Section 19 Flood Investigation

23 December 2020

Sully Moors Road, Vale of Glamorgan

Version 2

December 2023

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Revision History

Revision Ref/Date	Amendments	Issued to
December 2023	Version 1	Vale of Glamorgan Council
December 2023	Version 2 – updates following comments from VoG	Vale of Glamorgan Council

Contract

This report describes work commissioned by Michael Clogg on behalf of Vale of Glamorgan Council, by an email dated 10 May 2021. Jon Wilson and Faye Tomalin of JBA Consulting carried out this work.

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Purpose

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Executive summary

This report has been produced in-line with the duties placed upon The Vale of Glamorgan Council (VoCG) under Section 19 of the Flood and Water Management Act 2010. The Act states, "On becoming aware of a flood in its area, a Lead Local Flood Authority (LLFA) must, to the extent that it considers it necessary or appropriate, investigate:

a) which risk management authorities have relevant flood risk management functions and

b) whether each of those risk management authorities has exercised or is proposing to exercise those functions in response to the flood".

This Section 19 investigation provides a factual report of the storm event which occurred on 23 December 2020 and the flooding that happened at Sully Moors Road and Ty-Verlon Industrial Estate as a result. The investigation focuses on the area located on the roads and land around Sully Brook, Sully Drain and River Cadoxton to the northwest of Sully. It has also been informed in part by Section 19 data analysis for Dinas Powys produced by JBA Consulting in March 2021.

The Section 19 data analysis report identifies that due to a series of storm events which occurred throughout the month of December 2020, the soils were already saturated prior to the rainfall on 23 December 2020. The storm is reported to have been equivalent to a 1 in 20 year rainfall event, which equates to a 5% chance of occurrence in any given year.

The source of the flooding originated from the heavy storm event which caused widespread fluvial and surface water flooding.

The evidence gathered in this report demonstrates that the cause of the flooding was a result of heavy rainfall combined with already high water levels in the Sully Brook, Sully Drain and River Cadoxton, plus the highway drainage and surface water sewer systems were hydraulically locked and unable to discharge, resulting in flooding to Sully Moors Road, the surrounding areas and Ty-Verlon Industrial Estate.

However, it is noted that the capacity of the existing surface and highway drainage system is not fully understood and so the full impact of this reduced capacity cannot be accurately determined.

Key recommendations of this report include:

- Review maintenance plans for the Sully Brook, Sully Drain and River Cadoxton.
- Consider catchment options to reduce surface water flooding.
- Investigate the feasibility of increasing the current frequency of cleansing on the Sully Moors Road surface water drainage system.
- Liaison between VoGC and NRW on the areas of concern within the Cadoxton catchment.
- VoGC to consult with the Highway Authority on the highway surface water network, with regards to outfalls and stop valves which discharge on the Cadoxton River.
- VoGC to contact DCWW with regard to their assets in Ty-Verlon Industrial Estate.
- Undertake CCTV investigation of the condition and capacity of the of the highway drainage system.
- Review maintenance plan for the Highway network and surface water drainage.

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Abbreviations

AEP	Annual Exceedance Probability
DCWW	Dŵr Cymru Welsh Water
FWMA	Flood and Water Management Act 2010
JBA	Jeremy Benn Associates Ltd
LiDAR	Light Detection and Ranging
LLFA	Lead Local Flood Authority
LTA	Long Term Average
NRW	Natural Resources Wales
RMA	Risk Management Authority
SuDS	Sustainable Drainage System
STW	Sewage Treatment Works
S19	Section 19
TBR	Tipping bucket rain gauge
VoGC	The Vale of Glamorgan Council

Definitions

Annual Exceedance Probability: The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.

Risk: In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, and the consequence of the flood.

Surface water flooding: Flooding as a result of surface water runoff as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity, thus causing pluvial flooding.

1 Introduction

1.1 Background to investigation

As the Lead Local Flood Authority (LLFA) The Vale of Glamorgan Council (VoGC) has a duty to prepare and publish the results of investigations into significant flood incidents, as detailed within Section 19 (S19) of the Flood and Water Management Act 2010 (FWMA). The Act states, "On becoming aware of a flood in its area, a Lead Local Flood Authority (LLFA) must, to the extent that it considers it necessary or appropriate, investigate:

a) which risk management authorities have relevant flood risk management functions and

b) whether each of those risk management authorities has exercised or is proposing to exercise those functions in response to the flood".

This report has been prepared for the purpose of meeting the LLFA S19 requirements by providing a detailed, factual account of the flooding that occurred on 23rd December 2020 in Ty-Verlon Industrial Estate and the industrial area of Sully Moors Road and Hayes Road, Barry, Vale of Glamorgan, South Wales. During this event, Sully Moors Road (B4267), the main road linking Barry to Sully and Penarth, was flooded and closed over a length of approximately 800m between the roundabout at the junction of the Barry Dock link road (A4055) in the north and the Hayes Road roundabout in the south; Hayes Road was flooded west of this roundabout. Six businesses were reported to have flooded internally. The Ty-Verlon Industrial Estate to the northwest of Sully Moors Road also experienced flooding, with five business units reported to have flooded internally.

This report will focus on investigating the causes of the flooding in the Sully Moors Road area as a result of the storm event (Figure 1-1).

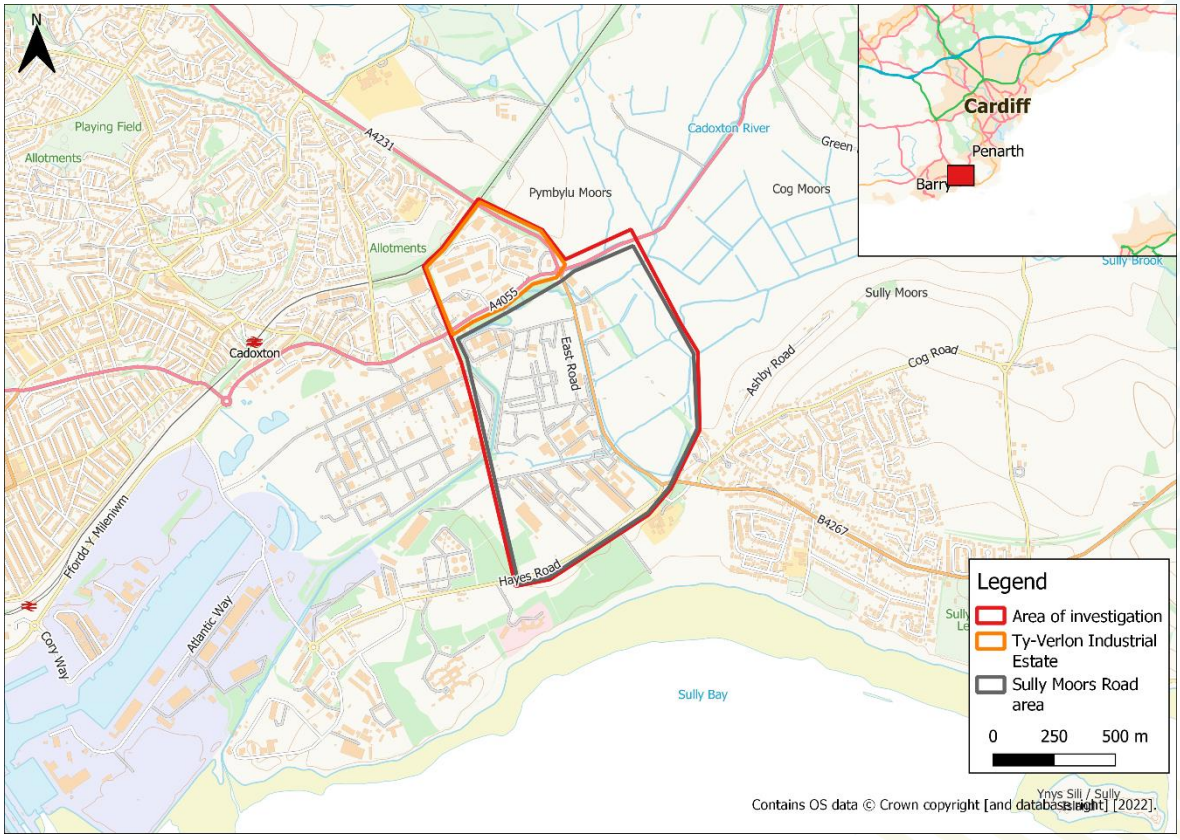


Figure 1-1: Overview map

Previous to this report, Section 19 reports have been undertaken by JBA Consulting for the areas of Sully, Lavernock Road and Dinas Powys on 23 December 2020, on behalf of The Vale of Glamorgan Council. This involved the collection and analysis of hydrological data relating to the flood event and documenting the findings. Where relevant, the analysis has been used in this S19 report.

To provide an accurate account of the flood event, this S19 Report for Sully Moors Road, Penarth will:

- Identify events leading up to the flood;
- Investigate the number of properties flooded;
- Investigate which Risk Management Authorities (RMAs) have flood risk management functions in respect of the flooding;
- Investigate whether each RMA has exercised or is proposing to exercise those functions in response to the flood.

1.2 Site location

The Sully Moors Road area is a highly industrialised and commercial area approximately 1km east of Barry Docks. Sully Moors Road (B4267) runs in a north-south direction through the eastern part of the area of investigation from the roundabout at junction of the Barry Dock link road in the north to the Hayes Road roundabout in the south. Hayes Road runs along the southern edge of the area in a westerly direction from the Hayes Road roundabout. Sully Moors Road is the main link to the businesses in the immediate area and the industrial estates within the Barry Docks area and provides an essential link for Sully and Penarth. West of Sully Moors Road the area is predominantly industrial with North Road and Horton Way providing access into this area from Sully Moors Road. The large Hexion chemical site is located in the southern extent of the industrial estate and the Vale Enterprise Centre lies between it and Sully Moors Road. To the east of Sully Moors Road in the north of the Sully Moors Road investigation area are commercial premises, whereas in the south of the investigation area it is bordered by the agricultural land of Sully Moors. Bordering the southeast edge of the investigation area is the large village of Sully.

The area is located within the Cadoxton River, Sully Coastal catchment. Three Main Rivers flow into the investigation area: Cadoxton River; Sully Brook; and Sully Drain.

The Cadoxton River flows in a predominantly southerly direction through the investigation area, culverted beneath Sully Moors Road and bordering the northern and western boundaries of the investigation area, and the industrial units to the west of Sully Moors Road.

The Sully Brook flows in a westerly direction from Cosmeston, west of Penarth, to pass centrally through the area of investigation before joining the Cadoxton River on the western edge of the area of investigation. There is a network of drainage channels in the agricultural land to the east of Sully Moors Road, of which the Sully Drain is the principal drainage channel. The Sully Drain flows parallel to the Sully Brook into the area of investigation before turning south and flowing in ditches along both sides of the Sully Moors Road to join the Sully Brook within the area of investigation.

Figure 1-2 shows the topography of the area using Opensource LiDAR data. Ground levels are shown to be relatively constant across the investigation area at approximately 6m above ordinance datum (AOD).

Sully Moors Road falls from a level of 7.12mAOD at its junction with Barry Docks Link Road at its northern extent, to a level of 6.1mAOD just south of the Sully Brook crossing. Ground levels rise to 8.1mAOD at the junction with Hayes Road. Hayes Road falls from a level of 8.02mAOD at the junction with Sully Moors Road to a level of 5.75mAOD at the western boundary of the investigation area.

Average ground levels across the Sully Moors within the investigation area is 5.7mAOD. Within the industrial area to the west of Sully Moors Road, average ground level is approximately 6.42m AOD - 6.14m AOD.

The Ty-Verlon industrial estate is in the north of the area of investigation, north of the Barry Dock link road (A4055). Sully View Road is the main access road into this estate from the Barry Dock link road.

Average ground levels across the Sully Moors within the investigation area is 5.7mAOD. Within the industrial area to the west of Sully Moors Road, average ground level is approximately 6.42m AOD - 6.14m AOD.

The Ty-Verlon industrial estate investigation area has a more varied topography with elevations falling relatively steeply from nearly 20m AOD in the northwest of the area to a low point just north of the A4055 at approximately 6.11m AOD. From here, elevations rise slightly to approximately 6.9m AOD along the A4055 which demarcates the southern edge of the area.

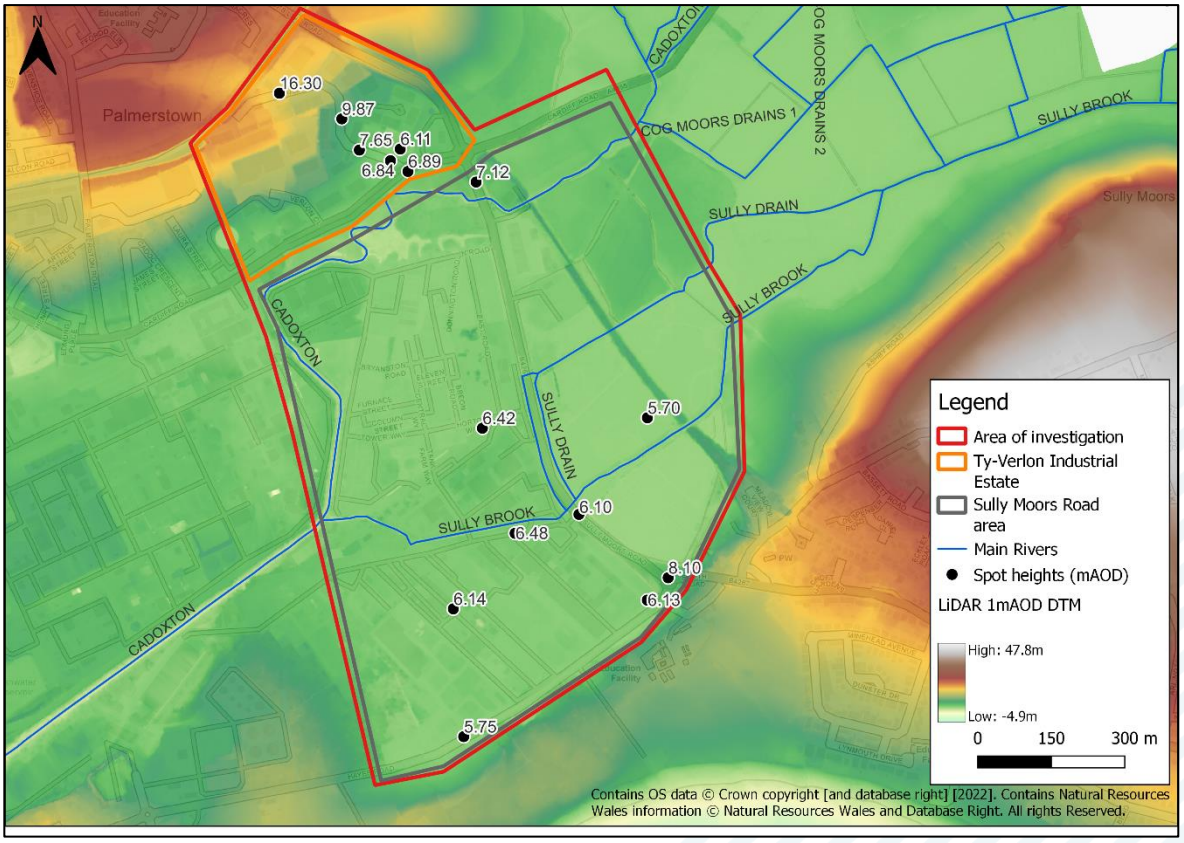


Figure 1-2: LiDAR

2 Roles and responsibilities

2.1 Duties under 'Flood and Water Management Act (2010): Section 19 - Local authorities: Investigations'

Under Section 19 of the Flood and Water Management Act 2010, the Lead Local Flood Authority, VoGC, have a duty to investigate and publish reports on flood events that occur within its area to the extent that it considers it necessary or appropriate.

