RODGERS LEASK
Consulting Civil & Structural Engineers

Glan Llyn, Newport

Site Wide Surface Water Drainage Strategy

Glan Llyn, Newport

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Addendum

For

St Modwen Ltd

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Summary

Rodgers Leask has been appointed by St Modwen Developments Ltd to undertake a comprehensive surface water drainage strategy to service the whole of the Glan Llyn development site, which provides an update to the approved Llanwern Regeneration Site Drainage Strategy (Halcrow Group Ltd, Dec 2005) and accounts for those areas of the site which have already been developed out (such as the Western Sub Area and parts of the Celtic Business Park) and those sub areas that are still to come forward for development.

As part of the site appraisal process it is necessary to demonstrate that the proposed development can be achieved with an acceptable risk of flooding. This report describes the results of the assessment and takes into account the recommendations of Technical Advice Note (TAN) 15 – Development & Flood Risk Areas (Welsh Government, 2004) in accordance with Planning Policy Wales. The report has also been developed through consultation with Natural Resource Wales (NRW).

This Surface Water Drainage Strategy has been prepared to demonstrate the principles of surface water management and that this can be achieved in a sustainable way without increasing flood risk to the site itself and neighbouring property and land. In summary this will be achieved by providing approximately 399,000m^3 of storage within the site, which will take the form of an extensive network of blueways/reens, lakes and other Sustainable Drainage Systems (SuDS). Such systems will enhance the aesthetics, biodiversity of the development in addition to providing essential water quality improvement to the surface water before being discharged to the Monks Ditch. The Monks Ditch, which is classified as Main River, flows through the development site and is subject to tide locking where it outfalls into the Severn Estuary approximately 4500m downstream.

It is proposed that surface water runoff from the development is pumped into the Monks Ditch, instead of the Severn Estuary which is the current situation, at a greenfield runoff rate of 3.5l/s/ha, which for a 214ha development area equates to a maximum pump rate of 750l/s. To assess the impacts of this additional water on the Monks Ditch and Caldicot Levels, Atkins Plc has undertaken a complex hydraulic modelling exercise of this system and proposed pumped discharge. The assessment concluded that the pumped discharge of surface water needs to be regulated and timed to discharge outside of tide locked conditions to ensure that the development did not cause detriment to flood risk downstream.

As such the surface water drainage strategy has taken account of the additional surface water runoff that will require storing if the development is unable to pump out to the Monks Ditch during tide locked conditions. In summary therefore the surface water drainage system will be able to store 399,000m^3 which will allow:

- the development to store surface water runoff during the 1 in 100 year storm event plus 30% climate change event in its entirety and without discharging to the Monks Ditch for the duration of that event;
- the surface water runoff from rural catchments to the north of the site during a 1 in 100 year plus 30% climate change event, without discharging to the Monks Ditch for the duration of the event;
- the additional storage of a 1 in 5 year sequential event; should the Glan Llyn's surface water drainage system be unable to fully empty before another storm event occurs; and

- the development to be raised above a 1 in 1000 year tidal breach event at the Transporter Bridge and the Goldcliff sea defence embankment.

It is considered that this assessment demonstrates that the proposed surface water drainage strategy ‘makes space for water’ and provides sufficient capacity to accommodate the necessary surface water and tidal flood storage required to make the development and the surrounding area safe from flood risk.

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Appendices

1.0 Introduction

1.1. Terms of Reference

Rodgers Leask Ltd has been commissioned by St Modwen Developments Ltd to produce a comprehensive site-wide surface water drainage strategy for the proposed Glan Llyn redevelopment site (formerly referred to as Llanwern Regeneration Site), Newport. The Glan Llyn redevelopment site covers an area of approximately 214ha which was formerly occupied by Llanwern Steelworks.

1.2. Background of Study

Halcrow Group Ltd previously prepared an overall, strategic Drainage Strategy and Flood Consequence Assessment to support an outline planning application (ref. 06/0471) for the redevelopment of the Glan Llyn site. These approved documents set out the framework for the overall design, proposed strategy and outline principles for the treatment and disposal of surface water flows and flood risk management which in part have been adopted as part of this drainage strategy.

In addition to these supporting documents, Atkins Plc has recently completed a 1D-2D hydrodynamic model of the Monks Ditch and Caldicot Levels, which covers an extensive area of approximately 55km^2. The results of this hydraulic modelling assessment have been used to inform this surface water drainage strategy and can be reviewed in Appendix E of this report. To substantiate the baseline conditions and the design of the proposed surface water drainage system contained within this report the following should be read in conjunction:

- Llanwern Regeneration Site Drainage Strategy (Halcrow Group Ltd, Dec 2005). Refer to Appendix B;
- Glan Llyn, Newport Flood Consequence Assessment Addendum (Halcrow Group Ltd, Nov 2010). Refer to Appendix C;
- Glan Llyn – Hydraulic Modelling: Impact of Assessment of Pumped Surface Water Discharge into the Monks Ditch (Atkins Plc, 2016). Refer to Appendix F.

1.3. Purpose of Report

The purpose of this report is to provide a comprehensive site wide surface water drainage strategy for the proposed Glan Llyn development, building upon the approved design principles and site parameters set out within the previous drainage strategy developed by Halcrow Group Ltd and incorporates the drainage strategy proposals already submitted for the Western Sub Area and Celtic Business Park Developments to provide a joined up approach, which are detailed in the following reports:

1) Glan Llyn – Western Sub Area Surface Water Strategy Addendum (Rodgers Leask Ltd, May 2012);

2) Celtic Business Park Road, Llanwern Drainage Strategy (Rodgers Leask Ltd, December 2014).

The surface water drainage strategy has been assessed with consideration to the potential flood risk to the Glan Llyn site itself, in addition to the impacts on flood risk to the Monks Ditch and Caldicot Levels downstream should surface water generated by the development be pumped into the Monks Ditch. This will be achieved through the sustainable management of surface water runoff both in terms of quantity and quality whilst taking into account the expectations of future climatic change, in accordance with the requirements set out in within Technical Advice Note (TAN) 15 – Development & Flood Risk Areas (Welsh Government, 2004).

1.4. Consultation

Consultation with Natural Resource Wales (NRW) has also formed a key part of this Surface Water Drainage Strategy, where basic hydraulic modelling and surface water design parameters have been agreed.

2.0 Existing Site Conditions

2.1. Site Location & Description

The Glan Llyn site covers an area of approximately 242ha, which comprises previously developed land and is located in Llanwern, which lies to the east of Newport and is centred on National Grid Reference 336820 (easting) and 186442 (northing). Refer to Appendix A for a site location plan.

During the 1960s the proposed development site was extensively developed as a steelworks which involved land raising and engineering improvement of the existing ground. However following the cessation of steel making operations in the 1990s the western area of the overall site is now largely unoccupied except for the residential development to the south west corner of the site which is already under way and a section of highway (located at the eastern end of the Glan Llyn site) to service the proposed Celtic Business Park. Drawing D12-084 512 in Appendix A shows the proposed site layout and what has already been developed.

The Glan Llyn site is dissected by Monks Ditch, which delineates the proposed residential from the commercial development. To the north the site is bounded by the Cardiff to Bristol railway line in addition to Corus Tata's sidings, the remaining steelworks to the east and Queen's Way Road to the south. Beyond the railway to the north lies Llanwern Golf Course and Llanwern Village, to the south, the Gwent Levels which is designated as a SSSI.

2.2. Catchment Description

The Glan Llyn site is relatively low lying and falls with the River Usk catchment, which is within the Eastern Valleys area of South Wales. The site lies to the east of the Usk Estuary and north of the Severn Estuary. Both waterbodies are designated sites and are recognised both internationally and nationally, respectively for their importance in terms of conservation.

2.3. Surface Water

2.3.1 Onsite Reen System

The Glan Llyn development site is almost hydrologically self contained, in that it has no connection with the Monks Ditch or the surrounding reen system and Cladicots Levels to the south of the development site.

The site is currently drained by a series of reens (open drainage ditches) and culverts (situated on piled foundations) running from north to south. These north to south drains, of which there are six, collect surface water runoff from the existing site and two small rural catchments to the north of the site/railway. All of these drains outfall into the Main East West Ditch (MEWD) to the south of the site which flows parallel to Queen's Way Road.

The MEWD is an unlined trapezoidal channel with grassed banks (see Figure 1) and flows eastwards into a settlement lagoon (Lagoon 14) located to the south of the steel works. From here a mix of foul and processed water (received from the steel works) and surface water runoff, is eventually pumped out to the Severn Estuary via two above ground pipelines. The quality and quantity of the pumped discharge falls under a statutory Integrated Pollution Prevention and Control (IPPC) licence.

Figure 1: Main East West Ditch culverted under Monks Ditch

Refer to Halcrow's drawing PI/FLRS/SK/W/801/001 in Appendix A for a drainage plan of the site and surrounding area before the Glan Llyn development commenced.

2.3.2 Offsite Reen System

In addition to the internal reen system there are a number of reens and watercourses surrounding the site which are controlled and maintained by NRW The following describes some of the main reens in the area:

- Oxleaze Reen and Barn Reen drain into Monks Ditch to the north west of the site. These convey water from the north and are maintained by NRW.
- Long Ditch Reen (Julian's Reen) is controlled and maintained by NRW. The reen passes through the development area from north to south and defines

the Western Sub Area (WSA) and Central Sub Area (CSA) proposed developments.

- Liswerry Pill Reen collects water from the residential Ringland and Moorgate estates. The reen discharges to the River Usk approximately 1km to the west of the site. It crosses the further north west corner of the Glan Llyn site and is classified as main river.
- Northern Field Ditches: Llanwern Golf course and farms to the north of the main rail line drain into 10 privately owned field ditches. These ditches drain under the main rail line into the North East West Ditch located between the main rail line and the Tata rail line. Six of these ditches then continue to flow through the Glan Llyn site.

These drains also discharge into the Main East West Ditch (MEWD), apart from the Liswerry Pill Reen.

Further details regarding the size and make up of each of these reens is provided in the Llanwern Regeneration Site Drainage Strategy (Halcrow Group Ltd, Dec 2005) in Appendix B.

2.3.3 Monk Ditch

The Monks Ditch is classified as Main River through the development site and is therefore maintained and enforced by NRW.

The Monks Ditch enters the site from the north via a two siphons 1A and 1B which flows under both the railway and Tata's sidings. The ditch continues to flow, independently of the surface water drainage system operated within the site, in a southerly direction in a deep piled concrete channel which is approximately 7m wide and 3m deep. The ditch then exits the site to the south under Queen's Way Road and the steelworks minor access road via two siphons (2A and 2B) (Refer to Figure 2).

The Monks Ditch then becomes a natural channel once more to the south of the site where it then flows through the Caldicot Levels and becomes the primary receiving watercourse to the extensive reen system. Approximately 4500m downstream of the site the Monks Ditch outfalls to the Severn Estuary, via a tidal exclusion gate which comprises 11 tidal flaps. During tide lock (high tide) local runoff collects in the reens until such time that it can discharge by gravity at low tide conditions. The two lowest areas in the Caldicot Levels are drained by pumping into high levels reens.

Figure 2: Monks Ditch (looking North)

2.4. Geology & Groundwater Conditions

The ground conditions in this area consist of made ground overlying highly compressible Estuarine Alluvium. The made ground is dense and granular comprising predominantly of slag with a high pH and containing lime. The development area has pockets of minor contamination and areas of fill. An element of remediation has already taken place and further remediation will be required but is considered not to be a constraint to the development.

Groundwater quality within the steels works site reflect the leachate data with elevated concentrations of some metals and ammonia. Groundwater contamination will be addressed under the site ground remediation strategy, with works practice measures being adopted to ensure there are no adverse impacts on water quality.

3.0 Flood Risk

3.1. Flood Consequence Assessment

To support an outline planning application for the development of the Glan Llyn development site (formerly known as the Llanwern Regeneration Site) ref. 06/0471 Halcrow Group Ltd were commissioned to undertake a Flood Consequence Assessment in March 2006 and subsequent addendum in November 2010 to assess the potential tidal flood risk to the development site. The Floods Consequence Assessment Addendum (FCAA), refer to Appendix C, tested three breach scenarios at what was considered strategic or sensitive locations that would manifest the most significant flood risk to the site. These included the:

1) Goldcliff sea defence embankment (south of the site);
2) Riverside retaining wall (west-northwest of the site on the River Usk); and
3) The embankment south of the Transporter Bridge (west-southwest of the site).

It was determined that two of these scenarios (Goldcliff Sea Defence and Transporter Bridge) only affected the site during a 1 in 1000 year extreme event. Both resulted in different predicted on-site flood water levels where the Transporter Bridge breach scenario affected the western area of the proposed development site (highlighted in orange in Figure 3) to a level of 6.5mAOD and the Goldcliff Sea Defence breach affected the central and eastern area of the site to a level of 6.3mAOD (highlighted in purple on Figure 3).

Figure 3: Indicative Extent of Proposed Minimum Development Levels

As such the FCAA recommended that the final development levels were raised to a minimum of 6.5mAOD in the western area and 6.3mAOD in the central and eastern area of the development site to reduce the flood risk to the development site. However in order to achieve the required land raising and not increase flood risk elsewhere it was determined that a flood compensation volume of 75,450m^3 in the western area and 72,900m^3 in the central and eastern area (a total of 148,350m^3) is required. As such the flood risk mitigation parameters are summarised in Table 1.

Development Area	Breach Scenario	Minimum Development Level (mAOD)	Flood Compensation Volume (m^3)
Western Sub Area	Transporter Bridge	6.5	75,450
Central Sub Area	Gold Cliff Sea Defence	6.3	72,900
Eastern Sub Area	Gold Cliff Sea Defence	6.3	
Celtic Business Park	Gold Cliff Sea Defence	6.3	Provided for within Central & Eastern Sub Area

Table 1: Flood Mitigation Design Parameters

The Celtic Business Park to the very east of the site is only partially subject to flooding from the Goldcliff breach scenario. It is proposed that levels within the business park are marginally raised. And the floodplain compensation required is provided for within the Central and Eastern Sub Areas.

The FCAA also determined that the Goldcliff Sea Defence breach would not directly impact the western area in terms of flooding. However the flooding of the Central and Eastern areas of the site would cause a delay of the western sub area being able to freely discharge surface water for a period of up to 24hours.

4.0 Proposed Development

4.1. Introduction

The proposed redevelopment of the Glan Llyn site will deliver a mixed use development, comprising circa 4000 dwellings, a local centre, a school and a business park. In addition extensive open green space incorporating blueways, greenways and lakes is also proposed which will provide significant opportunities for the improvement in the quality and quantity of surface water runoff from the development area.

4.2. Development to Date

Areas of the Glan Llyn site have already been developed comprising residential development, West Park, the Local Centre and associated highway within the Western Sub Area of Glan Llyn.

4.3. Development Sub Areas

For the purposes of the drainage strategy the developable area of the Glan Llyn site has been divided into four separate sub areas as listed in Table 2.

Development Area	Area (ha)
Western Sub Area	57
Central Sub Area	63
Eastern Sub Area	49
Celtic Business Park	45
TOTAL	**214**

Table 2: Development Sub Areas

The layout of the proposed development and the four sub areas are illustrated on drawing D12-084 514 in Appendix A.

5.0 Proposed Surface Water Drainage

5.1. Drainage Design Guidance

In accordance with TAN 15 and Planning Policy Guidance (Wales), any new or re-development should apply and give priority to Sustainable Drainage Systems (SuDS), which are designed to control surface water runoff close to where it falls and mimic natural drainage as closely as possible. Therefore in accordance with planning policy the proposed Glan Llyn development will implement a site storm drainage system that provides sustainable drainage measures consistent with the recommendations of TAN 15 and with due regard to the following industry standards:

- The SuDS Manual CIRIA C753;
- Defra/EA Flood & Coastal Erosion Risk Management R&D Programme – Preliminary Rainfall Runoff Management for Developments Rev E (2012);
- EA's pollution prevention guidelines (PPGs); and
- Sewers for Adoption 7th Edition.

5.2. General Drainage Design Parameters

NRW have specified that the proposed surface water drainage system discharges at a greenfield runoff rate of 3.5l/s/ha, which equates to a maximum discharge rate of 750l/s from the site, up to and including a 1 in 100 year storm event. Based on a discharge rate of 3.5 l/s/ha, WinDes has been used to determine the volume of storage required to attenuate surface water runoff from each sub area of the development (refer to Appendix D). In addition to the surface water storage volume required, the flood storage compensation volume required for each sub area has also been determined as summarised in Table 3.

Development Area	Rainfall Event Climate Change Factor	Impermeable Area	1 in 100 yr Surface Water Storage (m^3)	1 in 1000yr Tidal Breach Flood Storage (m^3)	Total Storage Required (m^3)
Western Sub Area (WSA)	30%	34.2	25,866	75,450	101,316
Central Sub Area (CSA)	30%	37.8	28,633	72,900	123,790
Eastern Sub Area (ESA)	30%	29.4	22,257		
Celtic Business Park	20%	40.5	31,405	Accommodated for within ESA & CSA	31,405

Development Area	Rainfall Event Climate Change Factor	Impermeable Area	1 in 100 yr Surface Water Storage (m^3)	1 in 1000yr Tidal Breach Flood Storage (m^3)	Total Storage Required (m^3)
TOTAL		**142**	**108,161**	**148,350**	**256,511**

Table 3: Surface Water & Flood Water Storage Requirements for each Sub Area Based on a Discharge Rate of 3.5l/s/ha

5.3. Surface Water Strategy

The strategic surface water drainage network across the site involving the location of reens and main attenuation features has been considered as part of the masterplanning process to ensure the development 'makes space for water' in addition to providing the necessary treatment required to achieve water quality targets. The indicative layout of the surface water drainage strategy is illustrated on drawing D12-084 512 in Appendix A. The attenuation and treatment of surface water from the site will be achieved via three main Sustainable Drainage Systems (SuDS):

1) **Blueways** – these will comprise a number of the existing reens in addition to the creation of new reens. These will act as the primary surface water channels throughout the site providing the necessary attenuation and treatment for surface water runoff and flood water storage from a tidal breach scenario. Where possible the blueways will be widened to provide additional storage volume and will sustain a permanent depth of water of approximately 300mm to enhance local biodiversity and aesthetics.

2) **Greenways** – it is proposed that these will be high level dry shallow channels which will channel overland surface water from the development plots into the blueways. The greenways will also attenuate tidal breach flood water. The volume of storage will depend on the level of connection with the blueway which will vary on site depending on finished plot levels.

3) **Lakes** – There will be a number of lakes and /or online ponds connected to the blueway system which will not only store surface water runoff but will also act as focal points for recreational areas and enhance the aesthetics of the Glan Llyn development.

A comprehensive schedule of the proposed surface water storage features (refer to Appendix E) sets out the design parameters of each feature and on this basis the available storage capacity. The schedule demonstrates that collectively the site has the ability to offer a total storage capacity of 398,570m^3. The entire reen/blueway network will be regraded to drain towards Monks Ditch, where following treatment, surface water flows will be pumped into the Main River instead of the Severn Estuary, thereby isolating the Glan Llyn surface water drainage system from the steelworks, providing an independent, maintainable system.

5.4. Discharging to the Monks Ditch

Given the ground levels adjacent to the Monks Ditch and the raised walls/engineered channel that contains the watercourse, surface water flows will have to be pumped in to the Monks Ditch. This will be achieved via two pumping stations:

1) Surface Water Pumping Station 1 (SWPS1) – which will receive flows from the WSA, CSA, ESA and northern catchments;
2) Surface Water pumping Station 2 (SWPS2) – which will receive flows from Celtic Business Park.

The location of these pumping stations is indicated on drawing D12-084 512 in Appendix A, however the actual discharge point of these pumping stations can be located anywhere along the Monks Ditch where ST Modwen are riparian owners. These pumping stations will discharge at a cumulative peak rate of 750l/s.

This proposal effectively adds water to the Monks Ditch and Caldicot Levels catchment, as all surface water is pumped directly out to sea the site currently contributes 0l/s greenfield runoff to the Monks Ditch catchment. However the Monks Ditch channel within the Glan Llyn site has the capacity to convey 31m^3/s based on cross sectional survey information and the mannings n calculation. The maximum flow during a 1 in 100yr + climate change event in the Monks Ditch is approximately 17m^3/s, which demonstrates that there is adequate capacity within the Monks Ditch to receive an additional pumped flow of 0.75m^3/s from the proposed development site without causing flooding.

However this available capacity within the Monks Ditch assumes that the receiving watercourse and reen system downstream has a free discharge into the Severn Estuary. As described in Section 2.3.3 the Monks Ditch and receiving Caldicot Levels downstream are tidally influenced and subject to tide locked conditions from the Severn Estuary for periods of between 3 to 8 hours on normal tides. It is during such conditions that the proposed pumped discharge of 750l/s into the Monks Ditch has the theoretical potential to increase flood risk downstream, even when discharged at a greenfield runoff rate, during a tide locked event.

On this basis NRW has requested that the proposed pumped discharge into the Monks Ditch be modelled and the impacts on flood risk understood to determine what mitigation measures are required to ensure that a pumped discharge does not cause a detriment to flooding in the local area, particularly during tide-locked conditions.

5.4.1 Hydraulic Modelling

Atkins Plc recently completed a detailed 1D-2D modelling study of the Monks Ditch through the site and extensive Caldicot Levels reen systems downstream to test the impacts of the M4Can Project on flooding risk and mechanisms. As such Atkins were commissioned to use this model for the purposes of testing the impacts of the proposed pumped discharge of surface water into the Monks Ditch.

Atkins has produced a technical note detailing the modelling approach adopted and results of the study (Refer to Appendix F). To summarise the model was used to test the following scenarios:

1) Baseline – the existing model was simulated with a 1 in 5 year, 1 in 100 year with climate change and 1 in 1000 year event to determine the baseline conditions for each flood event and use these results as a benchmark to determine the impacts of the proposed pumped discharge from the Glan Llyn site.
2) With Project: Constant Pumping Scheme – This tested the impact of pumping at a constant rate of 750l/s, regardless of tide locked conditions, which was simulated with a 1 in 5 year, 1 in 100 year with climate change and 1 in 1000 year. A simulation of a dry weather flow (no rainfall) was also tested.
3) With Project: Regulated Pumping Scheme – this modelling scenario involved applying a set of operating rules to the pumps, which allowed the pumps to operate only when certain conditions permitted i.e. when the Caldicot Levels were not tide locked. Specifically the pumps were turned off once water levels in the Monks Ditch rose to within 300mm of bank full level (lowest bank level 5.119mAOD located at the Whitson Electrical Substation 1km downstream of the site) given a switch off level of 4.819mAOD.

5.4.2 Results

All simulations were run with storm events (winter profile) of 12 hour duration as this was found to be on average the critical duration for the Caldicot Levels. The assessment indicated that the constant addition of 750l/s into the Monks Ditch could increase flooding in small local areas by up to 400mm. As shown in Figure 4.

To compensate for this impact the pumped discharge was regulated and limited to operating during periods when water levels in the Monks Ditch remained in channel and hence was found not to contribute or exacerbate flooding on the Caldicot Levels.

It was noted that the winter penning levels close to the Monks Ditch are 4.75mAOD and close to the tested trigger level of 4.819mAOD. As such, the pumps were predicted to be switched on for less than 2 hours during the onset of the design storms.

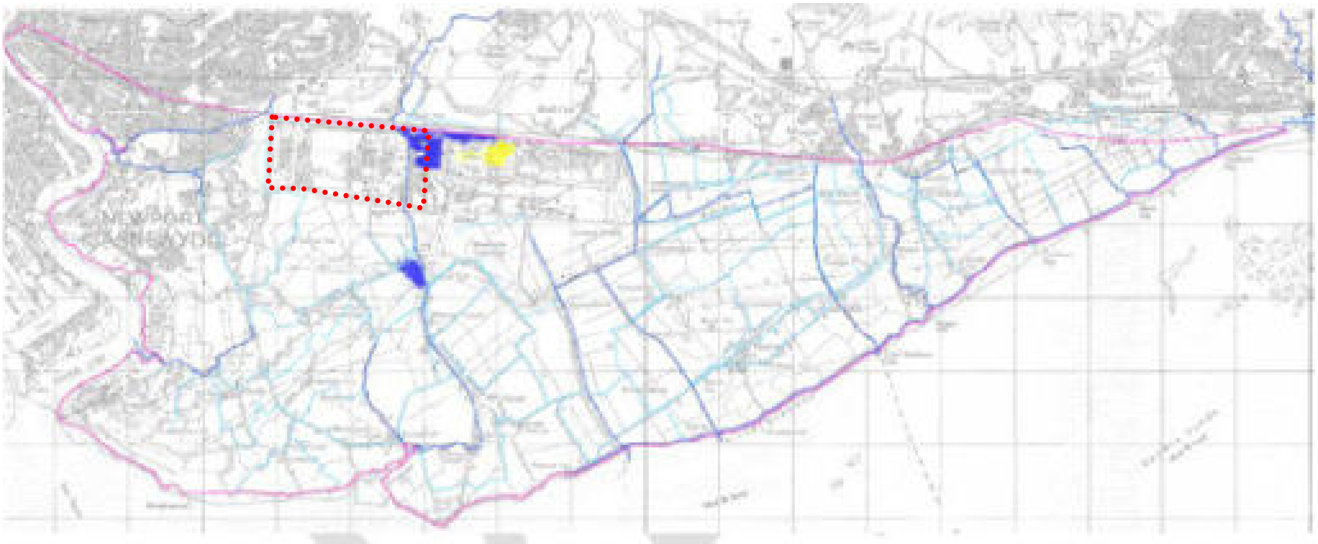


Figure 4: Constant Pumping Scheme: Areas of Increased Flood Depth

Due to the complex nature of the model, the simulation of each event took approximately three weeks to complete. As such only a discharge of 0l/s or 750l/s was considered, limiting the number of scenarios that could be tested in terms of varying pumped discharged rates and optimising the time pumps operated for. Further modelling work will be required to develop this concept and refine the pump trigger location and level. In practice however the pumping regime will be installed and monitored. The impact of the trigger level will be regularly reviewed and adjusted where found necessary. In this regard the proposed drainage system can be fine-tuned against the local flood risk issues.

5.5. Glan Llyn Storage Capacity

It is clear that during tide locked conditions that there is a requirement for the Glan Llyn development to make provision for the storage of additional surface water that cannot be pumped into the Monks Ditch and ensure that it can be safely stored on site. As a conservative approach it has been assumed that the site is unable to discharge to the Monks Ditch during a storm event with a critical duration of 12hrs. Therefore the total volume of water to be stored on site for a 1 in 100 year + 30% climate change storm event (with 0l/s discharge rate) has been determined using WinDes. These results are summarised in Table 4 and WinDes calculations in Appendix G.

Development Area	Total Area	Impermeable Area (ha)	1 in 100 yr Surface Water +30% Storage (m^3)	1 in 1000yr Tidal Breach Flood Storage (m^3)	Total Storage Required (m^3)
Whole Development Site	214	142	**131,900***	148,350	**280,250**

*Based on a 12hr duration storm

Table 4: Surface Water & Flood Water Storage Requirements for the Whole Site with a 0l/s discharge rate.

