1.0.2 The Land Quality and Hydrogeology chapter included a baseline assessment of the potential land quality conditions within the terrestrial footprint of the proposed development and the potential for environmental impacts associated with the development of the land.

1.1.0.3 The chapter also assessed the potential impact of the construction and operation of the proposed lagoon on groundwater conditions. URS concluded that the assessment would benefit from further investigation, assessment and modelling to allow better estimation of the potential for impacts on the groundwater regime within the intertidal zone. TLSB commissioned URS to undertake further evaluation of groundwater discharge within the intertidal zone and the potential impacts that might be associated with the tidal lagoon.

1.1.0.4 This report provides additional analysis of the likely current and future groundwater discharge regime within the area of intertidal zone that will be enclosed by the lagoon.

1.2 Background

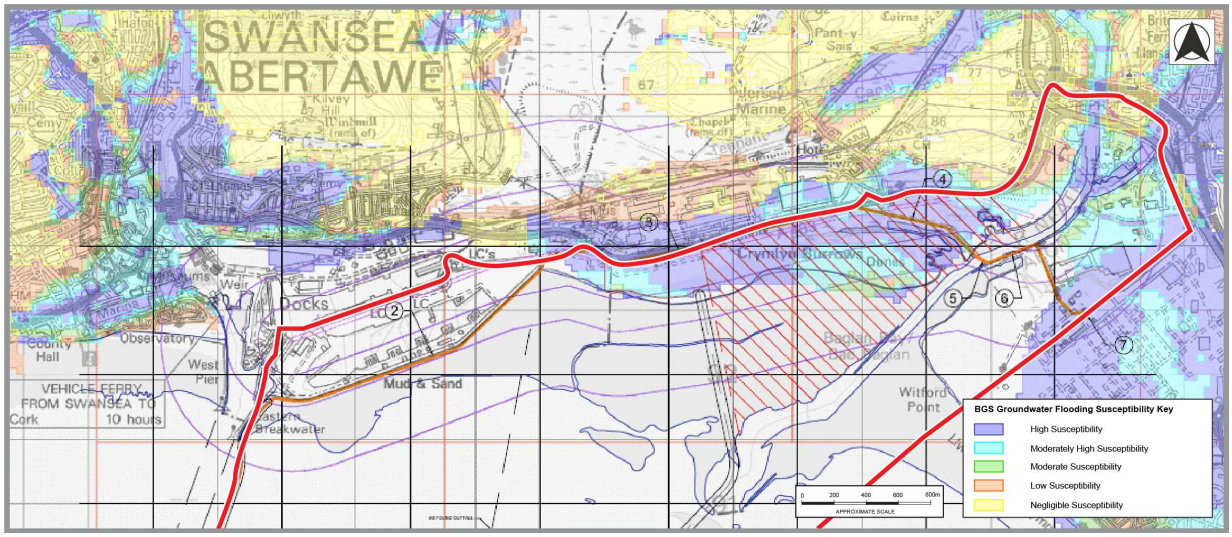
1.2.0.1 Operation of the lagoon for power-generation will require the water levels within the impounding basin to be managed, in order to provide sufficient head difference between the managed lagoon water level and the natural tidal water level within Swansea Bay. The managed head difference will be optimised over the full range of the tidal cycles (both twice daily flood / ebb cycles and monthly spring / neap cycles), to run the turbines efficiently.

1.2.0.2 The head difference is established by retaining the impounded lagoon high tide and introducing a time-lag as the natural tide level falls outside of the lagoon. Once sufficient head difference is established, power is generated on the falling tide, until the head difference is no longer sufficient to operate the turbines. In the latter part of the generation cycle the sluice gates are opened such that as much water is released as possible before the hold sequence on the returning tide is commenced. In this way the water levels within the lagoon are retuned as close as possible to that of the natural tide. The sluices are then closed until sufficient head difference is established for power generation on the incoming flood tide. This sequence is repeated over each flood / ebb tidal cycle, with the high water “holding level” and low water “sluicing levels” and associated holding lag time and power generation times all varied to optimise power generation across the full range of tidal conditions expected over each year. Appendix C1 shows a typical natural and managed cycle over a 24 hour period.

1.2.0.3 The proposed tidal lagoon encloses an intertidal area within Swansea Bay extending from the eastern wall of the River Tawe estuary across Swansea docks to the western

boundary of Crymlyn Burrows SSSI. In preparing the PEIR Chapter on Land Quality and Hydrogeology, URS identified that a proportion of the land along the foreshore / behind the foreshore within the proposed development area, is considered to be at risk from groundwater flooding, based on a published British Geological Survey (BGS) map classification.

1.2.0.4 PEIR Chapter 18, Figure 18.11, is replicated below to show the areas assessed by the BGS as being at "High Susceptibility" (purple) and "Moderately High Susceptibility" (pale blue) to groundwater flooding.



PEIR Figure 18.11: Groundwater Flooding Susceptibility mapping, including the northern redline study area boundary for the Project. **Sourced from Landmark Information Group Envirocheck® Report_ 43785108_1_1.**

1.2.0.5 Any modification of the groundwater regime within these areas, for example, as a result of changing the pattern of groundwater discharge through the intertidal zone, might result in higher or lower groundwater levels within the zone parallel and adjacent to the foreshore. With the "High Susceptibility" to groundwater flooding classification, any changes to groundwater levels within these areas could represent either a potential adverse or beneficial environmental effect.

1.2.0.6 The current groundwater levels in the foreshore area will reflect the available rainfall recharge within the groundwater catchment and the topography and hydrogeology of the groundwater catchment, including the area available for groundwater discharge through the intertidal zone. The groundwater flux through the intertidal zone will be controlled by the geometry of the discharge zone (area extent and depth of section), permeability of the beach deposits, the difference in groundwater head between the foreshore and the intertidal springs and seepage areas and the time available for discharge (controlled by the position and height of the tide).

1.2.0.7 Any changes to the existing groundwater system as a result of modifications to the tidal cycle might result in increases or decreases in groundwater level within the foreshore area, with the potential to increase / decrease groundwater levels and flood risk or to impact on groundwater salinity.

1.2.0.8 As discussed previously operation of the tidal lagoon will require that the natural tidal cycle is modified to maintain a seawater head difference between the enclosed lagoon waters and the external tidal waters of Swansea Bay. The head difference is established by holding the high tide level within the lagoon as the natural tide recedes or holding the low water prior to the incoming flood tide, effectively "shifting" the time-base between natural and operational tidal water level curve.

1.2.0.9 As such, holding the lagoon water at a different level to the natural tidal water level might result in changes to the groundwater flow pattern and discharge rates in and around the lagoon.

1.2.0.10 The western area, adjacent to Swansea Docks, is considered unlikely to be subject to any major changes in groundwater flow. The large body of water within the docks is currently held at a fixed head of approximately 4.74m above Ordnance Datum (mAOD). The Associated British Ports website (www.abports.co.uk/Our_Locations/South_Wales/Swansea/) states that Queen's Dock has a water depth of 10.67m, indicating that the docks infrastructure extends to a depth of at least -5.93 mAOD. The necessary low permeability of the docks' retaining construction results in no observed intertidal seepages along the foreshore adjacent to the docks.

1.2.0.11 The central and eastern areas of the foreshore that would be enclosed by the lagoon (from the former Queen's Dock oil terminal, through to the Swansea University Bay Campus (SUBC) and the eastern enclosing arm) do currently show intertidal groundwater discharges during the falling tide. Modification of the tidal cycle could potentially affect the groundwater gradient (head difference between standing groundwater level in the foreshore and the elevation of the spring discharges) that controls the rate of discharge and the time period available for groundwater discharge.

1.2.0.12 The area of foreshore between the former Queen's Dock oil terminal and the eastern lagoon enclosing arm is therefore the principal focus of this report. In terms of hydrologically sensitive features in the area, Crymlyn Bog SAC is located 400m to the north. Although distant, the potential effect on this feature will also be considered within this report.

1.3 Objectives

1.3.0.1 The principal objective of this report is to provide an assessment of the likely impact that construction, operation and decommissioning of the proposed tidal lagoon might have on groundwater discharges through the intertidal zone, and to assess whether such changes might result in associated environmental impacts.

1.4 Scope of works

1.4.0.1 To achieve the project objective presented above, URS and TLSB agreed that the assessment should be based on the following scope of work:

i. Review of topographic / bathymetric data for the foreshore area and intertidal zone to assess the extent and geometry of the intertidal zone.

ii. Definition of the areas enclosed by the natural high, mean and low tide marks, including variations between spring and neap tides (based on topographic map review, aerial photography review and walkover survey).

iii. Definition of the areas enclosed by the modified lagoon operation high and low water levels, again, including operational variations in the spring and neap tidal cycles.

iv. Delineation of those areas of the foreshore that would fall outside of the modified intertidal zone following the introduction of the modified tidal cycle; i.e. either fully submersed (below the modified low tide) or above the modified high tide.

v. Development of a detailed scale plan of the intertidal zone, with the features identified above mapped on to the plan drawing.

vi. Preparation of detailed sections through the intertidal zone groundwater discharge area to illustrate known / anticipated groundwater elevations, the current natural and proposed modified tidal limits and the expected groundwater gradients under each regime.

vii. Mapping of the current freshwater seepages / seepage zone and plotting of these onto the intertidal zone topographic plan and cross section drawings. Comparison of the current regime water level fluctuations and seepage areas with the modified tidal levels has been used to predict the future location of the freshwater seepage areas.

viii. Preparation of this report, presenting the data and intertidal zone plans / sections, along with an assessment of the likely changes in groundwater head gradients that might arise.