(1) On becoming aware of a flood in its area, a lead local flood authority must, to the extent that it considers it necessary or appropriate, investigate -

(a) which risk management authorities have relevant flood risk management functions, and

(b) whether each of those risk management authorities has exercised, or is proposing to exercise, those functions in response to the flood.

(2) Where an authority carries out an investigation under subsection (1) it must-

(a) publish the results of its investigation, and

(b) notify any relevant risk management authorities.

2.2 Risk Management Authorities

2.2.1 Lead Local Flood Authority

The Vale of Glamorgan Council has been established as the LLFA for its administrative area under the Flood and Water Management Act 2010. It is responsible for managing the risk of flooding from ordinary watercourses, surface runoff and groundwater.

Additionally, the LLFA takes on role of the Sustainable Drainage Systems (SuDS) Adopting and Approving Body in which they are responsible for approving designs and adopting and maintaining finished SuDS.

As the LLFA, VoGC have statutory duties:

1 to prepare local flood risk management strategies;

2 to comply with the National Strategy for Flood and Coastal Erosion Risk Management;

3 to co-operate with other authorities, including sharing data;

4 to investigate all flooding within its area, insofar as a LLFA consider it necessary or appropriate;

5 to maintain a register of structures and features likely to affect flood risk;

6 to contribute to sustainable development; and

7 through consenting powers on ordinary watercourses.

2.2.2 Natural Resources Wales

Natural Resources Wales (NRW) has statutory duties and permissive powers, including:

1. Operational responsibilities for flooding from main rivers, the sea and coastal erosion.
2. Oversight responsibilities in relation to all flood and coastal erosion risk management in Wales.

NRW's powers to manage flood risk include the management and maintenance of Main Rivers, the construction of new flood risk management assets and maintaining existing flood assets. NRW assesses developers' flood assessments (and supporting documentation) to decide if developers have met the requirements of Planning Policy Wales and Technical Advice Note 15: Development and Flood Risk in relation to the risks of flooding from main rivers, the sea and reservoirs. NRW is a statutory consultee in Local Authorities' planning processes and provides

support to Welsh Ministers in their preparation of the National Flood and Coastal Erosion Management (FCERM) Strategy.

NRW provides a direct flood warning service, primarily for areas at risk of fluvial and coastal flooding.

2.2.3 Highways Authority

The Vale of Glamorgan Council undertake the role of the Highways Authority, being responsible for the maintenance of all adopted highways in the Vale and their associated infrastructure. This includes ensuring the highway has a drainage system that controls the surface water that enters onto the highway, providing and managing highway drainage and roadside ditches to ensure they are clear of obstructions. The above duties and responsibilities of the Highways Authority are not applicable to Trunk Roads, which are the responsibility of the Welsh Government.

2.2.4 Dŵr Cymru Welsh Water

As a Water Utility Company, the role of Dŵr Cymru Welsh Water (DCWW) as a risk management authority is to manage the risk of flooding to water supply and sewerage facilities and flood risk arising from their infrastructure. The main responsibilities of the Water Utility Company are to:

- Ensure their systems have the appropriate level of resilience to flooding, and maintain essential services during emergencies;
- maintain and manage their water supply and sewerage systems to manage the impact and reduce the risk of flooding and pollution to the environment;
- advise LLFAs on how their assets affect local flood risk and work with RMAs to coordinate management of flood risk management assets; and
- work with developers, landowners and LLFAs to understand and manage risks

2.3 Other Authorities

2.3.1 Landowners and riparian owners

Riparian Landowners are legally responsible under common law for the maintenance of the land from the edge of the waterbed to the middle of the riverbed. The landowner is responsible for removal of obstructions caused within the boundaries of their land affecting the watercourse. This includes the maintenance of the bed, banks and any boundary features e.g. through routine clearance of debris and/or blockages.

2.3.2 Residents and property owners

Property owners are responsible for the protection of their own properties against flooding. Property owners have the right to defend their property provided they do not increase the risk of flooding to other properties.

2.4 Permissive Powers

Risk Management Authorities have direct permissive powers under the Flood and Water Management Act 2010, as well as the Land Drainage Act 1991. For NRW and the LLFA this includes:

- Powers to request information.
- The ability to raise levies for local flood risk management works (NRW only).
- Powers to designate certain structures or features that affect flood or coastal erosion risk.
- The expansion of powers to undertake works to include broader risk management actions.

- The ability to cause flooding or coastal erosion under certain conditions.

3 Stakeholder Engagement

Following the flooding in December 2020, VoGC carried out interviews with businesses in the Sully Moors Road investigation area. 8 Flood Incident Reports were received collating information on the following:

- Date of flooding;
- Extent of flooding to private land and properties;
- Depth of flooding on private land and in properties;
- Perceived source/cause of flooding;
- Impacts and estimated costs of damages.

In addition, VoGC conducted a meeting on 27th January 2021 with VoGC officers, councillors, NRW and representatives from affected businesses attending.

DCWW have provided asset records for both the Sully Moors Road and Ty-Verlon areas.

Photographs of flooding were provided by the businesses and via news articles of the flooding incident and have been used in investigations for this report.

4 Catchment characteristics

4.1 Catchment overview

The site is located in the Cadoxton River and Sully Brook catchments. The Sully catchment drains into the Cadoxton catchment to the west.

The topographic characteristics of the Cadoxton catchment are varied. Upstream of the moors and through the urban area of Dinas Powys the catchment topography is relatively steep. However, the Sully and Cog Moors and the area downstream of Sully Moors Road to the docks (the area of investigation) is low-lying and flat. High land south of Dinas Powys acts as a natural watershed for the Cadoxton catchment to the northwest and for the Sully Coastal catchment to the southeast.

The topographic characteristics of the Sully Coastal catchment are varied; higher land to the north and east of the site acts as a natural watershed, but the area of investigation is very low-lying and flat, consisting of floodplain. This floodplain is comprised of the large industrial area to the west of Sully Moors Road, a commercial area in the northeast of the area of investigation and to the east of Sully Moors Road the Sully Moors and Cog Moors, which are agricultural land.

The catchment is predominantly underlain by Triassic Rocks comprised of mudstone, siltstone, sandstone and conglomerate. There are smaller areas of Carboniferous Dinantian Rocks (limestone with subordinate sandstone and argillaceous rocks), and Jurassic Lias Group (mudstone, siltstone, limestone, and sandstone). The Ty-Verlon investigation area is underlain almost entirely by Triassic mudstones and conglomerate. Superficial deposits of alluvium (clay, silt, sand and gravel) are found along, and in the areas adjacent to, the watercourses; these underlie the entirety of the Sully Moors Road investigation area and the extreme south east of the Ty-Verlon investigation area. Soils are predominantly loamy and clayey with naturally high groundwater and impeded drainage, with freely draining soils in smaller areas to the north and south of the catchment.

4.2 River network

The River Cadoxton and its major tributary, the Sully Brook are both NRW Main Rivers and flow through the area of investigation. The source of the River Cadoxton is near Wenvoe, it then flows east and then south through Dinas Powys before flowing south-west through the northern edge of the area of investigation, and then along the western edge of the area. The Sully Brook's source is just west of Penarth and flows in a predominantly westerly direction. The Sully Drain branches off the Sully Brook as it flows across the low-lying area of the Sully Moors. Both the Sully Brook and Sully Drain flow south-west through the area of investigation, passing under the Sully Moors Road via bridges; the Sully Moors Drain flows south alongside both sides of the Sully Moors Road to join the Sully Brook next to this road within the area of investigation. The Sully Brook then joins the River Cadoxton on the western edge of the site before finally discharging into the Bristol Channel at Barry Docks (see Figure 4-1).

No known watercourses flow through the Ty Verlon Industrial Estate.

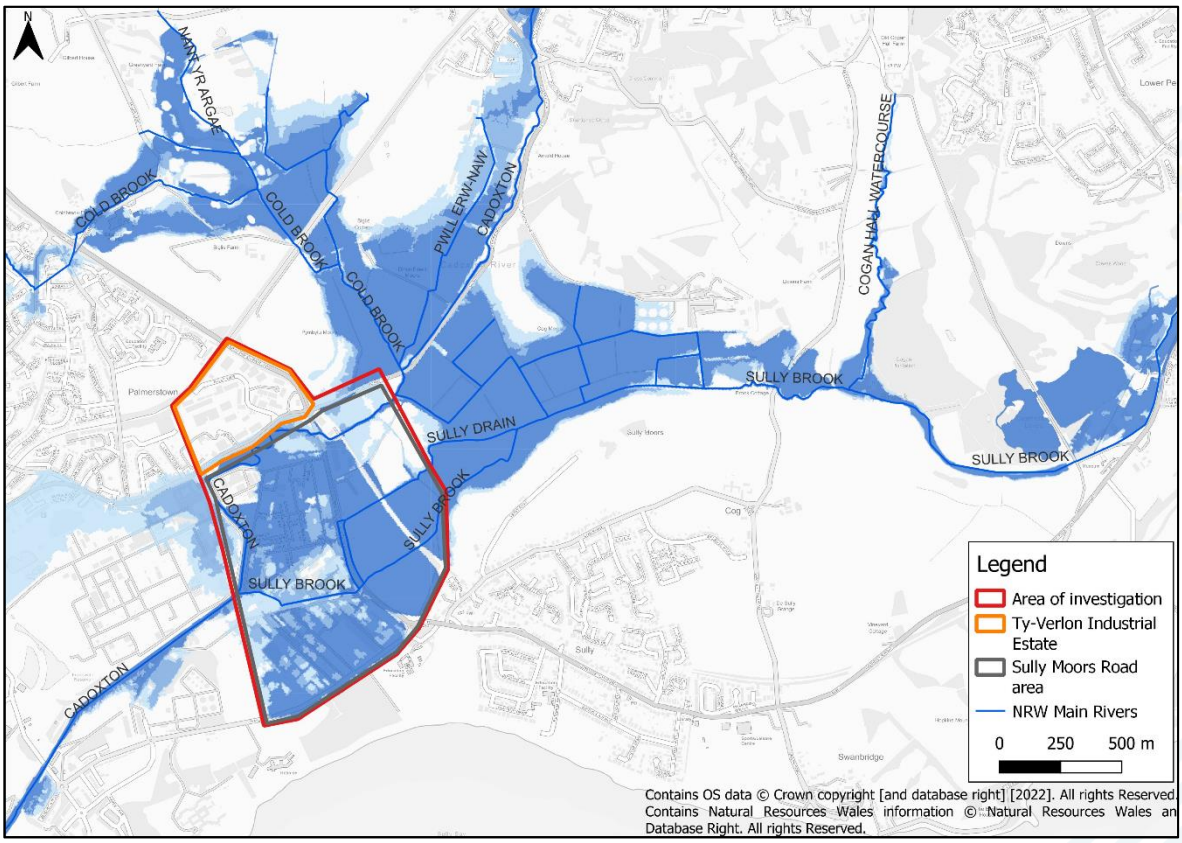


Figure 4-1: Map of NRW main rivers

4.3 Drainage system

It should be noted that responsibility for different sections of drainage systems lies with individual RMAs, and that RMAs have different system capacity targets for their drainage networks. DCWW aim to maintain a 1 in 30-year (3.3% AEP) capacity, while the Highways Authority aims to maintain a 1 in 5-year (20% AEP) capacity. It should be noted that any DCWW surface water system is designed to take roof and yard drainage only, whilst the highway network is designed to take flows from the highway only. Across the Vale of Glamorgan, the highway network is cleansed on a 15 to 18 month average rotation. Most systems are not designed with the intention of receiving sheeting overland flows from greenfield areas or floodwater from fluvial systems.

The Sully Moors Road investigation area is served by a combined public sewer network, at least one non-DCWW network, as well as a highway drainage network.

4.3.1 Sewer network

The public sewer network in the study area is comprised of a combined system. Large areas of the industrial units to the west of Sully Moors Road are served by a private system, not present on DCWW asset maps. The combined sewer drains towards to Cog Moors Wastewater Treatment Works east of the investigation area. DCWW asset maps are shown for Sully Moors Road in Figures 4-3, 4-4 and 4-5.

The Ty-Verlon industrial estate investigation area to the north is served by a public surface water network along Sully View Road, which discharges into a tributary of the River Cadoxton at Biglis Roundabout (Figure 4-2).