5.5.1 Northern Catchment Runoff Assessment

In addition to the surface water runoff generated by the development itself, the proposed surface water drainage system will also have to be able to accommodate the rural runoff from two catchments to the north of the site. Therefore an assessment of these two rural catchments has been undertaken to determine the peak greenfield runoff rate and volume of runoff entering the development site. This was achieved by manually mapping the contributing catchments based on Ordnance Survey mapping and FEH catchment boundaries (refer to Sketch 1 in Appendix A for the catchment contributing areas). Based on a cumulative contributing area of 170.66ha and FEH catchment descriptors specific to the study area, the rural runoff calculator in WinDes has been used to determine the peak greenfield runoff rate and volume for a 1 in 100 year storm event for varying durations. Refer to Appendix H for these WinDes results and Table 5 below for a summary of these results for the cumulative catchment runoff rates and volumes.

1 in 100yr Storm Duration	Runoff Vol (m^3)	1 in 100yr Q Max (l/s)	QBar (l/s)
720mins/12hrs	**48,537**	1,610	739
960mins/16hrs	52,879		
1440mins/24hrs	59,692		
2880mins/48hrs	73,538		

Table 5: Northern Catchment Greenfield Runoff Volumes for Varying Storm Durations

Therefore based on a critical storm duration of 720 mins/12 hrs, where the surface water drainage system cannot pump to the Monks Ditch, a total storage volume of 180,437m^3 (131,900m^3 + 48,537m^3) for surface water will be required within the system.

5.5.2 Total Onsite Storage Capacity

As demonstrated in Table 6 the proposed surface water drainage system which will have a total storage capacity of 399,000m^3 (as detailed in Appendix E) will have the capacity to store both the surface water runoff from the development site and northern catchments with no outfall to the Monks Ditch in addition to the tidal breach flood water. This leaves a surplus capacity of 70,213m^3 within the system.

Source	Storage Volumes Required (m^3)	Total Storage Vol Available within System (m^3)	Remaining Storage Available (m^3)
Surface Water System	131,900	399,000	70,213
Northern Catchment	48,537		
Tidal Breach Flood	148,350		
Total	**328,787**	**399,000**	**70,213**

Table 6: Storage Volume & Capacity Assessment

5.5.3 Surface Water Drain Down Assessment

Under such conditions the site would not need to pump discharge to the Monks Ditch until after the storm/flood event. Once the system is permitted to pump the site could fully discharge the stored surface water within 67 hours as demonstrated in Table 7.

Storm Event	Development Runoff Vol (m^3)	Northern Catchment Runoff Vol (m^3)	Total Runoff Vol (m^3)	Max. Pump/ Discharge Rate (l/s)	Drain Down Time (hrs)
1 in 100 yr (720min/12hr duration)	131,900	48,537	180,437	750	**67hrs**

Table 7: Time Taken for the Glan Llyn Surface Water Drainage System to Empty

However it could be argued that the maximum pump rate of 750l/s be increased to account for the greenfield runoff from the northern catchments and as such an additional 739l/s (QBar) be permitted to pass forward into the Monks Ditch, thereby increasing the maximum pump rate to 1,489l/s. This would reduce the drain down time to 34hours. However the increased pump rate would need to be tested in the hydraulic model of the Monks Ditch and Caldicot Levels to determine the impact of this additional flow on the receiving watercourse and reen system.

5.5.4 Sequential Storm Event

However it can be concluded at this stage that it would be reasonable to assess the impact of a sequential storm event before the surface water drainage system has time to fully empty. To understand the magnitude of an additional storm event the surface water drainage system could accommodate, the volume of rainfall for storm events with varying return periods has been assessed as provided in Table 8.

Storm Event	Development Rainfall Vol (m^3)	Northern Catchment Rainfall Vol (m^3)	Total (m^3)
1 in 1 year	35,230	13,791	**49,021**
1 in 2 year	41,317	16,176	**57,493**
1 in 5 year	49,737	19,906	**69,643**
1 in 10 year	59,103	24,872	**83,975**

Table 8: Sequential Rainfall Volumes

As shown in Table 6 the development has the capacity to store an additional volume of 70,213m^3, which equates to the volume of runoff generated from a 1 in 5 year storm event.

This demonstrates that even if the development is unable to discharge to the Monks Ditch, the proposed surface water drainage system has the capacity to store:

- a 1 in 100yr +cc storm event
- a 1 in 1000yr tidal breach event and
- a 1 in 5yr sequential rainfall event.

5.6. SuDS Treatment Train & Water Quality Enhancement

A sustainable drainage system will be adopted to minimise the impacts from the development on the quantity and quality of the runoff and maximise amenity and biodiversity opportunities. In seeking to sustainably drain surface water from the site the "Management Train" methodology as set out in CIRIA C753 will be adopted as part of the drainage strategy for the site. The Management Train is made up of the following components:

- Prevention – good site design and upkeep to prevent runoff and pollution (e.g. limited paved areas, regular pavement/car park sweeping, maintenance of oil interceptors and gulleys, clear adoption and maintenance programme of SuDS);

- Source Control – runoff control at/near to source (e.g. rainwater harvesting, green roofs, permeable paving; soakaways; swales);

- Site Control – water management from different onsite compartments (e.g. route water from roofs, impermeable paved areas to one infiltration/holding site); and

- Regional Control – integrate runoff management from a number of sites (e.g. into a detention pond).

As previously mentioned the main strategic attenuation features, which will provide the necessary site control, will include a network of reens (blueways), greenways, online ponds/pools and offline lakes. In order to deliver the treatment train philosophy the Glan Llyn development will also incorporate a combination of source control SuDS techniques to replicate, as closely as possible, the natural drainage from the site before development.

It is proposed that the following parameters are considered as a single treatment train:

- 25m of reen/swale;
- A pond with a width and length greater than 5 and 10 (respectively) times the adjacent swale width;
- A trapped gully (when in conjunction with a reen/swale);
- Permeable paving; and
- Filter trench 10m in length.

In delivery yards/commercial vehicle manoeuvring areas, the District Centre and Schools, three levels of treatment will need to be considered including oil separators (refer to Appendix I for further information regarding the types of pollution prevention measures and guidelines to be adopted as part of this development as agreed with NRW as per Planning Condition 35).

It is proposed that prior to leaving the site all surface water will be treated via a substantial treatment zone. These will be located at the most downstream point of the NEWD and the Kings Water Reen within the ESA and will comprise a graduated linear wetland/reed bed which will filtrate and adsorb any contaminants within the surface water runoff before being discharged from site. The location of these treatment zones are indicated on drawing D12-084 512 in Appendix A. Section 5.7 sets out how the water quality within the surface water drainage system will be monitored to ensure that remediation targets are being met to ensure that there is no adverse impact on the water quality of the receiving Monks Ditch and Whitson SSSI downstream.

5.6.1 SuDS Adoption & Maintenance

Even though the surface water drainage system will be designed to adoptable standards, the surface water drainage system, reen network and associated SuDS features will remain private and under the control of the Developer. The costs associated with maintaining the system will be recovered from the tenants and tenants/owners of plots on the site. The following table outlines general maintenance plan/requirements for the proposed reen system and SuDS features within the development.

Table 9: General Reen System/SuDS Maintenance Table

Regular Maintenance	Litter & debris removal from site	Monthly
	Amenity grass cutting at 35-50mm	As required
	Grass cutting to access routes, overflows and basin where required at 75-100mm not to exceed 150mm	As required
	Meadow grass, where appropriate, cut at 50mm and remove to wildlife or compost piles	Annually
	Manage wetland/reedbed planting in micropools by cutting and remove to wildlife or compost piles	As required
	Inspect and clear inlets, outlets, control structures and overflows	Monthly
	Deweeding of reen system	Quarterly
	Desilting/dredging of reen system	Annually
	Tree Inspection	Annually
	Wildlife Inspection	Annually
Occasional Tasks	Remove leaf accumulation	As required
	Cut back overhanging branches	As required

	Remove sediments from forebay, inlets and pre-treatment structures	
Remedial Work	Inspect and repair damage to inlets, outlets, banks and overflows	As required

5.7. Ground Contamination & Water Quality Monitoring

Atkins Plc has confirmed the following strategy relating to ground remediation and water quality monitoring:

The site has a history of industrial usage which includes the operation of a steel works over a period of 40 years. Contamination may therefore be present within the soils and groundwater resultant from past industrial uses within the undeveloped areas of the site. The outline planning permission for the site requires the land to undergo a comprehensive assessment of contamination potential. The assessment will include physical testing of soil and groundwater and modelling of the impacts of residual contaminants on the surface water environments, including the drainage network and downstream receptors such as Monks Ditch and Gwent Levels SSSI.

Where required remediation will be undertaken to reduce or mitigate the impacts of residual contamination on a range of receptors, including the surface water drainage network. Any remediation will be in accordance with quality criteria defined within a site specific Controlled Water Risk Assessment (CWRA) for the Glan Llyn development. The assessment of water stored within the surface water drainage system will take account the impacts of both predicted storm flows from the proposed developed areas and also likely groundwater baseflow in addition to likely surface water inputs from off-site flow. The criteria included within the CWRA will be modelled to be protective of the surface waters on site and the intended receiving surface waters.

The scope of remediation requirements and target criteria for the CWRA will be subject to approval by the regulators, including Cyfoeth Naturiol Cymru/Natural Resources Wales (CNC/NRW) in accordance with the planning conditions for the site. The surface water drainage proposal for the site has been considered in relation to impacts on the Gwent Levels SSSI and the Severn Estuary. The redevelopment of the site is committed to ensuring that there is no adverse impact on the water quality of the receiving Gwent Levels SSSI downstream of the site.

Commensurate with a phased development approach, which will see reclamation and remediation progress over a number of years, connection to a newly configured surface drainage system will only be proposed when phases are compliant with the site specific land and water quality criteria and have been agreed with CNC/NRW. The undeveloped areas of the site will continue to drain through the existing industrial discharge system (consented by CNC/NRW and operated by Tata) until the areas have been prepared and signed off by the regulators.

Overall the new drainage system is intended to convey surface water and run off through a privately maintained system (which will adopt a sustainable approach by including treatment trains and a series of SuDS) before entering the reen system. The CWRA will model a contribution of land drainage from the remediated and developed land that plausibly can enter the reens. However, this is anticipated to be a minor proportion of the overall surface water volume given that off site inflows will continue and it is proposed that drainage control at the Monks Ditch discharge will maintain a minimum volume of water within the reen system. Therefore, the drainage system is not intended to drain or control groundwater levels, and should also permit proportional dilution for potential contaminants that may exist in the land drainage that occurs.

During ongoing site redevelopment, protection of the reen system on developed areas will be provided by appropriately placed cordon sanitares comprising temporary cut off drains or clay liners which would seek to prevent incidental ingress from the undeveloped areas of site.

A comprehensive programme of surface water quality testing is currently in place and will continue during the redevelopment programme. Chemical testing will include regular analysis for contamination and water quality parameters within the existing reen system and the newly installed system to demonstrate compliance with the agreed targets. The frequency and duration of the monitoring will be agreed with CNC/NRW.

6.0 Conclusion

The purpose of this report is to provide a comprehensive surface water drainage strategy for the Glan Llyn (formerly known as the Llanwern Regeneration Site) development site, which received outline planning permission (ref. 06/0471) in 2006. As such this report builds upon the approved design principles and site parameters set out within the previous drainage strategy (Llanwern Regeneration Site, Halcrow 2005) and incorporates drainage strategy proposals already submitted for the Western Sub Area and Celtic Business Park Developments to provide a joined up approach.

The existing Glan Llyn development site comprises approximately 242ha of previously developed land, which as a legacy of that development is hydrologically self contained, in that it has no connection with the Monks Ditch (which dissects the site delineating the proposed residential from the commercial development) or the surrounding reen system and Caldicot Levels downstream. The exception being two small rural catchments to the north of the site that drain into the Glan Llyn development's existing reen system via a number of culverts under the Cardiff Bristol railway line. The site itself is currently drained via a network of reens which eventually drain to a settlement lagoon, located within Tata Steelwork's land to the south east of the site. From here a mixture of surface water, treated foul water and trade effluent is pumped directly out to the Severn Estuary.

The redevelopment of the Glan Llyn site will deliver a mixed use development, comprising circa 4000 dwellings, a local centre, a school and a business park, some of which has already been built. In addition extensive open green space incorporating blueways, lakes and attenuation ponds will also be prevalent within the proposed development, which will provide a maximum storage volume of approximately 399,000m^3.

The entire reen/blueway network will be regraded to drain toward the Monks Ditch, where following treatment, surface water flows will be pumped into the Main River instead of the Severn Estuary. To ensure that the water quality of the surface water achieves Environmental Quality Standards (EQS) before being discharged into Monks Ditch, substantial online treatment zones will be incorporated at the downstream point of the blueway network. Site specific land remediation and water quality target criteria will be agreed with CNC/NRW. The frequency and duration of the monitoring will also be agreed with CNC/NRW to ensure that there is no adverse impact on the water quality of the receiving Gwent Levels SSSI downstream of the site.

The surface water system will be designed to adoptable standards but will remain private in addition to the reen network and associated SuDS features.

Natural Resource Wales (NRW) have specified that surface water runoff from the proposed development be attenuated and discharged at a maximum discharge rate of 3.5l/s/ha up to and including a 1 in 100yr + climate change event, which equates to a peak discharge rate of 750l/s. It is proposed that surface water be discharged (via two pumping stations) into the Monks Ditch instead of directly out to sea, thereby enabling St Modwen to manage and maintain the development's surface water system in its entirety.

The Monks Ditch has the capacity to accept the additional 750l/s providing the Monks Ditch has a free discharge has a free discharge in to the Severn Estuary and is not tide locked 4500m downstream. It is during such conditions that pumping an additional 750l/s into the Monks Ditch system could have the potential to increase flood risk downstream, even if pumping at a greenfield runoff rate. As such detailed modelling study of the Monks Ditch and receiving Caldicot Levels has been undertaken to evaluate the potential impacts on flood risk and to determine what mitigation measures are required to ensure that the proposed pumped discharge dies not cause a detriment to flooding in the local area, particularly during a tide locked event.

This study determined that provided the pumped discharge into the Monks Ditch was regulated and limited to operate during periods when water levels in the Monks Ditch remained in channel, then there was negligible adverse impact on flood risk on the Monks Ditch and Caldicot Levels.

At this stage it can be reasonable to assume that a sequential storm event will have occurred before the Glan Llyn surface water drainage system has time to fully empty. To mitigate this impact the development will provide an additional storage capacity of 72,276m^3 (a total of 180,437m^3) to store the surface water runoff generated from the development site and the two rural catchments to the north of the site during a 1 in 100 year + 30% climate change storm event should the development not be able to pump any surface water into the Monks Ditch.

It has been determined that the system would take approximately 67hrs to, completely discharge 180,437m^3 of stored surface water once a flood/storm event had subsided and the pumps permitted to operate. During this timeframe it was considered highly probable that a sequential storm event of a 1 in 5 year return period could occur. As such a further storage capacity of 70,000m^3 has been designed into the Glan Llyn's proposed reen network to ensure the surface water runoff from a sequential storm event can be accommodated without causing flood risk to the development.

And lastly in addition to the storage of surface water, the Glan Llyn site will also make provision for an additional 148,350m^3 of tidal breach flood water, in the event that sea defences fail, providing a total of approximately 399,000m^3 of storage.

Therefore in summary even if the development is unable to discharge to the Monks Ditch, the proposed surface water drainage system will have the capacity to store:

- a 1 in 100yr +cc storm event
- a 1 in 1000yr tidal breach event and
- a 1 in 5yr sequential rainfall event.

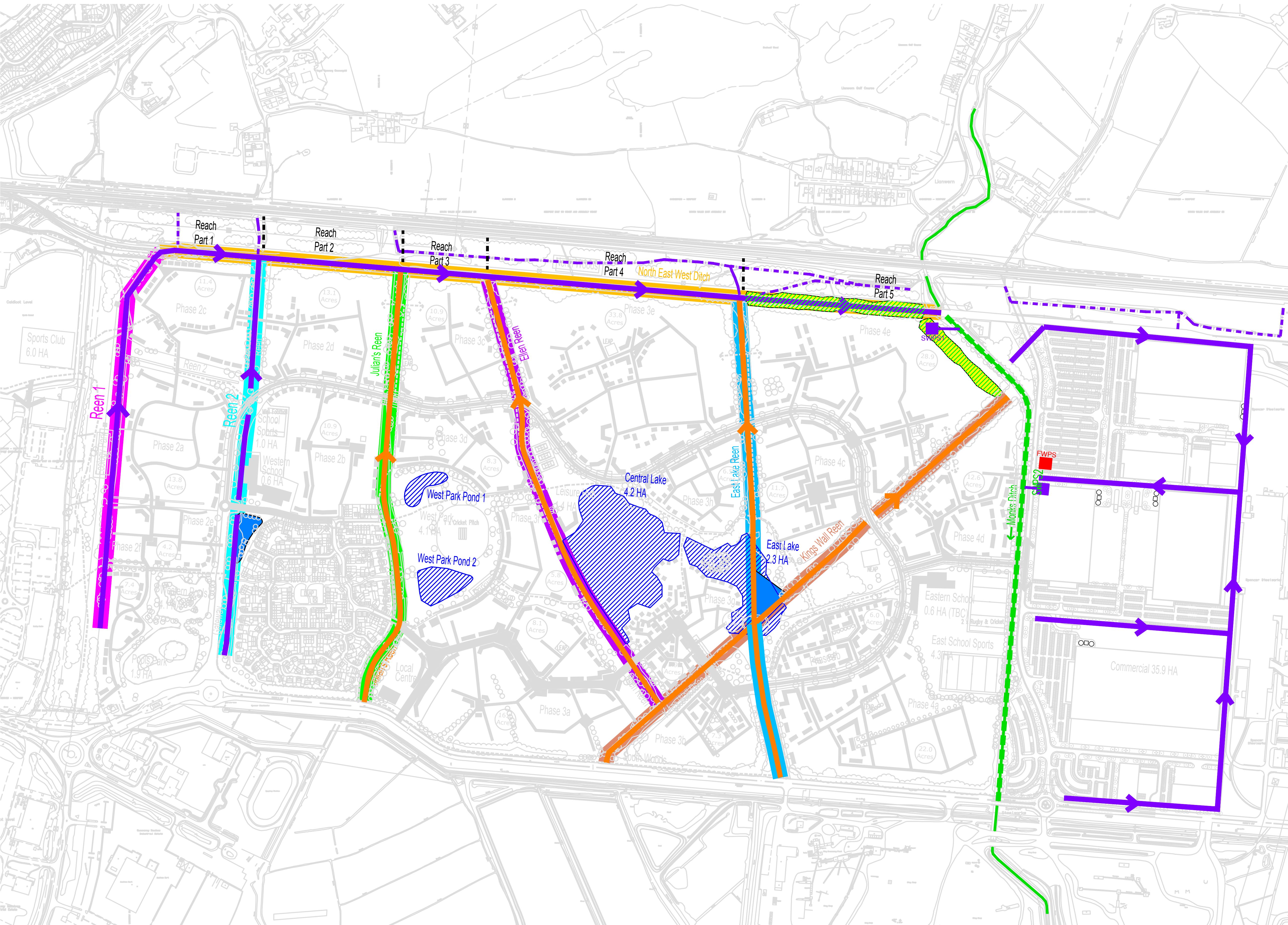
In conclusion, it is considered that this assessment demonstrates that the proposed surface water drainage strategy ‘makes space for water’ and provides sufficient capacity to accommodate the necessary surface water and tidal flood storage required to make the development and the surrounding area safe from flood risk.

During the detailed design of the proposed surface water system, it is recommended that further modelling be undertaken to fine tune the pumping regime and the optimal timing and rate at which the pumps operate (which will vary between 0l/s and 750l/s). In reality this will be an ongoing process as the development progresses and more surface water runoff comes online over the lifetime of the development, the impact of the pumping regime will be monitored and adjusted where necessary.

Appendices

Appendix A – Drawings

A3



Notes:

- Monks Ditch
- New/Upgrade on Site Reen
- Existing off site Reen
- Blueway
- On line Pond
- Existing High Level Lakes
- Surface Water Pumping Station
- Foul Water Pumping Station
- Online Treatment Zones

Rev.	Date	Amendments	By	Chk
C.	24/02/16	General Update	TC	AN
B.	19/08/15	General Update	AT	AN
A.	29/04/15	General Update	CB	CJ

RODGERS LEASK
Consulting Civil & Structural Engineers

Client
St Modwen

Project
Llanwern

Drawing Title
Overall Surface Water Drainage Strategy

Status
Information

Scale	Drawn	Checked	Date
A3@ 1:7500	CB	AC	11/03/15

Project No.	Drawing No.	Rev.
D12-084	512	C

File Path:
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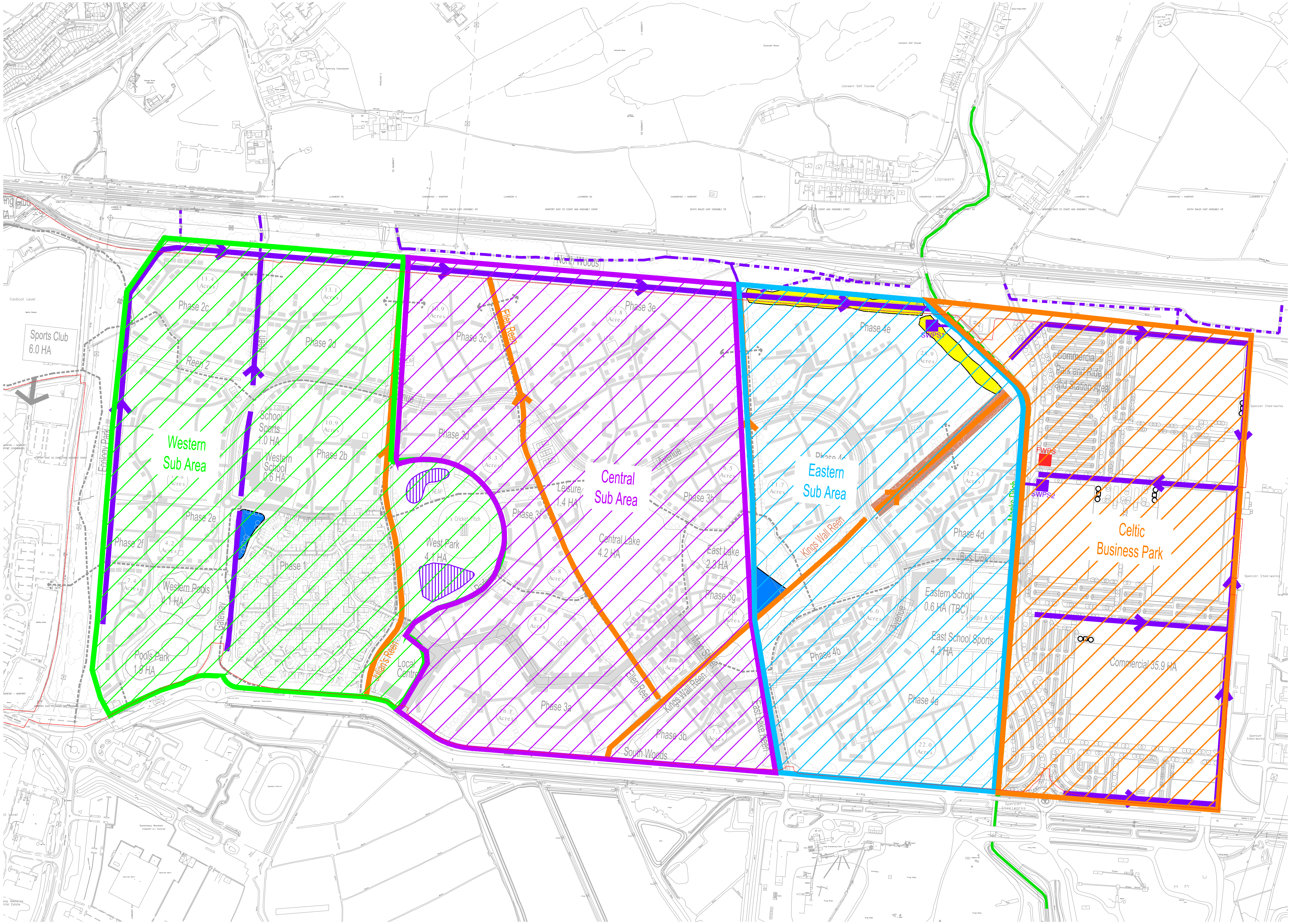
A3



Notes:

- Western Sub Area 57 Hectares
- Central Sub Area 63 Hectares
- Eastern Sub Area 49 Hectares
- Celtic Business Park 45 Hectares

Rev.	Date	Amendments	By	Chk

RODGERS LEASK
Consulting Civil & Structural Engineers

Client
St Modwen

Project
Llanwern

Drawing Title
Overall Surface Water Drainage Area Plan

Status
Information

Scale	Drawn	Checked	Date
A3@ 1:7500	AT	AC	11/03/15

Project No.	Drawing No.	Rev.
D12-084	514	

File Path:
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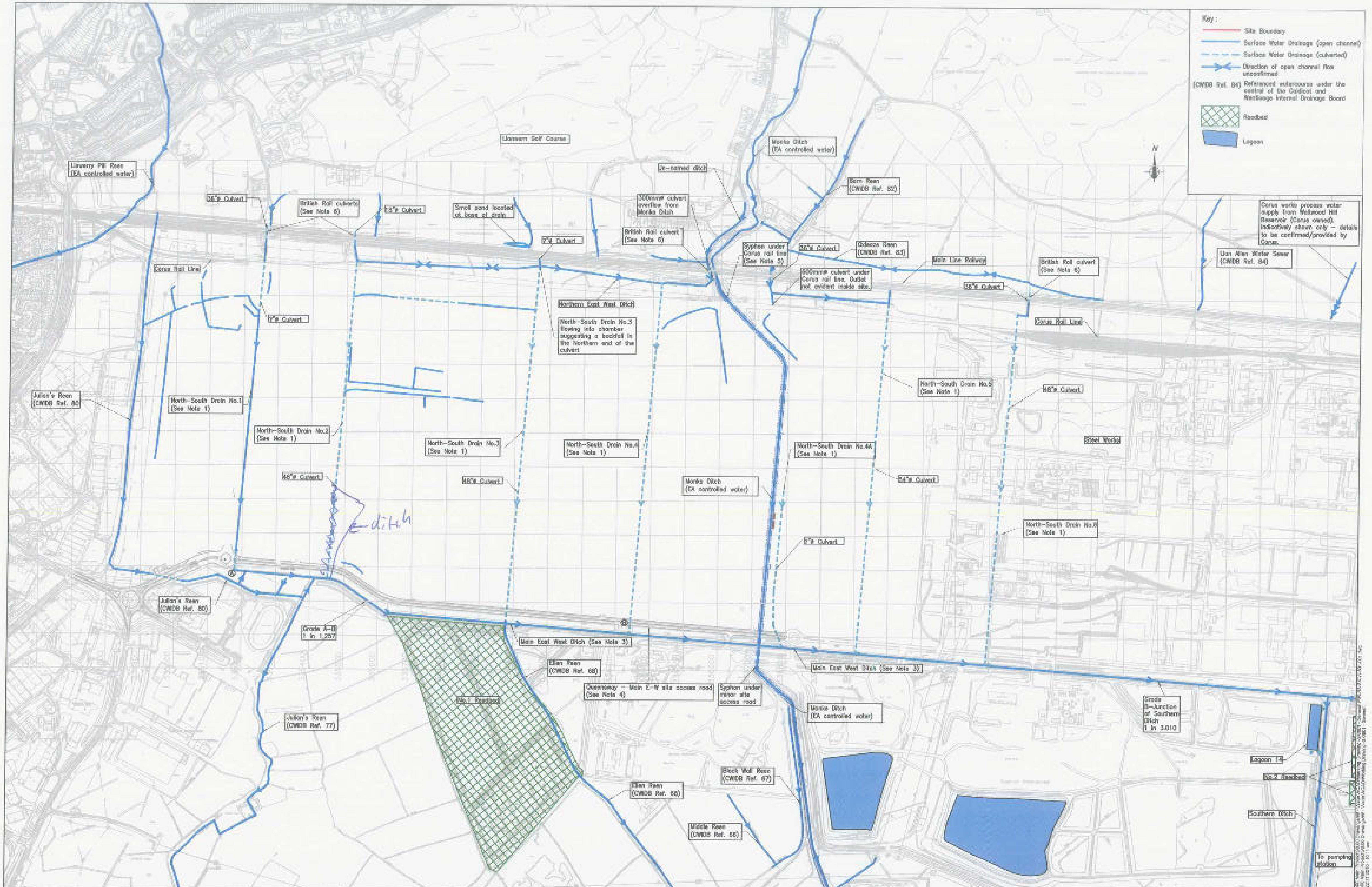


Halcrow Group Limited

Halcrow

Client

ST. MODWEN DEVELOPMENTS LIMITED

LLANWERN REGENERATION SITE

Notes

1. Refer to Corus Drawing No.850.05.10200 for detailed information of drains 1-6 inclusive.
2. For existing topographical survey information refer to Drawing No.PI/FLRS/SK-801, sheets 2&3 of 3.
3. Refer to Corus Drawing No.850.05.10201 for detailed information of ditch.
4. Refer to Richard Thomas and Baldwins Ltd Drawing Nos.2/127/5 to 2/127/11 inclusive for detailed information of road drainage layout and discharge arrangements to Main East-West Ditch.
5. Refer to Richard Thomas and Baldwins Ltd Drawing No.850/05/14204 for detailed information of inverted syphon under rail tracks.
6. Refer to Corus Drawing No.850.05.10200 for detailed information of British Rail culverts. Indicatively shown only.