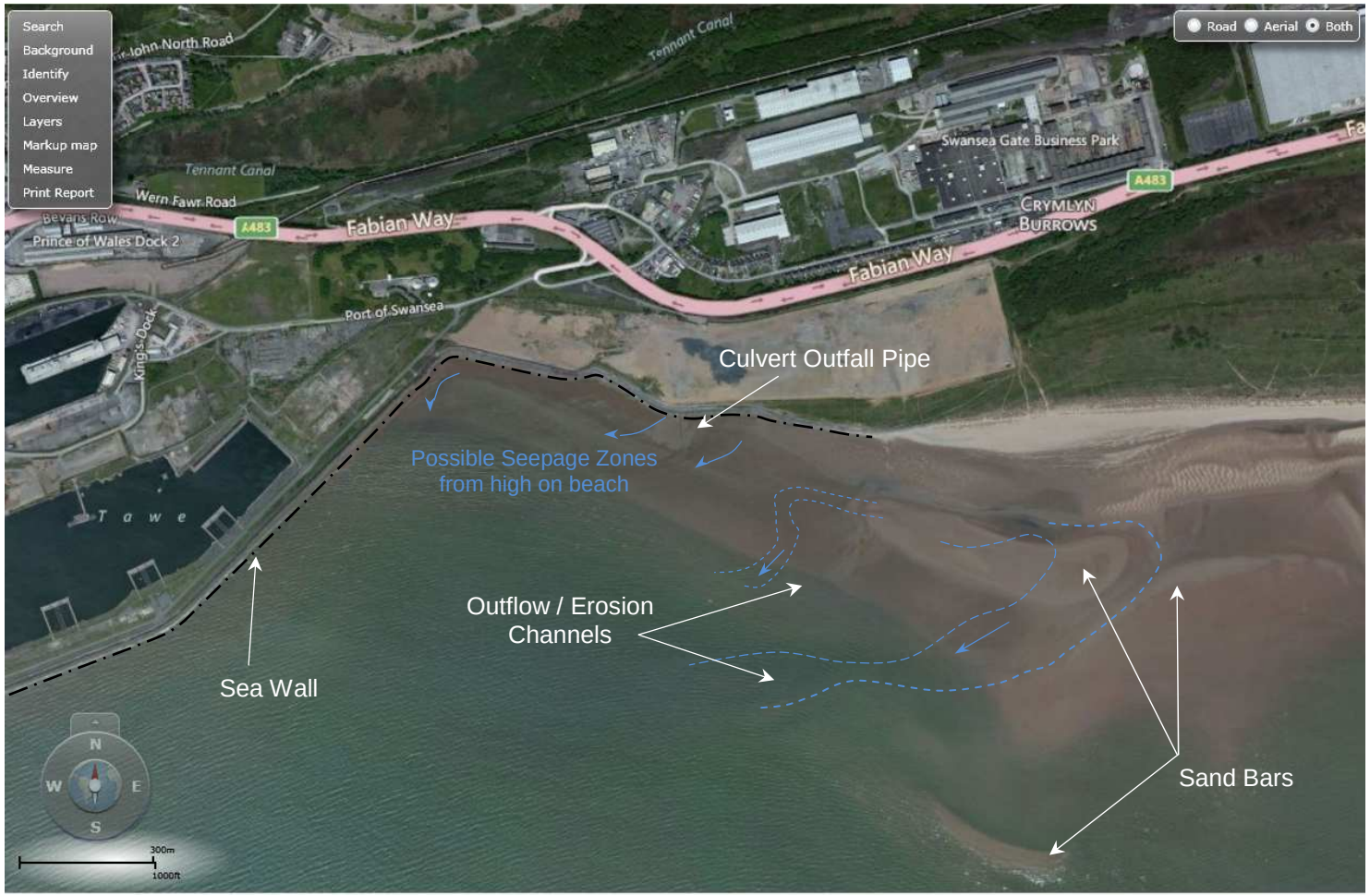
2.0 DATA REVIEW

2.1 Groundwater Discharge Locations

2.1.0.1 The locations of groundwater discharges on the foreshore has been assessed through the review of aerial photography, previous reports and site inspection.

Aerial Photographs

2.1.0.2 Aerial photographs of the site area from URS' in-house online database sources were reviewed in order to inspect the site setting and the intertidal zone. In particular topographic features which may indicate groundwater seepage to the intertidal zone were noted, along with changes which may influence or indicate groundwater flow into this zone.



Aerial Photograph 1. Aerial photography of the intertidal zone within the study area, with sand bars, erosion / outflow channels and seepage areas annotated. **Sourced from URS online mapping resource Ref.: http://geospatial.ursglobal.com/webmap/**

2.1.0.3 Aerial Photograph 1 shows that topographic rises and depressions are apparent on the beach; the most prominent feature being an outflow channel running in an west-east direction approximately half way between the existing Port seawall and low water mark and outflowing to the sea in the centre of the photograph. This feature is also marked on the Ordnance Survey map of the area which indicates the outflow channel is a semi-permanent feature.

Previous Reports

2.1.0.4 The Environmental Statement provided for the Swansea Bay Campus[1] includes some details of the intertidal zone that are relevant to this study. That report describes surface water/beach water sampling results from the intertidal zone to the immediate south of the SUBC i.e. inside the proposed lagoon area, to the west of eastern lagoon enclosing arm. It is reported that benzene and other volatile organic compounds were detected in two samples of water from the beach (TSBW5 and TSBW7). These locations are shown to be high up the beach profile, close to the sea wall/dunes in the area inspected by URS as described below. It is further reported that these compounds were not detected in samples collected from samples further down the beach. The samples were collected in 2007 when sample results also indicated high concentrations of VOCs within the former Transit Site tank farm. It is noted that the report indicates no detection of these contaminants in beach samples in April 2008, and no further data is available.

2.1.0.5 This data is useful in this assessment of the beach / intertidal zone groundwater seepages, as the detected VOCs effectively provide tracers for groundwater derived from above the foreshore area (in this case, contaminated groundwater from the former tank farm area). That the compounds were only detected in locations at the top of the beach infers that these were the only locations where there was a fresh groundwater contribution to the beach water. Conversely the lack of VOC detections further down the beach indicates a probable lack of groundwater contribution to shallow water in that area of the beach, which is inferred to comprise saline groundwater or tidal bank storage.

2.1.0.6 Appendix 14-2, Annex A – Site Geological and Hydrogeological Information (of the Bay Campus ES Report) is included as Appendix E of this report, along with a location plan for the onshore groundwater monitoring well locations and intertidal zone beach sampling locations (including TSBW5 and TSBW7, referred to above).

Site Inspection

2.1.0.7 A site inspection was conducted over a three hour period spanning two hours before low tide and one hour after low tide. The low tide at this time was at an elevation of approximately -4.4 mAOD (based on internet published tide tables for Swansea) indicating spring tide conditions.

[1] URS Corporation Ltd, (2010); Report Ref.: 49311733/, The Bay Science and Innovation Campus, Swansea University. Environmental Statement, 2010. Volume II & III Technical Appendix 14-1 & 14-2

2.1.0.8 The central and eastern areas of the foreshore within the proposed lagoon were inspected, along with a section of foreshore immediately east of the eastern enclosing arm (foreshore in front of Crymlyn Burrows). The intertidal area was inspected for topographic variations, groundwater seepages and any factors which may influence groundwater outflow onto the beach. Inspection began to the east of the proposed eastern lagoon arm and moved southerly towards the low tide mark before turning across the beach in a westerly direction, parallel to the coast and finally north towards the coastal sea defence wall. Locations are numbered in order of inspection and shown in Figure 1 of Appendix A.

2.1.0.9 The overall gradient of the intertidal zone was noted and the extent of areas of topographic highs and lows recorded using a hand held GPS instrument. These topographic features are plotted onto Figure 2 (of Appendix A) on the basis of the GPS readings taken and the grid lines marked on previous figures supplied to URS. The prominent outflow channel noted from aerial photographs and Ordnance Survey mapping was inspected to verify its location on the beach and water quality testing undertaken to determine whether the outflow was predominantly freshwater (freshwater groundwater discharge) or predominantly saline (either discharge of seawater bank storage from the beach deposits or denser saline groundwater from an underlying saline wedge).

2.1.0.10 The foreshore area was inspected for water seepages and locations noted using GPS co- ordinates and plotted as shown on Figure 2. The setting of each seepage was noted in relation to its outflow point onto the beach, any topographic differences surrounding the seepage which may influence it and its location in relation to the seawall in a west – east and north- south direction. Seepages were inspected for visual and olfactory observations, the findings of which are presented in Appendix B1. Field parameter readings of seawater and seepages were recorded including temperature, conductivity, dissolved oxygen, pH and redox potential as shown in Appendix B and discussed Section 2.2.

2.1.0.11 Whilst water seepages were observed over a large area of the beach, the more distinct areas of seepage were close to the existing Port / former tank farm seawall or sand dunes. In general, along the western section inspected, the seepages were from the base of the existing seawall, whilst to the east, where both dunes and seawall are present, the seepages occurred slightly away (approximately 100m) from the base of the wall/dunes. This data has been used in the preparation of two cross sections showing the topography of the land, the seawall/dunes and beach, areas of seepage and groundwater and seawater elevation.

2.1.0.12 The seawall / rock armour erosion protection was also inspected. In the western section of the inspection area it was observed to comprise large boulders with the reclaimed land immediately behind it. Further east the level of the seawall reduced and a series of sand dunes were noted behind the seawall.

2.1.0.13 The inspection was not extended further to the west due to previous observations indicating a lack of seepages in this area, i.e. adjacent to the standing water body of Queen's Dock. This is anticipated to be due to the presence of the constructed dock which will act as a barrier to shallow groundwater flow in this area.

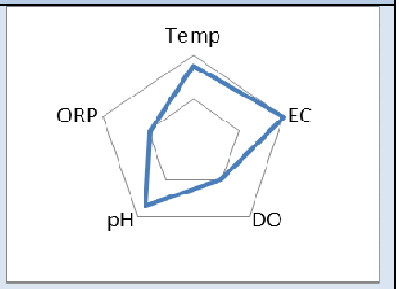
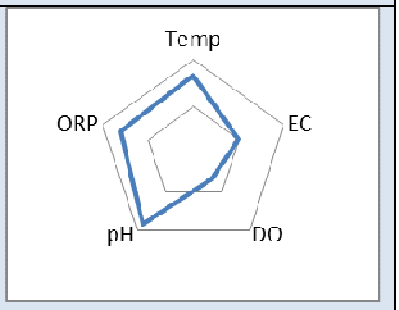
2.2 Groundwater Chemistry Review

2.2.0.1 As detailed above, readings of the temperature, electrical conductivity (EC), dissolved oxygen (DO), pH and oxygen reduction potential (ORP) were taken at a number of locations on the beach. Readings were taken from water discharging from seeps, or in rock pools and where required from shallow scrapes in the sand.

2.2.0.2 The readings obtained have been used to assess the salinity of the sampled water and therefore provide an indication of whether fresher groundwater is contributing to the discharge at a particular location. The EC readings provide a measure of salinity with the higher EC readings indicating more saline water. Readings were taken from a rock pool at Point 9 as this was anticipated to represent seawater and can therefore be used as a reference point for comparison and interpretation of the remaining data. The EC of this sample was the highest recorded at 43,849 µS/cm. DO can also be used as a good indicator of groundwater as DO would be expected to be lower in groundwater samples than in seawater. Temperature, pH and ORP do not provide such a strong indication of fresh groundwater or seawater, however they do add to the water quality signature of the samples.

2.2.0.3 In order to compare the readings taken and assess whether the water sampled had a fresh groundwater component, radar plots were produced for each sample. A nominal maximum value from the entire data-set was selected for each parameter, and the raw data for each sample location converted to a proportion of this maximum. This allows different parameters to be plotted on comparable scales as shown in Table 1.

Table 1: Selected Water Chemistry Data

Point	Parameter	Temp ℃	EC µS/cm	DO (mg/l)	pH (-)	ORP (mV)	Radar Plot
	Scale	20	43849	14	9	-350	
9	Value	17.57	43849	6.89	7.68	-169	
	Proportion of scale value	0.88	1.00	0.49	0.85	0.48	
19	Value	16.68	22153	4.53	8.13	-279	
	Proportion of scale value	0.83	0.51	0.32	0.90	0.80	

2.2.0.4 The example above shows a clear difference between the seawater reference sample (Point 9) and a sample indicative of a higher freshwater groundwater component (Point 19).