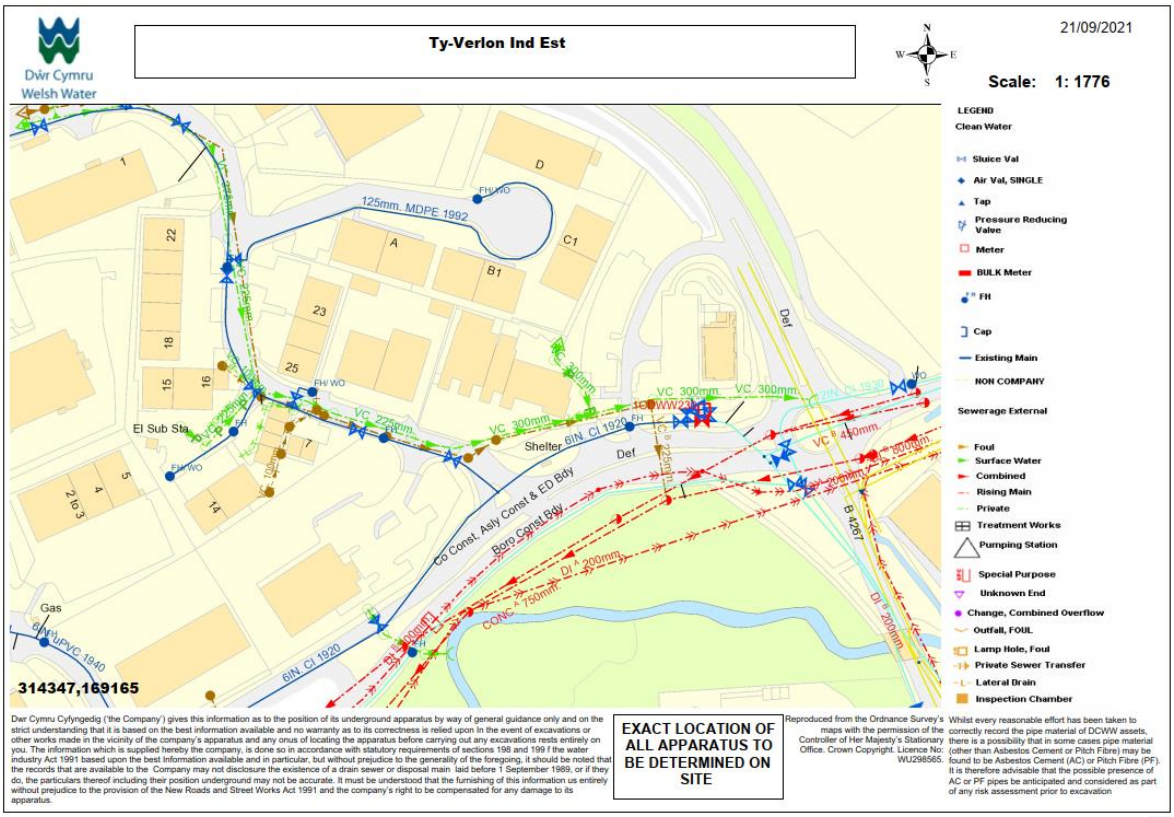


Figure 4-2: DCWW asset map – Ty-Verlon industrial estate

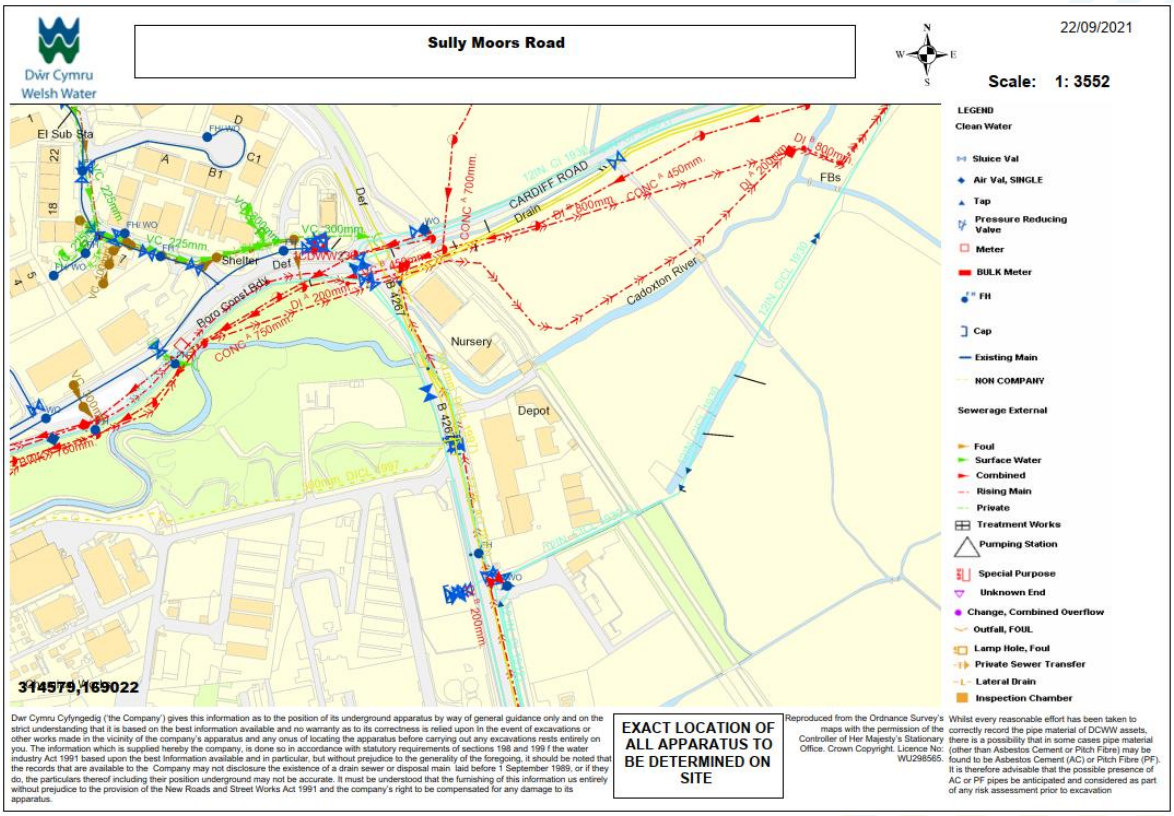


Figure 4-3: DCWW asset map - Sully Moors Road north

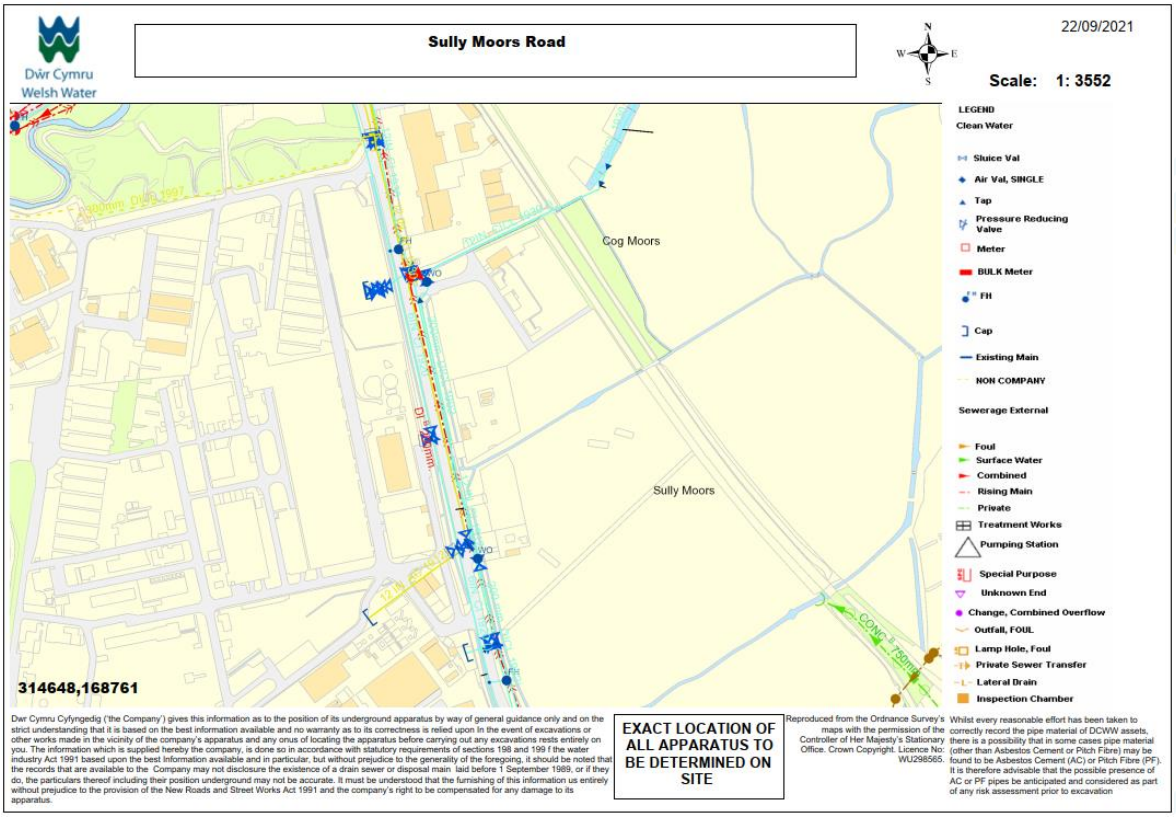


Figure 4-4: DCWW asset map - Sully Moors Road middle

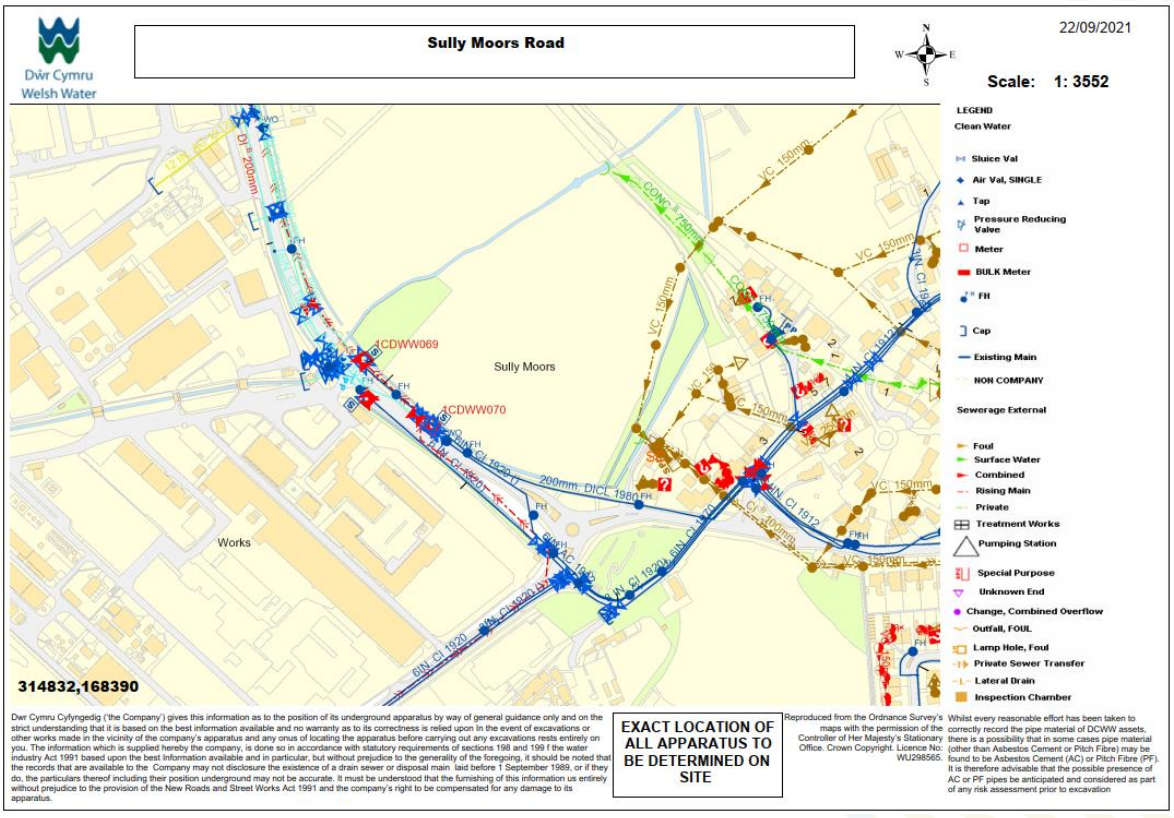


Figure 4-5: DCWW asset map - Sully Moors Road south

4.3.2 Highway drainage

Sully View Road in the Ty- Verlon Industrial Estate is served by highway gullies. It is therefore assumed that the highway network discharges into the River Cadoxton to the south of Ty-Verlon Industrial Estate.

Sully Moors Road is served by highway gullies that connect directly to the adjacent land drainage ditches and Sully Drain which conveys surface water to either the Cadoxton River in the northern extent of the investigation area or the Sully Brook to the southern extent.

Hayes Road drains via a piped and pumped system. The pumps are controlled by Hexion Chemicals, a large industrial site to the north of Hayes Road.

The highway gullies on Sully Moors Road and Hayes Road are reported to be cleansed on a 15 to 18 month average rotation.

5 Information gathering

5.1 Flood risk

5.1.1 Long-term flood risk information

5.1.2 Rivers

The NRW Flood Risk Assessment Wales map showing long-term flood risk from rivers indicates that Sully Moors Road is predominantly located within an area with a high risk of fluvial flooding, as shown in Figure 5-1. High risk of flooding means greater than 1 in 30 (3.3%) probability in any year.

The infrastructure of both Sully Moors Road and Hayes Road are at high to medium risk of flooding. Medium risk means between 1 in 100 (1%) and 1 in 30 (3.3%) chance of flooding in any year

The floodplains of the Sully Brook and Sully Drain are located both east and west of Sully Moors Road; the River Cadoxton's floodplain is located to the south of the river within the area of investigation, at high risk of flooding.

The Ty-Verlon industrial estate area is predominantly shown to be at very low risk of fluvial flooding. The Barry Docks link road (A4055) which runs along the southern boundary of the area is at low risk of flooding. A low risk equates to between a 1 in 1000 (0.1%) and 1 in 100 (1%) chance of flooding in any year.