Rev	By	Chkd	Apprvd	Date	Description
-	-	-	-	-	

Drawing

Existing Drainage Plan

(Sheet 1 of 3)

Drawn by: ZP — Date: Jan 08

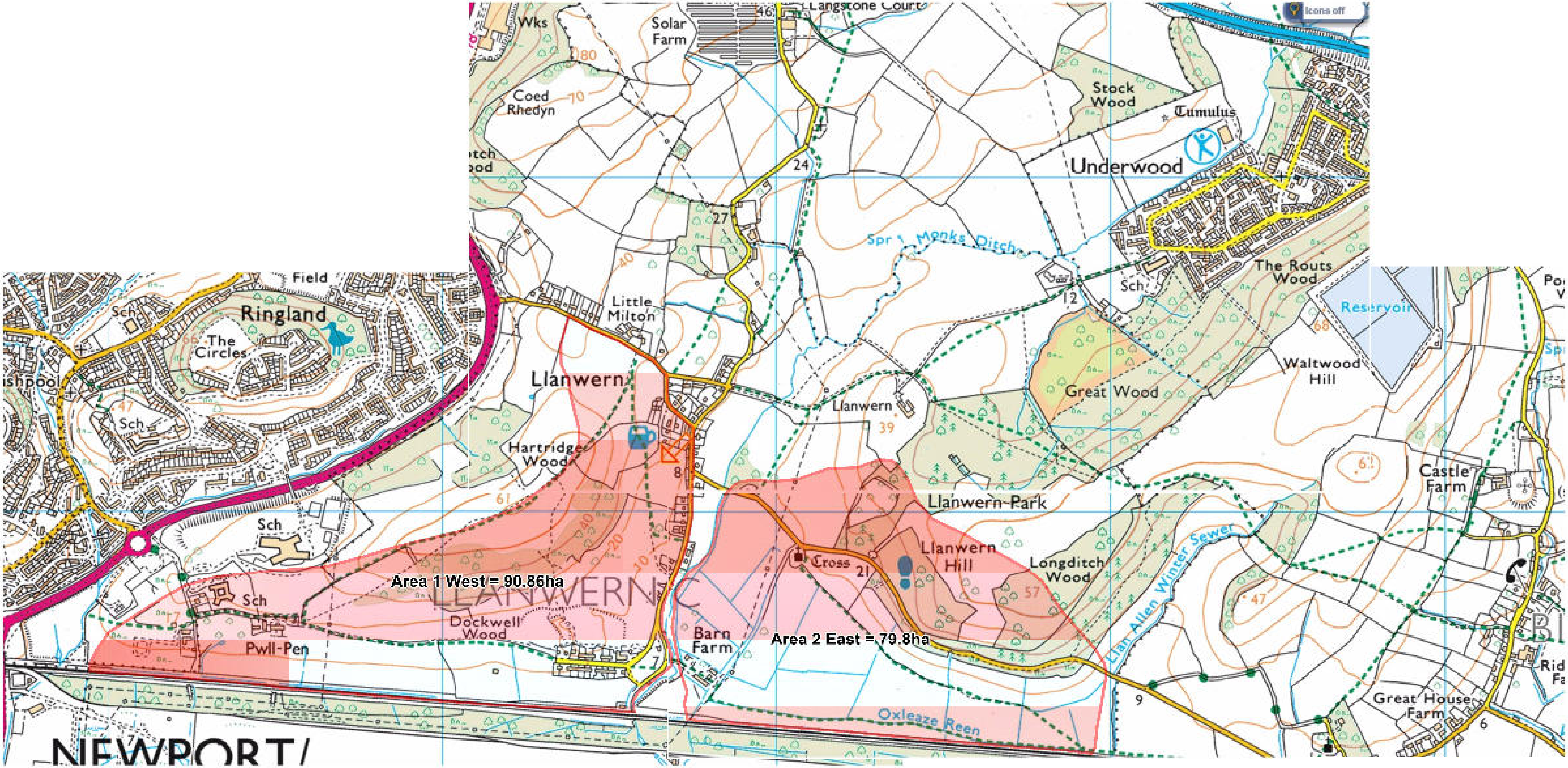
Checked by: AJWJ — Date: Feb 08

Approved by: MW — Date: Feb 08

Drawing No. PI/FLRS/SK/W/801/001

Revision

Drawing Scale: 1:5,000 at A1



Area 1 West = 90.86ha
Area 2 East = 79.8ha
Langstone Court
Wks
Solar Farm
Coed Rhedyn
Stock Wood
Tumulus
Underwood
Monks Ditch
The Routs Wood
Reservoir
Waltwood Hill
Great Wood
Llanwern
Little Milton
Ringland
The Circles
Field
Sch
Hartridge Wood
Llanwern Park
Castle Farm
Llanwern Hill
Cross
Longditch Wood
Llan Allen Winter Sewer
Dockwell Wood
Pwll-Pen
Barn Farm
Oxleaze Reen
Great House Farm
NEWPORT/
Icons off

Appendix B – Llanwern Regeneration Site Drainage Strategy Halcrow Group Ltd (Dec 2005)

St. Modwen Developments Ltd

Llanwern Regeneration Site
Drainage Strategy

December 2005

Halcrow Group Limited

St. Modwen Developments Ltd

Llanwern Regeneration Site
Drainage Strategy

December 2005

Halcrow Group Limited

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St. Modwen Developments Ltd
Llanwern Regeneration Site
Drainage Strategy

Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1.0		Draft Report	04/01/05	CS
2.0		Revised Report	14/12/05	CJ

Contents

1 Executive Summary

This Drainage Strategy Report has been prepared to demonstrate the principles of surface water management, land drainage and sewage disposal control which are to be adopted for the redevelopment of the Llanwern Regeneration Site (LRS) situated to the east of Newport, South Wales.

The report provides a complete and comprehensive drainage strategy to be used for the overall design of the development proposals at LRS and takes full account of the expectations for future climate change caused as a result of global warming.

The site is a brownfield site with all of the existing surface water runoff and foul water draining to an existing privately operated system which provides treatment prior to being pumped out to sea.

A separate Flood Consequences Assessment has been completed for the site which provides a strategic overview of potential sources and implications of flooding at the LRS, detailed assessment of tidal flooding, flood propagation modelling and proposed mitigation measures.

2 Introduction

2.1 Terms of Reference

Halcrow Group Limited have been commissioned by St. Modwen Development Limited to produce a comprehensive drainage strategy for the development of the LRS,

2.2 Background of Study

This report should be read in conjunction with the following reports:

- Llanwern Regeneration Site Flood Consequences Assessment – Halcrow (December 2005).
- Ecological Assessment – Halcrow (August 2004).
- Flood Study of Monks Ditch at Llanwern, Gwent- WS Atkins (July 2002).

The drainage system has been assessed with consideration to the potential flood risk to Llanwern Regeneration Site (LRS), which has been undertaken in accordance with guidelines set out in TAN 15 – Development and Flood Risk Areas, July 2004 and "Sewers for Adoption 5th Edition".

2.2.1 Site Description

This site is a key component of the regeneration strategy of the Newport Unitary Development Plan (UDP). The site is located east of Newport, within the Newport Eastern Expansion Area and was formerly part of the Corus steelworks site. To the west of the application site are the residential areas of Newport and Newport Retail Park. The Cardiff to Bristol railway line delineates the northern boundary beyond which is agricultural land and Llanwern golf club. To the east of the site is the remaining half of the Llanwern Corus Steelworks site, which will remain operational. South of the site is Queensway (the main access road through the site), beyond which there are employment areas and agricultural land. The LRS is a brownfield site, which has been cleared of above ground structures.

2.2.2 *Historical Context*

The site is shown on Ordnance Survey historical topographical plans to comprise open fields with numerous drainage ditches until about the 1960s. During the 1960s the site was extensively developed as a steelworks with the western end of the site (which is now proposed for residential redevelopment) forming stockyards for incoming raw materials used in the manufacture of steel. This industrial use is known to have required land raising and engineering improvement of the existing ground. Steel production lasted for approximately 30 years. Some remediation work will be necessary to ensure that the land is suitable for its future intended use. Once completed the remediation work will significantly improve the environmental quality of the site.

2.2.3 *Catchment Description*

The site location falls within the River Usk catchment, which is within the Eastern Valleys area of South Wales. The site lies to the east of the Usk Estuary and north of the Severn Estuary. The River Usk is recognised as nationally and internationally important for conservation by its designation as a Site of Special Scientific Interest (SSSI) and Special Area of Conservation (cSAC). The Severn Estuary is also recognised as an SSSI, Ramsar site, Special protection Area (SPA) and Special Area of Conservation (pSAC). The Severn Estuary has an immense tidal range and contains an intertidal zone of mudflats, sandbanks, rocky platforms and saltmarsh.

The LRS is a relatively low lying site situated north of the Gwent levels.

2.2.4 *Description of Proposed Development*

The LRS scheme will comprise up to 4000 new dwellings, centred around a series of themed lakes and a central loop road. The residential zones will be complemented by primary school provision and associated community related development.

3 Analysis of Existing System

3.1 Hydrology/Flood Regime

The Environment Agency's indicative flood plain mapping shows the LRS is within Zone C1 as defined by development advice maps referred to under TAN 15 Development and Flood Risk (July 2004). This is confirmed by the Flood Consequences Assessment for the LRS which has been completed (Halcrow, December 2005) and which should be read in conjunction with this report. The assessment has been completed in full consultation with the EA.

3.1.1 *Fluvial flooding*

Monks Ditch (to the east) and Liswerry Pill Reen (at the extreme north-west corner) are the only Main Rivers which cross the site.

The Caldicot levels are situated south of the site and are generally drained by a network of channels known locally as 'reens', discharging to 11 tide flapped outfalls to the Severn Estuary. During tide- lock (high tide) local run off collects in the reens until such time that it can discharge by gravity at low tide conditions. The two lowest areas on the Caldicot Level are drained by pumping into high level reens. This reen system is entirely separate from the LRS drainage network.

The main flood risk is from Coastal flooding from the tidal River Usk and the Severn Estuary. There are no reported flooding issues with the Ringland Way Reen, a tributary of the Liswerry Pill Reen.

Fluvial flooding has been considered in a report by WS Atkins '*Flood Study of Monks Ditch at Llanwern, Gwent*' (July 2002). This report provides details of flooding in Monks Ditch upstream of the site. The report concludes that the flood stage within Llanwern is not significantly affected by the capacity of Monks Ditch downstream of the Cardiff-London railway line. This includes the capacity of the tidal exclusion gates at Goldcliffe, together with the concrete channel and inverted siphons present within the Llanwern Steelworks.

The flood study of Monks Ditch by WS Atkins and consultations with EA, CWIDB and Corus confirm that there is a history of flooding associated with Monks Ditch to the north of the site near Llanwern Village. There are also reports from consultations with Corus staff which have established that Monks Ditch occasionally overtops within the LRS. The excess water ends up either in the corridor between the north rail siding and the main line or in the site land drains.

Which ever route it takes there is sufficient capacity in the existing and proposed systems to accommodate the flood water. There is therefore no risk of fluvial flooding within the site.

3.2 Surface Water System

The existing site is drained by a series of drainage culverts (on pile foundations) and reens (open drainage ditches) running from north to south. Within the LRS, these now the responsibility of St. Modwen. These north to south drains collect surface water runoff from the existing development and the catchment to the north of the railway. The positive drainage network from the former steelworks, which previously discharged to these drains, is unlikely to still be functioning. These drains discharge into the Main East West Ditch (MEWD), which then flows into a settlement lagoon and is eventually pumped out to sea via two above ground pipelines.

There is currently significant capacity in the surface water system. Heavy steel production which required some 16 million gallons of water per day has now ceased and the current water requirement for the production of steel strip is only 6 million gallons per day.

There are 11 north to south drains within the overall Corus/St. Modwen site. Six pass under the regeneration site (owned by St. Modwen) and five are within the Corus site. All of the drains outfall into the MEWD which flows at the south of the Queensway. All existing surface water drainage within and surrounding the site is shown on drawing numbers PI/BLSS-005-005 and PI/BLSS-005-006. The reens outside of Corus/St. Modwen ownership are either the responsibility of the EA or the CWIDB as indicated on the plan.

Drawing number PI/BLSS/005-011 provides a schematic layout of the existing surface water drainage at the site.

The quality and quantity of the pumped discharge falls under a statutory IPPC licence.

The following table summarises all land drainage systems within/adjacent to the site:

Drain	Description	Comments/location
North-South Drain 1	Part concrete culvert, part open ditch. Dimensions unknown.	Regeneration Site
North-South Drain 2	Concrete Culvert 48" dia.	Regeneration Site
North-South Drain 3	Concrete Culvert 48" dia.	Regeneration Site
North-South Drain 4	Concrete Culvert 54" dia.	Regeneration Site
Monks Ditch	(see below for further details).	Regeneration Site
North-South Drain 4a	Concrete culvert	Regeneration Site
North-South Drain 5	Concrete Culvert 54" dia.	Regeneration Site
North-South Drain 6 – 11	All in remaining steelworks side of site (New Llanwern)	New Llanwern Site
Liswerry Pill Reen	EA controlled main carrier reen.	Drains from the north crossing the extreme north west of the LRS next to the playing fields of the works sports and social club.
Longditch Reen	CWIDB controlled reen (see below for further details).	Drains from the north to south of the site adjacent to the west boundary of the LRS.
Northern Field Ditches	Privately owned field drains (see below for further details).	All field systems draining to the site.

3.2.1 *North –South Drains*

All the concrete pipes are protected by a reinforced concrete surround and are founded on concrete piles. The average depth of the drains is 3.5m to the top of the concrete surround and the estimated length of the piles is 10m.

The inlet structures are reinforced concrete manhole chambers (approx. 3m x 3m x 3m), which are situated above ground and receive the incoming field ditches from the north.

The southern outlet structures vary in detail, but are generally concrete outfalls, with concrete steps built in for access.

The major lateral connections into the north-south drains are made at large manholes (approximately 1.5m diameter, 3.m deep) of which there are 4-5 per drainage run (R.O.L.E. Project Engineering Infrastructure Report, Bay Associates, (September 2002).

3.2.2 *Main East- West Ditch (MEWD)*

The MEWD runs to the south of the site, parallel with Queensway. This ditch transports the water from the north -south drains and Queensway highway drainage into Lagoon 14 (as shown on drawing number PI/BLSS-005-006). The ditch is an unlined trapezoidal channel with grassed banks (approximate dimensions: depth of 1m, bed width of 2m and top width of 6m). The total length of the east-west ditch is 5km, 2km runs partly alongside the LRS. Several small pipelines carry services across the ditch.


Photo 1: Main East-West Ditch at the southern end of the site (looking east).


Photo 2: Drain outfall into main East-West ditch.

Photo 3: Service pipe crossing main East-West Ditch at the southern end of the site.

3.2.3 *Southern Ditch*

The MEWD flows into the southern ditch (see drawing PI/BLSS-005-006). A control gate directs the water into Lagoon 14. The southern ditch transports water from Lagoon 14 to the surface water pump house (approximately 1.2km away). The ditch is an unlined trapezoidal section ditch with grassed banks. The bed width is approximately 4m, top width approximately 20m and the depth 1m. The ditch, which is presently maintained by Corus, is in good condition.

3.2.4 *Monks Ditch (MD)*

Monks Ditch is classified as a main river, which is maintained by the EA. St. Modwen are now the riparian owners of the section of Monks Ditch that runs within the LRS. Monks Ditch transports water from above the Gwent levels and down to an outfall into the Severn Estuary. The ditch flows through the LRS in a 7m wide, 3m deep piled concrete channel. The ditch passes under the Corus freight line and the Cambrian Stone access road.

The condition of the channel appears to be good although plant growth inside the channel occurs in large patches along the entire length. Corus have maintained

Monks Ditch as it flows through their site, to a high standard. This ditch is independent of the surface water drainage system operated within the site. Outside of the site the ditch is the responsibility of the EA. Water is conveyed under the main and freight railway lines to the north of the LRS and access roads to the south within the four inverted siphon structures (see drawing PI/BLSS-005-006).

Under tide lock conditions, the Monks Ditch overtops its banks flooding an area of low lying land near to the Whitson (National Grid) Electrical Sub-station situated to the south of the LRS (see PI/BLSS-005-005).

3.2.5 *Northern Siphons*

Siphons 1A and 1B are shown on the attached drawing number PI/BLSS -005-006. They siphon flows in the Monks Ditch under the main railway line, the northern east west ditch and the Corus freight line.

3.2.6 *Southern Site Siphons*

Siphons 2A and 2B are located to the south of the LRS and flow underneath an access road, situated north of Queensway as shown in photo 4 below.

Siphons as Monks Ditch is culverted under the steelworks site access road located south of the site boundary.

Main east west ditch

Monks Ditch (south of site) crossing over main east west ditch.

Photo 4: Services crossing Monks Ditch within the Corus site

Monks Ditch.

Main east west ditch entering culvert.

Photo 5: Main east west ditch culverted under Monks Ditch.

3.2.7 *Local Reens*

There is an extensive network of reens around the site. The majority are not directly impacted by the regeneration proposals as the site is a self contained separate system. The following describes some of the main reens in the area:

- Oxleaze Reen and Barn Reen drain into Monks Ditch to the north west of the site; these carry water from the north and are maintained by the Caldicot and Wentlooge Levels Internal Drainage Board (CWIDB).

- Hundred Perches Reen is located to the east of the site (outside of the site boundary) and is maintained by the EA.

- Long Ditch Reen (Julian's Reen) is controlled and maintained by the CWIDB. The reen passes through the development area from north to south along the western boundary of Zone A.

- Liswerry Pill Rhine collects water from the residential Ringland and Moorgate estates. The reen discharges to the River Usk approximately 1 km to the east of the site. It crosses the extreme north west of the LRS next to the playing fields of the works sports and social club and is classified as a main river.

- Northern Field Ditches: Llanwern Golf course and farms to the north of the main rail line drain into privately owned field ditches. These ditches (drains 1- 10) pass under the main rail line and into a Corus/St. Modwen owned northern east-west ditch located between the main rail line and the Corus rail line. Drains 1-6 pass through the LRS site.

The Llanwern Regeneration and Corus sites are "self contained" and only collect land drainage from a small catchment of fields immediately to the north of the main railway. The site is not in hydrological connection with the Caldicot levels situated to the south of the LRS and is not linked with the other large reens/ditches in the area. The EA are responsible for maintaining Monks Ditch and Barn reen outside of the site boundary. Although these flows are currently conveyed through the site they have no adverse impact and do not pose a development constraint.

3.2.8 *Lagoon 14*

Lagoon 14 receives water from the MEWD and acts as a settlement lagoon for sediment and solids prior to discharge via an overflow weir outlet to the southern ditch and ultimately the pumping station. The lagoon is a concrete lined 130m x 30m pond with a storage volume of 7800m^3. Sludge is currently pumped from Lagoon 14 into slurry lagoons. Domestic foul effluent and process water also flows into Lagoon 14 from the reed beds.

Photo 6: Lagoon 14 and southern ditch (looking south).

3.2.9 *Existing Surface Water Features*

The existing pumping station (drawing numbers PI/BLSS-005-005 and PI/BLSS-005-006) pumps combined surface water, land drainage and treated works effluent from the site (via the Southern Ditch) to the Severn Estuary. It is envisaged that this pumping station will be adopted by the CWIDB.

3.3 *Foul Water System*

The existing domestic sewage discharge from the remaining Corus facilities on the LRS is pumped, via a series of ejector stations, from the source location to the main foul water rising main pipeline. The effluent is discharged into Reed Bed No. 2 where solids are removed and the water polished. The reed bed discharges into Lagoon 14, where further solids are removed. The water is then combined with the land drainage and surface water flows before being pumped to sea. The ejector stations are pumps that raise sewage by injecting compressed air into a pipe containing sewage into the foul rising main. Corus Strip Products Ltd currently operates and maintains the existing foul water drainage network

There is no connection to the public sewerage system from the site. Welsh Water does have wastewater treatment works at Nash that is 4 km to the south west of the site.

The main foul pipelines are generally located above the main surface water culverts.

3.3.1 *Trade Effluent*

Trade effluent from, the Corus works is discharged to the same combined system as the foul, surface water and land drainage.

3.3.2 *Geology*

The ground conditions in this area consist of made ground overlying highly compressible Estuarine Alluvium.

The natural geological deposits immediately underlying the site comprise soft alluvial clays, sporadic basel sands, gravels and peat. These deposits are typically 12m – 15m in thickness.

The natural estuarine deposits are overlain by fills which are dense and granular, predominantly slag with a high pH and containing lime.

3.3.3 *Contamination/water quality*

The development area has pockets of minor contamination and areas of fill. An element of remediation will be required but will not be a constraint to the development.

Groundwater quality within the steelworks site reflects the leachate data with elevated concentrations of some metals and ammonia. Organic contamination from hydrocarbons is indicated within the coke ovens and sinter plant areas adjacent to the stockpile area. Groundwater contamination will be addressed under the site ground remediation strategy, with works practices measures being adopted to ensure there are no adverse impacts on water resources.

Site to be redeveloped.

Evidence of stock piles and rubble, some areas of vegetation.

Photo 7: Site to be redeveloped.

4 Proposed Surface Water System

4.1 Introduction/Methodology

Regeneration proposals are to develop the site for residential, commercial and ancillary supporting uses; the initial proposed development is outlined on drawing number PI/BLSS-005-013. The regeneration will provide significant opportunities for improvement in the quality and quantity of surface water runoff from the site.

Discharge of the site drainage will be combined into the Corus system.

4.2 Proposal

Surface water runoff from the regeneration site is to maintain the existing east west ditch (located to the north of the site) which collects the flows from the north of the site. The ditch will distribute low flows from the land drains to the north of the site into three new channels which will outfall into three lakes within the site. The new open channels will also receive flows from the proposed development plots and will enable the control of fluvial flow and surface water runoff. These open channels will be designed to ensure no adverse impacts upstream and downstream of the site which would increase any flood risk to the application site and adjacent areas. The flows from the land drains to the north of the site will not be stored within the lakes. The hydrobrake, penstock (or similar) control from the lakes will be set to the greenfield runoff rate as calculated for the site runoff (0.417 cumecs) and in addition will allow the greenfield runoff rate (low flow) from the land drains to the north of the site. The lakes are a route for the land drainage flows and allow these flows to pass straight through to the MEWD situated south of Queensway. The total flow through the controls will be set to 2.7cumecs (0.417 + 2.28) to accommodate the site runoff and the calculated land drainage low flows (see section 4.3.1 below).

Flows entering the site from the northern catchments which exceed the low flows will discharge directly into the east west ditch bypassing the lakes. These excess flows will drain into an overflow channel which will have an unrestricted discharge into the MEWD replicating the existing situation.

4.2.1 *Land Drainage channels*

The design of the three open channels will be determined at detailed design. The attached plan (drawing number PI/BLSS-005-013) shows the proposed plot areas draining into each channel. Each channel will be a significant feature of the site and will be designed to accept all flows and provide combined amenity/ecological areas as well as drainage routes.

4.2.2 *Lakes*

The new development will be centred on three lakes surrounded by a substantial are of parkland. The lakes will be created in the centre of the LRS along the following themes:

Western Lake – Formal, Amenity, approximately 2.4 hectares

Central Lake – Recreational, approximately 4.6 hectares

Eastern Lake – Natural, approximately 2.4 hectares

These will act as balancing areas for the surface water runoff from the surrounding impermeable catchment and will also convey the water from the land drains to the north of the site. Drawing number PI/BLSS-005-013 illustrates the above proposals.

The relative levels of the lakes, recreational areas and development areas are provided in the FCA. Groundwater levels of 4.0 mAOD, required freeboard above the 1 in 100 year rainfall event level and volumes of water following a coastal defences breach scenario have all been considered in the sizing of the lakes. All outfalls into the lake will be above the groundwater level, to ensure they are not submerged at all times. The proposed finished floor levels for the site are at 7.0 mAOD. It is anticipated that the whole site will drain by gravity into the lakes, although it may be more advantageous for the proposed employment area to drain directly into the MEWD.

There will be two controlled outfalls from the lakes into the existing surface water system.

Flows from the lake system will be controlled by two control structures (hydrobrakes, penstocks or similar) to restrict outflows to equivalent greenfield runoff rate. This includes the 3.5 l/s/ha for the site runoff calculations and the existing greenfield runoff for the land drains coming in from the north of the site. The restricted flows will outfall into new channels which will direct flows to the existing MEWD.

The groundwater within the ponds will ensure water is present during dry weather.

4.3 *Storage Requirements*

The equivalent 'greenfield' runoff conditions for the surrounding area have been established in consultation with the CWIDB. The specific conditions for the development include:

- a greenfield runoff rate of 3.5 l/s/ha.
- Attenuation required for a 1 in 100 year event.
- General storage requirements for the surrounding area, which would also apply to the site, of 440m^3/ha of storage required for 100% impermeable area and 286m^3/ha storage required for housing (65% impermeable area). This assessment is based on a volume of 374 m^3/ha for 80% impermeable area.