2.2.0.5 The radar plots were then grouped by the sample location relative to the seawall/dunes, to assess where the principal groundwater contribution to seepages may occur. The results of this were as follows:

i. All of the readings taken from seepages close to the existing seawall had a reduced EC and DO and were all therefore indicative of a groundwater contribution to the seepage. This indication was particularly evident at Points 19, 23 and 24.

ii. Of the readings taken a short way down the beach, some indicated a groundwater contribution to the seepage whilst others more strongly indicated a saline component. In particular, the readings from Points 26, 28, 29 and 30 indicated a groundwater contribution. These are in the eastern section of the area examined, adjacent to the dunes. The data may indicate groundwater seepage occurs slightly further down the beach in this area, compared to the area to the west adjacent to the seawall.

iii. Of the readings taken further down the beach, all were very similar to Point 9 and were therefore indicative of seawater or seepage of seawater bank storage draining from the beach deposits. They did not indicate a groundwater contribution to seepages in this area of the beach.

2.2.0.6 In summary, the water quality data provides good evidence for groundwater seepage at the top of the beach only with seepages further down representing banked storage of seawater in the beach deposits. This is consistent with the groundwater level data and cross sections discussed below. Sample locations are shown in Figure 1, the water quality data is presented in Appendix B1 and the radar plots are presented in Appendix B2.

2.3 Groundwater Level Data Review

2.3.0.1 As part of this report, groundwater information from Appendix 14-1 and 14-2 Volume III of the Bay Campus ES (as referenced above) was used in the development of this Conceptual Site Model (CSM).

2.3.0.2 Boreholes along cross sections A-A' and B-B', as shown in Figure 1, were selected to demonstrate groundwater levels within the campus site area. The selected boreholes include TSBH068 to TSBH070 on cross section A-A', as shown in Figure 3, and TSBH040, TSBH045, TSBH050 and TSBH058 on cross section B – B', as shown on Figure 4.

2.3.0.3 Table 2 shows that all of the selected boreholes were installed within similar strata of silty sand, with the top of the well screen at 1mbgl and the base of the well screen at 6mbgl. The shallow slightly silty to very silty sand layer overlies an intermediate layer of silty / clayey strata of 0.5m -1.0m in thickness. The intermediate silty / clayey layer is reported at a depth of between 8.6mbgl and 12.7mbg. A shallower, thinner, layer of silty clay of 0.2m - 0.6m in thickness was also identified at 5.5mbgl to 6.0mbgl in some areas of the site. The depth to underlying glacial deposits and sandstone bedrock was

not proven during the site investigation works reported in the Bay Campus ES, but would be in excess of 12.7m bgl.

TABLE 2 – Summary of Groundwater Levels Behind Foreshore Area

Monitoring Well	Location	Ground Level (mAOD)	Average Groundwater Level (mAOD)	Geology	Installation	
					Top of screen (m)	Base of screen (m)
TSBH068	Section A-A'. To the west of SUBC.	6.04	3.03	Silty SAND	1	6
TSBH069	Section A-A'. To the west of SUBC.	6.37	4.02	Silty SAND	1	6
TSBH070	Section A-A'. To the west of SUBC.	5.75	4.41	Silty SAND	1	6
TSBH040	Section B-B''. Eastern part of SUBC.	6.24	5.47	Silty SAND	1	6
TSBH045	Section B-B''. Eastern part of SUBC.	6.22	4.72	Silty SAND	1	6
TSBH050	Section B-B''. Eastern part of SUBC.	6.04	5.10	Silty SAND	1	6
TSBH058	Section B-B''. Eastern part of SUBC.	6.09	5.57	Silty SAND	1	6

2.3.0.4 Groundwater levels for cross section A-A' vary from 4.41mAOD at the most northerly borehole, TSBH070, to 3.03mAOD at the most southerly borehole, TSBH068, over a distance of approximately 125m. This represents a hydraulic gradient of 0.01104. A hypothetical extension of this gradient southwards shows that the existing seawall intersects the projected groundwater level. During a site inspection, seepages were observed on the beach at the base of the seawall, suggesting that the seawall is triggering the discharge of groundwater along the toe of the seawall / base of the reclaimed development land.

2.3.0.5 Groundwater levels for the more eastern cross section B-B', vary from 5.47mAOD at the most northerly borehole, TSBH040, to 4.72mAOD at the most southerly, TSBH045, over a distance of approximately 330m. This represents a hydraulic gradient of 0.00227. During a site inspection, seepages were noted to be present on the beach approximately 100m south of the base of the wall, with no seepages observed at the base of the wall itself. The reduced hydraulic gradient in the east of the site and groundwater seepages noted to occur further down the beach profile, suggests that the seawall has less impact on groundwater flow within the eastern part of the foreshore frontage.

Summary

2.3.0.6 The review of strata types and groundwater elevations within the former tank farm / proposed campus site shows that the standing groundwater levels in these areas are higher than the top of the beach / foreshore. The break of slope at the dunes / seawall

corresponds closely with the location of groundwater discharges, which occur at, or reasonably close to, the base of the seawall / top of the beach.

2.4 Tidal Data Review

2.4.0.1 TLSB supplied tidal data showing the anticipated managed basin water level against the tidal level outside the basin, with the data presented to Ordnance Datum Newlyn (OD). URS understands that the tidal data was obtained from the Mumbles tidal gauge in 2003. The data isn't dated but represents approximately one full year of data split into readings taken, in the majority of cases, every 15 minutes. TLSB have added the managed tidal cycle to this data, therefore providing a full year's representative data for the anticipated managed cycle.

2.4.0.2 Charts showing the natural and managed cycles over one day (24 hours) and one month are presented in Appendices C1 and C2 respectively.

2.4.0.3 It can be seen from these that the managed cycle differs from the natural cycle as follows:

I. The managed level does not reach the extremes of high and low tide reached within the natural cycle.

II. The managed cap level (at either high or low tide) is altered depending on the height of the tide. For example, as shown in Appendix C1, when the natural high tide is higher, the capped level is also higher. This has been designed to maximise the power generation capacity from each tidal cycle whether they are relatively deep cycles (spring tides) or relatively shallow cycles (neap tides).

III. The tidal cycle is time-shifted with the managed cycle moved backwards. As can be seen in Appendix C2, the extent of the time shift is changed, with a larger difference in neap tides to spring tides (this can be observed by examining the time at which the water elevation crosses 0 mAOD on any particular cycle).

2.4.0.4 URS has used this data to extract information relevant to URS' examination of the relationship between groundwater level and the varying sea level as shown on the cross sections. This data was extracted as follows:

i. The high and low tide elevations in the natural tidal level were extracted by identifying any data points that were either higher or lower than the data points on both sides (i.e. 15 minutes before and after that data point). From this, 706 high tide elevations and 705 low tide elevations were extracted from the year's worth of data.

ii. The average, minimum and maximum high and low tides were then calculated for the natural cycle.

iii. The "capped" managed tidal water levels were extracted by identifying any data point that was higher than the previous data point, but the same as the next data point in the series for high tides, and lower than the previous data point but the same as the next data point in the series for low tides. This produces a data set with only one point for each capped level. From this, 704 high tide elevations and

705 low tide elevations were extracted from the year's worth of data. This is a peculiarity of the data set and the formula's used to extract the high and low tide elevations rather than there actually being less managed than natural cycles.

iv. The average, minimum and maximum high and low tides were then calculated for the managed cycle.

2.4.0.5 The results of the analysis were as follows:

Table 3: Calculated Tide Elevations

Calculated Parameter	Natural Cycle Elevation (mAOD)	Managed Cycle Elevation (mAOD)
Highest High Tide	5.41	4.30
Average High Tide	3.29	2.45
Lowest High Tide	1.18	0.96
Highest Low Tide	-1.09	-0.93
Average Low Tide	-3.18	-2.60
Lowest Low Tide	-5.22	-4.30

2.4.0.6 Given that this data covers a full year, and therefore covers the full annual lunar cycle it is considered to provide a good representation of the range of possible elevations of both the natural and currently proposed managed cycle.

2.4.0.7 This data has been used in the cross sections to compare the natural and managed seawater elevations to the groundwater elevations discussed above.

2.5 Beach elevation review / Preparation of scaled cross-sections

2.5.0.1 URS has been provided with drawings of the tidal lagoon arrangement including bathymetric data taken from a bathymetric survey undertaken in 2012. URS does not have access to the original bathymetric survey documents and the drawings provided do not indicate the datum used to draw the beach surface contours. It has however been reported to URS that the survey is to Chart Datum. For Swansea, Chart Datum is lower than Ordnance Datum by 5m.

2.5.0.2 The drawing provided has been used to create two scaled cross sections of the beach profile (corrected to Ordnance Datum). These have been extended in-land using ground elevation data from OS maps and from the SUBC Environmental Statement borehole elevation data referenced above (and included within Appendix E). The groundwater elevations from that Environmental Statement, site observations and the tidal elevations have then been added to the topographic profile to create two scaled representative cross sections of the land and beach from Crymlyn Bog/Industrial land in the north to the low tide mark in the south. These cross sections each cover an elevation change of approximately 12m over a lateral distance of approximately 2.7 km.

2.5.0.3 The locations of the cross sections are shown on Figure 1, Appendix A, with the cross sections presented as Figures 3 and 4 of Appendix A.

3.0 CONCEPTUAL MODEL

3.1 Groundwater-Intertidal Zone Conceptual Site Model

3.1.0.1 The main points of the CSM derived from the comparison and assessment of the data described above are:

i. Groundwater is present at a shallow depth on the land to the immediate north of the beach / foreshore.

ii. There is a groundwater gradient present on the landward side of the area, with groundwater behind the sand dunes/seawall flowing to the south towards the sea.

iii. Where the seawall is present, it intercepts the groundwater at a height of approximately 3m above the level of the beach. The open / boulder nature of the seawall means it will act as a natural drain to groundwater with groundwater anticipated to drain between the boulders to the base of the wall.

iv. Groundwater reaching the base of the seawall will encounter the less permeable sand of the beach and discharge at this level. This has been observed on site and is also indicated from both the water quality measurements presented in Appendix B and the location of the contaminant detections (benzene and other VOCs) close to the seawall during previous site investigations.

v. Where the seawall is lower or not present, the groundwater data indicates that groundwater is likely to be present at an elevation above the beach level in the sand dunes.

vi. The observation of seepages slightly away (100m) from the base of the sand dunes indicates groundwater is likely to discharge at a lower elevation down the beach in this area and not directly at the base of the dunes. This is also indicated by the water quality data from these locations which infers some freshwater contribution to the seepages observed further down the beach.

vii. Seepages of water from the sand further down the beach will largely be from banked storage of seawater (from the foreshore sediments) discharging at low tide. It is not anticipated that groundwater provides a significant contribution to these seepages. This is indicated from the water quality measurements presented in Appendix B and the lack of contamination (groundwater tracer) in these areas during previous site investigations.

viii. In areas where the seawall is present, the natural high tide elevation may be either above or below the groundwater elevation behind the seawall depending on the magnitude of the tide. However, the high tide elevation will always be above the level of groundwater seepage at the base of the sea wall irrespective of the magnitude of the tide.

ix. Similarly, where sand dunes are present, the natural high tide elevation may be either above or below the groundwater elevation behind the dunes depending on the magnitude of the tide. However in this area, the groundwater level is closer to the maximum high tide level. As above, the high tide elevation will always be above the level of groundwater seepage from the sand irrespective of the magnitude of the tide.

x. In all areas, the minimum (highest) low tide elevation is below that of the groundwater seepages i.e. at any low tide, the seepage areas will be exposed.

xi. For the area with seawall, the changes to the tidal cycle caused by the operation of the lagoon will change the elevation difference between the different elements of the tidal and groundwater conceptual model but will not change the overall relationship between the elements. The high tide range will still cross the standing groundwater level behind the seawall and will still be above the seepage elevation, but with smaller differences in elevation.

xii. For the area with sand dunes fronting the foreshore, it is probable that the groundwater behind the dunes will always be higher than the high tide i.e. the maximum managed high tide is below the groundwater elevation behind the dunes. This is a change from the natural cycle, where some high tides would peak at a higher elevation than the standing groundwater elevation.