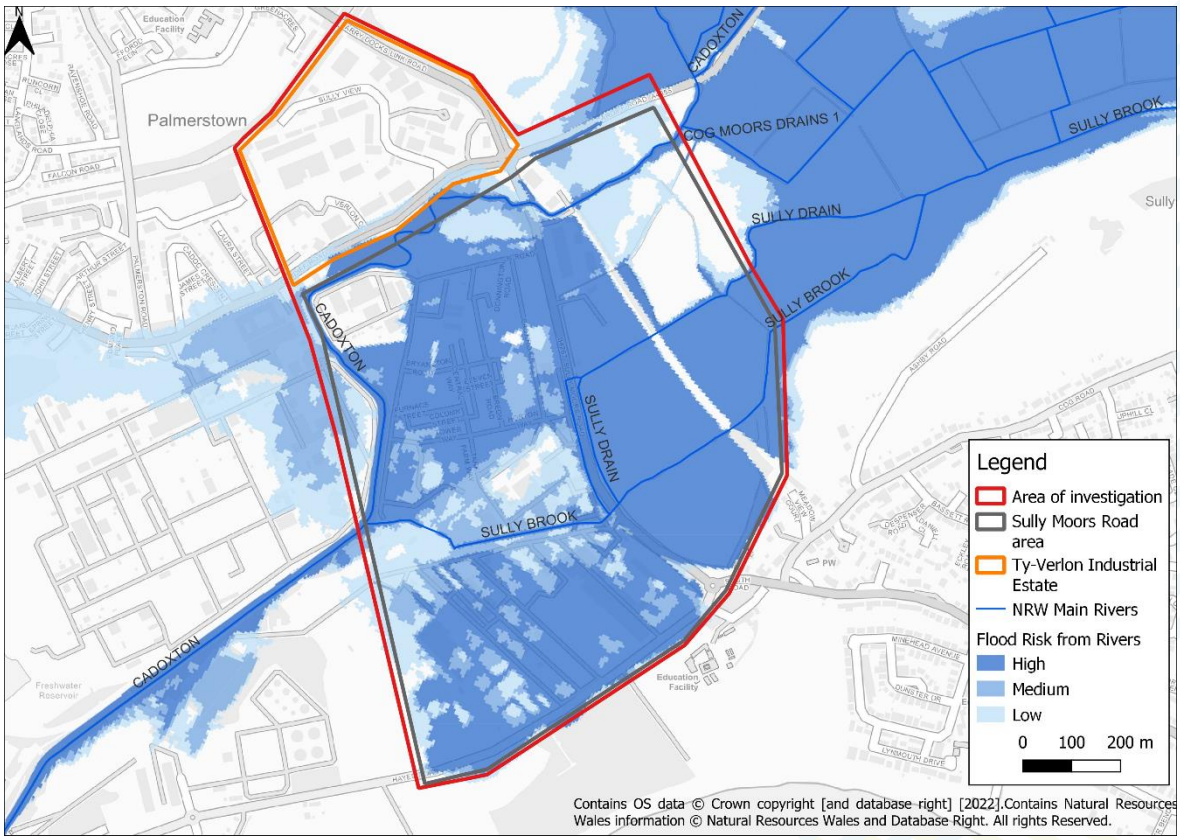


Figure 5-1: Risk of flooding from rivers (Flood Risk Assessment Wales (FRAW) map)

5.1.3 Tidal

The NRW FRAW map for flooding from the sea indicates that almost entirety of the investigation area has a low risk of tidal flooding, with only the north west section of the Ty-Verlon industrial estate area outside of this zone, as shown in Figure 5-2. A low risk of tidal flooding is equivalent to a chance of flooding of 0.1% and 0.5% in any given year.

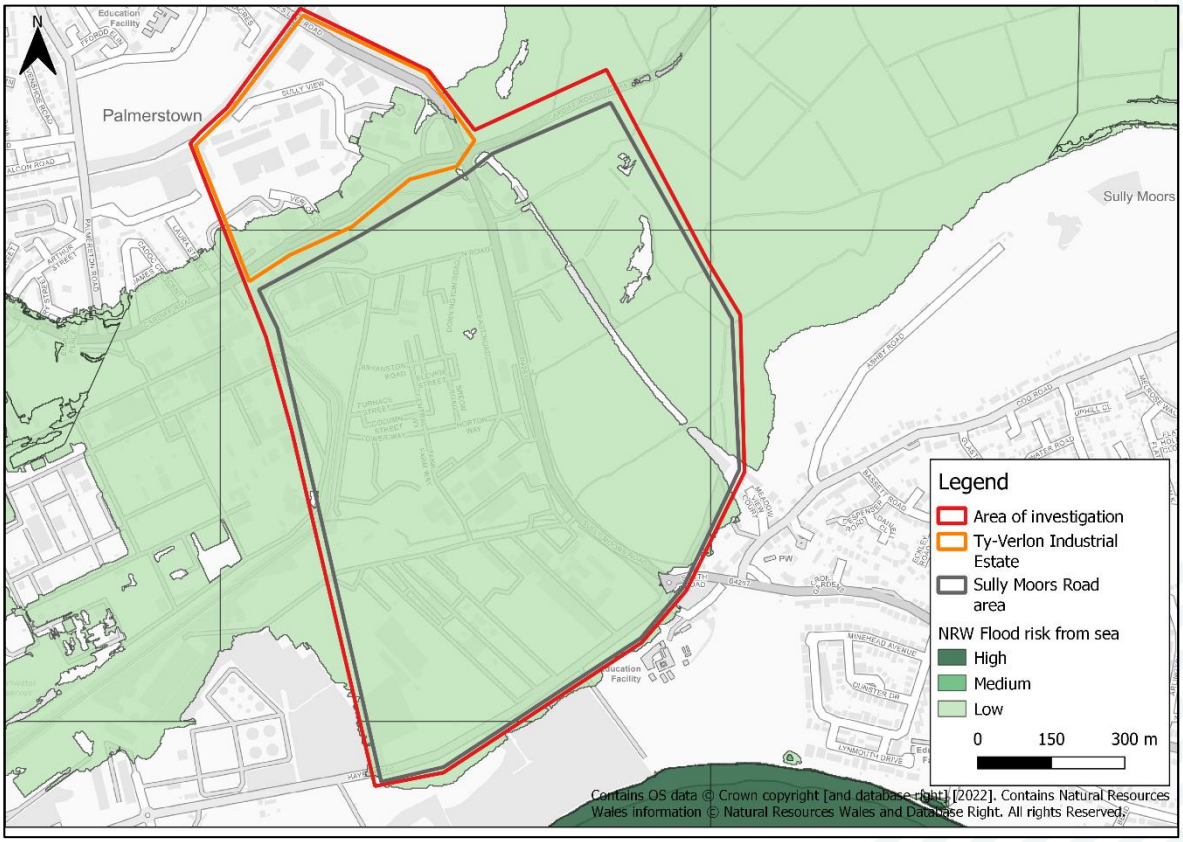


Figure 5-2: Risk of flooding from sea

5.1.4 Surface Water

The NRW FRAW Map for Surface Water shows that small, localised areas of the investigation area are at risk of surface water flooding. See Figure 5-3.

The south-westerly section of Hayes Road has a high risk of flooding from surface water, defined as a chance of flooding of greater than 1 in 30 (3.3%) in any year as a result of rainfall.

The industrial units to the west of Sully Moors Road have a medium to high risk of surface water flooding. Medium risk equated to between 1 in 100 (1%) and 1 in 30 (3.3%) chance of flooding in any year.

A small number of ditches alongside Sully Moors Road have a low risk of surface water flooding. This is equivalent to between a 1 in 1000 (0.1%) and 1 in 100 (1%) chance of flooding in any year as a result of rainfall.

In the Ty-Verlon industrial estate area a small area just north of the junction of Sully View Road with the Barry Docks link road (A4055) is at medium risk of surface water flooding.

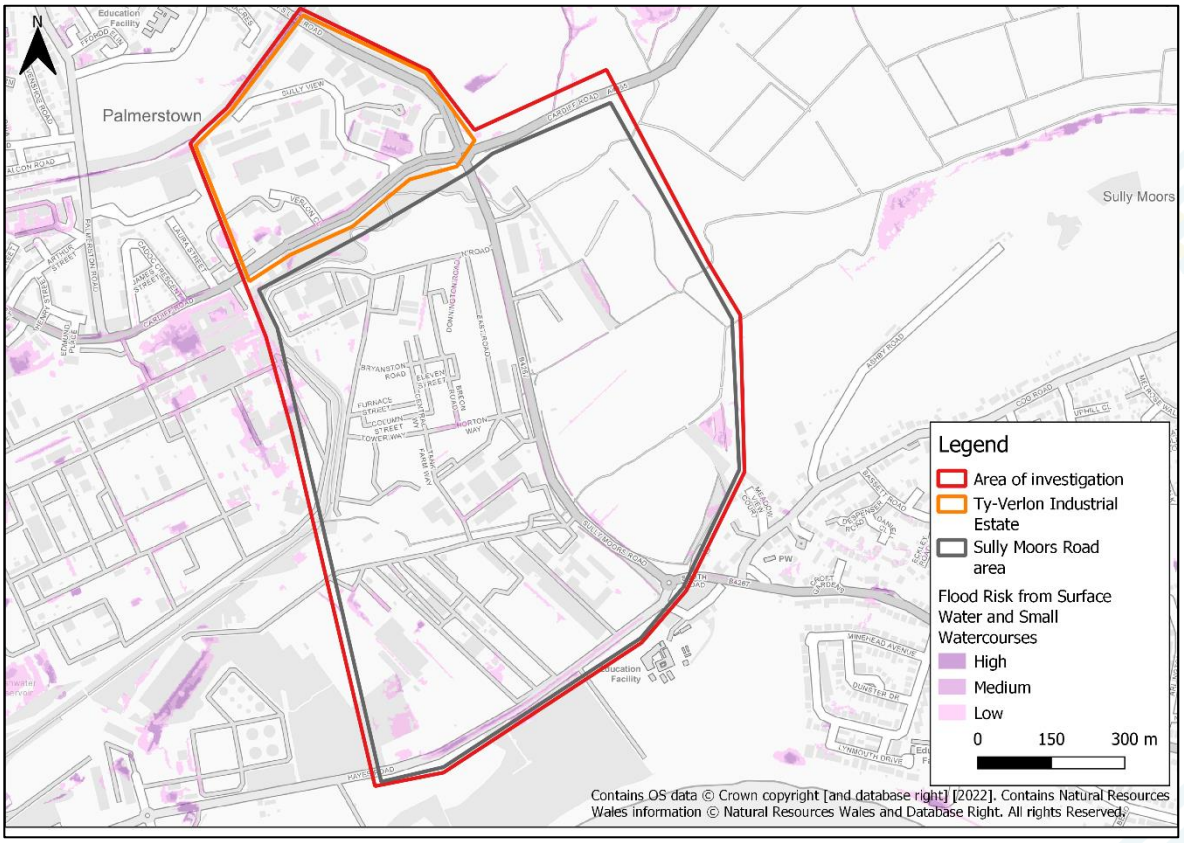


Figure 5-3: Risk of flooding from surface water

5.1.5 Groundwater

As groundwater levels rise in response to precipitation, groundwater can contribute to an increased level of surface water overland flow and a faster flow of water to river channels. However, flooding as a direct result of groundwater rising was not reported. Although groundwater is not considered to be a direct source of flooding for this event it is acknowledged that a substantial amount of rain fell over a short period of time and on an already saturated catchment, which is likely to have led to surcharging of sewers, combined with high water levels in the river.

5.1.6 Flood history

The Sully Moors Road area has a history of flooding, with several businesses referring to this in interviews conducted for the February 2020 VoGC Preliminary Flood Incident Report. In this preliminary report, one business reported flooding as occurring 4 times since 1985, another reported experiencing flooding approximately every 5 years since 1998. Six business within the current investigation area reported internal flooding during February 2020. Eight VoGC Flood Incident Report Forms from businesses within the investigation area have been received to further inform this report.

The Sully Flood Management Group met twice annually to address flooding locally, including specifically on Sully Moors Road, up until October 2021. The group includes representatives from NRW and VoGC Highways Department. The minutes (a recording) of this group's meeting on 27 January 2021 was provided to inform this report. After the October 2021 meeting the Chair of the group retired as a local councillor and the group has not been convened since.

6 Hydrological analysis of the December 2020 event

6.1 Conditions at the time

The overall rainfall for January to December 2020 was above average across most of the UK, particularly across western regions. December featured a series of cyclonic systems, with successive spells of unsettled weather generating rainfall over saturated ground. Overall, December rainfall was substantially above average with 139% of the long-term average (LTA) for the UK and in a broad portion of Wales rainfall exceeded 150% of the LTA.

Soil moisture deficits (SMD) were near-zero across the whole of the UK, the wettest soils for late December at a national scale since 2012, meaning there was little capacity for the ground to retain additional water. Mean river flows over January to December 2020 were exceptionally high in Wales. As a result of these conditions surface water flooding causing significant disruption was a recurrent characteristic of the month.

6.2 Overview of Event

The flood event on 23 December 2020 occurred in response to a short and intense storm event. A short sharp period of intense rainfall was observed between 09:00 and 10:00 at Cog Moors Sewage Treatment Works (STW) TBR rain gauge (the closest rain gauge to the site), recording 8.2mm in 1 hour. After a period of no rainfall for 1.5 hours and 1mm between 11:30 and 12:00 a longer period of persistent heavy rainfall between 12:45 and 18:00 occurred. During this 5.25hr period 47.8mm of rain fell with an average intensity of 9.1mm/hr. The maximum rainfall intensity occurred between 14:00 and 15:00 equalling >10mm/hr. Figure 6-1 below shows the rainfall hyetograph of the flood event at the Cog Moors STW TBR, as detailed in the Section 19 Data Analysis report undertaken by JBA Consulting.

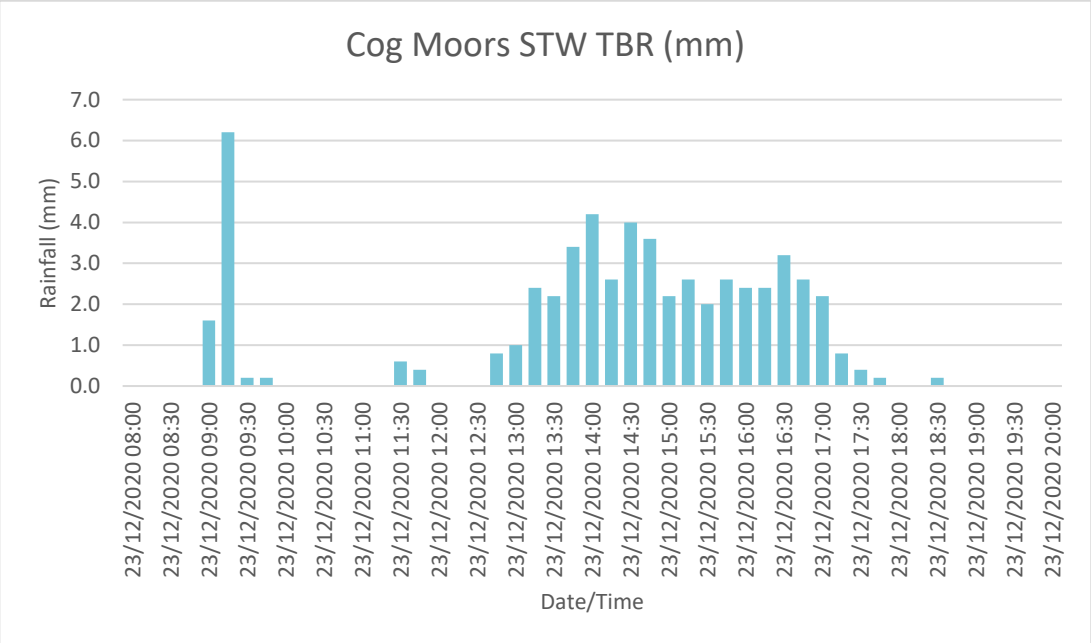


Figure 6-1: Rainfall hyetograph of December 2020 flood event

As described above, prior to the flood there had been a succession of storm events, which had left behind a highly saturated catchment. As a result of this there would have been little capacity for storage within the catchment.