Individual plot areas have been reviewed to assess the surface water storage and runoff requirements for the LRS. A summary of the development proposals based on the current illustrative masterplan is provided in table 4.2 below:

Table 4.2: LRS Surface water runoff requirements

Plot	Total Plot Area (ha)	% Impermeable area	Total Impermeable Area (ha)	Storage required based on above criteria (m^3)	Restricted runoff (l/s)	Discharge location
Sports Club (unaffected by development proposals)	6.0	80.0	4.8	1795.2	16.8	SUDS/Channel 3
Plot R1	10.7	65.0	7.0	1989.1	24.3	Channel 1
Plot R2	1.0	65.0	0.7	185.9	2.3	Channel 1
Plot R3	2.3	65.0	1.5	427.6	5.2	Channel 1
Plot R4	5.4	65.0	3.5	1003.9	12.3	Channel 1
Plot R5	3.3	65.0	2.1	613.5	7.5	Channel 1
District Centre and School	5.1	80.0	4.1	1525.9	14.3	Channel 1
Plot R6	13.9	65.0	9.0	2584.0	31.6	Channel 1b
Sports Park	4.3	80.0	3.4	1286.6	12.0	Channel 2
Plot R7	14.6	65.0	9.5	2714.1	33.2	Channel 2/3
Plot R8	5.7	65.0	3.7	1059.6	13.0	Channel 3
Plot R9	7.1	65.0	4.6	1319.9	16.2	East lake
Plot R10	1.0	65.0	0.7	185.9	2.3	East lake
Plot R11	3.4	65.0	2.2	632.1	7.7	East lake
Plot R12	16.3	65.0	10.6	3030.2	37.1	East lake
Plot R13	3.5	65.0	2.3	650.7	8.0	Central Lake
Plot R14	4.8	65.0	3.1	892.3	10.9	Central Lake
Plot R15	3.8	65.0	2.5	706.4	8.6	Central Lake
Plot R16	3.5	65.0	2.3	650.7	8.0	Central Lake
Plot R17	3.0	65.0	2.0	557.7	6.8	West lake
Plot R18	2.6	65.0	1.7	483.3	5.9	West lake
West Lake	2.4	100.0	2.4	1056.0	8.4	West lake
Central Lake	4.6	100.0	4.6	2024.0	16.1	Central Lake
East Lake	2.4	100.0	2.4	1056.0	8.4	East lake
Park Land	18.0				0.0	
Commercial Area	35.9	80.0	28.7	10741.3	100.5	Channel 3/East Lake/SUDS
Total Site	184.6	mixture	119.3	39171.8	417.5	

Note: Restricted runoff based on total impermeable area 120 ha at 3.5 l/s.

The proposed lakes cover 9.4 ha (94,000m^2); they will be approximately 2 metres deep, with an operational storage area of 0.5 m therefore providing 47,000m^3 of storage. This will provide more than adequate storage for the 1 in 100 year runoff volumes as set by the CWIDB criteria which total 39,000m^3. In addition to this storage combined with the available parkland area surrounding the lakes will accommodate flood flows for a 1 in 1000 year return period storm event breach scenario (as described in the FCA).

The sizing of the lakes provides a sustainable surface water system for the runoff from the site and means that when the intensity and duration of rainfall is significant, the lakes can attenuate flows above the 1 in 100 year event.

4.3.1 Land Drainage

The catchment upstream of the site has been assessed to determine land drainage flows. Two methods have been used which are appropriate to small catchments; these are the Packman Spreadsheet method and the modified rationale. The flow from the overall catchment is approximately 6 m^3/s for a 1 in 100 year return period storm event. Low flows equate to approximately 2.7 m^3/s

The restricted flow rates from the lakes and therefore the associated attenuation area within the lakes is designed to accommodate the site runoff for a 1 in 100 year storm event and land drainage during low flows. It would not be beneficial to restrict runoff from the land drains. The lakes would not provide sufficient storage for flows from the land drainage during a 1 in100 year storm event when the restrictions apply. Therefore the proposed land drainage system will accommodate the land drainage having a free discharge. The existing east west ditch located to the north of the site which collects the land drainage will channel the low flows into the new channels which discharge to the lakes. Excess land drainage flows above the low flow will bypass the controls and drain freely into the main east west ditch via a new channel which discharges into the existing land drain 4A adjacent to the Monks Ditch. .

4.4 Water Quality

The quality of the water in the lakes will improve as they become established. There is an existing duck pond within the site which is of good aesthetic quality supporting a large population of coarse fish and it is envisaged that the new balancing area will be of similar quality once the site is remediated. The lakes will be set into the natural estuarine alluvial deposits with normal impounded surface water levels dictated be the natural ground water level. The lakes will be fed by the existing watercourses which drain the land to the north. It is not considered necessary from a hydro(geo)logical viewpoint for the lakes to be lined as the water body will not be perched above a pervious base.

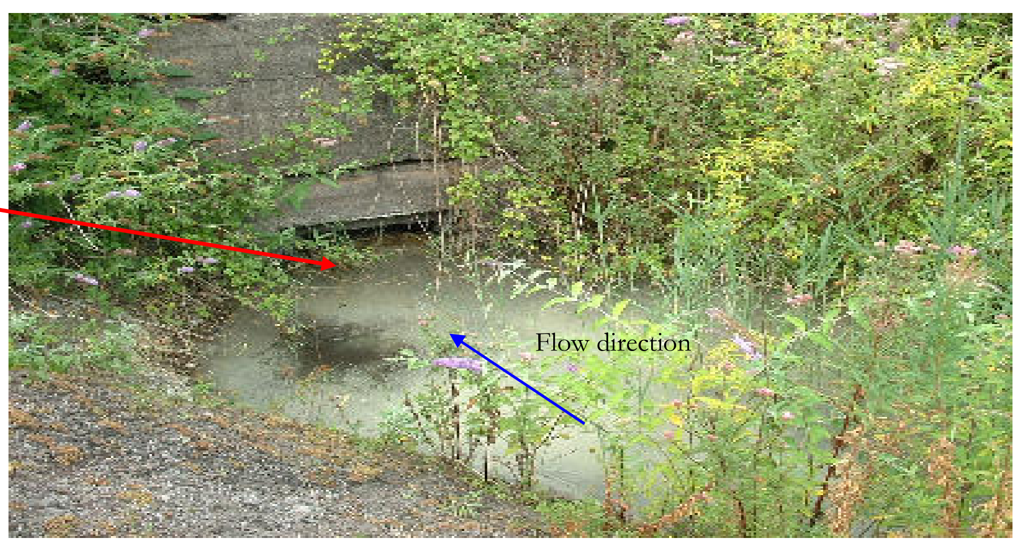
Systems will be incorporated to ensure the water quality within the land drainage system are maintained at acceptable levels, some of which are described below:

- SUDS will be incorporated with the design of plots and development areas. Given site conditions, these are most likely to comprise source control systems and attenuation structures such as swales and ponds, to restrict the rate of runoff. Infiltration systems will not be appropriate.

- Silt traps provide a very effective means of improving the quality of surface run-off and can be incorporated at various points along a drainage system.

- Oil interceptors and gully pots can be installed wherever water drains off hardstanding areas, in order to collect petrol and oil residues and grit.

- Booms can be placed around inflows into the main pond in order to trap oils and floating objects.



North South Drain 1 entering culverted section to the north of the site.

Photo 12: North south ditch entering a culverted section.

It is unlikely that Lagoon 14 will be used for the surface water runoff from the new development as settlement will not be required from the uncontaminated impermeable area runoff. However Lagoon 14 will remain in use and maintained by Corus.

4.5 Reservoirs Act

The Reservoirs Act 1975 provides the legal framework to ensure the safety of large raised reservoirs and applies to reservoirs that hold at least 25,000m^3 of water above natural ground level.

The Act does not apply to the lakes during normal flows as separate volumes of the lakes will not exceed the Reservoirs Act volumes.

4.6 Pumping Station and Improvement Works

4.6.1 Description of System

The Storm Water Pump Station pumps the combined surface, treated foul and process (trade) water from the entire site which is collected via the southern ditch (downstream of Lagoon 14) and pumped out to the sea (Severn Estuary, as shown on drawing number PI/BLSS-005-005). The pump house consists of three main parts:

- The water intake substructure.
- The pump room building.
- The switch gear building.

The inlet structure is a reinforced concrete channel (approx. 20m x 50m x 5m deep). A trash screen is provided at the entrance of the channel from the southern ditch and another is situated before the sump inlets. The reinforced concrete substructure consists of two large water sumps, which store the water before pumping. Each sump is connected to one of the main outlet pipelines and is served by a number of electric pumps.

The pump room building is steel framed with steel, glass and brick cladding. The building houses 8 electric pumps and the control equipment.

Water flows into the pump house from the southern ditch, passes through the trash screen into a concrete channel, which passes through further trash screens and into sumps 1 or 2. Pumps activate from level switches in the sumps, the water is pumped approximately 2.6 km to the sea (Severn Estuary). The outfall point is located just offshore of the sea defence embankment.

The pumping station was constructed between 1962 and 65. It is expected that this system will be adopted by the CWIDB.

4.6.2 *Alternative to pumping*

Options listed below have been explored to find a more sustainable approach rather than using the pumping station however these are not feasible:

- Pumping to existing reens to convey flows to the estuary.
- New drainage channel to discharge to the estuary along the line of the existing outfall pipes.

These options are not feasible due to problems associated with access to 3rd party land, land requisition and capacity in existing reens as discussed with the CWIDB.

The most feasible solution is to bring the pumping station to a reasonable standard for adoption by the CWIDB.

4.6.3 *Pipelines and Sea Outfall*

The sea outfall pipes which take water from the pump house to the sea outfall are 2.4km in length, they run above ground and are 60" & 42" diameter steel pipes, 10m length piled pipe supports are provided at 5m centres. The condition is reported to be good due to the ongoing painting programme which ensures the pipes are coated in bitumen and anodic protection at the sea end.

4.7 Conclusion

The surface water system will be designed in accordance with "Sewers for adoption 5th Edition", relevant British Standards and regulations, CWIDB standards and general good practice. All surface water runoff from the development will be discharged into the main lakes via a separate surface water system. The controlled outflow from the lakes will discharge into the existing Corus surface water system. Pollution prevention measures (in the form of SUDS, silt traps and interceptors) will be installed where appropriate. Flows from the site will not have any adverse environmental impact on the surrounding environment.

5 Proposed Foul Water Sewerage System

5.1 Introduction/Methodology

The foul water strategy is outline only and until all modelling currently being undertaken by Welsh Water is completed (see section 5.3.1) a detailed foul water sewerage strategy will not be able to progress. Welsh Water have indicated that the modelling will be completed early in 2006.

The foul system will be designed in accordance with "Sewers for Adoption 5th Edition", relevant British Standards and regulations.

5.2 Interim Foul Drainage arrangements

The development will take place in phases each of which will require foul sewerage. Regeneration timescales may not allow for the connection of initial phases to the public sewerage network and therefore an interim solution will be required. It is therefore proposed to drain the initial stages of housing via the existing Corus treatment system under the existing IPPC permit, subject to compliance with EA consent requirements.

5.3 Long Term Foul Drainage

Domestic foul sewerage will discharge to the public foul sewer network outfalling at Nash Waste Water Treatment Works (WwTW).

In addition to sewage from the proposed site, Corus will also connect its domestic sewage to the public foul sewer network.

Flows from the site may discharge via either of the following options:

1. A deep gravity sewer (constructed as per the existing piled north south land drains which dissect the site) with gravity sewers from each plot connecting into the deep sewer. The deep sewer will discharge to one terminal pumping station which will then pump flows into the existing Welsh Water Foul sewer system.

2. A pumping station will be required in each plot. Each plot could pump/gravitate to a single terminal pumping station. A short length of

gravity pipe is required prior to connecting the rising mains into the wet well. A final terminal pumping station would have to be pumped into a gravity fed system (no connection would be permitted to a rising main) prior to discharging to the existing public foul sewer network.

The most feasible option will be determined during detailed design and will be dependant on a full economic appraisal.

Welsh Water have indicated that in principle either option would be suitable for adoption.

5.3.1 *Welsh Water Modelling*

Modelling of the WwTW has been completed by Welsh Water, March 2005. The Nash WwTW Capacity Study report (Black and Veatch for Dwr Cymru Welsh Water, March 2005) includes a detailed analysis of the processes undertaken at the works and includes modelling results which provide simulations of the current situation at Nash WwTW and how the process would be affected by the addition of flows and loads from the proposed catchment developments. This report provides the following conclusions:

- The flow, including from the proposed development, is below the consented flow therefore the proposed growth in the catchment will not require a revision of the consent.
- The hydraulic capacity of the main stream is sufficient to allow the proposed development to the catchment area.
- Two new desludge pumps would help optimise the desludging operation from the primary settlement tanks.
- The sludge treatment stream is currently considered to be under capacity.
- Two or three centrifuges are required to ensure some standby capacity is available.

Welsh Water are undertaking further modelling to assess the capacity in the existing trunk sewers at the site. The results of the full study will inform Welsh Water how and where capacity is needed and can be released. Once this information is available a detailed foul sewerage drainage strategy can be completed.

5.4 *Corus*

In the long term Corus will need to connect their domestic foul sewage to the Welsh Water sewerage system as per the new development.

5.5 *Conclusion*

Foul water from the proposed development will connect into the existing public foul sewer, although in the short term a connection to Corus domestic foul sewerage system is proposed. The exact location will be determined at detailed design stage and is dependant on Welsh Water modelling results, capacity checks and improvement works.

The proposed sewer network will be designed in accordance with “Sewers for Adoption 5th Edition” and proposals for adoption.

6 Environmental Overview

6.1 Sustainable Drainage Systems (SUDS)

The EA requires that all applicable SUDS techniques are fully investigated. Infiltration systems are not appropriate as a result of the previous use of the site, and high groundwater table. All surface water runoff from the site will positively drain to the proposed lakes. Source control will only be adopted to restrict outflow from the lakes to the MEWD.

Pollution control measures will be adopted to ensure there is no adverse environmental impact on the water quality within the lakes. The lakes will provide a sustainable resource which will have many beneficial features, for example providing an opportunity to create habitats for wildlife.

Where possible SUDS will be incorporated with the design of plots and development areas to improve quality of surface water runoff. Given site conditions, these are most likely to comprise source control systems (i.e. porous paving) and attenuation structures such as swales and ponds, to restrict the rate of runoff.

Pollution prevention measures in accordance with the "Pollution Prevention Guidelines" published by the Environment Agency and other best practice guidance will be incorporated where appropriate.

6.2 Mitigation of Pollution

There is a known presence of contaminants at the site and consequently during construction, methods for preventing entry of contaminants into any gully, ditch or drain leading to a water course (land drains) will be agreed with the EA and the CWIDB.

6.3 SSSI

All site drainage proposals have been considered in relation to impacts on the Gwent Levels SSSIs and the Severn Estuary. The SSSI to the south of the site is of particular concern to the EA; as well as other consultees, regulators and stakeholders. Regeneration is therefore committed to ensuring that no adverse environmental impact on this area

The Severn Estuary meets several criteria for wetland of International Importance especially as a Waterfowl habitat. The quality of the site runoff will be an improvement to the existing situation; therefore ensuring that there is no risk of adverse impact to the Severn Estuary, local reens, drainage ditches and watercourses in the locality.

6.4 Groundwater mitigation measures

The majority of groundwater contamination issues will be addressed in the associated site remediation strategy. Detailed mitigation measures to ensure no adverse impact on groundwater will be adopted in full consultation with the EA, other consultees and regulators.

7 Maintenance & Land Drainage Issues

7.1 Adoption

It is proposed that Dwr Cymru Welsh Water or other appropriate sewerage undertaker will adopt the foul sewerage network and the CWIDB will adopt the land drainage systems south of the LRS. The pumping station will also be adopted by the CWIDB. Highway drainage will be the responsibility of the highway authority.

The lakes and drainage channels will function as public amenity and park land and it is envisaged that the developer will establish a management company to maintain and operate them. As an alternative, the developer may seek formal arrangements with organisations such as the CWIDB or local authority, to ensure that the features are properly maintained.

8 Conclusions

The existing site has an effective clearly defined land drainage network comprising an extensive network of reens, ditches, pipes and culverts which convey all surface water, land drainage, treated foul and trade effluent from the site to the Severn Estuary. The existing main drains which run directly through the site from north to south are numbered 1 to 6. The proposed development will utilise some of the existing land drainage and will ensure overall improvement is provided to the site and surrounding area in terms of water quality and quantity.

Surface water from the development site will discharge into the existing surface water system via newly constructed lakes. There will be controlled outlets from the lakes to the existing surface water system. Pollution control systems will be in place to ensure there are no risks of adverse environmental impacts on any receiving watercourse, ditch, reen or the surrounding environment. This system or an approved pollution prevention scheme will remain in place to ensure significant improvement is provided for the proposed site.

The foul water from the proposed site will discharge to Nash WwTW although the existing Corus system will be used in the immediate short term. The exact location of connection to the system is dependant on modelling work and improvement work currently being carried out by Dwr Cymru Welsh Water.

9 References

9.1 *Reports books and journals*

1. Technical Advice Note (TAN) 15: Development and Flood Risk, Planning Policy Wales (July 2004).

2. R.O.L.E. Project Engineering Infrastructure Report, Bay Associates, (September 2002).

3. Llanwern Regeneration Site Flood Consequences Assessment – Halcrow (December 2005).

4. Flood Study of Monks Ditch at Llanwern, Gwent- WS Atkins (July 2002).

5. Nash WwTW – Capacity Study (Newport Unlimited), Black & Veatch for Dwr Cymru Welsh Water (Marc 2005).

6. www.environment-agency.gov.uk

Appendix A

- Drawing Number PI/BLSS-005-005 Surface Water Features.
- Drawing Number PI/BLSS -005-006 Existing Drainage Plan.
- Drawing Number PI/BLSS-005-013 Proposed Surface and Foul water drainage.
- Drawing Number PIBLSS-005-011 Schematic of Site Drainage Layout.

Appendix C – Glan Llyn Flood Consequence Assessment Addendum (Halcrow Group Ltd, November 2010)

St Modwen Developments Ltd

Glan Llyn, Newport

Flood Consequences Assessment Addendum

November 2010

Halcrow Group Limited

St Modwen Developments Ltd

Glan Llyn, Newport

Flood Consequences Assessment Addendum

November 2010

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www.halcrow.com

St Modwen Developments Ltd

Llanwern Regeneration Site

Addendum to Flood Consequences Assessment

PI/FLRS/R005

Contents Amendment Record

This report has been issued and amended as follows

Issue	Revision	Description	Date	Signed
1	0	Draft	17 May 2010	M Phillips
2	1	Final	04 Nov 10	P Robinson

Contents

1 Introduction

This addendum is to be read in conjunction with the Llanwern Regeneration Site Flood Consequences Assessment (Halcrow, December 2005).

In 2005 Environment Agency Wales LiDAR data was available for a limited part of the study area (approximately 1km inshore from the coast, whereas the site is some 5km inland from the coast) and topographic data from Corus was available within the site from a survey undertaken in August 1959. It was necessary to obtain a digital terrain model (DTM) from an aerial survey flown in 2002 by Getmapping UK, to inform the coastal flood consequences assessment.

LiDAR data is now available from the Environment Agency Wales for the entire study area (from a survey flown in 2007) which has been used to provide an updated DTM to enable a review of the coastal flood consequences assessment. The LiDAR data has a higher resolution and shows that ground levels are typically higher than shown in the Getmapping UK DTM, see Figure 1.4.

The DTM was refined to include underpasses and culverts identified using 1:25 000 scale Ordnance Survey and knowledge of the site obtained during previous site visits undertaken during the development of the River Usk Tidal Strategy, see Figure 1.1. This updated DTM takes account of various changes which have been made to the landforms in the study area since the 2005 Flood Consequences Assessment was undertaken:

- Updated topographical surveys of the site and surrounding area
- River Usk east bank flood defence improvements, see Figure 1.3

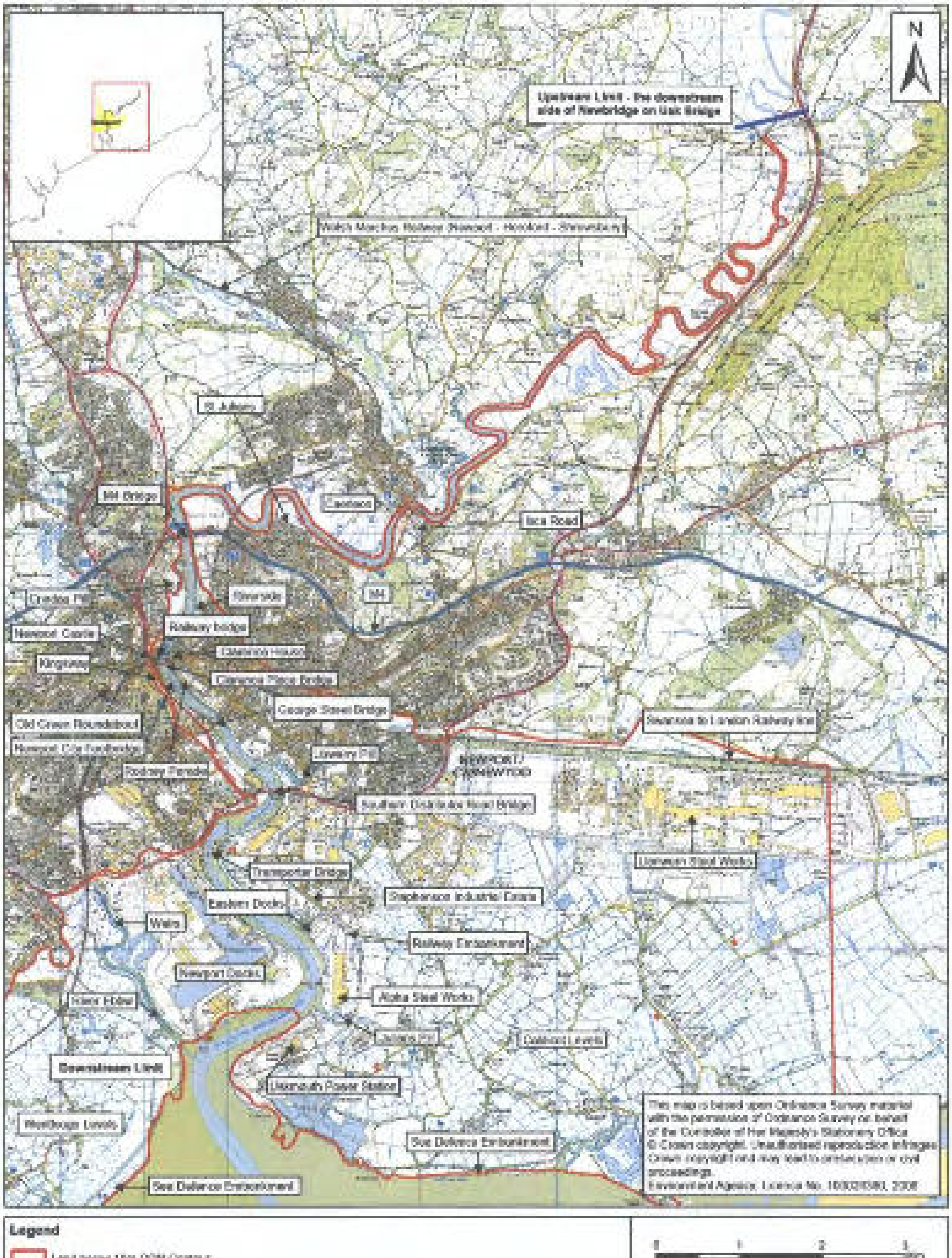


Figure 1.1: Study Area
(from River Usk Tidal Strategy, Draft Project Interim Report, Halcrow, June 2008)

Figure 1.2: Llanwern Development, Glan Llyn – Indicative Master Plan

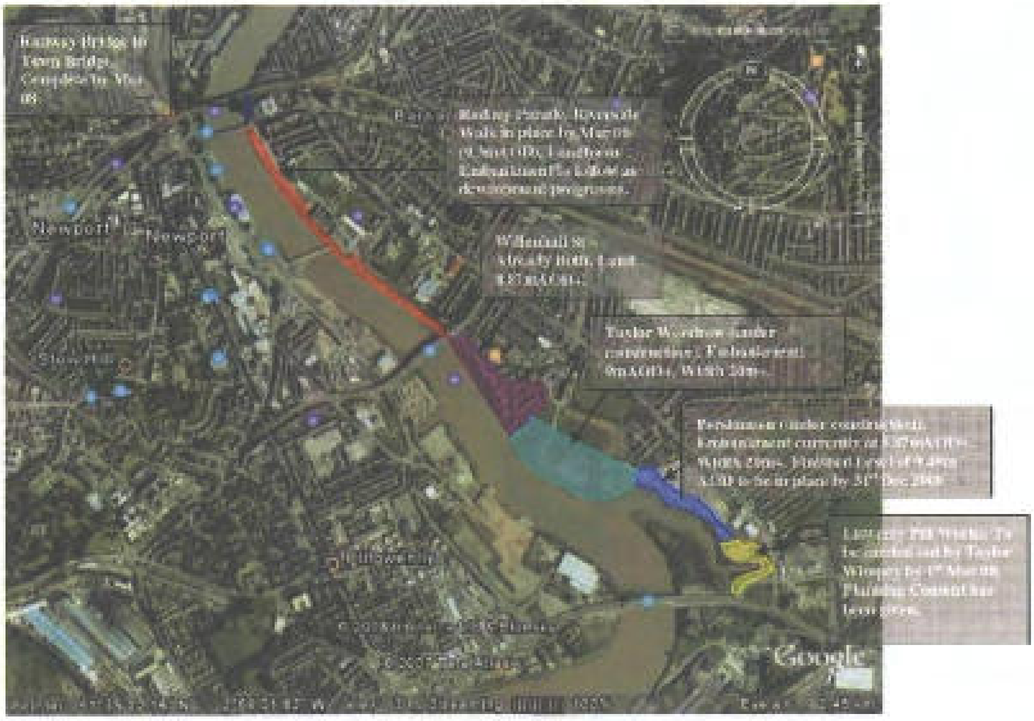


Figure 1.3: River Usk East Bank Defence Improvements
(from Newport Unlimited, January 2008)

Figure 1.4: Contour plot showing the difference between the Getmapping DTM (used for the 2005 Llanwern FCA) and Environment Agency Wales LiDAR data (used for this Addendum)

2 Coastal Flood Consequences Modelling Scenarios

2 1 *FLOOD3D flood propagation model*

Halcrow's three dimensional flood model FLOOD3D was used for the Llanwern Flood Consequences Assessment in 2005 and has been used for this further modelling work The model is based on complete 3 D Reynolds averaged Navier Stokes equations including hydrodynamic pressure The sigma coordinate transformation is used to transform the equations and the corresponding boundary conditions from the physical domain to the calculation domain The time splitting method is used to separate advection and diffusion terms from the pressure terms in the governing equations The pressure variable is further separated into hydrostatic and hydrodynamic pressures so that the computer rounding errors can be largely avoided The resulting hydrodynamic pressure equation is solved by a multigrid method while the hydrostatic pressure equations are solved very efficiently by an Alternating Direction Implicit (ADI) scheme The Roe's scheme is used for the convection terms which produce accurate results The technique of flooding and drying which was firstly developed by Falconer and Owens (1987) is used in the present model

With a given boundary condition at the breach location and also the DTM the flood model has been applied to investigate flooding consequences at and surrounding the Llanwern regeneration site

Assumptions adopted during coastal flood propagation modelling as follows are conservative and adopt the precautionary principle

- A tidal curve has been used to provide real time water level input boundary data to the FLOOD3D model
- Each breach remains open for a 48 hour period (flood water only flows through the breach when the level of the tide is greater than the ground level at the breach)
- No drainage out of the site or surrounding area during this period
- No allowance for wave action since the site is at least 4km distant from the coast

2.2 *Extreme Water Levels*

The extreme water levels used in the original Llanwern Flood Consequences Assessment (Halcrow, 2005) were as follows:

- Extreme water level along the coast: +9.18mODN. 1 in 1000year return period water levels including 50 years sea level rise (WS Atkins, 2001b)
- Extreme water level in the River Usk: +9.08mODN. 1 in 1000year return period water levels including 50 years sea level rise (provided by Richard Wicks, Environment Agency Wales)

In October 2006 Defra published updated sea level rise guidance in 2006, which assumes a 1000mm increase in sea level rise over the next 100 years, see Table 2.2 which is latest Environment Agency Wales guidance (December 2006). Further guidance was published by UKCIP09 in June 2009, which provides a range of future sea level rise scenarios of between 200mm and 800mm over the next 100 years, see Figure 2.1, however this has not yet been adopted by Defra or the Environment Agency Wales.