3.1.0.2 It has been assumed that the holding time of the lagoon tidal cycle presented for review will not substantially increase. Significant increases to this cycle may alter the conceptual model above and therefore the conclusions drawn from it.

3.1.0.3 The groundwater elevation data obtained from the SUBC Environmental Statement is provided as a mean groundwater level. It is therefore possible that with seasonal changes, the groundwater elevation may change sufficiently to change the relationship between the groundwater and tidal elevations. URS does not have sufficient data to assess this potential.

3.1.0.4 The CSM further to the west, in the area of Queen's Dock has not been examined in detail. Queens Dock is understood to be 10.67m deep (extending to -5.93 mAOD), and will therefore be below the level of the groundwater table and the full tidal range. It is anticipated to be acting as a block to groundwater flow at present, and this is not anticipated to change with the construction of the tidal lagoon. It is therefore excluded from this assessment and CSM.

4.0 CONCLUSIONS

4.0.0.1 As described in the proposed CSM, with the exception of the relationship between the maximum high tide and the standing groundwater level in the eastern area, the overall relationship between the different elements of the CSM are not anticipated to change with the operation of the lagoon.

4.0.0.2 The potential implications of the operation of the lagoon are discussed below:

I. **Seepages of groundwater to the beach.** The observed areas of groundwater seepage are at or towards the top of the beach profile. As the relationship between the high and low tide ranges and the seepages is not anticipated to change with operation of the lagoon, the seepage area should be exposed for a similar length of time on the natural and managed tidal cycles. The effect on the flow of groundwater from these seepages is therefore likely to be limited.

II. **Seepages of bank stored seawater to the beach.** These will not be affected by the changes to the high tide level, but may be affected by the changes to the low tide level. Changes in the storage of saline water on the beach are not considered to cause an issue in themselves but could impact on groundwater as described below.

III. **Disruption of the saline wedge.** In a typical intertidal zone, groundwater will flow towards the beach and will meet saline pore water stored within the sand. The interaction of the fresher groundwater and more saline pore water would be expected to create a saline wedge, with the less dense fresh water rising over the denser saline water and discharging somewhere in the intertidal zone (as evidenced by the restricted areas of fresh groundwater seepages towards the top of the beach profile). The tide will alter the nature of the saline wedge as it rises and falls and may retard discharge of the freshwater at certain parts of the tidal cycle. Alteration of the tidal cycle could therefore alter the saline wedge within the beach and subsequently impact groundwater discharge. In this case however, the groundwater table is effectively above the elevation of the beach. In the areas where the seawall is present, it is discharging through that wall rather than through the beach. The saline wedge is therefore unlikely to be controlling discharge of groundwater in these areas, and is only expected to have a limited impact on groundwater discharge adjacent to the sand dunes. Changes to the nature of the saline wedge at this site are therefore unlikely to lead to changes in the discharge of freshwater.

IV. **Saline intrusion into groundwater.** At times where the tidal water level is at a higher elevation than the freshwater component of groundwater, i.e. higher than the observed freshwater groundwater seepages, there may be some saline intrusion into groundwater through the seawall or the dunes. This condition occurs under the current natural tidal regime for every high tide.

4.0.0.3 URS does not have water quality data from the SUBC monitoring wells to assess the existing salinity of the groundwater behind the seawall / dune front, or the inland extent of any current saline intrusion. Assumptions can be made, based on the cross sections shown as Figures 3 and 4 and the EC data from the seepages at the base of the

seawall / dune front. The seepages record electrical conductivity readings in an order of magnitude higher than "typical" groundwater, suggesting some mixing of fresh groundwater and saline water along the coastal margin. The high tide elevations and standing groundwater elevations plotted on the cross sections, suggest that a freshwater / saline water mixing zone could extend several hundred metres inland under the highest natural high tide conditions.

4.0.0.4 In the western part of the study area (between the Port and the SUBC), the highest managed high tide level within the lagoon will be lower than the highest natural high tide level, but will remain above the standing groundwater elevation. The potential therefore remains for mixing of saline water and fresh groundwater under high tide conditions, although the net potential for saline intrusion will be reduced, compared to the current natural tidal cycle. This is because the managed high tide level will always be lower than the natural peak high tide.

4.0.0.5 In the eastern part of the study area, the groundwater is expected to remain at a higher standing elevation than the highest managed high water level within the operating lagoon. Any high tide saline water / fresh groundwater mixing zone is likely to be restricted to within 100-150m of the seawall (further inland, the groundwater level would be expected to be higher than the high tide level). It is therefore possible that the operation of the lagoon may slightly reduce the potential for any localised saline intrusion to groundwater along this short section of the coastline (broadly equivalent to the frontage of the proposed campus site).

4.0.0.6 No change in the potential for saline intrusion is anticipated in the area adjacent to the Queen's Dock. The high impounded water level and depth of the dock's construction is assessed as acting as a barrier to groundwater discharge to the intertidal zone, and as a barrier to saline intrusion from tidal waters.

4.0.0.7 Overall, the potential for limited saline intrusion along the coastal margin will remain under the managed tidal cycle that is required for lagoon operation. Managed high tide levels will be above the elevation of the observed groundwater discharges, resulting in a continuation of the mixing of tidal water and groundwater along a zone defined by the position of the seawall and a strip immediately inland of the seawall, where standing groundwater levels are lower than the high tide level. The reduced managed high tide levels would be expected to reduce the width of the mixing zone and therefore reduce the potential for saline intrusion, especially in the eastern area adjacent to the SUBC. The extent of any existing or future groundwater / tidal water mixing zone in this area is expected to be <200m, approximately half the 400m distance between the high tide mark and the Crymlyn Bog SAC. The lower standing groundwater levels beneath the former tank farm to the east of the SUBC might be expected to result in a continuation of near-current conditions. Managed tidal levels will be lower than current natural high tides, but will still be higher than groundwater within the adjacent plot of land. No groundwater level data has been reviewed for land to the north of Fabian Way. If groundwater levels north of the road remain low, with respect to the managed tidal elevation, then the potential for saline intrusion towards Crymlyn Bog will be similar to the current natural conditions.

i. **Groundwater levels.** Given that the operation of the lagoon will lower the maximum tidal high water level, and in some areas lower it below the standing

groundwater level, it is considered very unlikely that lagoon operation will cause a general rise in groundwater elevations beneath the land to the north of the proposed development. It is noted that the high tide level will become a flat plateau rather than a peak, however it will not be held at that plateau level for substantially longer than the tide would naturally be at that level. This plateau is therefore considered unlikely to cause a general increase in groundwater levels. The maximum low water elevation will also be reduced by the operation of the lagoon, however given that this is so far below the groundwater table and discharge zone / saline interface, alterations to this part of the tidal cycle are not anticipated to affect groundwater levels beneath the onshore area.

ii. **Groundwater flow regime.** Groundwater in areas outside of the lagoon will be able to discharge for a similar amount of time as groundwater in areas enclosed by the lagoon. However there will be a short time delay between the availability of those discharges inside the lagoon due to the delayed tidal cycle. If this delay was sustained (i.e. the water within the lagoon was permanently impounded) then it could lead to groundwater flowing laterally along the coastline towards the alternative available discharge zones. Given that the whole tidal cycle is delayed and not prevented, there will be limited times in the cycle where groundwater can discharge inside the lagoon area, but not outside of it (or *vice-versa*) due to the delay in the rising tide in the lagoon.

4.0.0.8 The potential for differential groundwater head levels between the areas inside and outside the lagoon area will also be switched around after each ebb / flood sequence. The theoretical groundwater flow direction would therefore switch every 6-7 hours, resulting in an overall cancelling out of the opposing groundwater flow vectors. Without a sustained head difference between the internal / external intertidal areas it is considered unlikely that the operation of the lagoon would cause a sustained lateral flow of groundwater parallel to the coast.

.

5.0 LIMITATIONS

URS Infrastructure & Environment UK Limited ("URS") has prepared this Report for the sole use of **Tidal Lagoon Swansea Bay plc** ("Client") in accordance with the Agreement under which our services were performed (**Proposal Ref.: 47065127\letter\ Groundwater Intertidal Zone Discharge: Conceptual Site Model Development – URS Fee Proposal, 10th September 2013**). No other warranty, expressed or implied, is made as to the professional advice included in this Report or any other services provided by URS. This Report is confidential and may not be disclosed by the Client nor relied upon by any other party without the prior and express written agreement of URS.

The conclusions and recommendations contained in this Report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by URS has not been independently verified by URS, unless otherwise stated in the Report.

The methodology adopted and the sources of information used by URS in providing its services are outlined in this Report. The work described in this Report was undertaken between 20 September 2013 and 27 September 2013 and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.

Where assessments of works or costs identified in this Report are made, such assessments are based upon the information available at the time and where appropriate are subject to further investigations or information which may become available.

URS disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report, which may come or be brought to URS' attention after the date of the Report.

Certain statements made in the Report that are not historical facts may constitute estimates, projections or other forward-looking statements and even though they are based on reasonable assumptions as of the date of the Report, such forward-looking statements by their nature involve risks and uncertainties that could cause actual results to differ materially from the results predicted. URS specifically does not guarantee or warrant any estimate or projections contained in this Report.

Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Where field investigations are carried out, these have been restricted to a level of detail required to meet the stated objectives of the services. The results of any measurements taken may vary spatially or with time and further confirmatory measurements should be made after any significant delay in issuing this Report.