The outcome of this high volume of rainfall falling on a saturated catchment was rapid flows of surface water run-off across non-permeable urban surfaces and slopes. Normally permeable surfaces became saturated leading to more surface run-off. The Cadoxton River and Sully Brook rapidly rose and flooded the Sully Moors. This then severely affected the local highway drainage network and Sully Moors Road and surrounding businesses succumbed to flooding.

This also caused problems for the surface water sewer network, which was unable to cope with a large volume of water over this short timeframe.

The days following the event were comparatively dry in the area with short periods of light rainfall on the 24 and 26 December and no additional impacts resulting from the additional rainfall were reported, however the Sully Moors Road area remained flooded during this period.

7 Source-pathway-receptor analysis

7.1 Source

7.1.1 River

Three NRW main rivers, run through the area of investigation: the Sully Brook and Sully Drain flow through the middle of the investigation area and the River Cadoxton flows along the northern boundary of the Sully Moors Road Investigation Area. The source of the River Cadoxton is near Wenvoe, flowing east and then south before flowing south-west through the northern edge of the area of investigation, then in a predominantly southerly direction before finally discharging into the Bristol Channel near Barry Docks; it passes beneath Sully Moors Road via a bridge.

The Sully Brook is one of the largest tributaries of the River Cadoxton. The source of the Sully Brook is located west of Penarth, and it flows in a predominantly south-westerly direction. The Sully Drain branches off the Sully Brook as it flows across the low-lying area of the Sully Moors. Both the Sully Brook and Sully Drain flow south-west through the area of investigation, passing under Sully Moors Road via bridges; the Sully Moors Drain then splits before turning south to flow in ditches along both sides of the Sully Moors Road to join the Sully Brook next to Sully Moors Road within the area of investigation.

The River Cadoxton and the Sully Brook are tidally influenced as they flow through the investigation area. The majority of the Sully Moors Road investigation area is categorised as an 'Area benefitting from flood defences from the sea' by NRW. The investigation area includes a small, 105m stretch of bund along the River Cadoxton at the north-eastern corner of the investigation area. This defence is classified as in 'Fair' condition by NRW.

It was anecdotally claimed in the VoGC chaired meeting 'Flooding on Sully Moors Road and Hayes Road, Sully' held on 27th January 2021, that temporary work being carried out on the tidal flap valve at the outfall of the River Cadoxton restricted the outflow of flood water, resulting in flood water backing up on the River Cadoxton and Sully Brook, and increasing the potential for hydraulic locking of the drainage system. The form and timing of the works at the Cadoxton Outfall is described in a report compiled by NRW, presented in Appendix A.

The Ty-Verlon Industrial Estate area of the investigation is not directly affected by fluvial flooding, with no known watercourses flowing through this investigation area.

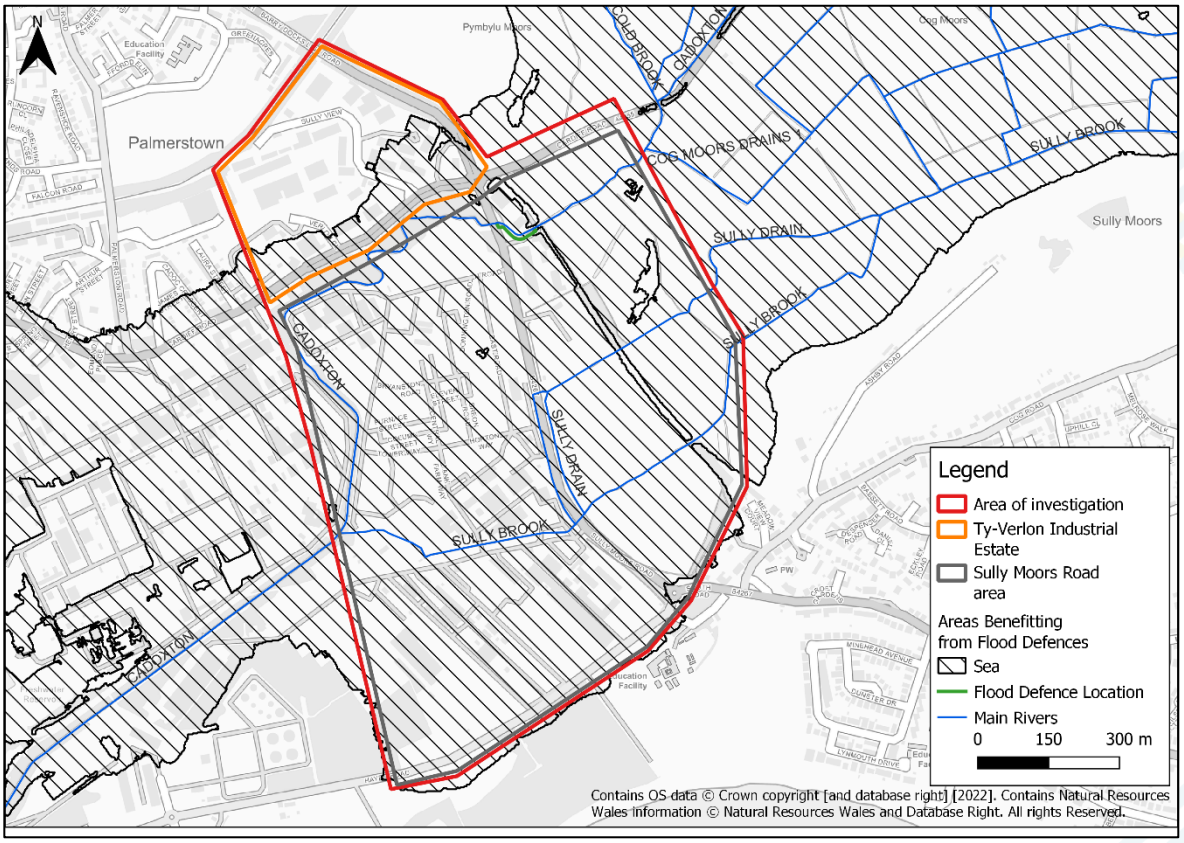


Figure 7-1: Areas benefitting from flood defences

7.1.2 Extreme rainfall

The primary source of the flood water is the extreme rainfall experienced across South Wales on 23 December 2020.

This investigation presents Cog Moors STW TBR gauge data due to it being the closest gauge to the site being investigated. Rainfall totals at other local rain gauges were also assessed for the 23 December 2020 event (detailed in Table 7-1 Table 7-1 Rainfall gauge data) that provide context for the storm event across South Wales. Note: rain fell at slightly different times at the gauges, hence the period and duration vary for each.

The findings indicate that the Cog Moors STW TBR gauge recorded substantially larger rainfall totals than at the other gauges within the vicinity of the storm event. NRW has indicated confidence in the Cog Moors STW TBR gauge due to the data being consistent between the primary and secondary gauges that operate independently and after quality checks undertaken on 31 December following the event. Rainfall radar data did not indicate a localised storm around Cog Moors STW TBR, so it is unclear why local rainfall totals differ so substantially from other rain gauges.

The Dinas Powys S19 Data Analysis Report provided an analysis to estimate the flood frequency of the event. The inference of flood rarity from rainfall data is seldom accurate, as treating rainfall rarity as a measure of flood rarity neglects the complex scenarios leading to flood formation. Therefore, a flood frequency specific to the site investigated in this S19 report is not inferred. However, the rainfall frequency estimation suggested Cog Moors STW TBR indicates a frequency of about 5% AEP (20yr return period) and the other rain gauges suggest a frequency of about 70% to 20% AEP (1.5yr-5.0yr return period) across the wider area.

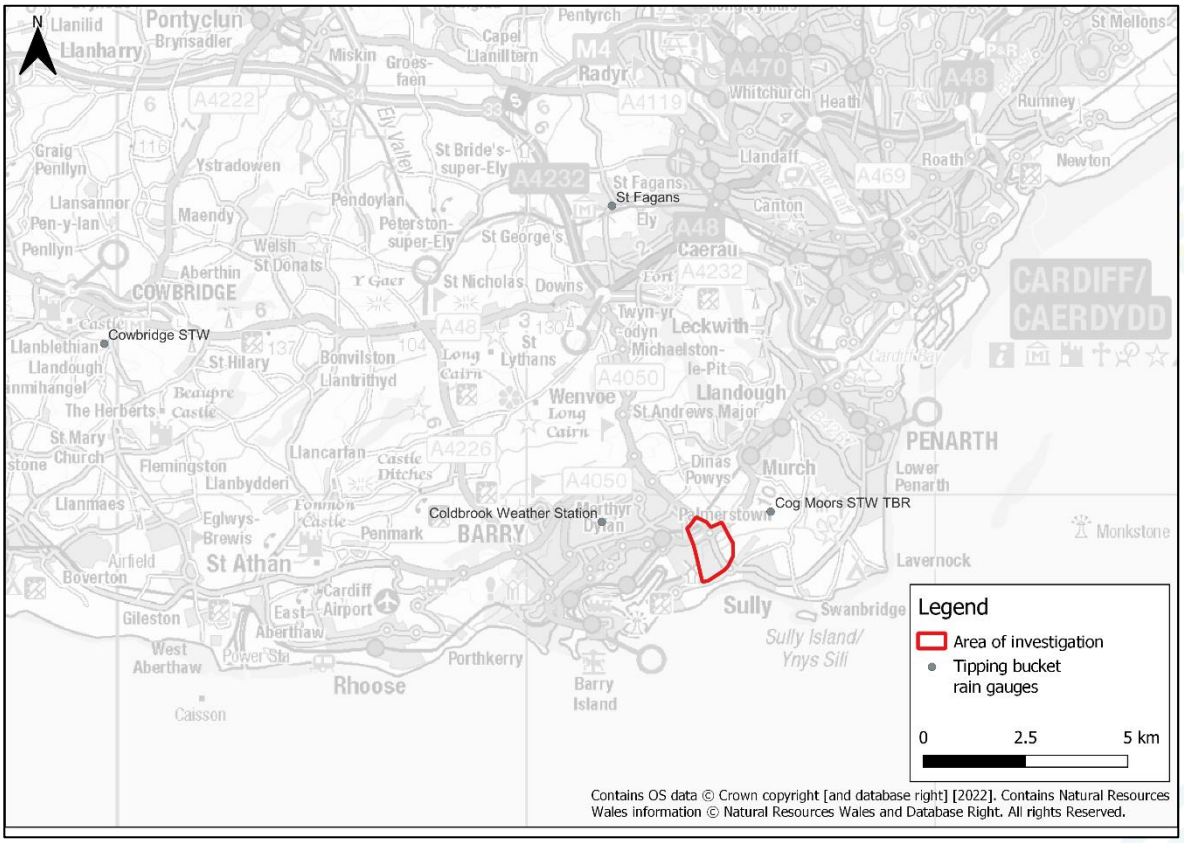


Figure 7-2: Rainfall gauge locations

Table 7-1 Rainfall gauge data

Rain gauge	Distance from site location (km)	Rainfall (mm) on 23/12/2020	Coordinates (XY)
Cog Moor STW TBR	2.07	47.8 in 5.25 hrs	315986,169586
		57.2 in 9.75 hrs	
Cold Brook Weather Station	6.19	29.0 in 5.25 hrs	311853,169334
		37 in 9.75 hrs	
St Fagans TBR	9.69	30.8 in 5.25 hrs	312103,177055
		43.6 in 9.75 hrs	
Cowbridge TBR	18.84	28.8 in 6.75 hrs	299675,173689
		35.2 in 9.25 hrs	

7.1.3 Groundwater

As groundwater levels rise in response to precipitation, groundwater could contribute to an increased level of surface water overland flow and a faster flow of water to river channels. Due to the rapid onset of this flood event and the absence of reliable evidence of this source, groundwater is not considered to be a direct source of flooding for this event.

7.2 Pathway

7.2.1 Fluvial

In the Sully Moors Road investigation area, the main fluvial pathway is from exceedance of the channel capacity of the Sully Brook and Sully Drain. This resulted in floodwater overtopping the banks of these watercourses onto the Sully Moors to the east of the investigation area. Floodwater then flowed onto Sully Moors Road. It is understood that whilst the River Cadoxton may have also reached capacity and flooded into its functional floodplain, the flood defences retained water within the immediate river corridor, reducing the likelihood that flood waters from the River Cadoxton flowed onto Sully Moors Road or the adjacent commercial properties to the east.

Flood water from the Sully Brook and Sully Drain flowed in a westerly and northerly direction from the watercourse onto the moors and subsequently onto Sully Moors Road. Water flowed overland to the commercial premises located on the eastern side of Sully Moors Road, resulting in 6 properties flooding internally. Flood water flowed along Sully Moors Road onto North Road and Horton Way, and an un-named road (all access roads of the industrial estate to the west of Sully Moors Road). From this location, flood water entered the wider industrial estate, resulting in widespread flooding. Flood water flowed into a southerly direction onto Hayes Road at the southern extent of the investigation area.

Fluvial flood water pathways were not a direct causal factor in the flooding of the Ty- Verlon Industrial Estate. However the high level of water in the River Cadoxton, and its tributaries, did cause hydraulic locking of the surface drainage system across this area. This, in turn, resulted in flooding of the Ty- Verlon Industrial Estate.