Return period	APO	Year				
		2000	2008	2028	2058	2108
1 in 1 year	63%	7.7	7.7	7.8	8.1	8.7
1 in 2 year	39.4%	7.8	7.9	7.9	8.2	8.8
1 in 5 year	18.1%	8.0	8.0	8.1	8.3	9.0
1 in 10 year	9.5%	8.1	8.1	8.2	8.5	9.1
1 in 20 year	4.9%	8.2	8.2	8.3	8.6	9.2
1 in 50 year	2%	8.4	8.4	8.4	8.7	9.4
1 in 75 year	1.3%	8.4	8.4	8.5	8.8	9.4
1in 100 year	1%	8.5	8.5	8.5	8.8	9.5
1 in 200 year	0.5%	8.5	8.6	8.6	8.9	9.5
1 in 500 year	0.2%	8.8	8.8	8.9	9.1	9.8
1 in 1000 year	0.1%	8.9	8.9	8.9	9.2	9.9

Table 2.2 Extreme Tide Levels at Newport (River Usk and along the coast) from River Usk Tidal Strategy Draft Project Interim Report produced for Environment Agency Wales (Halcrow, June 2008). Tide levels are based on ABP Research and Consultancy 2000, Gwent Levels Hydraulic Modelling Study Objective A: Joint Probability Surge Tide and Wave Analysis and include latest guidance on sea level rise (Defra, Oct 2006).

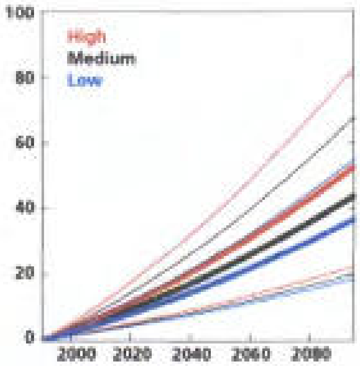


Figure 2.1: Relative sea level (RSL) rise over the 21st century for South Wales (Cardiff) showing central estimate values (thick lines) and 5th and 95th percentile limits of the range of uncertainty (thin lines). Values are in cms relative to 1990 (UKCIP09)

Two extreme water level scenarios have been considered for the latest model runs, as follows:

- Extreme water level along the coast, +9.23mODN, 1 in 1000 year return period water levels including 50 years sea level rise
- Extreme water level along the coast, +9.9mODN, 1 in 1000 year return period water levels including 100 years sea level rise.

2.3 *Breach Scenarios*

Three breach scenarios have been considered:

1. **Goldcliff sea defence embankment** (south of the site) a 200m wide breach in the embankment down to +6.75mODN, see Figure 2.2, which allows a 750mm depth of material within the breach following embankment failure.

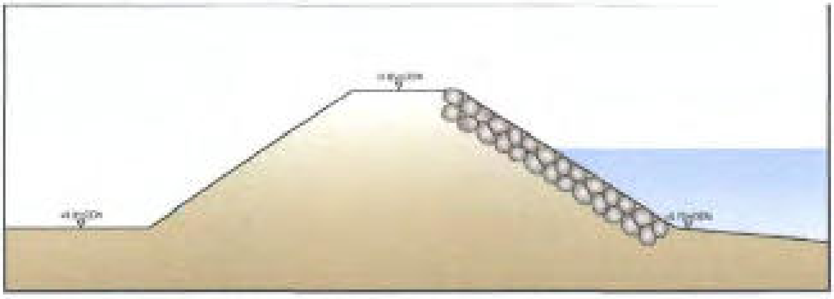


Figure 2.2: Goldcliff sea defence embankment cross-section

2. **Riverside retaining wall** (west-north-west of the site) a 50m wide breach, extending from south from Corelli Street, down to existing ground level, see Figure 2.3. This was identified as the most sensitive breach location (with respect to flood risk to the wider area of Newport) during flood propagation modelling undertaken for the River Usk Tidal Strategy.

3. **Embankment south of the Transporter Bridge** (west-south-west of the site), a 50m wide breach down to existing ground level.

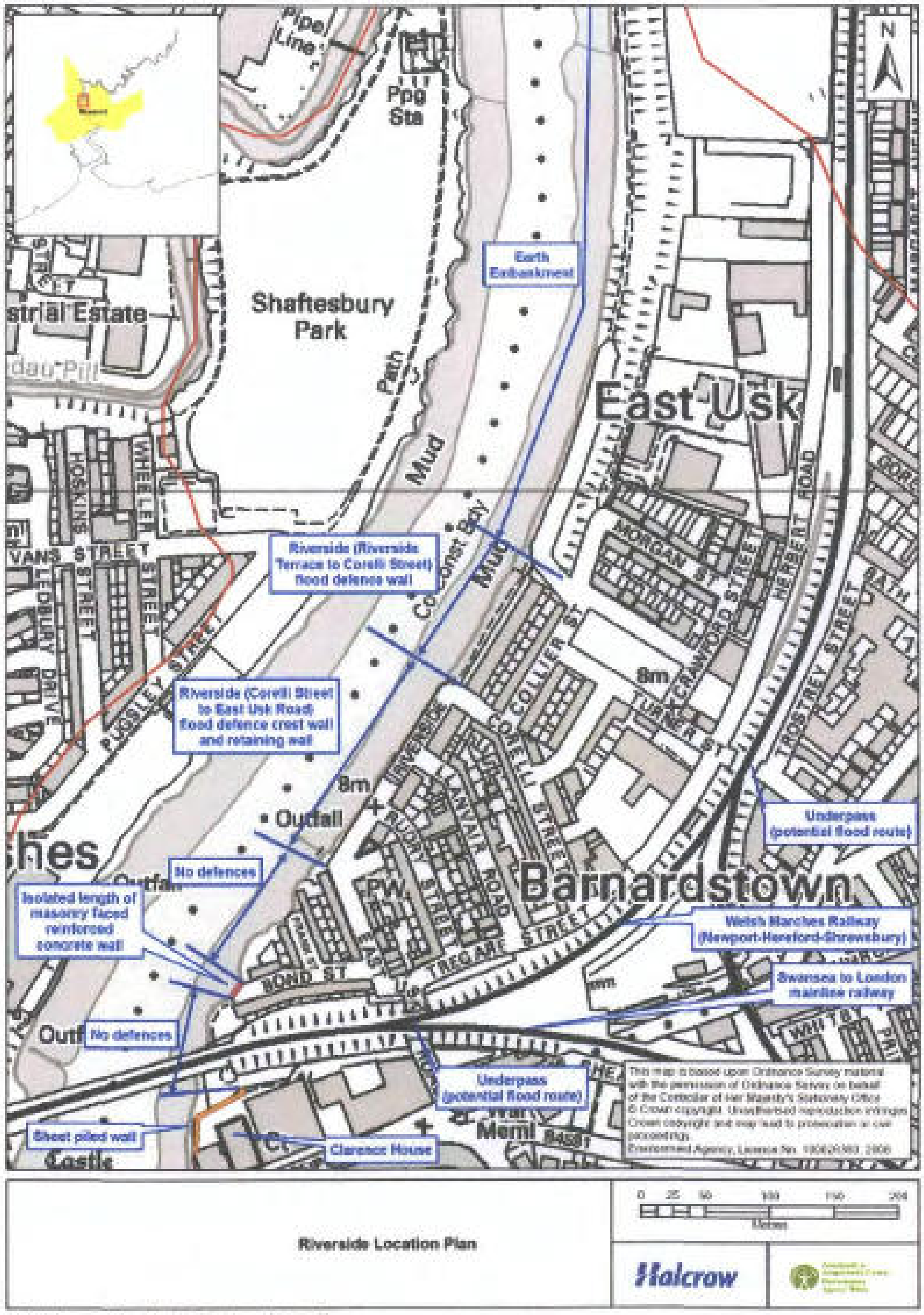


Figure 2.3: New breach location (100m south from Corelli Street, Riverside)

3 Modelling Results and Proposed Mitigation Measures

The updated DTM was used in the FLOOD3D model to run each of the three baseline breach scenarios (Goldcliff sea defence embankment, Riverside retaining wall and embankment south of the Transporter Bridge) for each extreme water level (+9.23mODN and +9.9mODN, 1 in 1000 year return period water levels including 50 years and 100 years sea level rise respectively) to identify the potential flood risk to the Llanwern regeneration site. The boundary of the site has been shown in blue on all of the figures.

Proposed mitigation measures to reduce the risk of flooding to the development and the adjacent area have been identified (including ground raising within the development site and the creation of blueways/ ditches/ reens and flood storage areas). Further modelling will be undertaken to inform detailed design of the proposed mitigation measures.

3.1 *Goldcliff sea defence embankment*

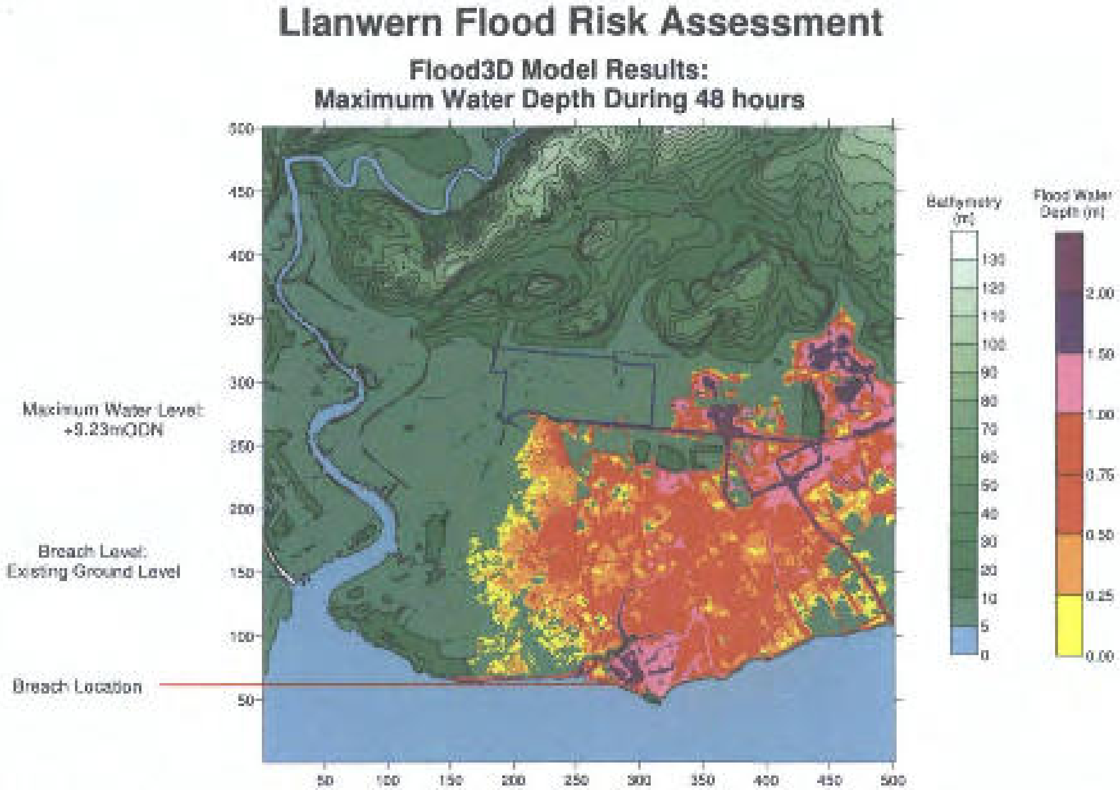


Figure 3.1.1: **Goldcliff sea defence embankment, 9.23mODN water level**

Baseline Scenario

Water volume within site: 14,000 m^3

Averaged water surface elevation within site: 6.0mODN

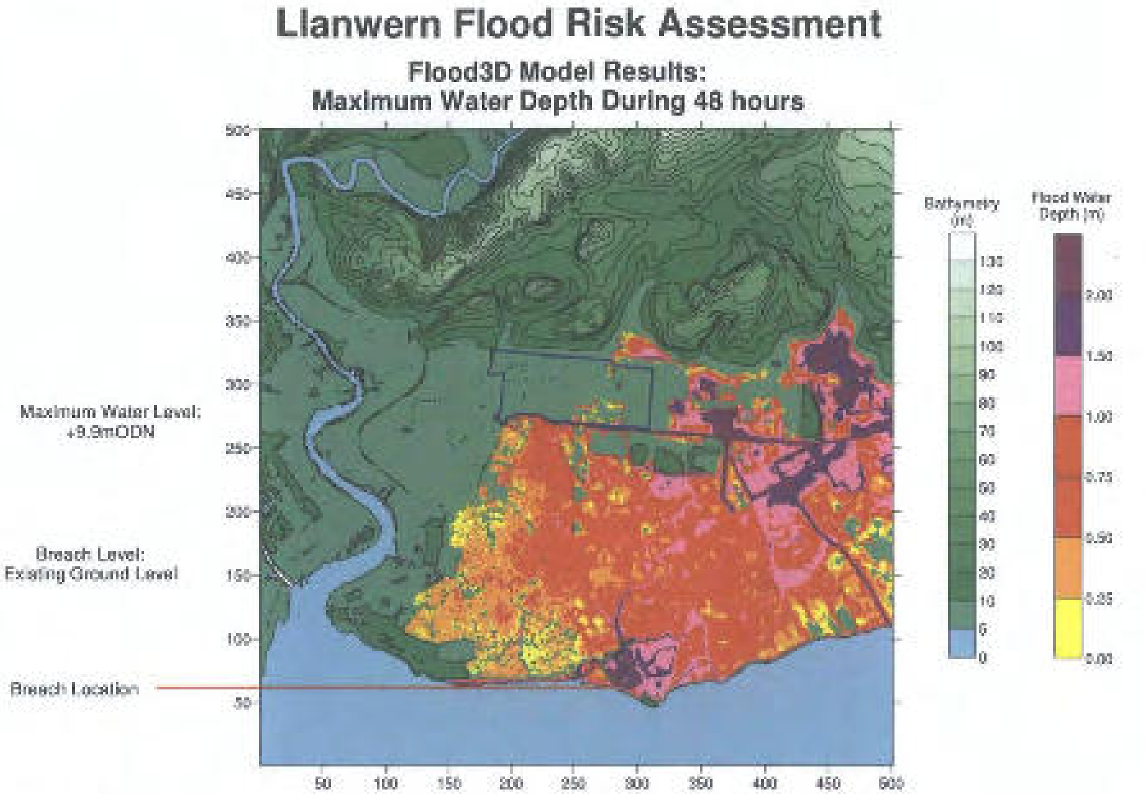


Figure 3.1.2: **Goldcliff sea defence embankment, 9.9mODN water level**

Baseline Scenario

Water volume within site: 72,900 m³

Averaged water surface elevation within site: 6.3mODN

Proposed Mitigation Measures

The areas identified as being flooded within the proposed development site will be raised. The flood volume displaced will be accommodated within the central /east lake areas with blueways/ ditches/ reens taking the flows from the north and south, the levels of which will need to be developed further during detailed design.

3.2 *Riverside retaining wall*

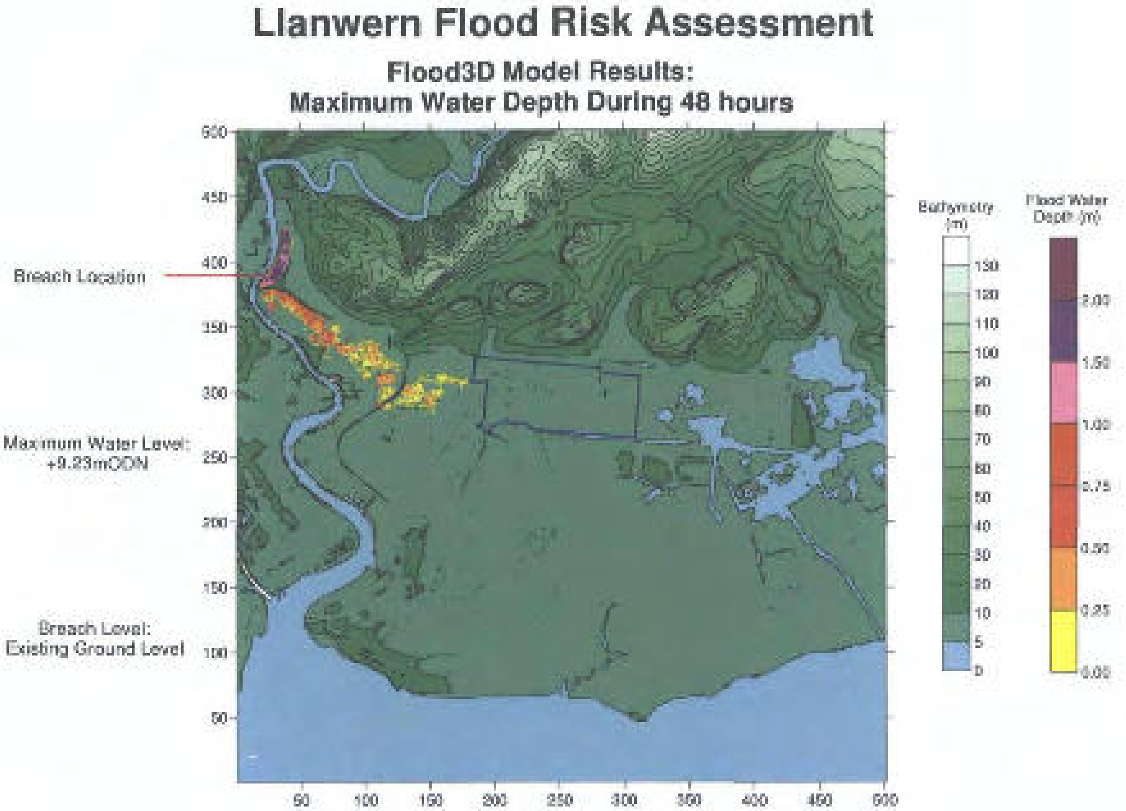


Figure 3.2.1: **Riverside retaining wall, 9.23mODN water level**

Baseline Scenario

Water volume within site: $0m^3$

Averaged water surface elevation within site: N/A

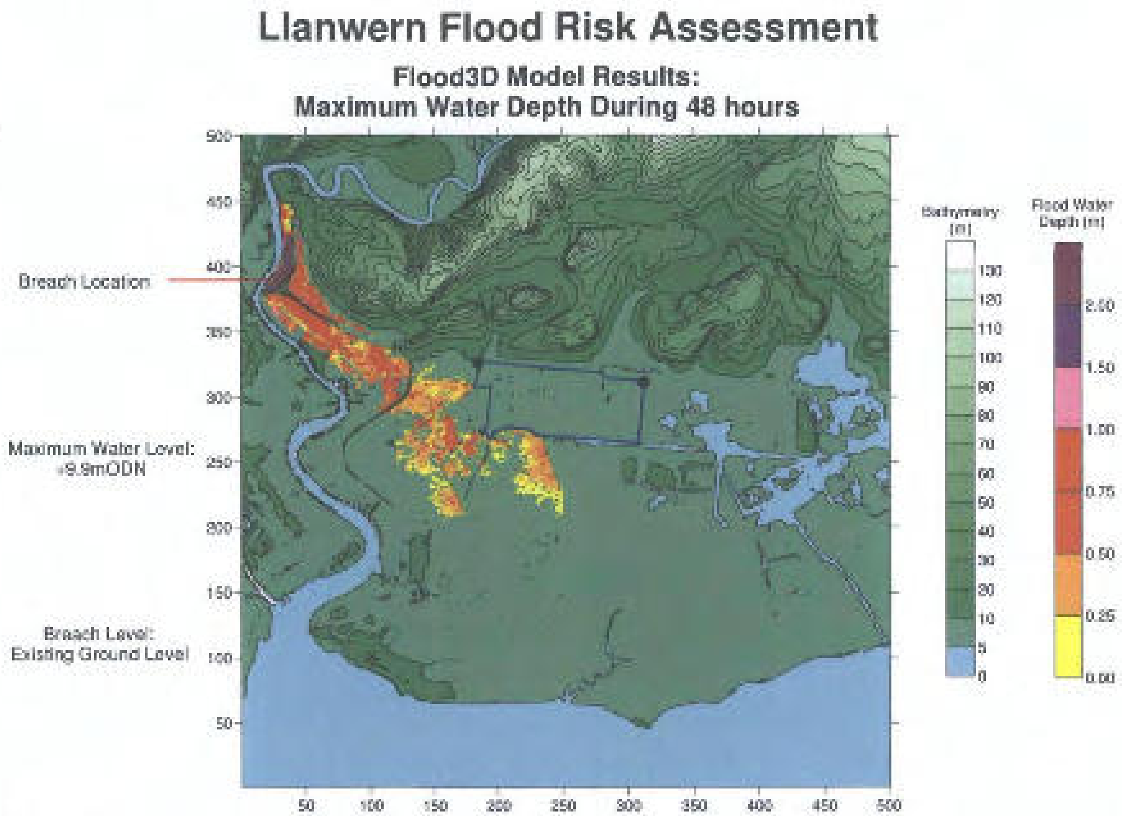


Figure 3.2.2: **Riverside retaining wall, 9.9mODN water level**

Baseline Scenario

Water volume within site: 0m³

Averaged water surface elevation within site: N/A

Proposed Mitigation Measures

No flooding to be accommodated.

3.3 *Embankment south of the Transporter Bridge*

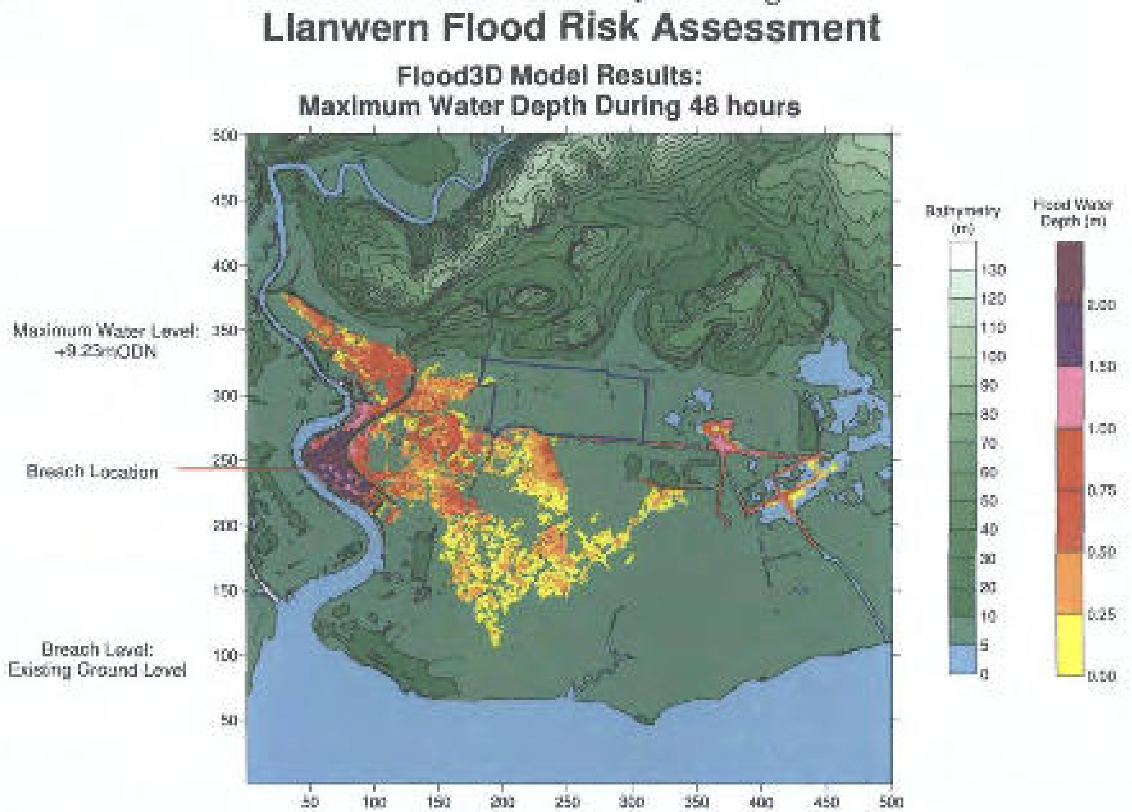


Figure 3.3.1: **Embankment south of the Transporter Bridge, 9.23mODN water level**

Baseline Scenario

Water volume within site: 2,500 m^3

Averaged water surface elevation within site: 6.0mODN

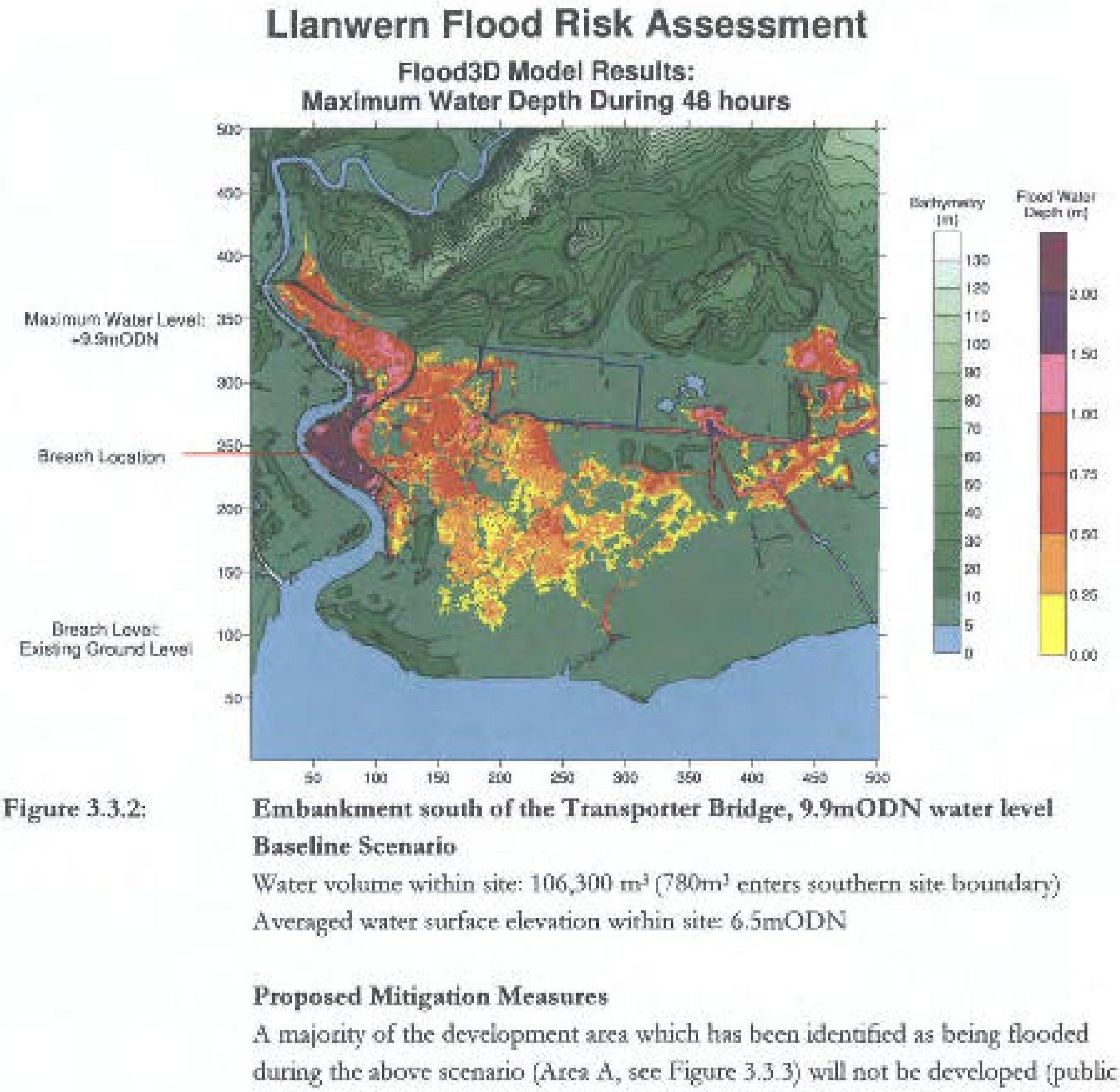


Figure 3.3.2: **Embankment south of the Transporter Bridge, 9.9mODN water level Baseline Scenario**

Water volume within site: 106,300 m³ (780m³ enters southern site boundary)
Averaged water surface elevation within site: 6.5mODN

Proposed Mitigation Measures

A majority of the development area which has been identified as being flooded during the above scenario (Area A, see Figure 3.3.3) will not be developed (public open space and playing fields) and be allowed to function as a flood storage area. Analysis has concluded that 75,450 cubic meters of water will need to be accommodated as a result of raising the level of the remaining development area which is at risk from flooding (Area B, see Figure 3.3.3). The volume of water displaced by raising the development area will be accommodated within the ponds/open space in the West Park and via blueways/ ditches/ reens, taking the flows from the west and south, which will be developed further during detailed design.