APPENDIX A FIGURES

DO NOT SCALE

N

SWANSEA SCIENCE AND INNOVATION CAMPUS

LINE OF MHWS

LINE OF MLWS

SWANSEA CHANNEL

NEATH CHANNEL

SWANSEA MIDDLE EAST FAIRWAY BUOY

SWANSEA MIDDLE WEST FAIRWAY BUOY

SWANSEA OUTER FAIRWAY BUOY

REFER TO DWG 5108073-SK-231 FOR TURBINE & SLUICE ENTRANCE

PROPOSED LOCATION FOR A NEW MONKSTONE LIGHT

PROPOSED NEW TRAINING WALL

PROPOSED LOCATION FOR THE STARBOARD BUOY PROVIDING THE GUIDE FOR ENTERING THE NAVIGABLE CHANNEL

KEY

1 - 30 Location Points

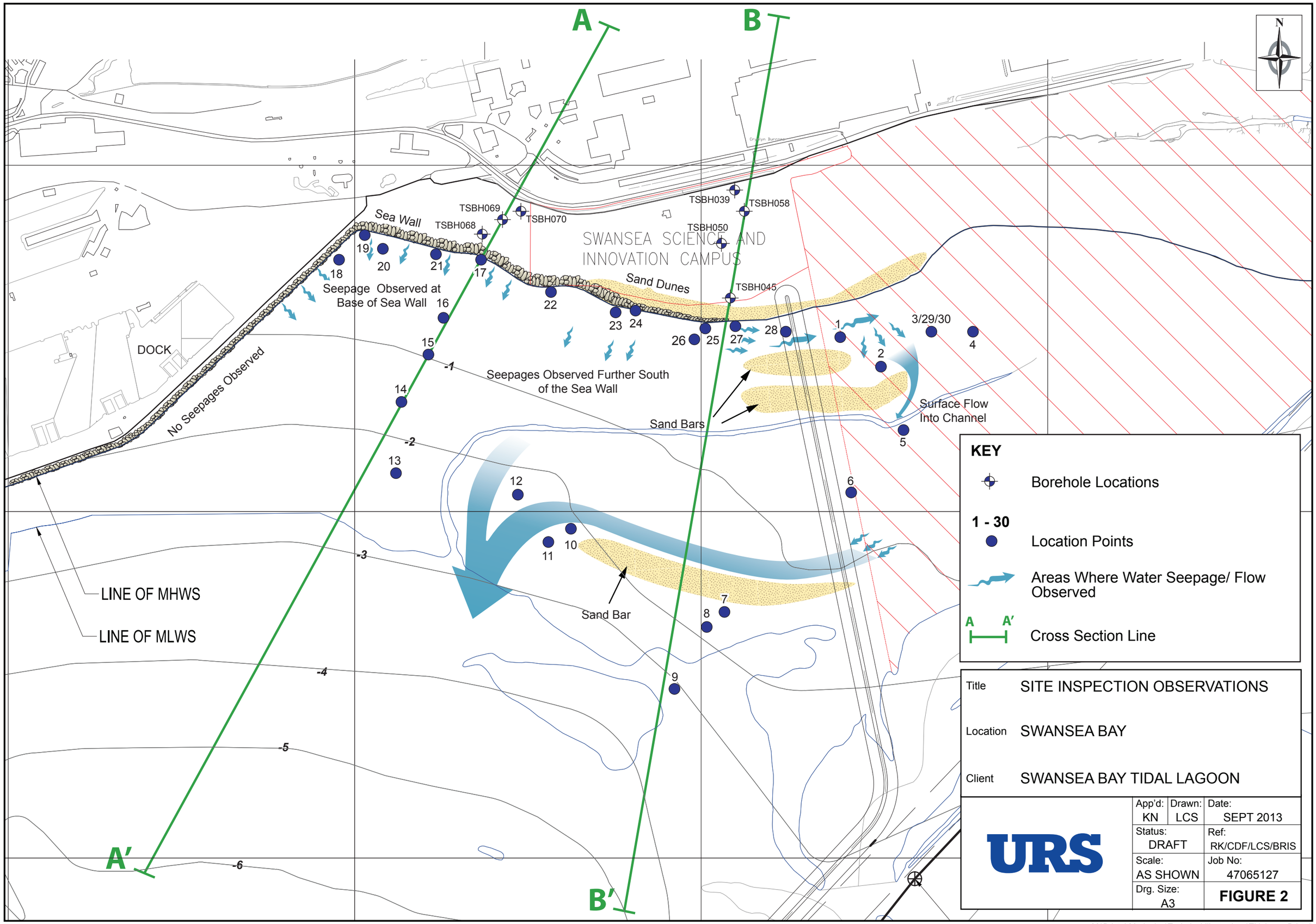
A A′ Cross Section Line

Title	SITE INSPECTION LOCATIONS
Location	SWANSEA BAY
Client	SWANSEA BAY TIDAL LAGOON

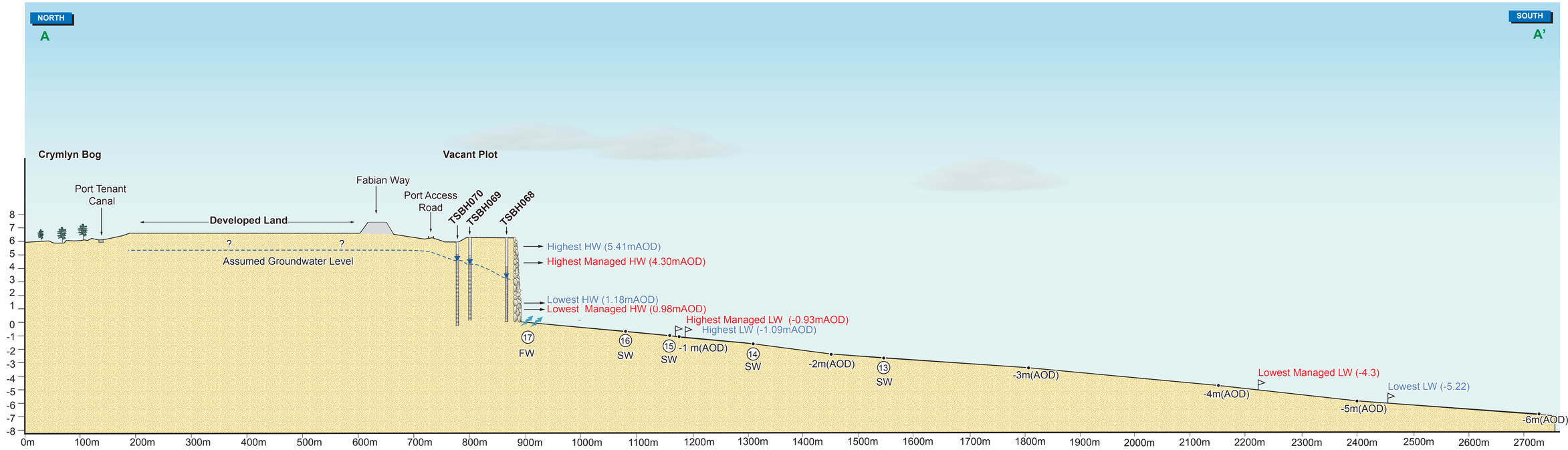
URS

App'd:	Drawn:	Date:
KN	LCS	SEPT 2013
Status: DRAFT		Ref: RK/CDF/LCS/BRIS
Scale: AS SHOWN		Job No: 47065127
Drg. Size: A3		**FIGURE 1**

M:\Bristol-Marketing\Technical Illustrations\TI jobs on Bristol\



M:\Bristol-Marketing\Technical Illustrations\TI jobs on Bristol\



KEY

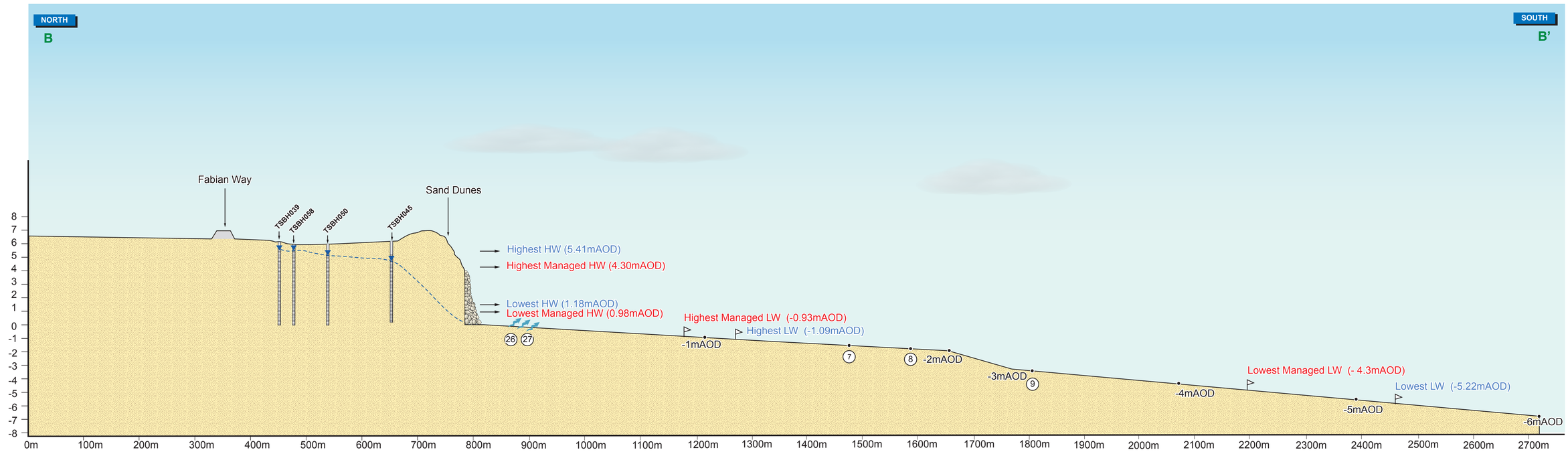
	Water Seepages
Highest LW	Highest Natural Low Water
Lowest Managed HW	Lowest Managed High Water

Title	CROSS SECTION A - A'
Location	SWANSEA BAY
Client	SWANSEA BAY TIDAL LAGOON

URS

App'd: KN	Drawn: LCS	Date: SEPT 2013
Status: DRAFT		Ref: RK/CDF/LCS/BRIS
Scale: AS SHOWN		Job No: 47065127
Drg. Size: A1		**FIGURE 3**

M:\Bristol-Marketing\Technical Illustrations\TI jobs on Bristol\



KEY

Water Seepages

Highest LW — Highest Natural Low Water

Lowest Managed HW — Lowest Managed High Water

Title	CROSS SECTION B - B'
Location	SWANSEA BAY
Client	SWANSEA BAY TIDAL LAGOON

URS

App'd:	Drawn:	Date:
KN	LCS	SEPT 2013
Status: DRAFT		Ref: RK/CDF/LCS/BRIS
Scale: AS SHOWN		Job No: 47065127
Drg. Size: A1		**FIGURE 4**

M:\Bristol-Marketing\Technical Illustrations\TI jobs on Bristol\

APPENDIX B BEACH WATER QUALITY MEASUREMENTS

B1: Water Quality Readings and Notes

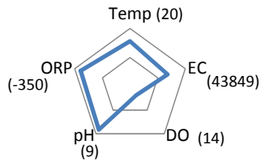
B2: Graphical Representation of Water Quality Readings