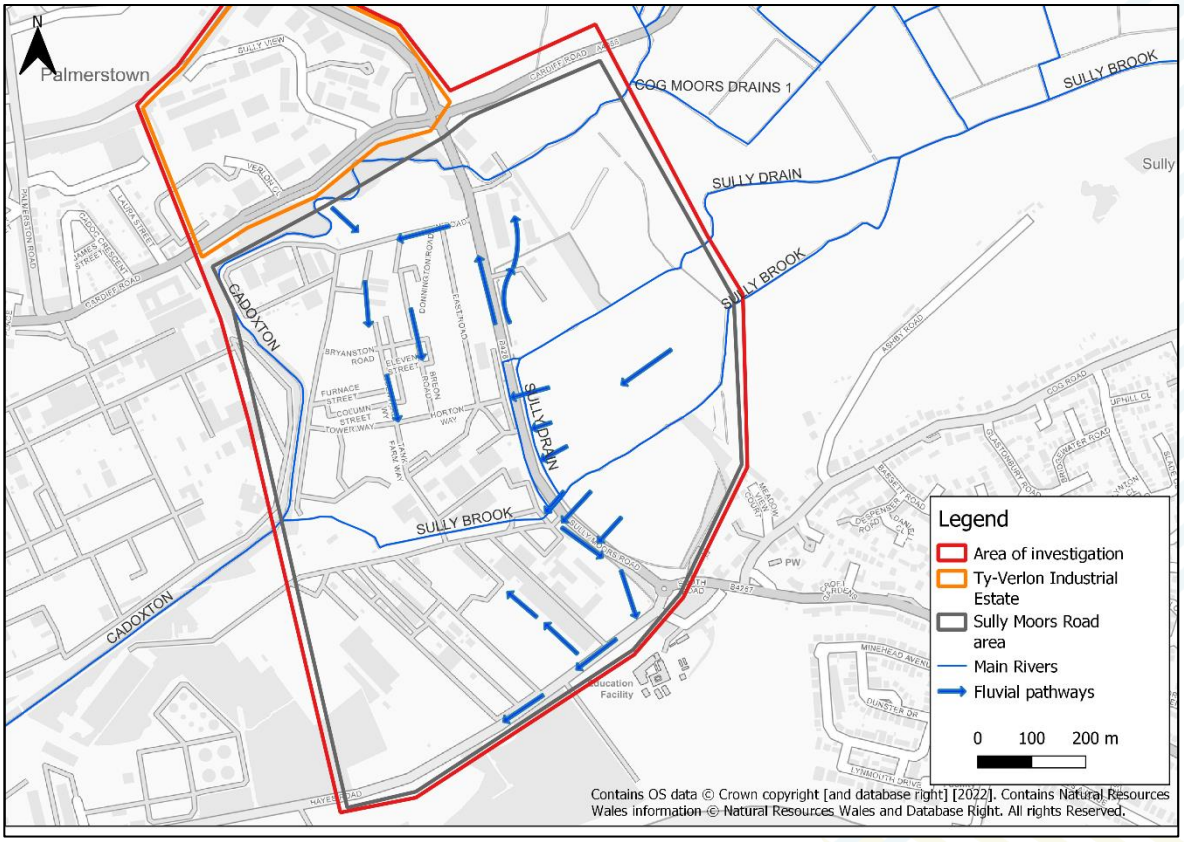


Figure 7-3: Fluvial flood water pathways

7.2.2 Surface water and drainage

Due to the high intensity of rainfall during the storm period, surface water pooled directly on impermeable surfaces, such as roads and pavements and the large industrial sites that occupy much of the western part of the Sully Moors Road investigation area, where it normally discharges into the private surface water sewer networks. Due to high water levels in the surrounding watercourses, the private surface water sewer systems were hydraulically locked and unable to discharge, exacerbating flooding in the investigation area.

Sully Moors Road is served by highway gullies that connect directly to the adjacent land drainage ditches which discharge into either the Cadoxton River or Sully Brook. The highway network was hydraulically locked as a result of the high water levels within the watercourses during the rainfall event resulting in backing up of the system and surcharging of the highway network during the flood event.

There are no reports of flooding from the DCWW combined system during this flood event.

In the Ty-Verlon Industrial Estate investigation area, water flowed along the main access route of Ty Verlon Industrial Estate (Sully View Road) and into the lower units (units 1-5) of Biglis House (located on the north east corner of the junction of Sully View Road and the Barry Dock link road). Due to the high intensity of rainfall on the day, surface water pooled directly on impermeable surfaces, such as roads and pavements within the industrial estate and flowed downhill to Biglis House. Reports indicated that water backed up through the drainage system into the units. It is unknown as to whether this was the highway system, or public surface water system in this area.

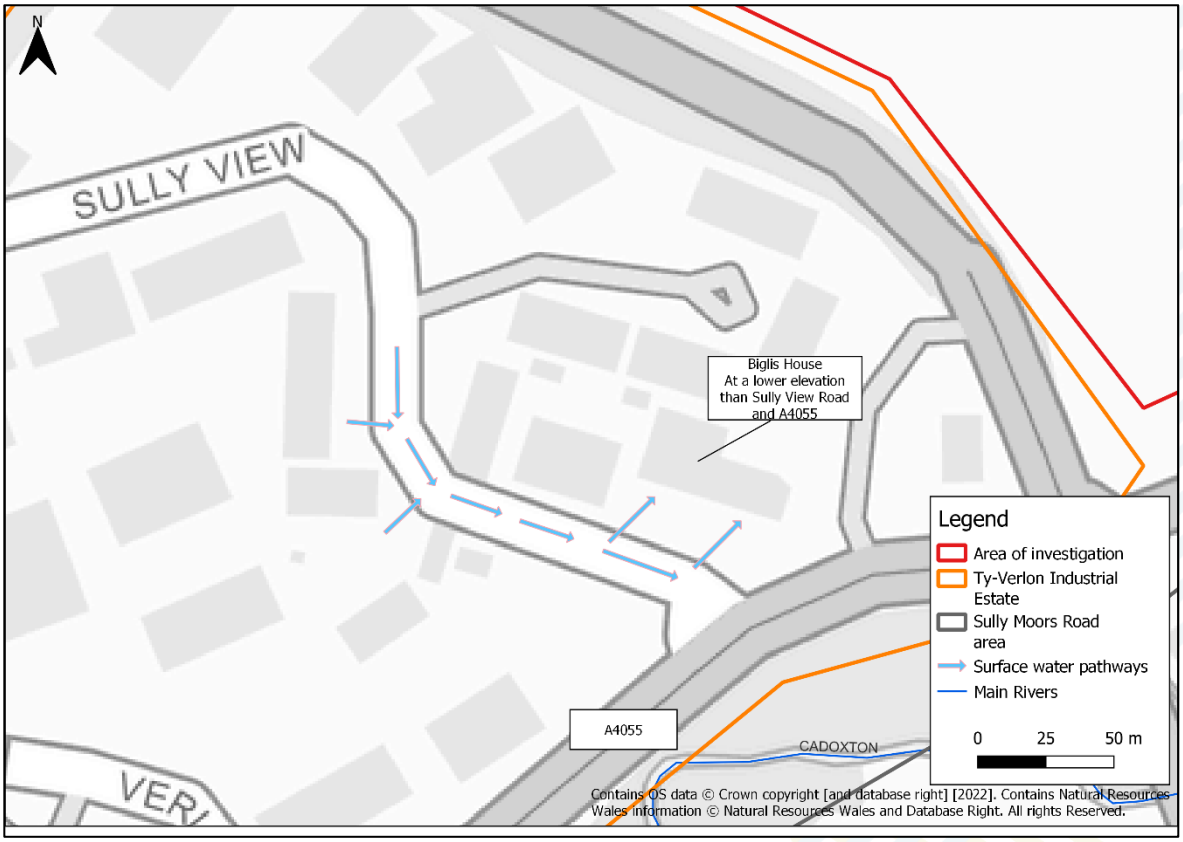


Figure 7-4: Surface water flood water pathways in the Ty-Verlon industrial estate

7.3 Receptor

7.3.1 People

No residential properties were affected in the area of investigation. However, businesses were affected by the flooding either directly or indirectly as access routes were blocked by the floodwater thus meaning businesses had to close for the duration of the flood. Due to the timing of the flood event over the Christmas holiday period, some businesses suffered less impact from closure than would have been the case at other times, however some businesses were still unable to open their premises over one month after the flood.

The floodwater blocking Sully Moors Road and Hayes Road resulted in disruption to journeys, therefore impacting the wider community which was also experiencing significant flood events.

The emotional impact of experiencing flooding and how it can have a harmful impact on mental health is well documented. This is true to business and property owners, with flooding resulting in temporary (and sometimes permanent) business closure and unexpected costs for business recovery. Business owners in this area reported numerous historic flood events at this location, resulting in this event having the potential to add to existing unrest and anxiety surrounding flooding.

7.3.2 Property

A range of industrial and commercial property was directly flooded. Six of the Flood Incident Reports collected by VoGC recorded internal flooding to businesses close to the River Cadoxton and the Sully Drain in Sully Moors Road investigation area with flood depths varying between 75mm and 600mm. Reported damage to properties varies from £7,000 to £50,000. Areas of the industrial estate were reported to be under water from 17:00 hours on 23rd December until 28th December.

An additional two businesses recorded external property flooding in Flood Incident Reports, generally to storage units and yards, with serious damage to assets being recorded (Figure 7-5, Figure 7-6).

Across the Ty Verlon Industrial Estate, 5 units of Biglis House are also reported to have flooded internally. Whilst exact details are still unknown, it is estimated that flooding impacted the units around mid to late afternoon of 23rd December with the surface water discharging into the River Cadoxton when river levels had receded.

Figure 7-5: Flooding of commercial property in the north east of the area of investigation.

Figure 7-6: Flooding of commercial property in the north east of the area of investigation.

7.3.3 Infrastructure

Sully Moors Road (B4267), the main road linking Barry to Sully and Penarth, was flooded and closed over a length of approximately 800m between the roundabout at the junction of the Barry Dock link road (A4055) in the north and the Hayes Road roundabout in the south; Hayes Road was flooded and closed west of this roundabout, but the total distance cannot be ascertained from the data supplied. Indicative flood extents along Sully Moors Road and Hayes Road are shown in Figure 7-7. Flood depths have not been formally reported. Due to the timing of the event, exact details are unknown, however there are reports of the flood duration being 3-4 days in some areas of the industrial estate.

Road access into Sully and to the important industrial and commercial estates in the Sully Moors Road area was severely restricted due to flooding and closure of Sully Moors Road, resulting in loss of business and widespread traffic problems. The loss of business was reduced by the timing of the event over the Christmas holiday period.

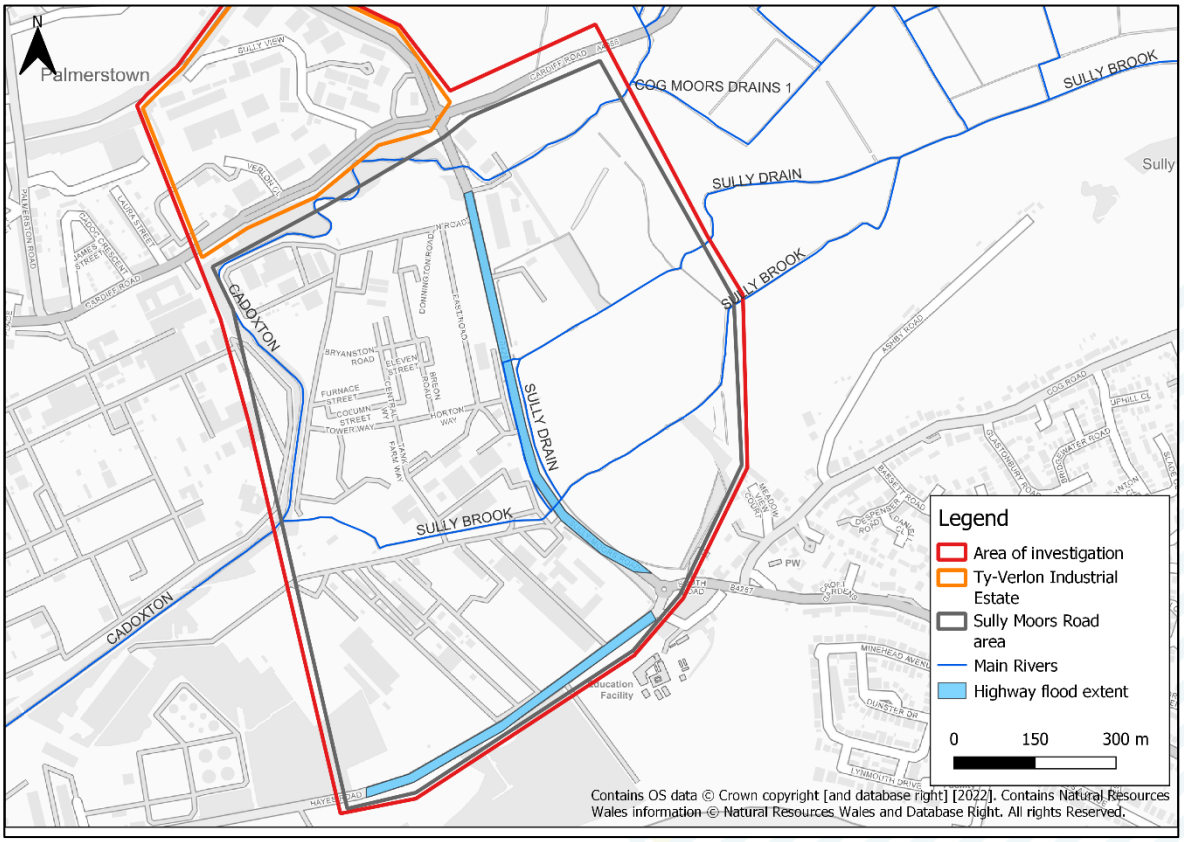


Figure 7-7: Highway flooding

8 Causal factors

Determining the exact cause of flooding is complicated and flooding often results from a combination of factors. Where location specific issues, such as blockages, are identified these will be described in the following section.

The primary cause of flooding to the Sully Moors Road area is limited channel capacity of the River Cadoxton, Sully Brook and Sully Drain resulting in overtopping of the river channels and floodwater spilling onto the floodplain. Fluvial flood water flowed in all directions, across the Sully Moors and along Sully Moors Road resulting in property and highway flooding across the investigation area. The extent of flooding correlates well to the 'high' flood risk extent on the FRAW risk of flooding from rivers map. High antecedent rainfall conditions in December resulted in initial conditions of a saturated catchment and high river levels.