Figure 3.3.3: Flooded Areas

3.4 *Development Levels*

The proposed minimum development level is to be the greater level of;

- T1000 tidal breach inundation level
- T200 tidal breach inundation level + 200mm
- 100yr (inc. climate change) for the existing watercourses and surface water run-off/attenuated water levels + 600mm

3.4.1 *T1000 Tidal Breach Level*

As stated above, parts of the site are at risk from a tidal breach flood from two separate 1 in 1000 year breach scenarios, both resulting in different predicted on site flood water levels; **6.5m AOD** and **6.3m AOD** from the Transporter Bridge and Goldcilff Sea Wall breaches, respectively (see Figures *3.1.2. Goldcliff sea defence embankment, 9.9mODN water level Baseline Scenario* and *3.3.2 Embankment south of the Transporter Bridge, 9.9mODN water level Baseline Scenario* for the respective areas of inundation).

3.4.2 *T200 Tidal Breach Level + 200mm*

The following levels have been taken at Uskmouth (from Penarth to Chepstow tidal modelling study produced by Atkins).

Return Period/Year	2009	2059	2109
T200	8.58	8.92	9.57
T1000	8.89	9.23	9.88

The 2109 T200 level (9.57m AOD) is more than the 200mm freeboard **lower than the T1000 levels** and is therefore deemed to be less onerous than the T1000 level.

3.4.3 *100yr (inc. climate change) surface water run-off/attenuated water levels + 600mm*

The operational depth of the on site storage/attenuation (e.g. lakes and reens) will typically be 1m, the operational invert level of which will typically be 4.1m AOD. Therefore the 1 in 100yr surface water run-off/attenuated water levels = 4.1m AOD + 1m + 0.6m = 5.7m AOD, which is lower than both the Transporter Bridge and Goldcliff Sea Wall breach flood water levels.

3.4.4 *Proposed Levels*

The appropriate minimum development and finished floor levels are **6.5m AOD** and **6.3m AOD** in the western and central/eastern areas respectively. The indicative **6.5m AOD** and **6.3m AOD** minimum level development areas are shown on Figure 3.4.1 below. The areas of the site not proposed to be developed are also indicated.

It should be noted that the range of existing site levels in these areas are;

- Western area: typically 6.2m AOD to 7.5m AOD (with localised low spots at around 5.5m AOD)
- Central/eastern area: typically 5.8m AOD to 7.5m AOD

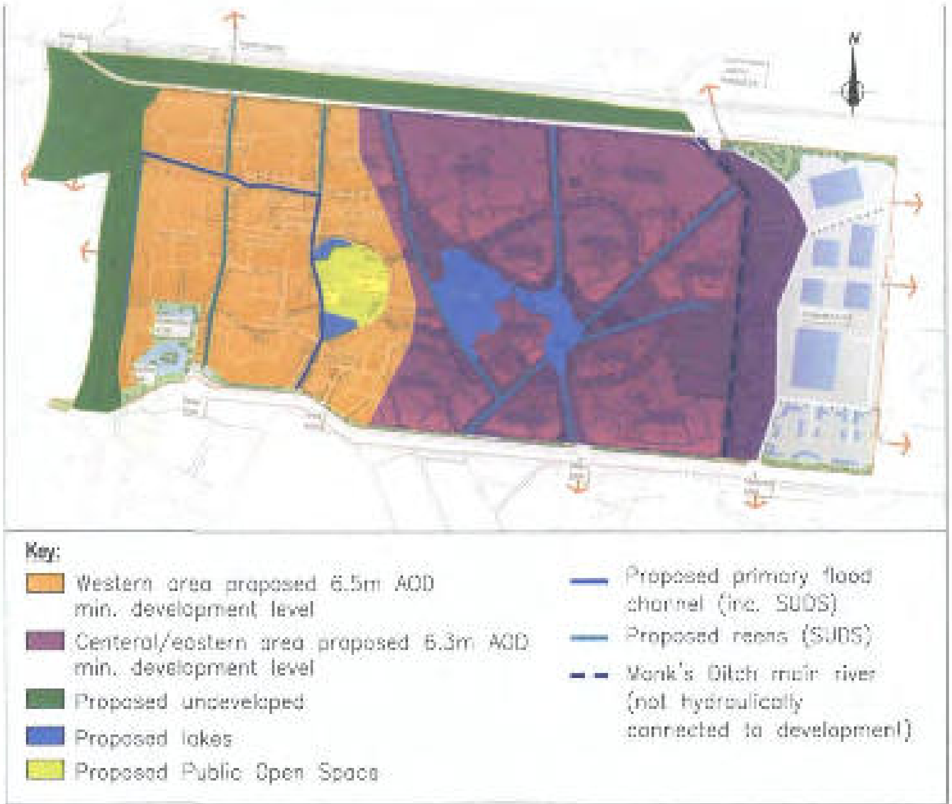


Figure 3.4.1: **Indicative Extent of Proposed Minimum Development Levels**

3.5 ***Emergency Access***

The original Flood Consequences Assessment concluded that an emergency access to the Newport Southern Distributor Road (SDR) at the north west corner of the site would be required as a result of flooding to the east of Newport following a breach of the Upper River Usk east bank defences (refer to FCA 2005, ch 6.1). This requirement has been formalised in planning condition No 14.

Upon inspection of the affects of the above updated flood modelling on the same highway network, it can be seen that for each breach scenario an emergency access will not be required as a clear route is maintained to/from the development to the higher ground to the north of the site via Queensway Meadows, the eastbound SDR and on to the M4 at Coldra.

With specific regard to the Transporter Bridge 9.9ODN breach – the scenario predicted to have the greater impact on the east Newport highway network – Figures 3.5.1 and 3.5.2 below are close-ups of the 3D model results from Figure 3.3.2, showing the clear route to/from the development to the higher ground to the north.

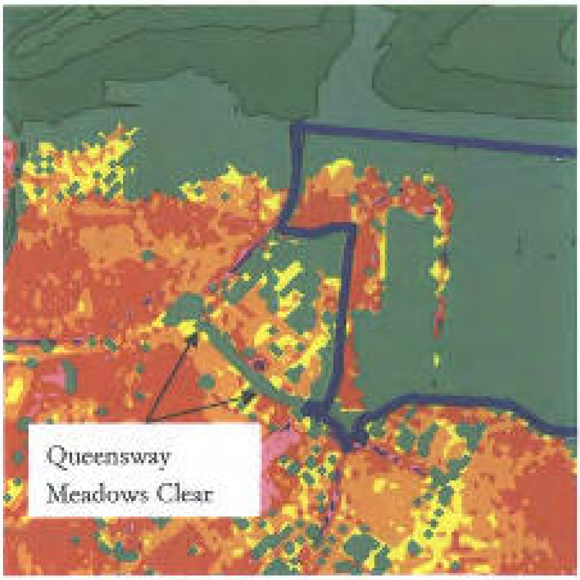


Figure 3.5.1: **Embankment south of the Transporter Bridge, 9.9mODN. Queensway Meadows Clear Route**

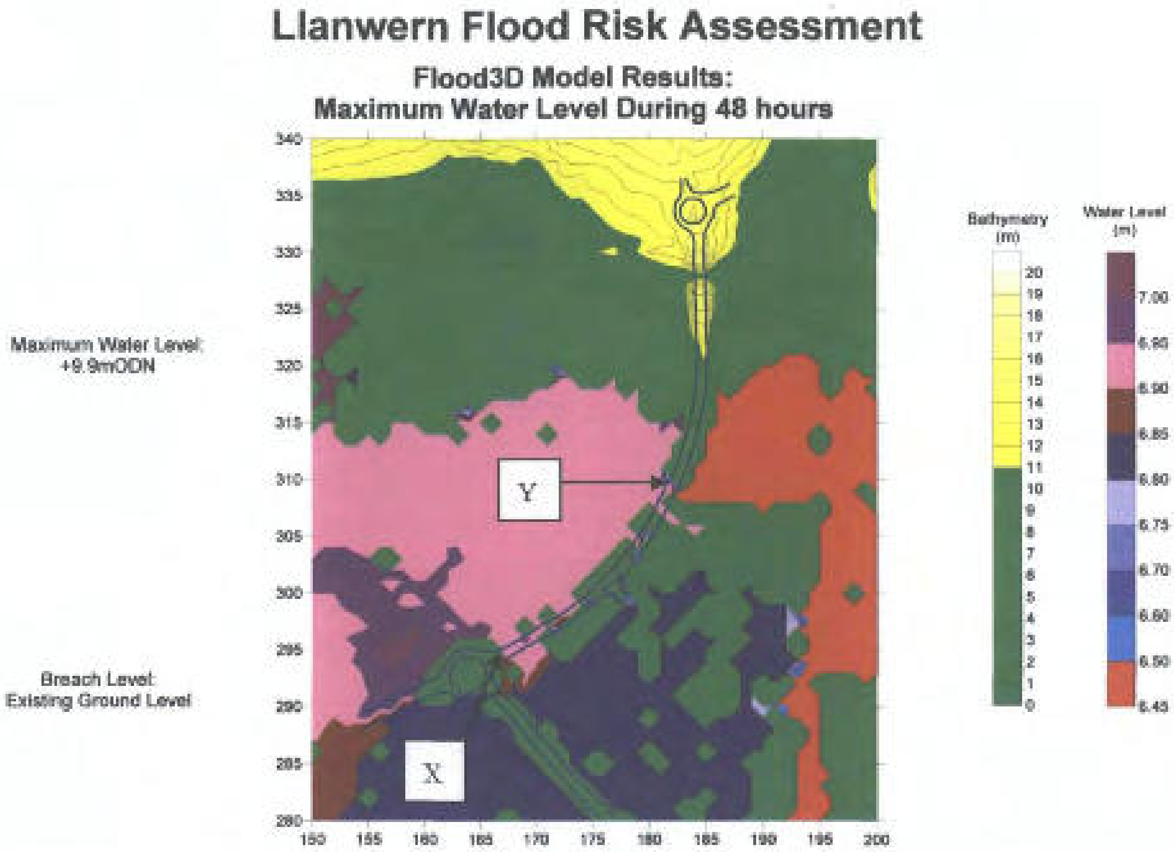


Figure 3.5.2: **Embankment south of the Transporter Bridge, 9.9mODN water levels along SDR**

The above figure indicates that flood water will cross the line of the SDR with a maximum water level of 6.95m ODN. This water will be conveyed by the existing culverts and reens that pass under the SDR as the road levels along this section of the SDR are above the maximum water level (SDR road level of 6.96mODN at point X and 14.95mODN at point Y).

4 Summary of Results

As a result of improvements to the River Usk east bank undertaken by others and the availability of improved and extended LiDAR survey data, both of which were undertaken subsequent to the 2005 Flood Consequences Assessment submitted with the outline planning application, this addendum demonstrates that

- The site is only affected by a Goldcliff sea wall or Transporter Bridge breach and not from a breach of the Riverside retaining wall
- The volume of flood water entering the site from a Transporter Bridge breach (106 269m³) is significantly reduced from that predicted in the 2005 FCA (170 000m³) and will be at an average level of 6.5m ODN
- 75 450m³ of that volume will enter the development area
- The volume of flood water entering the site from a Goldcliff sea wall breach is predicted to be 72 900m³ at an average level of 6.3 ODN
- The Queensway Meadows road will not be subject to flooding in any of the breach scenarios modelled
- Flood water crossing the SDR under the Transporter Bridge breach scenario will be at a level lower than the existing road

5 Conclusion

The results of this addendum to the Flood Consequences Assessment demonstrate that

- Under the Transporter Bridge breach scenario the predicted flooded area inside the site but outside the development area will not be developed and will act as a flood storage area This will cater for 30 818m³ of the predicted volume entering the site

- The remaining 75 150m³ of flood water predicted to enter the development area is approximately 64% less than stated in the 2005 FCA (170 000m³) This volume will be temporarily allowed for within the existing undeveloped topography until such time as that area is developed and it will then be catered for in the development reens and lakes

- Areas affected by the flood water predicted from the Transporter Bridge breach will be developed at a minimum level of 6 5m AOD (refer to chapter 3 4 and Figure 3 4 1)

- Under the Goldcliff sea wall breach scenario the predicted volume of flood water entering the site is 72 900m³ This volume will be temporarily allowed for within the existing undeveloped topography until such time as that area is developed and it will then be catered for in the development reens and lakes

- Areas affected by the flood water predicted from the Goldcliff sea wall breach will be developed at a minimum level of 6 3m AOD (refer to chapter 3 4 and Figure 3 4 1)

- The design of the reens and lakes will be developed further through Reserved Matters and planning discharge submissions and detailed design

- An emergency access for vehicles above the predicted flood levels (in accordance with planning condition No 14) is no longer necessary However the route will remain for pedestrian and cycle access

Appendix D – WinDes Calculations @ 750l/s Discharge

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	3.080	0.080	7.5	7603.7	O K
30 min Summer	3.109	0.109	13.5	10365.1	O K
60 min Summer	3.142	0.142	22.0	13468.3	O K
120 min Summer	3.177	0.177	32.8	16809.7	O K
180 min Summer	3.197	0.197	39.8	18761.5	O K
240 min Summer	3.212	0.212	45.0	20153.5	O K
360 min Summer	3.234	0.234	53.1	22235.5	O K
480 min Summer	3.249	0.249	58.9	23731.4	O K
600 min Summer	3.262	0.262	63.7	24882.9	O K
720 min Summer	3.271	0.271	67.3	25803.8	O K
960 min Summer	3.286	0.286	72.7	27185.0	O K
1440 min Summer	3.303	0.303	79.4	28861.5	O K
2160 min Summer	3.315	0.315	83.7	29987.6	O K
2880 min Summer	3.320	0.320	85.4	30462.5	O K
4320 min Summer	3.327	0.327	87.6	31107.3	O K
5760 min Summer	3.331	0.331	89.1	31520.3	O K
7200 min Summer	3.333	0.333	89.8	31696.7	O K
8640 min Summer	3.333	0.333	89.8	31724.8	O K
10080 min Summer	3.333	0.333	89.6	31648.7	O K
15 min Winter	3.090	0.090	9.3	8515.5	O K
30 min Winter	3.122	0.122	16.7	11607.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	118.653	0.0	591.5	27
30 min Summer	80.930	0.0	1039.6	42
60 min Summer	52.662	0.0	2986.7	72
120 min Summer	32.979	0.0	4293.0	132
180 min Summer	24.630	0.0	5105.3	192
240 min Summer	19.920	0.0	5697.8	250
360 min Summer	14.772	0.0	6594.8	370
480 min Summer	11.926	0.0	7235.5	490
600 min Summer	10.092	0.0	7714.9	608
720 min Summer	8.799	0.0	8081.1	728
960 min Summer	7.080	0.0	8573.1	966
1440 min Summer	5.200	0.0	8930.6	1444
2160 min Summer	3.809	0.0	17366.8	2160
2880 min Summer	3.050	0.0	17898.8	2484
4320 min Summer	2.225	0.0	17447.4	3200
5760 min Summer	1.781	0.0	30303.9	3984
7200 min Summer	1.499	0.0	30941.2	4768
8640 min Summer	1.303	0.0	30933.6	5616
10080 min Summer	1.157	0.0	30250.5	6448
15 min Winter	118.653	0.0	729.5	27
30 min Winter	80.930	0.0	1274.6	42

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	3.159	0.159	27.1	15080.5	O K
120 min Winter	3.198	0.198	40.0	18819.6	O K
180 min Winter	3.221	0.221	48.3	21002.1	O K
240 min Winter	3.237	0.237	54.4	22556.6	O K
360 min Winter	3.261	0.261	63.5	24879.8	O K
480 min Winter	3.279	0.279	70.3	26549.0	O K
600 min Winter	3.292	0.292	75.2	27832.7	O K
720 min Winter	3.303	0.303	79.4	28859.1	O K
960 min Winter	3.319	0.319	85.1	30401.4	O K
1440 min Winter	3.339	0.339	91.7	32300.4	O K
2160 min Winter	3.354	0.354	96.3	33661.7	O K
2880 min Winter	3.359	0.359	97.8	34160.6	O K
4320 min Winter	3.364	0.364	99.3	34619.3	O K
5760 min Winter	3.365	0.365	99.7	34779.2	O K
7200 min Winter	3.364	0.364	99.3	34631.0	O K
8640 min Winter	3.360	0.360	98.2	34310.6	O K
10080 min Winter	3.356	0.356	97.0	33895.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	52.662	0.0	3608.4	72
120 min Winter	32.979	0.0	5151.4	130
180 min Winter	24.630	0.0	6102.6	188
240 min Winter	19.920	0.0	6792.5	248
360 min Winter	14.772	0.0	7828.7	364
480 min Winter	11.926	0.0	8561.0	482
600 min Winter	10.092	0.0	9103.7	600
720 min Winter	8.799	0.0	9514.2	716
960 min Winter	7.080	0.0	10053.8	950
1440 min Winter	5.200	0.0	10396.8	1406
2160 min Winter	3.809	0.0	20094.8	2076
2880 min Winter	3.050	0.0	20643.9	2684
4320 min Winter	2.225	0.0	20010.3	3328
5760 min Winter	1.781	0.0	34697.2	4224
7200 min Winter	1.499	0.0	35419.9	5120
8640 min Winter	1.303	0.0	35408.1	6048
10080 min Winter	1.157	0.0	34619.4	6864

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.320	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 34.200

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	11.400	4	8	11.400	8	12	11.400

Model Details

Storage is Online Cover Level (m) 6.000

Tank or Pond Structure

Invert Level (m) 3.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	95000.0	3.000	98306.1

Hydro-Brake Optimum® Outflow Control

Unit Reference	MD-SFP-0390-1197-2500-1197
Design Head (m)	2.500
Design Flow (l/s)	119.7
Flush-Flo™	Calculated
Objective	Future Proof
Diameter (mm)	390
Invert Level (m)	3.000
Minimum Outlet Pipe Diameter (mm)	450
Suggested Manhole Diameter (mm)	Site Specific Design (Contact Hydro International)

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	2.500	119.5
Flush-Flo™	0.659	119.5
Kick-Flo®	1.558	95.0
Mean Flow over Head Range	-	100.5

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake Optimum® as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	11.4	1.200	111.6	3.000	130.6	7.000	197.5
0.200	40.8	1.400	105.0	3.500	140.8	7.500	204.3
0.300	78.2	1.600	96.3	4.000	150.3	8.000	210.8
0.400	109.5	1.800	101.9	4.500	159.1	8.500	217.2
0.500	117.8	2.000	107.3	5.000	167.5	9.000	223.3
0.600	119.3	2.200	112.3	5.500	175.5	9.500	229.3
0.800	118.6	2.400	117.2	6.000	183.1		
1.000	115.7	2.600	121.8	6.500	190.5		

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	3.739	0.739	131.4	8231.6	O K
30 min Summer	4.004	1.004	131.5	11234.7	O K
60 min Summer	4.296	1.296	131.5	14576.0	O K
120 min Summer	4.601	1.601	131.5	18095.5	O K
180 min Summer	4.772	1.772	131.5	20078.9	O K
240 min Summer	4.888	1.888	131.5	21438.6	O K
360 min Summer	5.051	2.051	131.5	23354.1	O K
480 min Summer	5.158	2.158	131.5	24616.2	O K
600 min Summer	5.233	2.233	131.5	25500.8	O K
720 min Summer	5.286	2.286	131.5	26134.7	O K
960 min Summer	5.352	2.352	131.5	26914.0	O K
1440 min Summer	5.389	2.389	131.5	27354.6	O K
2160 min Summer	5.363	2.363	131.5	27045.8	O K
2880 min Summer	5.319	2.319	131.5	26518.9	O K
4320 min Summer	5.209	2.209	131.5	25211.8	O K
5760 min Summer	5.093	2.093	131.5	23849.0	O K
7200 min Summer	4.976	1.976	131.5	22466.1	O K
8640 min Summer	4.857	1.857	131.5	21070.9	O K
10080 min Summer	4.731	1.731	131.5	19601.4	O K
15 min Winter	3.828	0.828	131.5	9231.4	O K
30 min Winter	4.124	1.124	131.5	12603.8	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	117.869	0.0	6866.1	26
30 min Summer	80.655	0.0	9269.8	41
60 min Summer	52.662	0.0	13926.6	70
120 min Summer	33.079	0.0	17320.1	130
180 min Summer	24.738	0.0	19070.9	190
240 min Summer	20.035	0.0	20069.5	250
360 min Summer	14.880	0.0	20595.6	368
480 min Summer	12.026	0.0	20324.3	488
600 min Summer	10.185	0.0	20048.7	606
720 min Summer	8.886	0.0	19800.5	726
960 min Summer	7.157	0.0	19375.7	964
1440 min Summer	5.263	0.0	18693.1	1440
2160 min Summer	3.861	0.0	37410.3	1800
2880 min Summer	3.093	0.0	38101.8	2172
4320 min Summer	2.260	0.0	34810.7	2988
5760 min Summer	1.812	0.0	48906.5	3816
7200 min Summer	1.527	0.0	51426.0	4680
8640 min Summer	1.327	0.0	53532.5	5528
10080 min Summer	1.180	0.0	55271.3	6352
15 min Winter	117.869	0.0	7699.8	26
30 min Winter	80.655	0.0	10139.7	41

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	4.452	1.452	131.5	16364.1	O K
120 min Winter	4.795	1.795	131.5	20346.4	O K
180 min Winter	4.985	1.985	131.5	22576.3	O K
240 min Winter	5.116	2.116	131.5	24113.7	O K
360 min Winter	5.301	2.301	131.5	26306.4	O K
480 min Winter	5.424	2.424	131.5	27775.7	O K
600 min Winter	5.512	2.512	132.4	28825.6	O K
720 min Winter	5.577	2.577	134.1	29596.9	O K
960 min Winter	5.660	2.660	136.2	30598.7	O K
1440 min Winter	5.725	2.725	137.8	31370.9	Flood Risk
2160 min Winter	5.701	2.701	137.2	31082.5	Flood Risk
2880 min Winter	5.638	2.638	135.6	30326.8	O K
4320 min Winter	5.489	2.489	131.8	28548.9	O K
5760 min Winter	5.321	2.321	131.5	26542.1	O K
7200 min Winter	5.145	2.145	131.5	24455.9	O K
8640 min Winter	4.965	1.965	131.5	22335.4	O K
10080 min Winter	4.773	1.773	131.5	20093.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	52.662	0.0	15562.3	70
120 min Winter	33.079	0.0	19079.9	128
180 min Winter	24.738	0.0	20535.2	186
240 min Winter	20.035	0.0	20860.7	246
360 min Winter	14.880	0.0	20603.5	362
480 min Winter	12.026	0.0	20371.2	478
600 min Winter	10.185	0.0	20196.3	596
720 min Winter	8.886	0.0	20060.2	712
960 min Winter	7.157	0.0	19862.1	940
1440 min Winter	5.263	0.0	19720.4	1388
2160 min Winter	3.861	0.0	40363.7	2016
2880 min Winter	3.093	0.0	39325.3	2284
4320 min Winter	2.260	0.0	36424.8	3204
5760 min Winter	1.812	0.0	54767.5	4152
7200 min Winter	1.527	0.0	57558.8	5048
8640 min Winter	1.327	0.0	59859.4	5968
10080 min Winter	1.180	0.0	61701.5	6864

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.314	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 37.800

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	12.600	4	8	12.600	8	12	12.600

Model Details

Storage is Online Cover Level (m) 6.000

Tank or Pond Structure

Invert Level (m) 3.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	11000.0	3.000	12143.7

Hydro-Brake Optimum® Outflow Control

Unit Reference	MD-SHE-0425-1323-2500-1323
Design Head (m)	2.500
Design Flow (l/s)	132.3
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Diameter (mm)	425
Invert Level (m)	3.000
Minimum Outlet Pipe Diameter (mm)	450
Suggested Manhole Diameter (mm)	Site Specific Design (Contact Hydro International)

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	2.500	132.1
Flush-Flo™	0.800	131.5
Kick-Flo®	1.717	110.1
Mean Flow over Head Range	-	112.4

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake Optimum® as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	11.4	1.200	128.2	3.000	144.4	7.000	218.5
0.200	41.2	1.400	124.6	3.500	155.7	7.500	226.0
0.300	80.8	1.600	117.5	4.000	166.1	8.000	233.2
0.400	117.6	1.800	112.6	4.500	176.0	8.500	240.3
0.500	126.7	2.000	118.5	5.000	185.3	9.000	247.1
0.600	129.7	2.200	124.2	5.500	194.1	9.500	253.7
0.800	131.5	2.400	129.5	6.000	202.6		
1.000	130.5	2.600	134.7	6.500	210.7		