Name Swansea Bay Tidal Lagoon Walkover
Date 19/09/2013

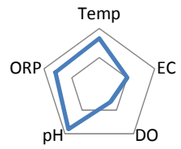
			Co - Ords		Reading				
Point	Time	Observations	Northing	Easting	Temp °C	EC µS/cm	DO (mg/l)	pH (-)	ORP (mV)
1	11:40	Channel flowing east, joining main channel.	70386	72504					
2		Channel flowing east, joining main channel.	70498	92423	17.2	41160	8.88	6.5	-147.4
3		Possible seepage, ≈2m	70637	92509	16.58	33975	8	7.4	-177.4
4		Pool near bend in main channel.	70706	92526	16.04	35362	5.1	7.24	-177.4
5		Main channel (Map)	70528	92235					
6	12:00	Main channel (Map)	70401	92092	16.94	43434	7.5	7.41	-162.1
7		Southern channel sandbar.	70116	91795					
8		Issues from southern sandbar.	70030	91728	17.61	42700	7.26	7.64	-167.3
9		Rockpool	69981	91587	17.57	43849	6.89	7.68	-168.8
10		Southern channel	69519	91968					
11	12:30	Southern channel							
12		Main channel	69450	92057	17.65	42980	8.44	7.55	-164.2
13		On western N-S transect	69113	92149					
14	13:08	On western N-S transect	69167	92323	18.31	43724	10.9	7.83	-166.2
15	13:15	On western N-S transect	69222	92475	18.96	43688	13.2	8.01	-162.5
16	13:20	On western N-S transect	69263	92553	19	43,337	11.06	8.24	-162.2
17		Shoreline, flow from base of rocks, NVO.	69349	92713	15.51	30345	5.08	8.33	
18	13:55	Sweet organic/chemical odour, no sheen.	68922	92729	15.66	29743	2.5	8.22	-312.9
19		Very strong foul sewer odour.	69004	92800	16.68	22153	4.53	8.13	-278.5
20	14:10	Seepage into rockpool, NVO.	69066	92768	17	36673	6.9	7.96	-194
21	14:15	Cloudy grey -white.	69240	92752	17.01	38286	3.9	7.95	-236.7
22		Conduit pipe, drier sand zone ~10m either side.	69544	92641					
23		Central shoreline, seepages from base of rockline ceased. Sand dunes begin, heading east.	69725	92644	15.93	26656	6.73	8.09	-202
24		Wet sand line approximately 20m south of shoreline heading east.	69774	92608	16.87	15468	3.4	8.32	-204.5
25		Eastern conduit, no flow from pipe. Drier area of sand surrounding pipe.	70004	92578					
26		Just south-west of point 25.	69995	92555	16.9	33000	4.23	7.89	-206.1
27	15:00	Stream issue from pebbles at shoreline, east of fence line.	70078	92586	16.01	33156	5.4	7.68	-193.7
28	15:05	Stream flowing south after low tide.	70200	92533	16.74	35685	6.9	7.91	-194.7
29		Rock pool similar to point 4, to compare with earlier readings	70667	92522	15.97	33408	8.19	7.97	-206.2
30		Shallow pit dug to encourage flow - for comparison with readings from point 29.	just west of 29	just west of 29	16.07	29978	6.79	7.94	-212.9

DO - Dissolved Oxygen
EC - Electrical Conductivity
ORP - Oxygen Reduction Potential
NVO - No Visual or Olfactory evidence of contamination

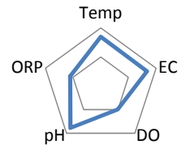
Point 18



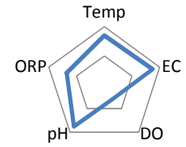
Point 19



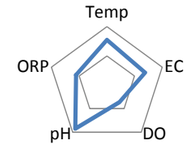
Point 20



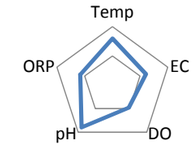
Point 21



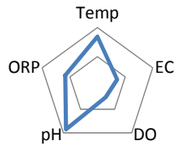
Point 17*



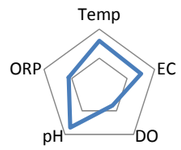
Point 23



Point 24

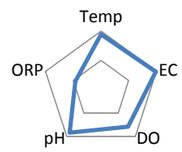


Point 27

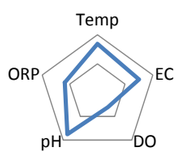


Point readings taken from the top of the beach - close to the base of the seawall or dunes as appropriate.
Readings from Points 19, 23, and 24 in particular are indicative of groundwater seepage due to the relatively low Electrical Conductivity (EC) and low Dissolved Oxygen (DO). In these examples the EC is close to or below 50% of the EC of the seawater readings below.
Readings from the remaining Points also show a fresh-water element as the EC and DO are low compared to the seawater readings below

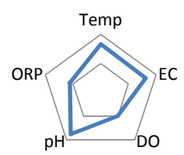
Point 16



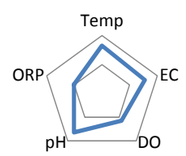
Point 26



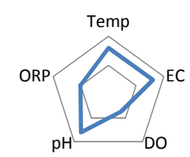
Point 28



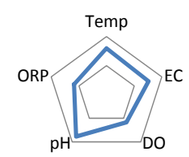
Point 3



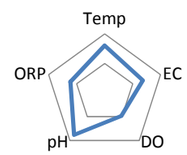
Point 4



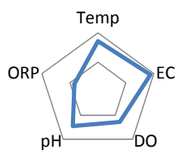
Point 29



Point 30



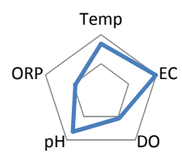
Point 2



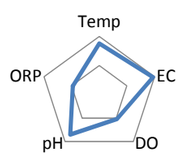
Point readings taken from the middle to upper sections of the beach but not immediately adjacent to the seawall/dunes.
Readings from Points 26, 28, 29 and 30 in particular are indicative of groundwater seepage due to the relatively low EC and DO and are comparable to readings from Point 17 above. All these points are adjacent to the dunes rather than the seawall and may be indicative of groundwater seepage further out on the beach in the east.

Point readings taken from the middle to lower reaches of the beach.
From site observations, readings from Point 8 and 9 were assumed to represent seawater. The similarity of other readings to this indicates they all represent seawater. This data is therefore not indicative of groundwater discharge in readings from the lower sections of the beach.

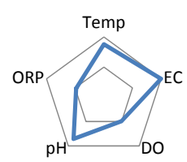
Point 6



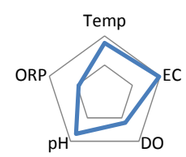
Point 8



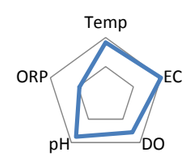
Point 9



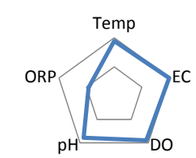
Point 12



Point 14



Point 15



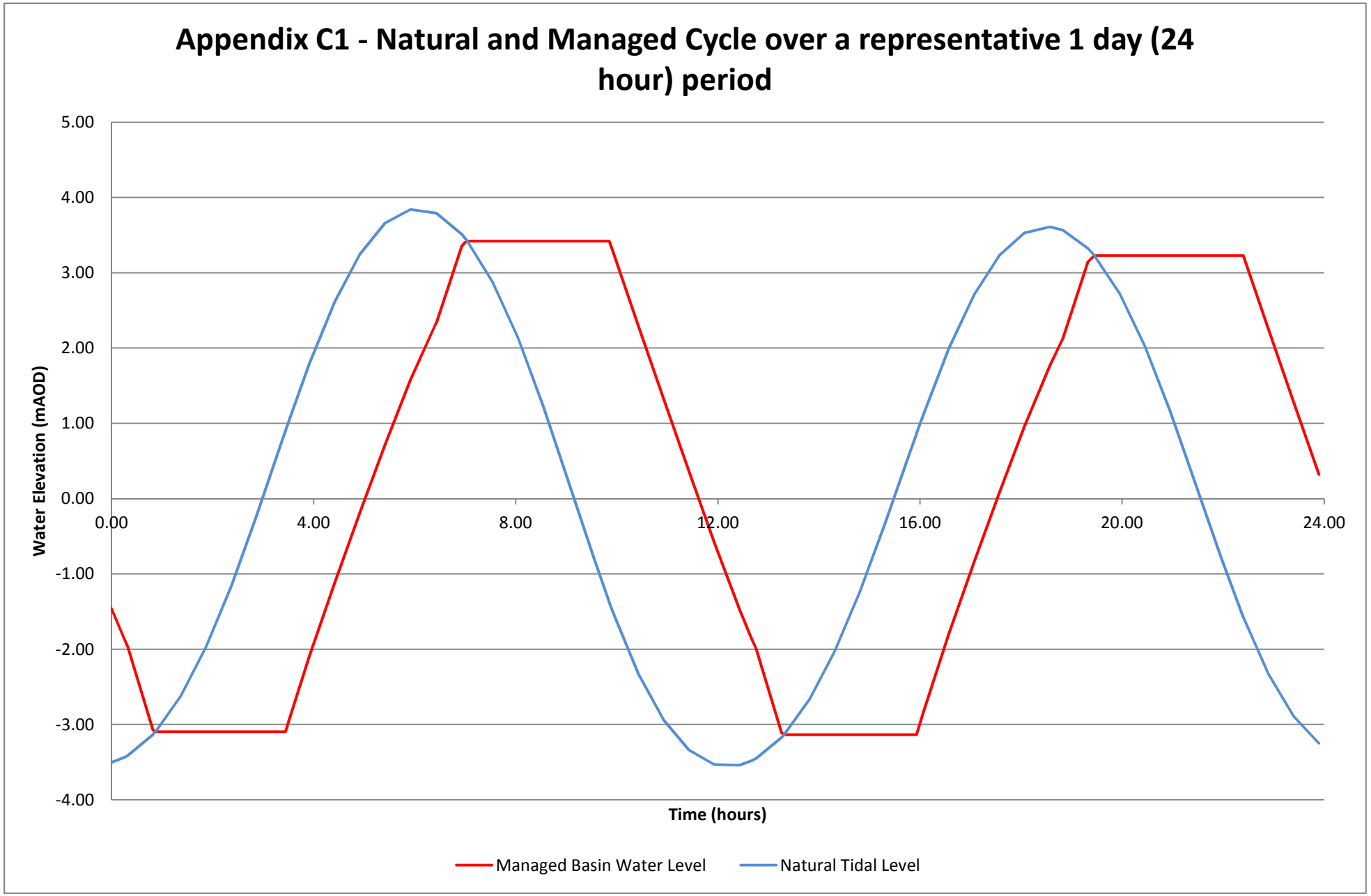
* there was no ORP data for Point 17, therefore an average value was assigned to this to allow the plot to be drawn.
All readings have been converted to a proportion of a nominal maximum value as shown in brackets on Point 18 above, for Conductivity this is taken as the reading from Point 9 as this is considered to represent seawater.