During this flood event, the discharge capacity of the River Cadoxton was restricted by temporary work on the outfall. A report detailing the form and timing of activities undertaken by the appointed contractor on site was subsequently compiled by NRW and presented to the LLFA in May 2021, see Appendix A. Whilst it is possible the temporary works contributed to an increase in the depth and / or duration of flooding, the direct impact on the flood extent cannot be quantified. However, it is not considered likely that these impacts would have significantly influenced the reported flooding impacts.

The Hexion Chemicals site, Hayes Road and the Vale Enterprise Centre are drained via a piped and pumped system. The pumps are controlled by Hexion Chemicals. As stated by Hexion Chemicals in the VoGC meeting on 27 January 2021 and in the VoGC Preliminary Flood Incident Report, the Hexion Chemicals pumps were running at full capacity from 23 December to 28 December, however it took around 4 days to clear this unprecedented volume of flood water.

Given the timing of the event, in winter, vegetation coverage in channel will have been at its lowest, and as a result the impact of any vegetation is likely to be minimal across most of the site. NRW reported that field maintenance had been carried out since the February 2020 flood event, but the roadside ditches had not yet been cleared. Given the site location, volume and duration of flooding during this event, it is considered unlikely that vegetation within the channel would have significantly impacted on the extent of flooding during this event. Following the flooding, dredging was carried out to the outfalls on the Sully Moors Road on 17 May 2021.

Hydraulic locking of the highway and private surface water sewers in the area resulted in surface water being unable to discharge into the Sully Brook, Sully Drain and River Cadoxton. Much of the western part of the Sully Moors Road area of investigation consists of industrial estate, with a large proportion of impermeable surfaces causing surface water runoff. High water levels in the receiving watercourses resulted in surface water systems being surcharged for the duration of the flood event. The NRW surface water flood map is largely in line with the recorded flood extent for this event. Surface water flooding is not considered to be the main source of flooding for this event in the Sully Moors Road area.

Hydraulic locking of the highway and surface water sewers in the Ty-Verlon Industrial Estate area resulted in surface water being unable to discharge into the River Cadoxton. The NRW surface water flood map correlates well with the properties that reported flooding in the Ty-Verlon Industrial Estate. In this area, water flowed along Sully View Road and into the lower units of Biglis House (units 1-5). Sully View Road descends from elevations of over 15 mAOD in the north of the estate to 6.11 mAOD on the south-west side of Biglis House. Due to the high intensity of rainfall on the day, surface water pooled directly on impermeable surfaces, such as roads and pavements within the industrial estate and flowed downhill towards Biglis House where units 1-5 suffered internal flooding. Due to high water levels in the River Cadoxton during the storm event, the highway drainage and surface water sewer systems were hydraulically locked and unable to discharge, resulting in flooding to this lower section of Ty-Verlon industrial estate. When the water levels in the River Cadoxton had receded the surface water discharged directly into the river.

9 Conclusion and recommendations

9.1 Conclusions

This report has detailed the investigation into the flooding of Sully Moors Road and Ty Verlon Industrial Estate on 23 December 2020. This investigation has reviewed evidence provided by responders and businesses and has been informed by a Section 19 data analysis for Dinas Powys produced by JBA Consulting.

Within the area of investigation, the impacts from the storm event primarily occurred in two areas: the Sully Moors Road and Hayes Road area including the neighbouring industrial/commercial estates; and Ty-Verlon industrial estate.

The impact of the event in the Sully Moors Road area was that at least 6 commercial/industrial properties experienced internal flooding, along with road closures to key highway links between Barry and Sully. Flooding resulted in damage to property and highway closures, impacting on access to businesses and on the wider community travelling around the county. In the Ty-Verlon industrial estate there were reports of internal property flooding to several businesses.

The evidence gathered in this report demonstrates that for both areas the cause of flooding was due to heavy rainfall resulting in exceedance of channel capacity of the Sully Brook, Sully Drain and River Cadoxton; and also in rapid surface water flows. This was likely exacerbated by hydraulic locking of the surface water network in the area, resulting in increased surface water flows especially within the Ty-Verlon industrial estate.

The below actions are recommended in response to these findings.

9.2 Recommendations

Risk Management Authority/Stakeholder	Recommended actions
LLFA / Highway Authority (VoGC) / NRW	Assess the merits of installing a level gauge on the Sully Brook to assist with warning and informing of local businesses and highway users, and improved monitoring of extreme events.
Riparian Owner / Maintainer (Private Landowner/NRW)	Review maintenance actions and frequency for the Sully Brook, Sully Drain and River Cadoxton.
Highways Authority (VoGC)	Consider catchment options to reduce the risk and impact of surface water flooding to Sully Moors Road and Hayes Road
Highways Authority (VoGC)	Undertake an assessment of the condition and capacity of the local highway drainage system.
Property Owners	Consider flood risk to own properties; to install property flood resilience (PFR) where necessary in liaison with the appropriate RMAs.
Property Owners/ LLFA	Undertake an assessment of the condition and capacity of the private drainage network within the industrial estate, and review maintenance regime.
LLFA / Highway Authority / NRW / Local	Continued engagement between local stakeholders and risk management authorities through Sully Flood Management Group.

businesses / Local ward members	
VOGC (LLFA)	Consider adding Sully Brook and Cadoxton catchment as an area where new development requires specific hydraulic control within forthcoming updates to the Local Flood Risk Management Strategy

Appendix A: NRW Temporary Works Report

Cadoxton Outfall

Cyfoeth Naturiol Cymru
Natural Resources Wales

Construction Site Activities Report

	Name	Role
Produced By	Mark Groves	Project Executive - NRW
Reviewed By	Bethan Jones	Project Manager - NRW
Checked By	Sam Price	Site Supervisor – Arup

This report is a factual account of activities at the construction site at the River Cadoxton outfall, Barry Docks, managed by Dyer and Butler (the "contractor"). The report covers the time periods of the 28th February 2020 and 23rd December 2020 storm events. It has been prepared for the Operations Manager (Flood & Water Management) of Natural Resources Wales. The report does not include any root cause analysis of the flood events.

Outfall Arrangements Prior to Works Commencing

Prior to works commencing in 2018, the outfall comprised a bridge structure with a 2.1m diameter circular top hung flap mounted on a concrete headwall on the downstream face, with a steel pipe installed in the culvert. A debris screen was mounted on the upstream face of the outfall which required weekly clearance and was identified as a particularly difficult and hazardous screen to clear. The conveyance of water through the culvert had therefore been restricted due to the debris screen, culvert and top hung flap. Upstream of the outfall there is a fixed upstand weir, the top of the weir plate stands at 3.568mAOD (Above Ordnance Datum). Downstream of the outfall was a rubble weir. The top of the weir stood at 3.34m AOD. The bridge deck stands at 8.05mAOD. There was no remote monitoring such as CCTV or telemetry installed at the outfall.

A site plan and a river schematic, along with photographs of the site prior to works commencing can be seen below.

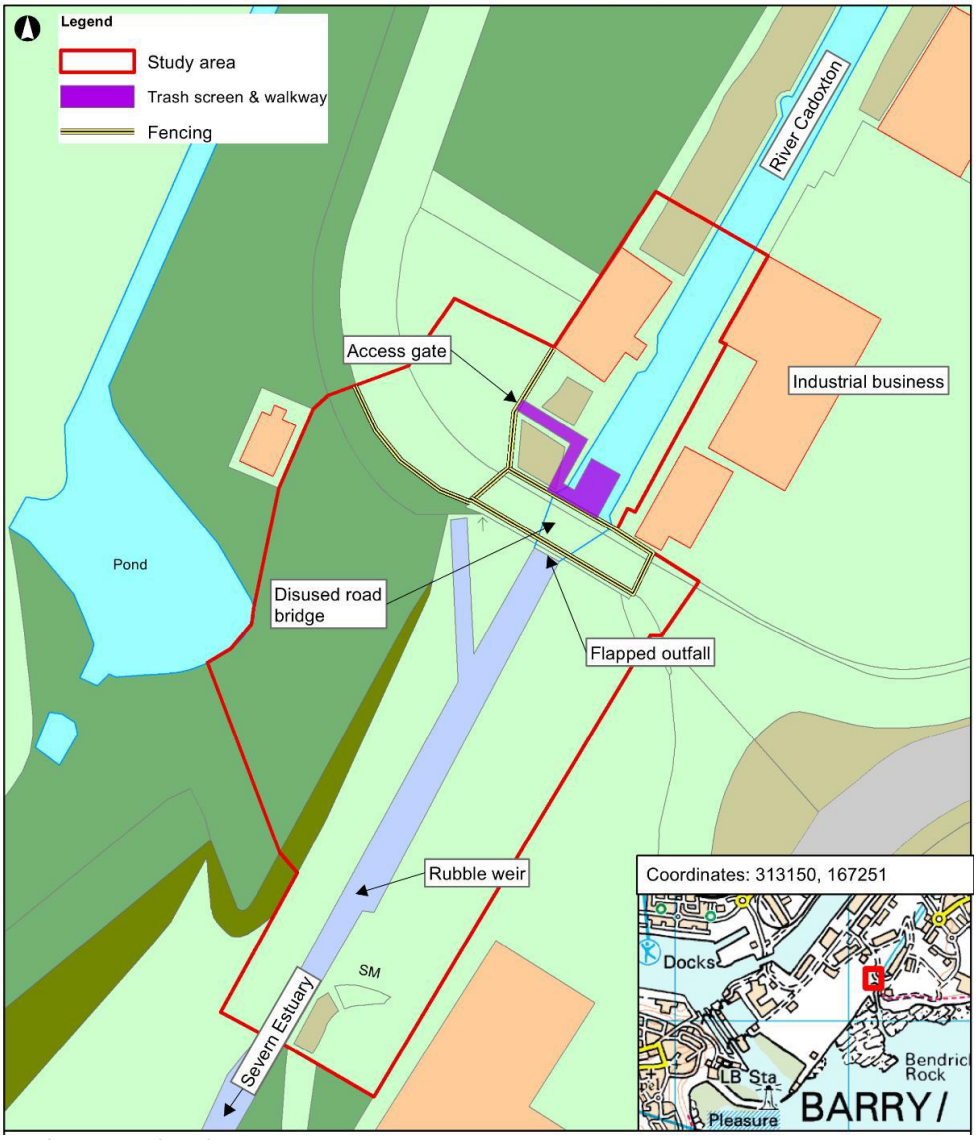


Figure 1 - Site Plan

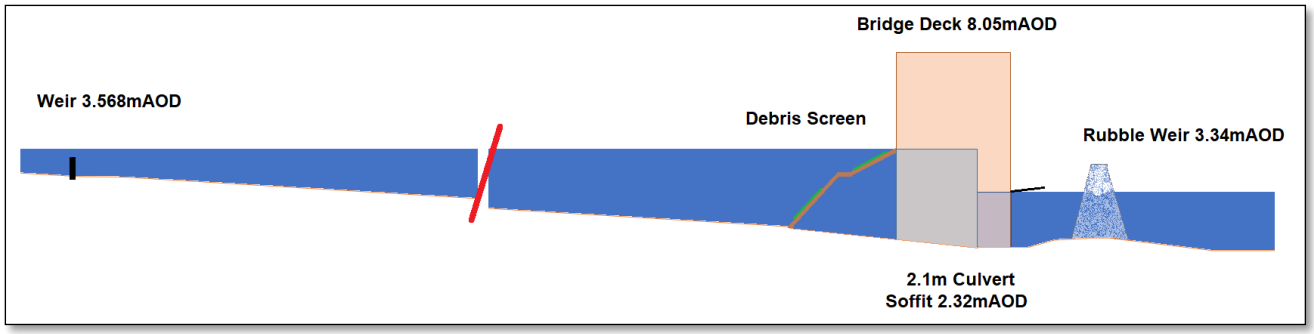


Figure 2 - Indicative River Schematic Pre-Works

Photograph 1 - Fixed Weir Upstream

Photograph 2 - General View of the North Elevation of the Bridge

Photograph 3 - General View of the South Elevation of the Bridge

Photograph 4 - General View Looking Downstream of the Bridge

Outfall Arrangements in February 2020

During the flood events of February 2020, the contractor was managing the site, however no construction works were being undertaken. In 2019, the contractor installed river level telemetry sensor at the fixed weir upstream, recording live river data every 10 minutes, and CCTV looking toward the north face of the outfall to allow the site to be monitored remotely. When the contractor was off site the CCTV was being used to monitor the culvert inlet for blockages at the outfall, and the telemetry to monitor river levels at the weir.

To facilitate construction works and create a sufficiently dry working area, the contractor had constructed a temporary dam upstream of the outfall and installed pumping arrangements to over pump the fluvial flows around the working area. The dam crest was constructed to 3.4mAOD. When river flows exceeded the pump capacity the temporary dam overtopped, and fluvial flows passed through the working area and out through the 2.1m culvert and top hung flap.

In 2019 the contractor had removed the upstream debris screen and the downstream rubble weir. The proposed penstock had not been installed. Without the penstock in place the contractor deemed the risk of saline intrusion or tidal ingress upstream was too great to remove the old top hung flap and 2.1m culvert.

In the winter of 2019/20, when no construction works were being undertaken, the contractor withdrew the over pumping arrangements, however the temporary dam was not removed from the river.

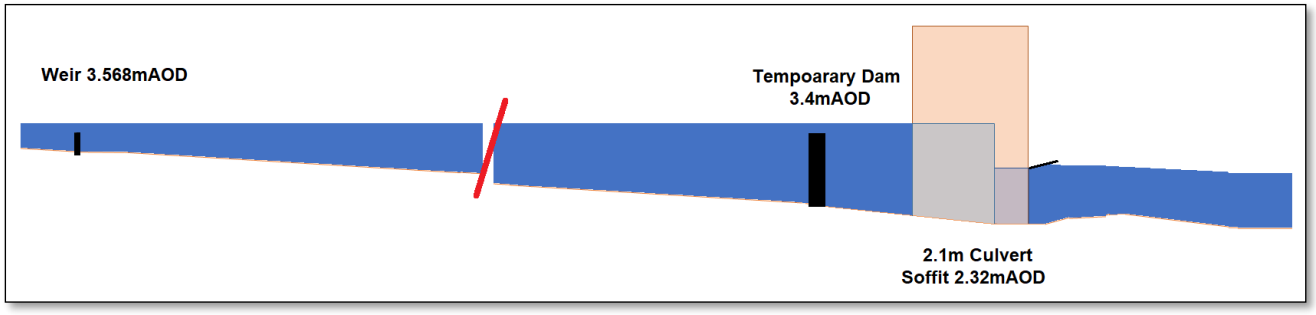


Figure 3- Indicative River Schematic Feb 2020

Outfall Arrangements in December 2020

The contractor recommenced construction activities in July 2020. Between mobilising and December 2020, several modifications were made to the temporary works arrangements. Pumping capacity was reconfigured to 4 x 12” and 1 x 8” pumps. The 12” pumps were connected to a manifold and discharged to the estuary via 2 x 16” lines. A temporary dam was constructed downstream of the existing one, consisting of a 5.34mAOD dam and a 1m diameter outfall pipe with top hung flap.