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	3.747	0.747	102.6	6442.5	O K
30 min Summer	4.011	1.011	102.6	8765.1	O K
60 min Summer	4.300	1.300	102.6	11332.0	O K
120 min Summer	4.600	1.600	102.6	14023.1	O K
180 min Summer	4.767	1.767	102.6	15535.3	O K
240 min Summer	4.879	1.879	102.6	16557.5	O K
360 min Summer	5.036	2.036	102.6	17996.1	O K
480 min Summer	5.139	2.139	102.6	18937.0	O K
600 min Summer	5.210	2.210	102.6	19591.0	O K
720 min Summer	5.260	2.260	102.6	20054.6	O K
960 min Summer	5.320	2.320	102.6	20611.1	O K
1440 min Summer	5.349	2.349	102.6	20880.4	O K
2160 min Summer	5.315	2.315	102.6	20567.8	O K
2880 min Summer	5.265	2.265	102.6	20107.5	O K
4320 min Summer	5.147	2.147	102.6	19014.6	O K
5760 min Summer	5.028	2.028	102.6	17914.4	O K
7200 min Summer	4.906	1.906	102.6	16805.0	O K
8640 min Summer	4.783	1.783	102.6	15678.2	O K
10080 min Summer	4.643	1.643	102.6	14411.5	O K
15 min Winter	3.837	0.837	102.6	7225.6	O K
30 min Winter	4.132	1.132	102.6	9833.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	118.653	0.0	5519.3	26
30 min Summer	80.930	0.0	7384.6	41
60 min Summer	52.662	0.0	10945.5	70
120 min Summer	32.979	0.0	13568.2	130
180 min Summer	24.630	0.0	14918.0	190
240 min Summer	19.920	0.0	15671.8	250
360 min Summer	14.772	0.0	15994.6	368
480 min Summer	11.926	0.0	15777.6	488
600 min Summer	10.092	0.0	15560.3	606
720 min Summer	8.799	0.0	15366.2	726
960 min Summer	7.080	0.0	15037.0	964
1440 min Summer	5.200	0.0	14516.5	1440
2160 min Summer	3.809	0.0	28938.9	1800
2880 min Summer	3.050	0.0	29594.5	2168
4320 min Summer	2.225	0.0	27050.0	2988
5760 min Summer	1.781	0.0	37450.6	3816
7200 min Summer	1.499	0.0	39356.3	4680
8640 min Summer	1.303	0.0	40957.5	5528
10080 min Summer	1.157	0.0	42296.0	6344
15 min Winter	118.653	0.0	6176.7	26
30 min Winter	80.930	0.0	8045.9	41

Summary of Results for 100 year Return Period (+30%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	4.456	1.456	102.6	12723.7	O K
120 min Winter	4.793	1.793	102.6	15769.0	O K
180 min Winter	4.979	1.979	102.6	17468.1	O K
240 min Winter	5.105	2.105	102.6	18627.3	O K
360 min Winter	5.284	2.284	102.6	20279.3	O K
480 min Winter	5.403	2.403	102.6	21379.3	O K
600 min Winter	5.486	2.486	102.6	22159.8	O K
720 min Winter	5.547	2.547	103.5	22728.4	O K
960 min Winter	5.625	2.625	105.0	23455.4	O K
1440 min Winter	5.680	2.680	106.1	23977.4	O K
2160 min Winter	5.648	2.648	105.5	23673.1	O K
2880 min Winter	5.580	2.580	104.1	23031.9	O K
4320 min Winter	5.422	2.422	102.6	21555.8	O K
5760 min Winter	5.248	2.248	102.6	19941.3	O K
7200 min Winter	5.067	2.067	102.6	18274.6	O K
8640 min Winter	4.881	1.881	102.6	16570.7	O K
10080 min Winter	4.671	1.671	102.6	14663.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	52.662	0.0	12227.5	70
120 min Winter	32.979	0.0	14938.7	128
180 min Winter	24.630	0.0	16023.7	186
240 min Winter	19.920	0.0	16187.4	246
360 min Winter	14.772	0.0	15971.1	362
480 min Winter	11.926	0.0	15783.3	478
600 min Winter	10.092	0.0	15644.0	596
720 min Winter	8.799	0.0	15536.8	712
960 min Winter	7.080	0.0	15385.3	940
1440 min Winter	5.200	0.0	15297.2	1388
2160 min Winter	3.809	0.0	31304.4	2016
2880 min Winter	3.050	0.0	30528.3	2280
4320 min Winter	2.225	0.0	28240.0	3204
5760 min Winter	1.781	0.0	41940.1	4152
7200 min Winter	1.499	0.0	44055.8	5048
8640 min Winter	1.303	0.0	45816.4	5968
10080 min Winter	1.157	0.0	47287.0	6864

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.320	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+30

Time Area Diagram

Total Area (ha) 29.400

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	9.800	4	8	9.800	8	12	9.800

Model Details

Storage is Online Cover Level (m) 6.000

Tank or Pond Structure

Invert Level (m) 3.000

Depth (m)	Area (m²)	Depth (m)	Area (m²)
0.000	8500.0	3.000	9508.7

Hydro-Brake Optimum® Outflow Control

Unit Reference	MD-SHE-0380-1029-2500-1029
Design Head (m)	2.500
Design Flow (l/s)	102.9
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Diameter (mm)	380
Invert Level (m)	3.000
Minimum Outlet Pipe Diameter (mm)	450
Suggested Manhole Diameter (mm)	Site Specific Design (Contact Hydro International)

Control Points	Head (m)	Flow (l/s)
Design Point (Calculated)	2.500	102.6
Flush-Flo™	0.769	102.6
Kick-Flo®	1.680	84.6
Mean Flow over Head Range	-	88.0

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake Optimum® as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)	Depth (m)	Flow (l/s)
0.100	10.7	1.200	99.4	3.000	112.1	7.000	169.4
0.200	37.8	1.400	96.0	3.500	120.8	7.500	175.2
0.300	71.9	1.600	89.2	4.000	128.9	8.000	180.8
0.400	95.7	1.800	87.4	4.500	136.5	8.500	186.3
0.500	99.5	2.000	92.0	5.000	143.7	9.000	191.6
0.600	101.6	2.200	96.4	5.500	150.6	9.500	196.7
0.800	102.6	2.400	100.5	6.000	157.1		
1.000	101.5	2.600	104.5	6.500	163.4		

Summary of Results for 100 year Return Period (+20%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
15 min Summer	3.769	0.769	141.1	8185.6	O K
30 min Summer	4.041	1.041	141.2	11133.1	O K
60 min Summer	4.339	1.339	141.2	14387.3	O K
120 min Summer	4.647	1.647	141.2	17787.8	O K
180 min Summer	4.817	1.817	141.2	19689.1	O K
240 min Summer	4.932	1.932	141.2	20966.5	O K
360 min Summer	5.090	2.090	141.2	22749.0	O K
480 min Summer	5.192	2.192	141.2	23896.5	O K
600 min Summer	5.261	2.261	141.2	24677.8	O K
720 min Summer	5.308	2.308	141.2	25217.0	O K
960 min Summer	5.362	2.362	141.2	25825.1	O K
1440 min Summer	5.376	2.376	141.2	25985.6	O K
2160 min Summer	5.339	2.339	141.2	25566.0	O K
2880 min Summer	5.284	2.284	141.2	24939.0	O K
4320 min Summer	5.152	2.152	141.2	23442.9	O K
5760 min Summer	5.017	2.017	141.2	21925.1	O K
7200 min Summer	4.880	1.880	141.2	20393.1	O K
8640 min Summer	4.733	1.733	141.2	18748.6	O K
10080 min Summer	4.573	1.573	141.2	16968.6	O K
15 min Winter	3.861	0.861	141.2	9180.9	O K
30 min Winter	4.166	1.166	141.2	12491.4	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
15 min Summer	109.526	0.0	6986.9	26
30 min Summer	74.704	0.0	9470.3	41
60 min Summer	48.611	0.0	13905.9	70
120 min Summer	30.442	0.0	17318.5	130
180 min Summer	22.736	0.0	19186.8	190
240 min Summer	18.388	0.0	20399.6	250
360 min Summer	13.636	0.0	21743.7	368
480 min Summer	11.009	0.0	21890.1	486
600 min Summer	9.315	0.0	21649.6	606
720 min Summer	8.122	0.0	21390.9	724
960 min Summer	6.535	0.0	20900.9	962
1440 min Summer	4.800	0.0	20035.3	1380
2160 min Summer	3.516	0.0	37183.5	1720
2880 min Summer	2.815	0.0	38978.8	2108
4320 min Summer	2.053	0.0	37080.1	2944
5760 min Summer	1.644	0.0	47621.8	3760
7200 min Summer	1.384	0.0	50057.3	4616
8640 min Summer	1.202	0.0	52117.1	5448
10080 min Summer	1.068	0.0	53786.5	6160
15 min Winter	109.526	0.0	7844.8	26
30 min Winter	74.704	0.0	10435.7	41

Summary of Results for 100 year Return Period (+20%)

Storm Event	Max Level (m)	Max Depth (m)	Max Control (l/s)	Max Volume (m³)	Status
60 min Winter	4.499	1.499	141.2	16155.3	O K
120 min Winter	4.846	1.846	141.2	20005.5	O K
180 min Winter	5.036	2.036	141.2	22142.4	O K
240 min Winter	5.165	2.165	141.2	23591.0	O K
360 min Winter	5.345	2.345	141.2	25639.2	O K
480 min Winter	5.464	2.464	141.2	26985.0	O K
600 min Winter	5.546	2.546	142.4	27923.1	O K
720 min Winter	5.604	2.604	144.0	28592.8	O K
960 min Winter	5.675	2.675	145.9	29411.6	O K
1440 min Winter	5.716	2.716	147.0	29879.5	Flood Risk
2160 min Winter	5.662	2.662	145.6	29260.0	O K
2880 min Winter	5.593	2.593	143.7	28462.7	O K
4320 min Winter	5.409	2.409	141.2	26367.2	O K
5760 min Winter	5.211	2.211	141.2	24120.3	O K
7200 min Winter	5.006	2.006	141.2	21806.6	O K
8640 min Winter	4.788	1.788	141.2	19359.6	O K
10080 min Winter	4.528	1.528	141.2	16469.3	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Discharge Volume (m³)	Time-Peak (mins)
60 min Winter	48.611	0.0	15559.9	70
120 min Winter	30.442	0.0	19206.3	128
180 min Winter	22.736	0.0	21037.9	186
240 min Winter	18.388	0.0	21986.2	244
360 min Winter	13.636	0.0	22229.3	362
480 min Winter	11.009	0.0	22015.6	478
600 min Winter	9.315	0.0	21813.1	594
720 min Winter	8.122	0.0	21636.7	710
960 min Winter	6.535	0.0	21339.2	938
1440 min Winter	4.800	0.0	20917.4	1380
2160 min Winter	3.516	0.0	41144.4	1964
2880 min Winter	2.815	0.0	41959.1	2228
4320 min Winter	2.053	0.0	38690.2	3160
5760 min Winter	1.644	0.0	53338.5	4096
7200 min Winter	1.384	0.0	56053.7	4976
8640 min Winter	1.202	0.0	58347.0	5888
10080 min Winter	1.068	0.0	60309.8	6648

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.000	Shortest Storm (mins)	15
Ratio R	0.320	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+20

Time Area Diagram

Total Area (ha) 40.500

Time From:	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**	**Time From:**	**(mins) To:**	**Area (ha)**
0	4	13.500	4	8	13.500	8	12	13.500

Model Details

Storage is Online Cover Level (m) 6.000

Tank or Pond Structure

Invert Level (m) 3.000

Depth (m)	**Area (m²)**	**Depth (m)**	**Area (m²)**
0.000	10500.0	3.000	11618.0

Hydro-Brake Optimum® Outflow Control

Unit Reference	MD-SHE-0437-1418-2500-1418
Design Head (m)	2.500
Design Flow (l/s)	141.8
Flush-Flo™	Calculated
Objective	Minimise upstream storage
Diameter (mm)	437
Invert Level (m)	3.000
Minimum Outlet Pipe Diameter (mm)	450
Suggested Manhole Diameter (mm)	Site Specific Design (Contact Hydro International)

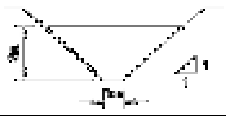
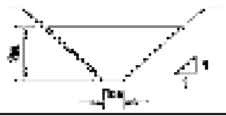
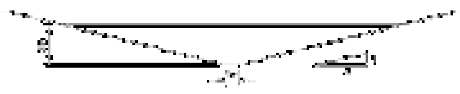
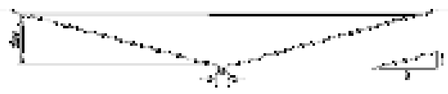
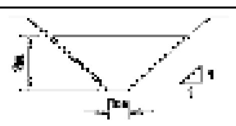
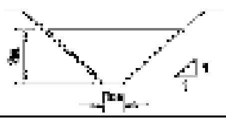
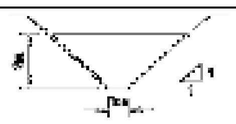
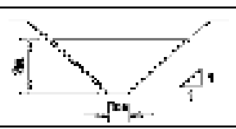
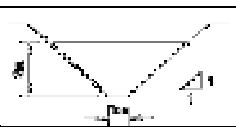
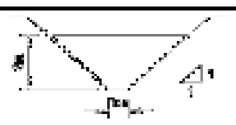
Control Points	**Head (m)**	**Flow (l/s)**
Design Point (Calculated)	2.500	141.2
Flush-Flo™	0.809	141.2
Kick-Flo®	1.737	118.3
Mean Flow over Head Range	-	120.2

The hydrological calculations have been based on the Head/Discharge relationship for the Hydro-Brake Optimum® as specified. Should another type of control device other than a Hydro-Brake Optimum® be utilised then these storage routing calculations will be invalidated

Depth (m)	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**	**Depth (m)**	**Flow (l/s)**
0.100	11.6	1.200	137.7	3.000	154.3	7.000	233.5
0.200	42.1	1.400	134.1	3.500	166.4	7.500	241.5
0.300	83.2	1.600	127.1	4.000	177.6	8.000	249.3
0.400	122.8	1.800	120.3	4.500	188.1	8.500	256.8
0.500	135.7	2.000	126.7	5.000	198.0	9.000	264.1
0.600	139.0	2.200	132.7	5.500	207.5	9.500	271.2
0.800	141.1	2.400	138.4	6.000	216.5		
1.000	140.1	2.600	143.9	6.500	225.2		

Appendix E – Proposed Surface Water Reen Schedule

Glan Llyn Surface Water Drainage System Design Parameters

Reen Name	Status	Survey Required	Profile	Capacity m3 upto 6.1AOD
Reen 1	Partly Built / Designed		 Length: 800m, cross sectional area = 12m3	9,600
Reen 2	Mostly Built / Designed	Yes	 Length:800m, cross sectional area = 12m3	9,600
Phase 1 Pond	Built	Yes	Pond plan Area 3330m3 to be confirmed with survey Depth 3.2m	10,560
Julian's Reen	Designed		 Length:820m, cross sectional area =48m3	39,360
Ellen's Reen	Designed		 Length: 1180m, cross sectional area = 48m3	56,640
East Lake Reen	Conceptual		 Length: 890m, cross sectional area = 48m3	42,720
Kings Wall Reen	Conceptual		 Length: 1020m, cross sectional area = 48m3	48,960
NEWD Reach 1	Designed		 Length: 170m, cross sectional area = 12m3	2,040
NEWD Reach 2	Designed		 Length: 280m, cross sectional area = 12m3	3,360
NEWD Reach 3	Conceptual		 Length: 180m, cross sectional area = 12m3	2,160
NEWD Reach 4	Conceptual		 Length: 500m, cross sectional area = 12m3	6,000
NEWD Reach 5	Conceptual		 Length: 360m, cross sectional area = 12m3	4,320
Central Lake	Conceptual		Plan area 42,000 m2 Flooding Depth 1.75m	73,500
East Lake	Conceptual		Pond Plan area 23,000m3 Flooding Depth 1.75m	40,250
West Pond 1	Partly Built / Designed		Park area pond	8,000
West Pond 2	Partly Built / Designed		Park area pond	9,500
Celtic Business Park	Designed		 Length: 2650m, cross sectional area = 12m3	32,000
TOTAL				**398,570**

Appendix F – Technical Note: Hydraulic Modelling – Impact assessment of pumped surface water discharge into the Monks Ditch (Atkins Plc, May 2016)

Technical note

Project:	Glan Llyn	**To:**	Andrew Catmur, Andrea Nelmes - Rodgers Leask
Subject:	Hydraulic modelling – impact assessment of pumped surface water discharge into the Monks Ditch	**From:**	Mike Vaughan Yiwen Zhao
Date:	17 May 2016	**cc:**	

1. Introduction

The proposed development at Glan Llyn occupies a brownfield site on the former Tata steelworks at Llanwern. The proposed (revised) surface water drainage strategy for the site relies on a pumped discharge to the Monks Ditch, a Main River under the control of Natural Resources Wales.

It is intended that the surface water runoff from the development is treated and attenuated / stored on site, in a series of reens, ponds and lakes. The number and size of these features, means that the site affords a large volume of storage. However, an eventual discharge to the Monks Ditch will be required to maintain the storage and evacuated excess water. Given the ground levels in the vicinity, the discharge is to be pumped into the Monks Ditch: the pumped discharges would be up to a rate of 750l/s, with 500l/s from the west (residential) site and 250l/s from the east (commercial) site.

This study assesses the impact of this discharge on Monks Ditch, the Caldicot Levels. However, this discharge will be 'new' water, with previous runoff from the operational steelworks site having been intercepted, collected and pumped to the Severn Estuary via the steelwork's own pumping system.

This note describes the approach and findings from a study to evaluate the impact of the Glan Llyn pumped surface water on flood risk along the Monks Ditch.

1.1. Approach

Given the known interaction of waters across the wider Caldicot Levels, hydraulic modelling of the channel system, including Monks Ditch, primary reens and wider field drainage network, was proposed to demonstrate that the pumped surface water system was capable of discharging without causing detriment to the existing flood risk and land drainage situation.

Use has been made of an existing 1D/2D model of the Caldicot Levels. The model consists of a 2D domain covering the low-lying areas of the Caldicot levels and simplified 1D elements to simulate the main hydraulic elements, (main river reens). Hydrological inputs are used to represent flows from catchments to the north with direct rainfall techniques being used to simulate storms over the Caldicot Levels.

A 1D only model was also developed to help assimilate the hydraulic behaviour, undertaken using FloodModeller.

2. Hydrology

Hydrological analysis was undertaken to provide rainfall hyetographs for the hydraulic model, as well as the fluvial inflows to represent flow contribution from upper catchments that lie outside of the domains.

Rainfall return periods of 1 in 100yr plus climate change and 1 in 1000yr were assessed in accordance with TAN15. A 1 in 5yr storm was tested to provide a pseudo-validation of the model under a magnitude of event likely to have been observed in the recent past.

A range of storm durations from 1 hour to 24 hours was considered to establish the worst case scenario for rainfall and tide lock through hydraulic modelling. The winter storm of a 12hr critical duration was established for the Caldicot Levels from the M4CaN project, and considered to be appropriate for this study.

The Monks Ditch itself, at the northern boundary of the steelworks site, has a catchment area of approximately 20km^2 with an annual average rainfall of 990mm. The catchment draining from the north was found to generate a median flow of 5.4m^3/s (winter storm) with a corresponding site rainfall of 32.17mm, with the 100yr event causing some 16.1m^3/s from the upstream catchment and some 86.04mm rainfall on the site. The 1 in 1000 year estimate was 27.2m^3/s with 147.07m of rainfall across the site.

Direct rainfall was applied to the whole 2D model domain except the extent of the Llanwern steel works site as the area is served by a dedicated pumping station which currently discharges outside of the system.

MHWS tidal boundary at each tidal outfall were also included in this model. The phasing of the tide cycle and the storm profile was determined by a sensitivity analysis for the M4CaN project, and considered to be appropriate for this study as well.

3. Hydraulic Modelling

The hydraulic modelling assessment provides an understanding of flood risk and flood mechanisms. An existing hydraulic model of the Caldicot Levels was tested for this study. This model is a combined 1D-2D hydrodynamic model of the Caldicot Levels of approximately 55km^2 in total area, developed using ESTRY (1D) and TUFLOW (2D) software packages.

The set-up of the existing model is not ideal for the purpose of evaluating the impacts of the proposed Glan Llyn pumped surface water on flood risk along the Monks Ditch. The level of detail contained for the Monks Ditch system originates from a combination of LiDAR and data from Natural Resources Wales: no specific topographic survey has been taken of the Monks Ditch for this study. However the model has been used as a high level assessment to provide an indication whether or not the Glan Llyn drainage strategy would work.

A 1D only FloodModeller representation was developed for Monks Brook, taking the LiDAR based data of the Monks Ditch and linking it with spill units to two reservoir units to represent the Levels either side of the watercourse. These reservoirs were described by level area data taken from LiDAR. The same outfall structures, rainfall and hydrological inflows were applied to this mode.

3.1. Baseline

The existing model, a 1D-2D model of 5m grid resolution, was simulated past the peak of a flood event for the purpose of the project. To understand the existing fluvial system in response to a storm event, especially for the Monks Ditch and surrounding area, simulation up to 72 hours (Existing_001) was tested. Rainfall on the site and the Steel Works site are excluded for the baseline, as it does not contribute to runoff on the Caldicot Levels. It should be noted that the model contains little survey data and should not be used to predict absolute values of water level.

To further understand the impacts of the proposed pumped discharge in everyday use, the baseline model was also run with baseflows and tidal boundaries only, to represent the existing dry weather condition (Existing_Dry_001).

To investigate the longer term response duration for the Monks Ditch, a simpler 2D model of 50m grid resolution with 1D outfalls, was developed. This was resimulated up to 2400 hours (Existing_001_50m).

A simple calculation of total inflows, total outfall capacity and volume of free flows during low tides was also assessed to evaluate the outputs from the simplified 2D model.

3.2. With-project

The ‘with project’ model contains the proposed pumping stations for the Glan Llyn site. These provide two discharges into the Monks Ditch: from the west serving the residential development site discharging up to 500l/s; and from the East serving the commercial site, outfalling 250l/s. Hence a combined discharge of 750l/s was included in the with-project model.

The two pumps were included to provide a discharge into the Monks Ditch. They do not remove water from a representation of the development site, but instead form a dummy boundary to the system. Pumped discharges were represented as 1D inflows directly linked to the 1D network at two locations on the Monks Ditch (336672.94 187237.87; 336777.72, 186933.35). As with the baseline model, no rainfall is applied to the Glan Lyn (and rest of the steelworks) site.

The models have been used to gain an appreciation of the fluvial hydraulics of the Monks Ditch and how the proposed pumped drainage system could impact on the flood risk situation in the locality.

3.2.1. Constant pumping scheme

To test the impact of the pumping and evaluate the need for any restriction on pumping, the pumps were first simulated with a constant discharge. Hence the pumps remains on at all times and issued the 750l/s constant discharge into the Monks Ditch, regardless of conditions (Proposed_001).

The Proposed_001 model was simulated for the 5yr, 100cc and 1000yr events. Simulation of the dry weather scenario was also tested for a 24 hour simulation (Proposed_Dry_001).

3.2.2. Regulated pumping scheme

A second set of simulations were then made to demonstrate that if the pumps were only operated when certain conditions permit, that any impact on flooding could be negated. This was undertaken by applying operating rules to pumps, which turned the pumps off once water levels in the Monks Ditch rose to within 300mm of bankfull level (lowest bank level *5.119mAOD*) at 4.819mAOD. At this location the watercourse has some 400m length of low bank, promoting flooding within the reens and levels in that locality.

Two modelling approaches (Proposed_002a; Proposed_002b) were tested within the ESTRY TUFLOW model given the indirect means in which the software represents this.

3.3. Simulations

Simulations were undertaken for the 1 in 100 year plus Climate Change (+cc) and for the 1 in 1000 year 12 hour duration storms (winter profile) in both the baseline and ‘with project’ scenarios. The 12 hours event and winter profile storms were found to be, on average, critical for the Caldicot Levels.

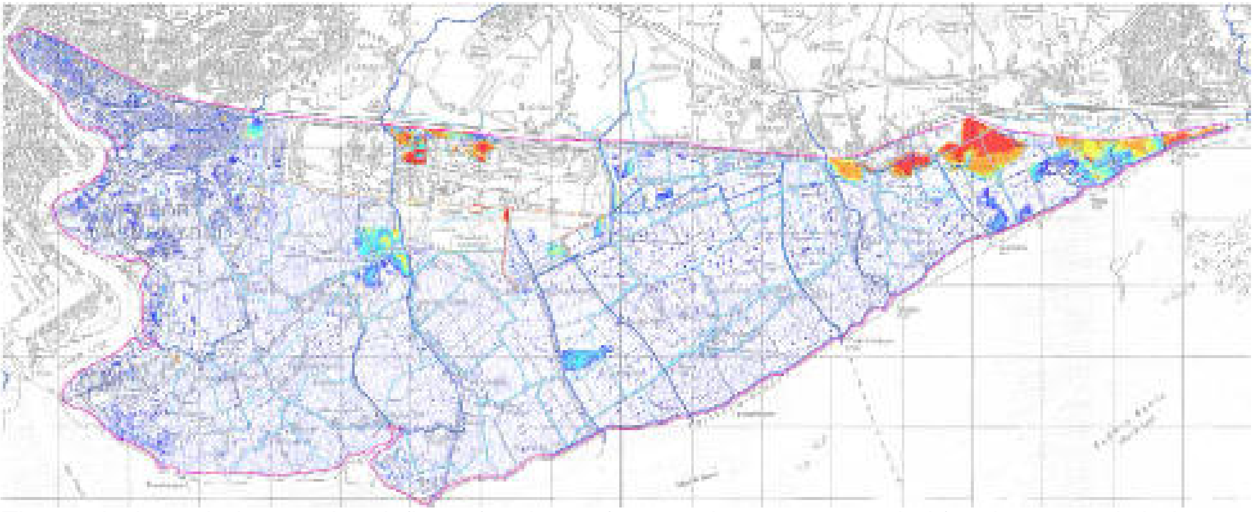
Model simulations were made by routing rainfall and flows against the mean high water spring (MHWS) tide. The value of the MHWS tide was calculated at each outfall location by interpolating between the published values at Cardiff, Newport and Chepstow. For the climate change simulations, 1.03m was added to the value of the MHWS tide to represent potential sea level rise over a 100 year scheme life.

3.4. Validation

The 1 in 5 year storms was tested to provide a pseudo-validation of the model for an event that likely to have been observed in the recent past.

Simulations in the area of the Levels do indicate a pattern of flooding characterised by relatively extensive flooding in the fields without any major disruption of the local road network. This tends to support the anecdotal reports that there has been no property flooding over the last 30 years.

Figure 1 – baseline flooding expected from the 1 in 5 year event



The model is not being used to define a flood level for a particular return period flood event. It is being used to determine the impact of the proposed Glan Llyn surface water drainage on the local flood risk and thus it is the change in flood level between pre and post project simulations that is important.

It should be noted that we are simply comparing the situation pre and post development of Glan Llyn project and that any inaccuracies in the modelling are contained in both the pre and post project models.