APPENDIX C TIDAL ELEVATION GRAPHS

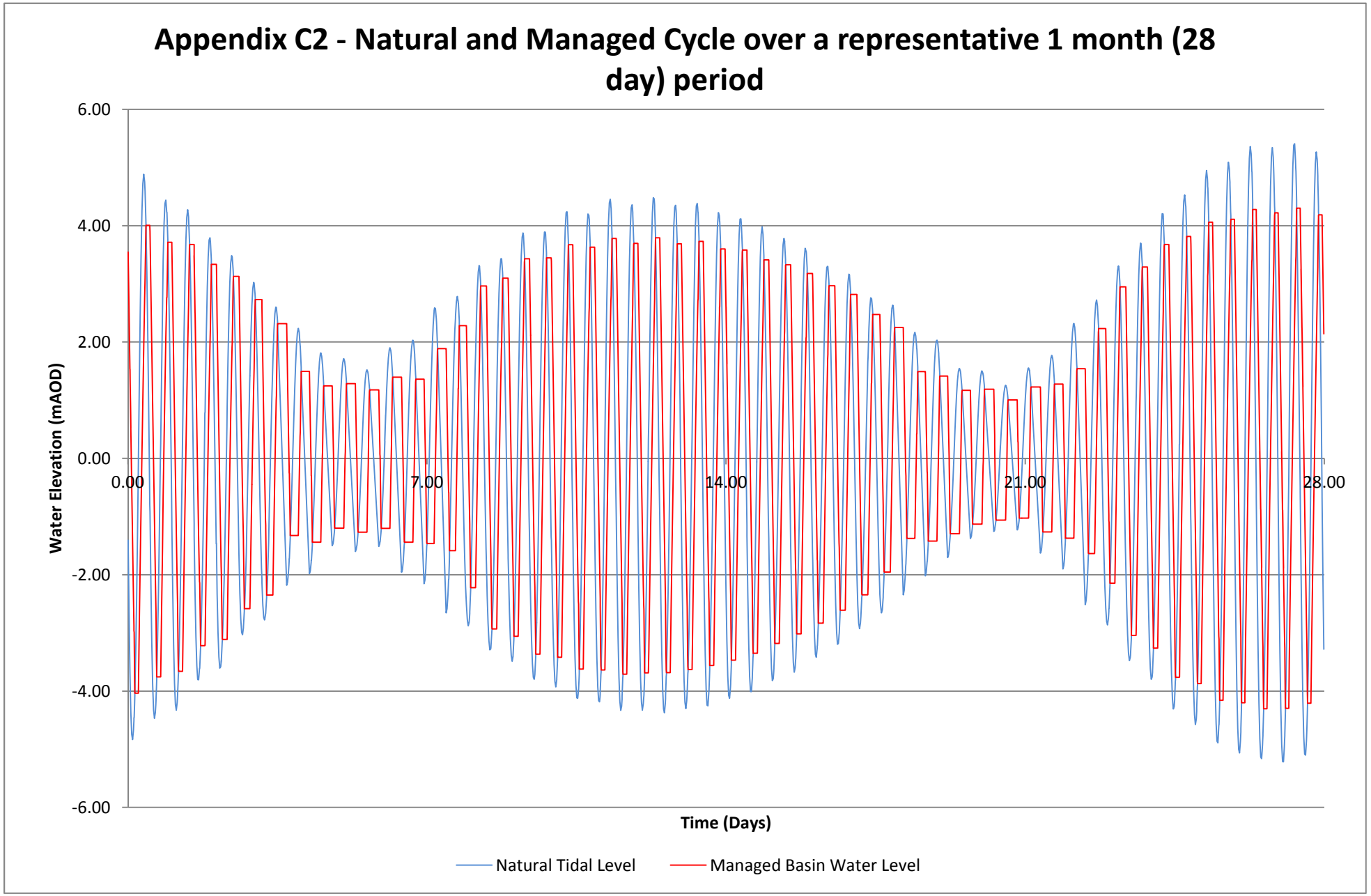
C1: Natural and Managed Cycle over a representative 1 day (24 hour) period

C2: Natural and Managed Cycle over a representative 1 month (28 day) period

Appendix C1 - Natural and Managed Cycle over a representative 1 day (24 hour) period



Appendix C2 - Natural and Managed Cycle over a representative 1 month (28 day) period



APPENDIX D PHOTOGRAPH APPENDIX

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 1	Date: September 2013

Description:
Seepages into channel noted near the eastern arm of the Lagoon arm (facing north).

Photo No. 2	Date: September 2013

Description:
Channel observed to the east of the eastern Lagoon arm (facing west).

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 3	Date: September 2013

Description:
Water flow into channel observed to the east of the eastern Lagoon arm (facing north).
Points 1 to 5 and 29 to 30 are located in this area as shown in Figure 2.

Photo No. 5	Date: September 2013

Description:
Channel observed to the east of the eastern Lagoon arm (facing east).

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 6	Date: September 2013

Description:
Channel observed to the east of the eastern Lagoon arm with a sand bar evident on the left hand side of the photo (facing north west).

Photo No. 7	Date: September 2013

Description:
Second channel observed to the south of mapped channel where groundwater readings of Point 6 were taken.

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 8	Date: September 2013

Description:
Groundwater seepages observed along the base of the seawall on the western side of the proposed site area.

Photo No. 10	Date: September 2013

Description:
Area around most easterly conduit pipe where seepages do not appear. This may be due to conduit acting as a preferential flow pathway directing seepage along its course.

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 11	Date: September 2013

Description:
Beach area near Point 22 as shown on Figure 2 where seepage outflow was observed to be further south of the sea wall. This coincides with the beginning of the sand dunes behind the sea wall and the tapering out of the seawall (facing west).

Photo No. 12	Date: September 2013

Description:
As described above in Photo No. 11 seepages are noted to be further out from the sea wall on the eastern side of the proposed site area (facing east).

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 13	Date: September 2013

Description:
Seepages on the eastern side of the proposed site area which occur further south from the seawall compared with the western side of the site Debris can also be seen on the seawall in the back ground indicating high water tides rise up the seawall.

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 15	Date: September 2013

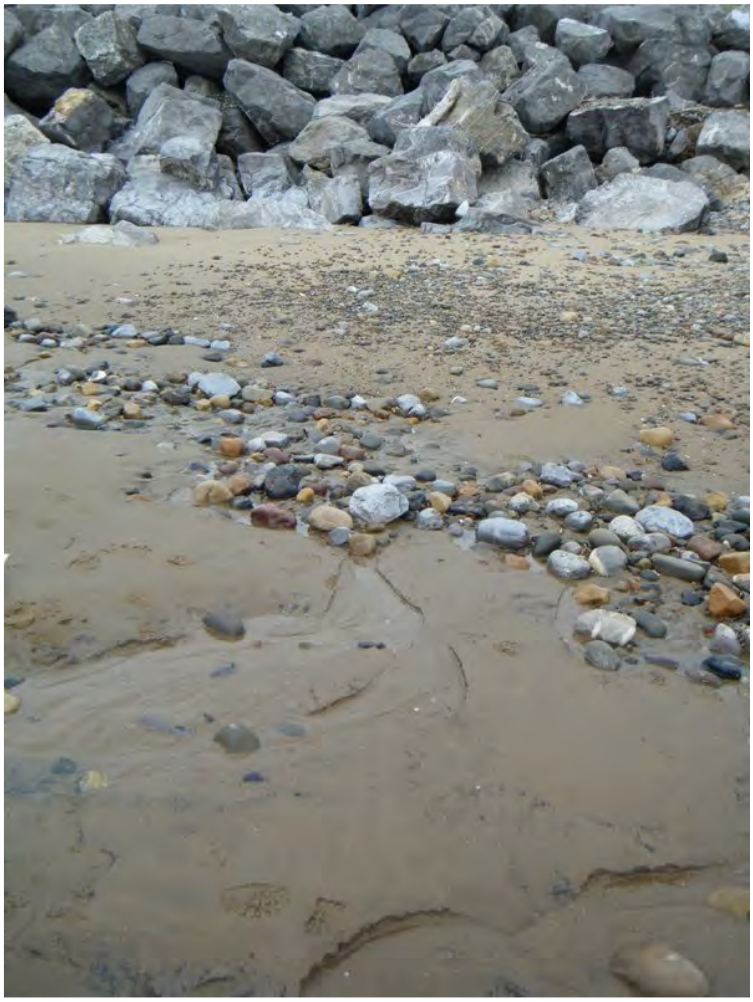
Description:
YSI readings taken at dug channel to induce flow and elimnate ponded water as shown at Point 23 on Figure 2. Water chemistry results placed this location in the fresh water grouping.

PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 16	Date: September 2013

Description:
Water seepages at Point 27 as shown on Figure 2. Water chemistry readings for this location placed it in the freshwater groupings.



PHOTOGRAPHIC LOG

Client Name: Tidal Lagoon Swansea Bay	Site Location: Swansea Bay	Project No. 47065127

Photo No. 17	Date: September 2013

Description:
Stream noted to the east of the western Lagoon arm with shale to the north of it.

Photo No. 18	Date: September 2013

Description:
Stream flow joining channel at Points 1 & 2 as shown on Figure 2.

APPENDIX E ANNEX A – SITE GEOLOGICAL AND HYDROGEOLOGICAL INFORMATION. APPENDIX 14-2 OF THE BAY SCIENCE AND INNOVATION CAMPUS ENVIRONMENTAL STATEMENT.