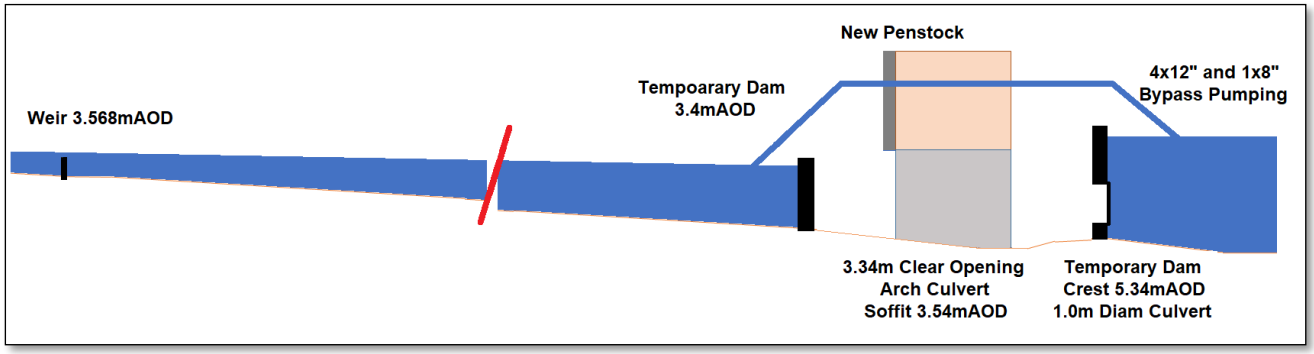


Figure 4 - Indicative River Schematic Dry Working Area

The contractor installed the penstock at the upstream side of the outfall structure and had broken out the 2.1m pipe, concrete back fill and top hung flap. After removing the backfill, the contractor repaired the arch of the culvert and further improved its hydraulic efficiency by repairing rough and scoured sections.

In fluvial events which exceed the capacity of the pumps, the upstream temporary dam overtops, passing water through the dry working area, and discharging through the temporary downstream dam. At high tides, when the river level is lower than the tide, the river would be tide locked, however the pumps can remain active, allowing discharge of the of the river where normally it would not be possible.

The tidal dam is designed to exclude high tides up to 11.44mACD (Above Chart Datum, ACD in this area is +6.1mAOD, top of dam is 5.34mAOD), during spring tides this level is exceeded. In these events and when the river level is lower than the maximum tide, the contractor manages the operation of the penstock, lowering it when the tide rises above the tidal dam, closing the inlet to the culvert reducing the risk of tidal ingress upstream. When the tide recedes again the contractor manages the reopening of the penstock. During high tides below 11.44mACD, the penstock can remain open if tidal ingress is being managed. When this is possible, it minimises the period of artificial tide locking.

The Cadoxton river is an ungauged river, and therefore there is no hydrological station along its reach that can collect river flows. Where actual data is available, it can be used and extrapolated to predict flows for events unseen during the period the data was collected. In instances such as the Cadoxton, where no flow data is available, theoretical predictions can be made using specialist software to estimate river flows. The contractor accessed and used data produced using a best practice tool for estimating flows in ungauged catchments.

The data, along with other factors, was considered by the contractor when determining the sizing of the combined temporary works system of over pumping and outlet pipe. The contractor states that the combined system was capable of conveying flows of up to 21,400m3/hour in ideal conditions. The temporary system can only convey maximum flows in ideal conditions (2m fluvial head, tides below the outlet pipe, flap fully open) and there is a risk of failure (pump failure, outlet pipe blockage, flap failure etc). The height of the downstream dam was restricted to 5.34mAOD, by the contractor, who stated that the upstream lowest known riverbank level is at least 5.6mAOD. It is assumed by the

contractor that in scenarios where river flows exceed the capacity of the pumps and pipe, the dam can overtop, as there is 'freeboard' between the top of the temporary dam and the lowest known riverbank level

During the flood events of December 2020, the contractor was monitoring the site. No works were planned for the period between 18th December 2020 and 4th January 2021. As there was limited activity on site the contractor informed Natural Resources Wales that they had arranged an out of hours rota to ensure the site was monitored over the period and teams could respond to site. Between the 18th December 2020 and 4th January 2021, predicted tides would not exceed 11.44mACD, as such the contractor deemed there was no requirement to operate the penstock thereby removing the chance of failure and human error of operating the penstock at high tides, leaving the penstock to act as a backup structure should the temporary flap fail.

On 22nd December 2020, the contractor had arranged for servicing of the pump generators to ensure they were fully operational for the Christmas period. Following the issue of an amber weather warning for rainfall in the area, the contractor visited site at 11:00am on the 23rd, to check that the temporary system was fully functional, and the pumps were working and fuelled. Tides that night were neap tides (8.67mACD or 2.57mAOD), that would be lower than both the downstream and upstream temporary works. Once all checks were completed the contractor left site at around 02:00pm, just after high tide had passed.

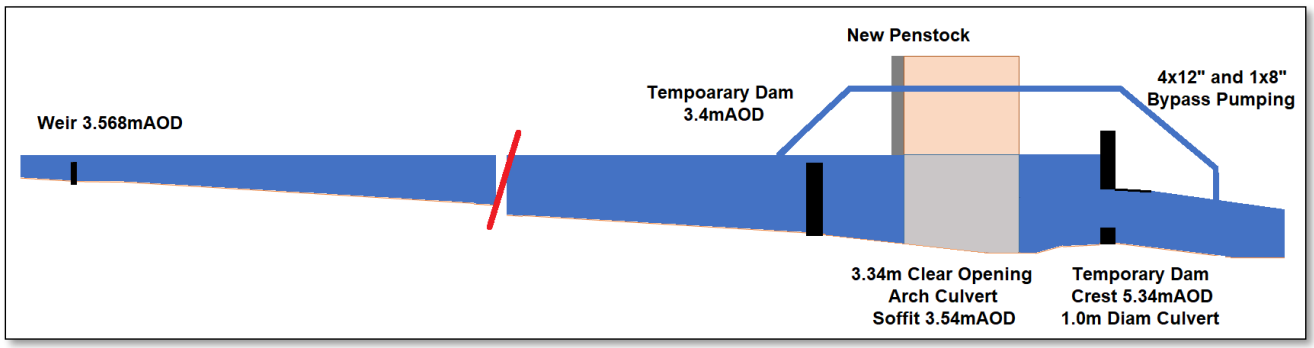


Figure 5 - Indicative River Schematic Dec 2020

Telemetry records show, that at approximately 09:00pm on the 23rd, river levels exceeded the contractors previously stated level that correlates to out of bank flow upstream. At approximately 01:30am on the 24th, the contractor who was monitoring the telemetry reported river levels higher than any previously recorded since the telemetry was installed. The contractor reported to site on the morning of the 24th. The contractor stated that pumps were fully operational, the dams were in place and overtopping, there were no signs of blockages or failures with the temporary works systems but river levels at the site were the highest they had observed. The contractor organised for a concrete breaker attachment to be delivered to site. When it arrived, it was connected to an excavator and used to partially demolish the tidal dam, removing approx. 350mm from the crest. The partial demolition was completed by 11:00am.

Telemetry records show that river levels peaked at 07:50am, remained stable until 09:40am at which point they began to fall.

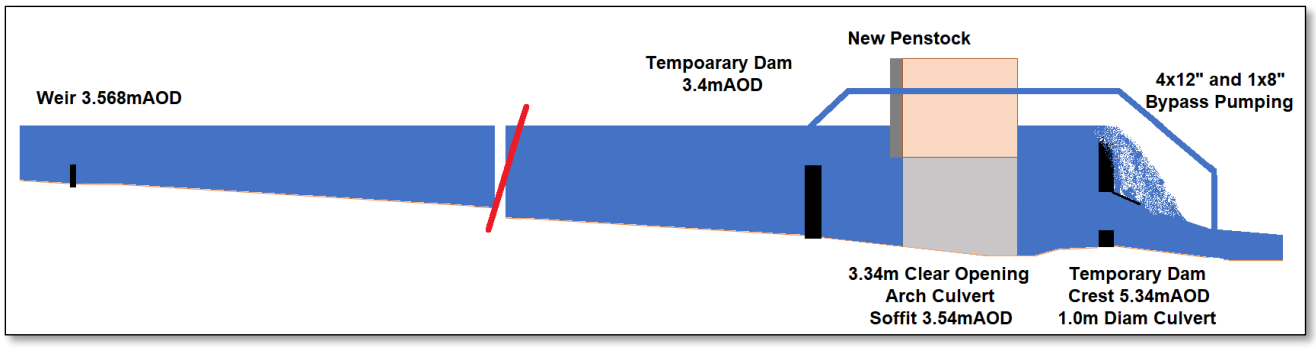
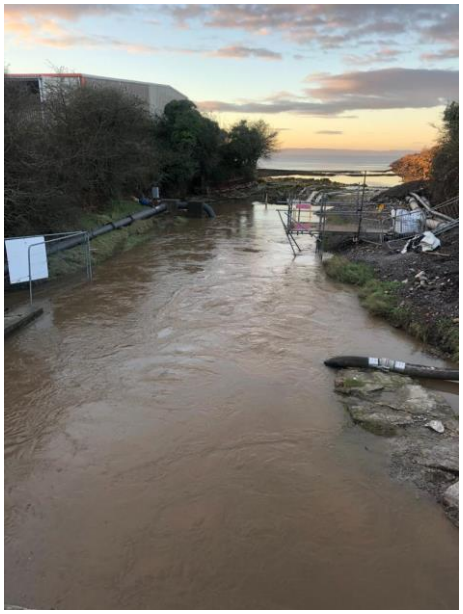


Figure 6 - Indicative River Schematic 24th Dec 2020 at 09:00am.

Photograph 5 – 24th Dec View Looking Upstream of the Bridge



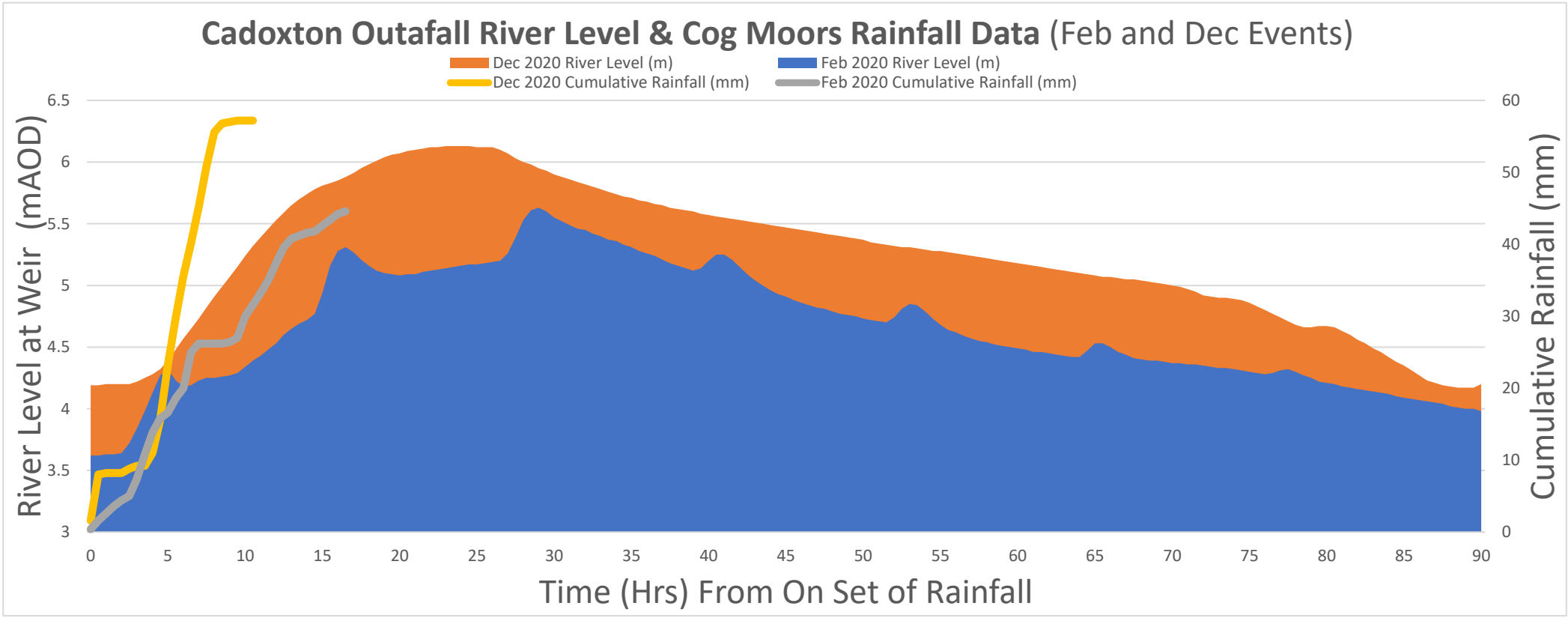
Photograph 6 – 24th Dec View Looking Downstream of the Bridge

Photograph 7 – 24th Dec View Looking Upstream Toward the Bridge

February and December Flood Events

Key Figures

	February	December
Rainfall	46.6mm over 18 hours On set 28th 05:30am	57.7mm over 9.5 hours On set 23rd 08:30am
High Tides	28-Feb - 10.81mACD (4.71mAOD) 28-Feb - 10.63mACD (4.53mAOD)	23-Dec - 8.87mACD (2.77mAOD) 23-Dec - 9.02mACD (2.92mAOD)



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