4. Results

The hydraulics of the Caldicot Levels can be considered to be low energy systems where runoff from the catchments from the north readily disperses into the network of reens, field ditches and low lying fields and wetland areas.

Outfalls from the Levels onto the coastal foreshore are tide locked for periods of between 3 and 8 hours on normal tides. Surface water runoff is held within the reens, ditches and low lying land areas before discharging onto the foreshore during intertidal periods.

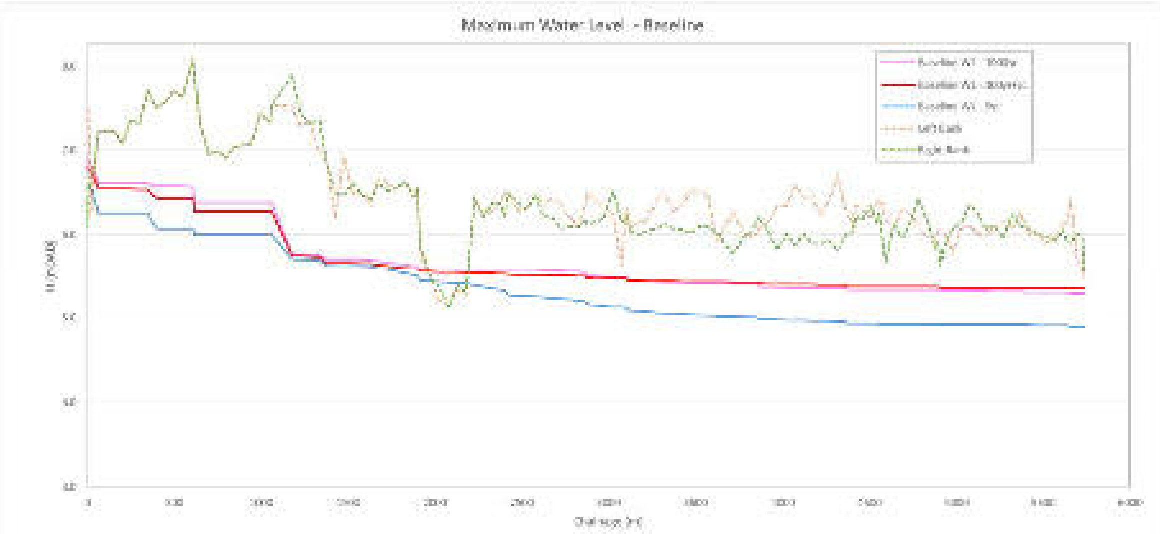
4.1. Baseline

The predicted flood extents and the depths of flooding for the baseline conditions during a 1 in 100 year with climate change and a 1 in 1000 year event indicate a relatively constant flood level across the levels for both baseline and with-project conditions. The varying flood depths reflect slight undulations in ground level.

Spatial variation of the flood response was found across the Caldicot Levels from the test. Flood levels of the Monks Ditch were predicted to slightly drop, after 68 hours for the 100 year climate change event and 55 hours for the 1 in 5 year and 1 in 1000 year events, although flood levels of several watercourses receded significantly (approximately 20% of the peaks) after 20 hours for the three events. This indicates that the Monks Ditch receives water from the surrounding land during the recession of a flood.

Figure 2. shows the maximum water levels in the Monks Ditch, predicted from the 72 hour simulations. Water levels were predicted to be within the bank except for two low spots: 1) between the two proposed pumped discharge locations; 2) approximately 900m downstream of the site.

Figure 2. Maximum Water Levels in the Monks Ditch



4.2. With project

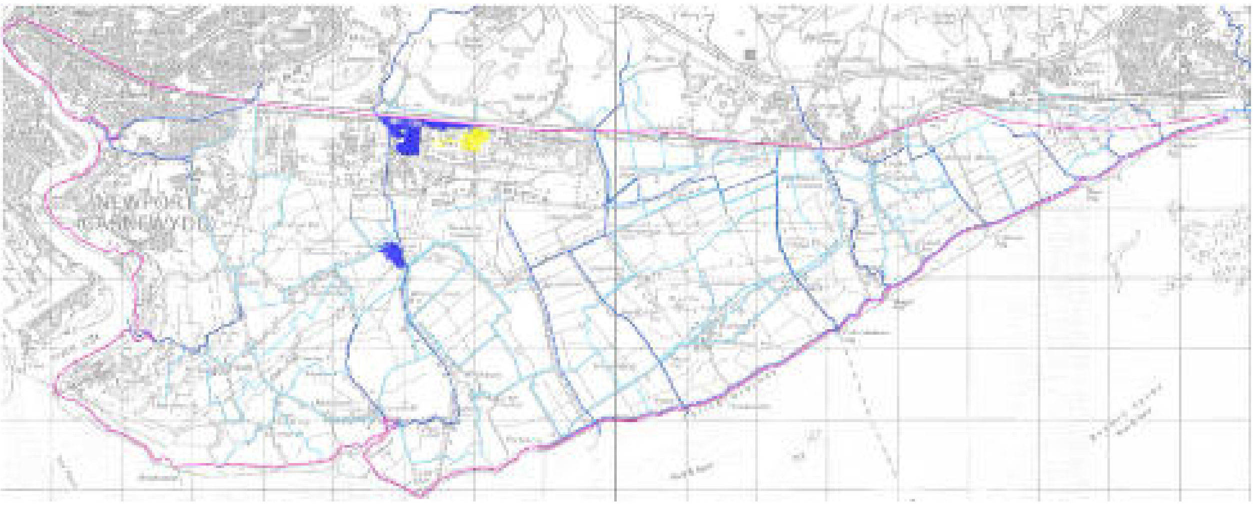
The impact of the Glan Llyn pumped discharge has been determined by plotting a series of difference grids to compare the pre and post project simulations. The grids show the level difference grid derived from the pre and post project simulations.

4.2.1. Constant pumping scheme

For the most part the modelling suggests no change in flood risk. However, there are some small areas of increased flood depths, as shown in Figure 3 . In the first instance, the constant pumping during a dry weather flow event was predicted to increase water levels around Moorbarn Farm and the electricity sub station, by up to 100mm.

At the 1 in 5 year event, the discharge appears to force more water along the northern boundary of the steelworks site, presumably a result of slight backing up in the shallow gradient channel and passing over a low spot in the eastern bank. This manifests itself as a change in a low spot, and results in up to 400mm additional flooding in one location (covering 9.3ha – shown in yellow below). More typically changes of 100mm were predicted.

Figure 3 – Change in predicted flood depths, 1 in 5 year event, constant pumping regime



In the 1 in 100 year event with climate change, this impact increases in area, although the difference in flood level is back to 100mm. The largest spread of increase is seen in the 1 in 1000 year event, although the change in water level is lower at approximately 100mm.

No impact was predicted at the tidal outfalls for any event tested.

In all conditions, the model indicates the Monks Ditch to remain in channel except for localised low spots at Moorbarn Farm and the electricity sub station, and the eastern bank at the northern boundary of the steelworks.

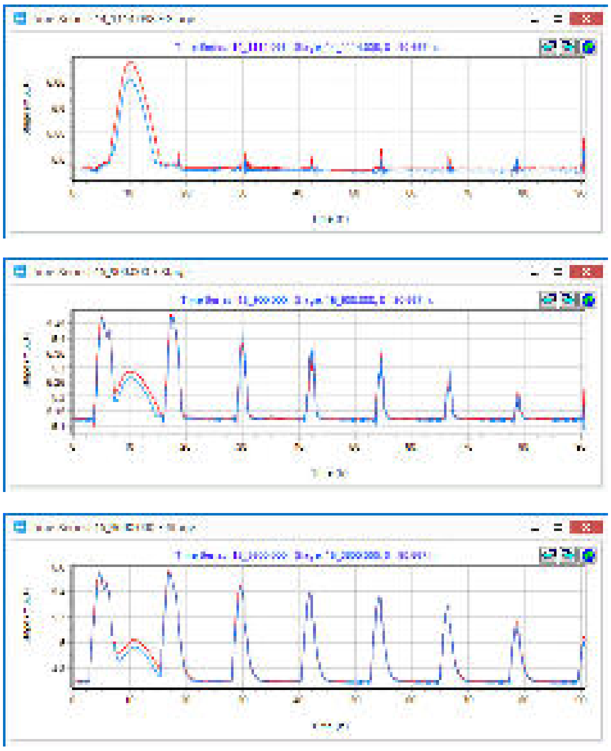


Figure 4 – 1 in 5yr stage hydrographs (site, low spot, coastline)

Output from the 1D only model indicates the impact of the constant rate pumping during the passage of the flood. The charts below show the 1 in 5 year event under baseline and with-pumping conditions. These clearly demonstrate that the additional flow has a relatively large impact on flood stage during the event, and that outside the main flood hydrograph that the impact on water level is limited. For example, within the Glan Llyn site, the pumped discharge adds some 40mm to the peak level, whilst outside the main flood this drops to less than 5mm. The impact also diminishes downstream, with the tidal signal (tidelock) becoming more prominent and the impact of the pumping even less.

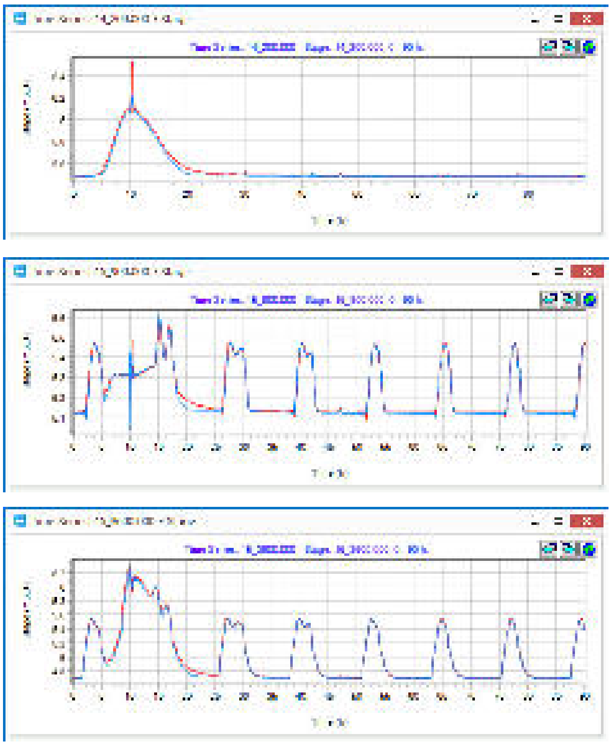


Figure 5 – 1 in 100yr CC stage hydrographs (site, low spot, coastline)

The results from the 1 in 100 year with climate change model indicate a lesser impact of the additional water during the flood, being masked by the much higher water levels in general. The charts show the 1 in 100 year event with climate change under baseline and with-pumping conditions. These demonstrate that the additional flow again has a minor impact outside the main flood hydrograph. For example, within the Glan Llyn site, the pumped discharge adds approximately 40mm to the peak level, whilst outside the main flood this drops to less than 5mm. The impact also diminishes downstream, with the tidal signal (tidelock) becoming more prominent and the impact of the pumping even less.

4.2.2. Regulated pumping scheme

The regulated scheme was predicted to have little impact on the existing flood risk along the Monks Ditch and surrounding area, although similar (but less) impacts (less than 300mm) were predicted on the steelworks site, as shown in Figure 6 (in cyan). The difference grids do show a reduction in the extent of any increase in water level – indicating that the regulated pumping mitigates the impact of a constant discharge.

Figure 6 - Change in predicted flood depths, 1 in 5 year event, regulated pumping regime

It was noted that the winter penning levels close to the Monks Ditch are 4.75mAOD and close to the tested trigger level of 4.819mAOD. As such, the pumps were predicted to be switched on for less than 2 hours during the onset of the design storms which could be adjusted with further, more detailed, assessment.

5. Discussion

In summary, the work indicates that constant pumping during any condition could cause detriment to flood risk on the Caldicot Levels. This was predicted to be as much as 400mm in places. The magnitude of difference is explained by the 2D terrain, where areas locally surrounded by higher ground receive a certain amount of water under the baseline conditions. With additional water in the system, water levels increase slightly, leading to a more obvious flow of water into that low spot. As such, the 400mm is not indicative of water levels across the wider area, but merely a localised effect.

The regulated pumping regime was shown to limit this by proving less water into the system when It can least accept it.

Additional checks and assessments were undertaken to prove the modelling and demonstrate the ability of the pumped drainage system to work.

5.1. Conveyance along Monks Ditch

The canalised section of the Monks Ditch through the existing Llanwern site has a conveyance capacity of approximately 22m^3/s, estimated to be the 1 in 100 year flow with 30% allowance for climate change, based on a free discharge. With minor improvements to a localised section of the right bank, the Monks Ditch could accommodate an additional 750l/s pumped from the proposed Glan Llyn development.

However it remains necessary to determine how and when the proposed development can pump into the Monks Ditch during a tide locked scenario without increasing flood risk within the Caldicot Levels.

5.2. Outfalls

Checks were made on the capacity of the modelled tidal outfalls in relation to the dry weather baseflows and proposed site discharge rates.

The table below shows the data of the modelled outfalls and a calculation of the total outfall capacity based on free flow condition.

Asset ID	Location	NGR	Model ID	Shape	Length (m)	US Invert (mAOD)	DS Invert (mAOD)	Width or Dia (m)	Height (m)	Number	Q (full)
212985	LISWERRY PILL SEA DOOR	ST3296487034	LISWERRY	Circular**	119.7	3.7	3.6	1**	n/a	2	1.20
212988	SPYTTY REEN SEA DOOR	ST3283786939	18_1150.000	Circular**	49.98	2.368	2.99	1**	n/a	2	1.31*
215970	WEST PILL	ST4661686330	ST46568640	Circular	162.7	4.87	3.81	0.6	n/a	1	0.43
215971	COLLISTER PILL	ST4525785603	ST45238568	Circular	250.2	4.2	3.25	1.22	n/a	1	2.18
215972	MAGOR PILL	ST4384084870	ST43848487	Circular	36.11	2.936	2.86	1.15	n/a	1	1.38
215973	COLDHARBOUR PILL	ST4312784228	ST43118425	Circular	57.35	3.31	3.31	1.22	n/a	1	1.12*
216325	WINDMILL REEN	ST4098583149	ST40978315	Rectangular	45.02	4.83	2.35	1.53	1.375	2	33.45
216326	ELVER PILL	ST3972482945	ST39718294	Circular	45.57	4.7	3.31	1.33	n/a	1	7.76
216731	MONKS DITCH OUTFALL - GOLDCLIFF PILL	ST3689182968	ST36898297	Rectangular	17.29	3.958	3.37	2	1	2	23.64
216732	FISHERS GOUT OUTFALL - GOLDCLIFF PILL	ST3671283019	ST36708302	Circular	10	3.7	2.87	1.22	n/a	2	20.35
310174	JULIANS REEN SEA DOOR	ST3345084119	JULIANS	Circular	72.66	3.118	2.48	1.22	n/a	1	3.31
Total Q (full)											***96.13***

* Flow based on slope of 0.001 assumed

** Modelled data assumed as data missing from NWR outfall data and sea door reports

The estimate provides for a total discharge capacity of 96m^3/s from the Caldicot Levels under full bore but free discharge conditions.

The lowest outfall level is at 2.93m AOD, being at Magor Pill. Hence, on a mean high water spring tide (MHWS), the outfall will be operating freely for some 6.5 hours. With a capacity of 1.38m^3/s on a full bore, this outfall could release some 32,292m^3 water during low tide.

The highest outfall level is at 4.87m AOD, being at West Pill. Hence, on a MHWS tide, the outfall will be operating freely for some 8.7 hours. With a capacity of 0.43m^3/s on a full bore, this outfall could release some 13,467m^3 water during low tide.

The average outfall invert is 3.9m AOD with a free discharge period against a MHWS tide of 4.8hours. With this data, and the combined discharge rate of 96m^3/s, the total contained runoff volume of 161,040m^3 could be discharged to sea in 28 minutes – assuming no baseflow or other fluvial component.

An assessment was made to the volume of water entering the Levels system from both the rainfall and catchment inflows from the north. Given the assumption of no infiltration losses, no travel time etc, the total input volume for baseflow, 5yr and 100cc year events were 98M m^3, 99M m^3, 117M m^3 respectively. Consideration was then made of the period that each outfall would operate under free discharge, and the volume of water that could be passed on each tide. It was determined that within 52hours all three events could have exited the system. The reality is a longer duration as the flows out will be driven by the varying head ups of the outfalls. However, the order of magnitude is important here.

Consideration of the total baseflow entering the system from the nine inflows reveals a combined input to the system of 7.1m^3/s. Again, the capacity of the outfalls can readily accommodate this flow and the additional 750l/s proposed.

This demonstrates that the existing system is more than capable of discharging the added inflows to sea during low flow periods.
With the conveyance capacity of the Monk's Ditch being some 30m^3/s at the site, and 1 in 100 year peak flow, with climate change allowance, of 21m^3/s, it can readily accommodate the pumped 750l/s during low tide.

ATKINS

5.3. Summary

The assessment has indicated that the constant addition of 750l/s into the Monks Ditch could locally increase flooding in the vicinity by up to 400mm during the 1 in 5 year event although the impact is limited to less than 50mm in the watercourse itself. To compensate for this, the scheme should consider regulating the pumped discharge to times when the Levels system can accept it. Tests undertaken for a regulated discharge were based on a single trigger assumption, which demonstrated that the impact could be reduced. This will require hydrometric data for the Monks Ditch: a telemetry gauge to 'observe' water levels and report back to control the pumps. Furthermore, the 1D only model shows that by stopping pumping during a flood, that the impact on water levels could be as little as 5mm in Monks Ditch. The duration of this 'closed' period is indicated as 15 hours on the 12 hour duration storm, although this will need to be tested further and evaluated for range of duration events.

Hand-calculations on the system indicate that it is readily capable of accepting more water and discharging to sea.

It is clear that the addition of new water into the Monk's Ditch increases the volume which the watercourse has to convey, and that this could force a small amount of water along the reens to the north of the steelworks site. As such, it is recommended that the outfall point for the two pumped discharges is moved to the most southerly location on the Monks Ditch within the development site. At this location, the drop in channel bed, and water level, will prevent any detrimental effects from being propagated around the north of the site. The modelling implies that this could help maintain baseline conditions, with prevention of the increases along the northern steelworks boundary, alongside the neutral impact downstream along Monks Ditch.

In practice, the pumping regime will be installed and monitored over a period of years. The impact of the trigger level will be reviewed constantly and adjusted where found necessary. In this regard, the proposed drainage system will be fine-tuned against the local flood risk issues. This will be undertaken in conjunction with Natural Resources Wales.

6. Conclusion

In conclusion the results of the assessment indicate that the surface water drainage strategy for the Glan Llyn development can be effective in managing the flood risk on the development without causing detriment to those on the Caldicot Levels.

Minor and isolated increases in flood depth can be mitigated by regulating the discharge of water into the Monks Ditch, and limiting them to periods when water levels in the channel remain in bank – and hence not contributing to flooding on the Levels. This could be combined with telemetry on the tidal outfalls to confirm when the Levels system is able to discharge.

It should be noted that the testing has only considered a discharge of 750l/s, or 0l/s. In practice, the pumps could be controlled with variable discharge up to the maximum. Furthermore, the assessment goes someway to indicating that a higher discharge rate may be achievable, so evacuating the Glan Llyn system quicker.

The storage provided by the site affords acceptable consequences with respect to flood risk. The impact of a controlled pumped discharge into Monks Ditch also provides acceptable consequences, which can be managed over time.

Further work will be required to develop the concept and refine the trigger location and level. It is also recommended that a bespoke hydraulic model is developed for the Monks Ditch. This model should be developed to specifically address the need to test a controlled discharge into the system, removing the complexity of the Levels where possible and so enabling a more robust and usable tool for Glan Llyn. However, in principle, the scheme to control discharges from Glan Llyn and minimise any detriment in flood risk works.

Appendix G – WinDes Calculations @ 0l/s Discharge

Summary of Results for 100 year Return Period (+30%)

Critical storm not identified, please run longer storm durations.

Storm Event	Max Level (m)	Max Depth (m)	Max Volume (m³)	Status
15 min Summer	4.168	0.168	41918.4	O K
30 min Summer	4.202	0.202	50433.4	O K
60 min Summer	4.243	0.243	60678.1	O K
120 min Summer	4.292	0.292	73003.9	O K
180 min Summer	4.325	0.325	81344.1	O K
240 min Summer	4.351	0.351	87833.3	O K
360 min Summer	4.391	0.391	97867.8	O K
480 min Summer	4.423	0.423	105675.2	O K
600 min Summer	4.449	0.449	112157.5	O K
720 min Summer	4.471	0.471	117748.0	O K
15 min Winter	4.188	0.188	46948.6	O K
30 min Winter	4.226	0.226	56485.5	O K
60 min Winter	4.272	0.272	67959.5	O K
120 min Winter	4.327	0.327	81764.3	O K
180 min Winter	4.364	0.364	91105.4	O K
240 min Winter	4.393	0.393	98373.3	O K
360 min Winter	4.438	0.438	109611.9	O K
480 min Winter	4.473	0.473	118356.2	O K
600 min Winter	4.502	0.502	125616.4	O K
720 min Winter	4.528	0.528	131877.7	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	157.440	0.0	19
30 min Summer	94.711	0.0	34
60 min Summer	56.975	0.0	64
120 min Summer	34.274	0.0	124
180 min Summer	25.460	0.0	184
240 min Summer	20.618	0.0	244
360 min Summer	15.316	0.0	364
480 min Summer	12.403	0.0	484
600 min Summer	10.531	0.0	604
720 min Summer	9.213	0.0	724
15 min Winter	157.440	0.0	19
30 min Winter	94.711	0.0	34
60 min Winter	56.975	0.0	64
120 min Winter	34.274	0.0	124
180 min Winter	25.460	0.0	184
240 min Winter	20.618	0.0	244
360 min Winter	15.316	0.0	364
480 min Winter	12.403	0.0	484
600 min Winter	10.531	0.0	604
720 min Winter	9.213	0.0	724

Rainfall Details

Rainfall Model	FEH
Return Period (years)	100
Site Location	GB 335600 186350 ST 35600 86350
C (1km)	-0.027
D1 (1km)	0.391
D2 (1km)	0.364
D3 (1km)	0.347
E (1km)	0.297
F (1km)	2.414
Summer Storms	Yes
Winter Storms	Yes
Cv (Summer)	0.750
Cv (Winter)	0.840
Shortest Storm (mins)	15
Longest Storm (mins)	720
Climate Change %	+30

Time Area Diagram

Total Area (ha) 142.000

Time From:	**(mins) To:**	**Area (ha)**
0	4	142.000

Model Details

Storage is Online Cover Level (m) 6.000

Tank or Pond Structure

Invert Level (m) 4.000

Depth (m)	**Area (m²)**
0.000	250000.0

Appendix H – Northern Catchment Greenfield Runoff Assessment

IH 124 Mean Annual Flood

Input

Return Period (years)	100	Soil	0.400
Area (ha)	170.660	Urban	0.000
SAAR (mm)	965	Region Number	Region 9

Results	**l/s**
QBAR Rural	738.6
QBAR Urban	738.6
Q100 years	1610.1
Q1 year	649.9
Q2 years	686.0
Q5 years	893.7
Q10 years	1048.8
Q20 years	1204.6
Q25 years	1258.5
Q30 years	1302.2
Q50 years	1429.9
Q100 years	1610.1
Q200 years	1824.3
Q250 years	1898.1
Q1000 years	2356.0

Greenfield Runoff Volume

FEH Data

Return Period (years)	100
Storm Duration (mins)	720
Site Location	GB 335600 186350 ST 35600 86350
C(1km)	-0.027
D1(1km)	0.391
D2(1km)	0.364
D3(1km)	0.347
E(1km)	0.297
F(1km)	2.414
Areal Reduction Factor	1.00
Area (ha)	170.660
SAAR (mm)	958
CWI	123.053
SPR Host	25.130
URBEXT (1990)	0.0974

Results

Percentage Runoff (%)	33.44
Greenfield Runoff Volume (m^3)	48536.650

Appendix I – Technical Note Revision to Condition 35

Glan Lyn Development

Revision to the Planning Condition 35

The current planning condition 35 states:

Prior to being discharged into any watercourse, surface water sewer or soakaway system, all surface water drainage from parking areas and hardstandings shall be passed through an oil interceptor, the capacity and design of which must be submitted to and approved in writing by the Local Planning Authority prior to its installation. The approved interceptors shall be retained as such thereafter.

Reason: To prevent pollution of the water environment.

We have undertaken a background research on what Natural Resources Wales, who are the successor to EA Wales might want/are currently applying/planning to apply; and this is detailed below.

We have liaised informally with NRW and we believe NRW are satisfied to have the condition amended to make the solution less prescriptive in the use of interceptors provided what is proposed and implemented is appropriate and complies with national guidelines.

We consider that if 2 or 3 levels of treatment are provided, as appropriate, then pollution of the water environment will be avoided.

We propose that on this site the following are considered to be a single treatment train:

- 25m of reens/swales
- A pond with a width and length greater than 5 and 10 (respectively) times the adjacent swale width
- A trapped gully (when in conjunction with a reen/swale)
- Permeable paving
- Filter trench 10m in length

In delivery yards/commercial vehicle manoeuvring areas and, the District Centre and the Schools, particularly if they have buses, 3 levels of treatment will need to be considered including an interceptor.

Given the above a revised condition could be as detailed below.

Prior to being discharged into any watercourse, surface water sewer or soakaway system, all surface water drainage from road, parking areas and hardstandings shall be passed through an oil interceptor or another mechanism that removes hydro-carbons from surface water the design and capacity of which shall be submitted to and approved in writing by the Local Planning Authority prior to its installation. The interceptor or other mechanism shall be installed as approved and shall be retained thereafter.

All surface water drainage from parking areas and hard standings shall be provided with suitable treatment, the capacity and design of which must be submitted to and approved in writing by the Local Planning Authority prior to its installation. The approved treatment system shall be retained as such thereafter.

Reason: To prevent pollution of the water environment.

Other Relevant Data

A research of what guidance referenced by Natural Resources Wales has been undertaken.

There is a draft document “Consultation Document Introducing Pollution Prevention: PPG 1”. This would indicate that an environmental risk assessment based approach should be used to determine the correct approach to be followed with respect to treating surface water runoff. This would consider the various parts of the site, in overall terms this being residential or commercial.

The assessment would cover the following steps:

- Understand your drainage systems
- Know the difference between surface and foul drains. This being a new development there would be no combined drains.
- Consider groundwater protection.

The various SUDS elements on the site are already well known and are marked on the general plan layouts. There will be suitable site wide maintenance for all aspects of the site including the drainage and sustainable drainage.

Surface water may be contaminated by oil at a number of different points. Measures need to be in place to prevent this oil from polluting the environment as specified in Pollution Prevention Guidance (PPG) 3. These points include:

- car parks typically larger than 800m^2 in area or for 50 or more car parking spaces
- smaller car parks discharging to a sensitive environment
- areas where goods vehicles are parked or manoeuvred
- vehicle maintenance areas
- roads
- industrial sites where oil is stored or used
- refuelling facilities
- any other site with a risk of oil contamination.

Trapped gully pots can provide adequate protection for smaller car parks that are too small to justify the installation of a separator, but they must be properly maintained.

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