Borehole ID	Easting	Northing	GL (mOD)	Mean SWL (mOD)	DTW (m)	Top of screen (m)	Base of screen (m)	Mid point of sat screen (mOD)	Thickness of Shallow Unit	Thickness of Silty/Clayey	Thickness of Lower Sand	Ground Level L1 Top (mAOD)	Base of Basement L1 Base (mAOD)	Base of Shallow Unit L2 Base (mAOD)	Base of Silty/Clayey Unit L3 Base (mAOD)	Base of Lower Sand L4 Base (mAOD)
EPBH002	270344.105	192961.434	6.04	5.47	0.57	1.50	4.50	3.04	>4.5			6.04	4.15	-	-	-
EPBH004	270449.912	193001.091	5.84	5.38	0.46	1.50	6.00	2.09	>8			5.84	4.15	-	-	-
EPBH006	270701.36	193097.53	6.32	5.22	1.10	1.50	4.50	3.32	>4.5			6.32	4.15	-	-	-
EPBH008	270764.45	193117.37	6.40	5.25	1.15	1.50	4.50	3.40	8.5	1.5		6.40	4.15	-2.1	-3.6	-
EPBH0010	270943.55	193170.51	6.47	5.18	1.29	3.00	5.00	2.47	7.25	0.25	>0.5	6.47	4.15	-0.78	-1.03	-
EPBH0012	271089.71	193186.41	6.91	6.01	0.90	1.50	4.50	3.91	>5			6.91	4.15	-	-	-
EPBH0014	271205.55	193217.68	5.91	4.31	1.60	1.50	6.00	2.11	7.1	>0.4		5.91	4.15	-1.19	-	-
EPBH0016	271391.12	193251.9	6.85	4.95	1.90	1.50	4.50	3.65	>4.5			6.85	4.15	-	-	-
EPBH0018	271618.92	193210.95	5.02	4.79	0.23	1.50	4.50	2.02	6.3	>1.2		5.02	4.15	-1.28	-	-
EPBH0020	271772.168	193166.329	4.87	3.77	1.10	1.50	4.50	1.87	>4.5			4.87	4.15	-	-	-
EPBH0022	271973.735	193127.26	4.92	3.43	1.49	1.50	6.00	1.17	9.8	>0.2		4.92	4.15	-4.881	-	-
EPBH0024	272287.39	192983.58	5.63	2.14	3.49	1.50	4.50	1.64	>4.5			5.63	4.15	-	-	-
TSBH001	269583.06	192748.52	7.20	4.16	3.04	1.00	5.50	2.93	>6			7.20	4.15	-	-	-
TSBH002	269552.15	192729.81	6.62	3.81	2.81	1.00	6.00	2.22	>6			6.62	4.15	-	-	-
TSBH003	269537.46	192690.04	6.49	3.54	2.95	1.00	6.00	2.02	>6			6.49	4.15	-	-	-
TSBH004	269497.07	192699.33	6.79	3.35	3.44	3.00	8.00	1.07	>8			6.79	4.15	-	-	-
TSBH005	269620.68	192838.22	7.27	4.90	2.37	1.00	6.00	3.09	>6			7.27	4.15	-	-	-
TSBH006	269692.06	192740.48	6.73	4.61	2.12	1.50	4.50	3.42	>10.1			6.73	4.15	-	-	-
TSBH007	269596.00	192765.47	6.71	4.23	2.48	1.00	4.00	3.47	>6			6.71	4.15	-	-	-
TSBH008	269630.39	192758.45	7.00	4.49	2.51	1.00	6.00	2.75	>6			7.00	4.15	-	-	-
TSBH010	269544.76	192851.88	6.91	4.85	2.06	1.00	6.00	2.88	>6			6.91	4.15	-	-	-
TSBH011	269676.78	192771.55	6.77	4.78	1.99	3.00	8.00	1.27	6	1	>1	6.77	4.15	0.77	-0.23	-
TSBH012	269662.23	192711.42	7.05	4.15	2.90	1.00	6.00	2.60	>6			7.05	4.15	-	-	-
TSBH013	269745.51	192721.02	6.00	4.47	1.53	1.00	6.00	2.24	>8			6.00	4.15	-	-	-
TSBH014	269571.06	192848.64	7.03	5.04	1.99	1.00	6.00	3.04	>6			7.03	4.15	-	-	-
TSBH015	269642.73	192696.63	7.12	3.97	3.15	1.00	6.00	2.55	>6			7.12	4.15	-	-	-
TSBH016	269743.3	192781.64	6.58	4.87	1.71	1.00	6.00	2.73	>6			6.58	4.15	-	-	-
TSBH017S	270040.91	192870.36	6.58	5.68	0.90	1.00	6.00	3.08	>6			6.58	4.15	-	-	-
TSBH017D	270040.92	192870.67	6.53	6.16	0.37	7.20	9.20	-1.67	9.20	>0.8		6.53	4.15	-2.67	-	-
TSBH018S	269723.01	192698.72	6.67	4.23	2.44	1.00	6.00	2.45	>6			6.67	4.15	-	-	-
TSBH018D	269722.88	192698.65	6.69	4.25	2.44	10.00	12.00	-4.31	11.50	0.50	1.60	6.69	4.15	-4.81	-5.31	-6.91
TSBH020	269661.17	192821.31	7.01	5.17	1.84	3.00	8.00	1.51	>8			7.01	4.15	-	-	-
TSBH021	269751.84	192826.51	6.61	4.82	1.79	1.00	6.00	2.72	>6			6.61	4.15	-	-	-
TSBH022	269698.28	192807.87	6.91	5.01	1.90	1.00	6.00	2.96	>6			6.91	4.15	-	-	-
TSBH023	269762.42	192754.22	6.95	5.18	1.77	1.00	6.00	3.07	>6			6.95	4.15	-	-	-
TSBH024	269808.95	192693.62	5.64	4.44	1.20	3.00	6.00	1.14	>6			5.64	4.15	-	-	-
TSBH025	269806.36	192759.86	6.41	5.00	1.41	1.00	6.00	2.71	>6			6.41	4.15	-	-	-
TSBH026S	269791.44	192812.26	6.85	5.30	1.55	1.00	6.00	3.08	>6			6.85	4.15	-	-	-
TSBH026D	269791.61	192812.48	6.82	5.57	1.25	8.00	10.00	-2.18	10.00	>2		6.82	4.15	-3.18	-	-
TSBH029	269892.71	192700.95	6.41	4.86	1.55	1.00	6.00	2.64	>6			6.41	4.15	-	-	-
TSBH030	269897.82	192781.53	6.57	4.97	1.60	1.00	6.00	2.77	5.60	>0.4		6.57	4.15	0.97	-	-
TSBH031	269875.18	192833.24	6.70	5.20	1.50	3.00	8.00	1.20	>8			6.70	4.15	-	-	-
TSBH032	269612.24	192735.48	7.30	4.24	3.06	1.00	6.00	2.77	>6			7.30	4.15	-	-	-
TSBH033	269579.47	192697.38	6.69	3.00		1.00	6.00	1.85	>6			6.69	4.15	-	-	-
TSBH034S	269579.37	192697.19	6.52	3.66	2.86	1.00	6.00	2.09	>6			6.52	4.15	-	-	-
TSBH034D	269579.47	192697.38	6.50	3.13	3.37	11.50	12.50	-5.50	10.70	0.50	>1.3	6.50	4.15	-4.2	-4.7	-
TSBH035	269649.19	192734.07	7.05	4.32	2.73	1.00	6.00	2.69	>6			7.05	4.15	-	-	-
TSBH036	269970.23	192844.13	6.28	5.63	0.65	1.00	6.00	2.78	>6			6.28	4.15	-	-	-
TSBH038	270094.6	192886.82	6.19	5.57	0.62	1.00	6.00	2.69	>6			6.19	4.15	-	-	-
TSBH039	270127.09	192904.2	6.61	5.87	0.74	1.00	6.00	3.11	>6			6.61	4.15	-	-	-
TSBH040	270203.12	192900.73	6.24	5.47	0.77	1.00	6.00	2.74	>6			6.24	4.15	-	-	-
TSBH041	270002.61	192801.43	5.68	5.09	0.59	1.00	6.00	2.18	>6			5.68	4.15	-	-	-
TSBH043	270106.31	192751.01	5.87	4.93	0.94	1.00	8.00	1.37	>8			5.87	4.15	-	-	-
TSBH044	270115.31	192713.34	5.78	4.71	1.07	1.00	4.50	3.00	5.50	0.20	>0.3	5.78	4.15	0.28	0.08	-
TSBH045	270151.86	192720.82	6.22	4.72	1.50	1.00	6.00	2.47	>6			6.22	4.15	-	-	-
TSBH046	270249.6	192763.86	5.86	4.81	1.05	1.00	8.00	1.34	5.40	0.10	>2.5	5.86	4.15	0.46	0.36	-
TSBH047S	270289.85	192741.03	6.17	4.66	1.51	1.00	6.00	2.42	>6			6.17	4.15	-	-	-
TSBH047D	270290.02	192740.49	6.23	4.30	1.93	13.00	14.00	-7.27	12.20	0.50	>1.3	6.23	4.15	-5.97	-6.47	-
TSBH050	270153.07	192815.92	6.04	5.10	0.94	1.00	6.00	2.54	>6			6.04	4.15	-	-	-
TSBH051	270076.92	192823.69	5.86	5.31	0.55	1.00	6.00	2.36	>6			5.86	4.15	-	-	-
TSBH052	270062.16	192777.87	6.15	4.99	1.16	1.00	6.00	2.57	>6			6.15	4.15	-	-	-
TSBH053	270000.03	192730.27	5.8	4.78	1.02	1.00	6.00	2.29	>6			5.80	4.15	-	-	-
TSBH054	270123.34	192789.76	5.91	5.01	0.90	1.00	6.00	2.41	>8			5.91	4.15	-	-	-
TSBH057	270254.5	192934.4	6.15	5.70	0.45	1.70	6.70	1.95	8.80	0.70	>0.5	6.15	4.15	-2.65	-3.35	-
TSBH058	270179.17	192875.29	6.09	5.57	0.52	1.00	6.00	2.59	>6			6.09	4.15	-	-	-
TSBH060	269312.49	192828.98	5.66	4.36	1.30	1.00	6.00	2.01	>6			5.66	4.15	-	-	-
TSBH061S	269508.17	192856.07	6.95	4.76	2.19	3.00	8.00	1.45	>8			6.95	4.15	-	-	-
TSBH061D	269508.01	192856.19	6.98	4.62	2.36	10.00	11.00	-3.52	8.60	1.40	>1.6	6.98	4.15	-1.62	-3.02	-
TSBH062	269366.89	192872.24	5.92	4.83	1.09	1.00	6.00	2.38	>6			5.92	4.15	-	-	-
TSBH063S	269279.76	192895.83	5.96	4.92	1.04	1.00	6.00	2.44	>6			5.96	4.15	-	-	-
TSBH063D	269279.66	192896.4	5.95	4.80	1.15	8.00	10.00	-3.05	10.00	>2		5.95	4.15	-4.05	-	-
TSBH066	269242.2	192814.85	6.12	3.97	2.15	1.00	6.00	2.05	>6			6.12	4.15	-	-	-
TSBH067	269293.37	192857.48	5.84	4.53	1.31	1.00	6.00	2.19	>6			5.84	4.15	-	-	-
TSBH068	269291.34	192760.81	6.04	3.03	3.01	1.00	6.00	1.54	>6			6.04	4.15	-	-	-
TSBH069	269347.97	192812.46	6.37	4.02	2.35	1.00	6.00	2.20	>6			6.37	4.15	-	-	-
TSBH070	269382.09	192830.04	5.75	4.41	1.34	1.00	6.00	2.08	>6			5.75	4.15	-	-	-
TSBH071	269414.3	192817.38	5.77	4.27	1.50	1.00	6.00	2.02	>6			5.77	4.15	-	-	-
TSBH073	269539.41	192824.45	6.73	4.61	2.12	3.00	8.00	1.23	>2.2			6.73	4.15	-	-	-
TSBH074	269497.18	192833.2	6.81	4.84	1.97	2.00	8.00	1.81	>8			6.81	4.15	-	-	-
TSBH075	269429.72	192847.29	5.89	4.62	1.27	1.00	6.00	2.26				5.89	4.15	5.89	-	-
TSBH077	269482.56	192780.87	6.6	4.13	2.47	3.00	8.00	1.10	>8			6.60	4.15	-	-	-
TSBH079	269460.08	192733.83	6.48	3.55	2.93	3.00	8.00	0.98	>8			6.48	4.15	-	-	-
TSBH080	269401.46	192752.7	6.93	3.49	3.44	3.00	8.00	1.21	>8			6.93	4.15	-	-	-

Notes:
GL - Ground Level
SWL - Standing Water Level